Society for Integrative and Comparative Biology
with the
Animal Behavior Society
American Microscopical Society
The Crustacean Society

2013 SICB

Annual Meeting

3-7 January

San Francisco, California

Abstract Book

43.5 ABBOTT, EM*; AZIZI, E; Univ. of California, Irvine; *abbotte@uci.edu*

The timing of muscle recruitment alters series elastic function during lengthening contractions

During eccentric contractions muscles are actively lengthened to dissipate energy. While eccentric contractions are physiologically common, muscle injury and soreness are often associated with actively lengthened muscle fibers. It has been suggested that series elastic elements (tendons and aponeuroses) may act as mechanical buffers to mitigate these potentially damaging outcomes. During eccentric contractions, strain energy is initially loaded into series elastic elements before tendon recoil stretches the muscle fascicles. By temporarily storing elastic energy, tendons can slow the rate of stretch applied directly to fascicles and can therefore function in attenuating power. Here we examine how the timing of muscle activation relative to muscle lengthening may alter the effective utilization of tendons in attenuating power. Using an *in vitro* muscle-tendon preparation, we test the prediction that muscle recruitment in anticipation of lengthening can reduce the rate and magnitude of stretch applied directly to muscle fascicles. Plantaris muscles of *Rana catesbeiana* (bullfrog) were instrumented with sonomicrometry crystals to measure muscle fascicle length. MTU length, force and power were measured by a servomotor. The MTU was lengthened at a constant speed while being stimulated at either 50ms before (early-start), concurrent with, or 50ms after (late-start) MTU lengthening. We find that the magnitude and rate of stretch applied directly to the fascicles decreased when the muscle was stimulated in advance of lengthening (early-start). We conclude that motor control strategies used during energy dissipating tasks can determine the degree of power attenuation by series elastic elements. Supported by NSF grant 1051691.

P1.138 ABOLINS-ABOLS, M*; KETTERSON, E D; Indiana University; *mabolins@indiana.edu*

Interaction between HPA and HPG axes in two rapidly diverging Oregon Junco (Junco hyemalis thurberi) populations.

How life histories evolve depends upon complex interactions among multiple traits that vary in their degree of interdependence. Two of the most important physiological systems across vertebrate taxa are the hypothalamic-pituitary-gonadal (HPG) axis, which regulates reproductive phenotype, and the hypothalamic-pituitary-adrenal (HPA) axis, which regulates metabolism and the stress response. The two axes have been shown to be mutually inhibitory, potentially giving rise to a fundamental physiological constraint as manifested in the evolution of slow and fast life histories. However, some comparative studies of animal physiology contradict the inhibitory relationship between the HPA and HPG axes and point to independent evolution of both axes. For example, blood levels of corticosterone and testosterone (T), the end products of HPA and HPG function, are positively, not negatively, correlated in two recently diverged populations of the Oregon Junco (*Junco hyemalis thurberi*) in southern California. We compared the direction and strength of the interaction between the HPA and HPG axes in individuals and populations by injecting wild birds with corticotropin releasing hormone (CRH), a major activator of the HPA axis, followed by an injection of gonadotropin releasing hormone (GnRH), a major activator of the HPG axis. We predicted that if the HPA axis inhibits the HPG axis, then CRH injection should suppress a rise in T after GnRH injection compared to animals injected with saline. Alternatively, if the axes function more independently, then a rise in T should be independent of whether animals received a CRH injection. We will describe individual- and population-level sensitivity of the HPA axis, as well as the interaction between HPA and HPG axes in these two populations.

110.6 ABRAMYAN, J.*; LEUNG, K. J.; MERCHANT-LARIOS , H.; RICHMAN, J.M.; The University of British Columbia, Universidad Nacional Autónoma de México; *abramyan@dentistry.ubc.ca*

Craniofacial ontogeny in turtles: the role of bone morphogenetic protein in the loss of palatal shelves

Turtles are an enigmatic group of vertebrates whose divergent skull morphology is still at the forefront of scientific discussion. While turtles pass through a conserved stage of primary palate development found in all amniotes, we have found that turtles diverge during secondary palate ontogeny. The typical condition for amniotes is to form outgrowths from the medial sides of the maxillary prominences called palatal shelves. In mammals, the shelves fuse in the midline and form a bony hard palate that completely separates the nasal and oral cavities. In birds and squamates, palatal shelves develop on the lateral sides of the oral roof but remain unfused, leaving a natural cleft. Here, we conclusively excluded the presence of vestigial palatal shelves at any time during the ontogeny of the craniofacial complex in two branches of turtles, a side-necked turtle (*Emydura subglobosa*) and a sea turtle (*Lepidochelys olivacea*). Additionally, through comparative analysis of avian and testudine (*E. subglobosa*) craniofacial gene expression patterns, we have identified a distinct lack of mesenchymal Bone Morphogenetic Protein 2 (*BMP2*) expression in the maxillary prominences of *E. subglobosa*. In previous work we showed that when BMP signaling is blocked in the chicken embryo maxillary prominence, a complete loss of palatal shelves occurs. These intriguing avian data suggest that loss of BMP expression in the turtle at an early time in their evolutionary history contributes to the loss of palatal shelves. This work is supported by an NSERC grant to JMR. JA holds an NIH Ruth L. Kirschstein PDF.

P2.140 ABUHAGR, A. M.*; CHANG, E. S.; MYKLES, D. L.; Colorado State University, 2UC Davis Bodega Marine Laboratory, Bodega Bay, California; *aliabuhagr@gmail.com*

Comparing the effects of molt manipulation on mechanistic Target of Rapamycin (mTOR) in molting gland (Y-organ) of blackback land crab, Gecarcinus lateralis and green shore crab, Carcinus maenas

Regulation of the molt cycle in decapod crustaceans is controlled by the X-organ/sinus gland complex in the eyestalks. The complex secretes molt-inhibiting hormone (MIH) that suppresses production of molting hormone (ecdysteroids) by molting glands (Y-organs or YOs). In most decapods molting is induced by eyestalk ablation (ESA), or autotomy of 5 or more walking legs (Multiple Leg Autotomy, MLA). However, the green shore crab *C. maenus* (both color morphs) is refractory to ESA and MLA. The mechanistic Target of Rapamycin (mTOR) pathway is highly conserved among all metazoans; it functions as a nutrient sensor for cellular growth and is up-regulated in mammalian cancers. cDNAs encoding mTOR components (mTOR, Rheb, Akt, and S6K) were cloned from land crab, *Gecarcinus lateralis*, and green crab, *Carcinus maenas*. The purpose of this study was to quantify and compare the effects of molt manipulation (ESA and MLA), on mTOR pathway components (mTOR, Rheb, Akt, and S6K), in *G. lateralis* and *C. maenas* by qPCR. mTOR, which controls global translation of mRNA into protein, appears to be involved in YO activation. Rapamycin, an mTOR inhibitor, is a potent inhibiter of YO edysteroidogenesis. YO activation is required for transition to the committed state, as indicated by the prolonged effect of rapamycin on ESA animals. We hypothesize that up-regulation of mTOR signaling is necessary for YO hypertrophy and increased ecdysteroidogenesis during premolt. qPCR data indicate that ESA activates mTOR signaling in the *G. lateralis* YO, but not in the *C. maenas* YO. Supported by NSF (IOS-0745224).

130.4 ACKERLY, KL*; WARD, AB; Adelphi University, Adelphi University ; *kerriackerly@yahoo.com*
Determining the relationship between vertebral morphology and burst swimming performance
Ectothermic aquatic vertebrates are particularly sensitive to the effects of environmental conditions during early development, which can significantly impact adult morphology, performance, and survival. Previous research has highlighted the sensitivity of diverse groups of amphibians and fishes to the effect of temperature during early development on vertebral morphology. Vertebral morphology has also been shown to significantly impact an individual's swimming performance, which is a crucial aspect of their survival. In this study, we investigated the relationship between the effect of temperature on vertebral development and the subsequent effect of any discrepancy on burst swimming performance in two model aquatic vertebrates, zebrafish (*Danio rerio*) and axolotls (*Ambystoma mexicanum*). Embryos of both species were collected and evenly distributed between a range of species appropriate temperatures prior to the onset of somitogenesis. Following development, startle responses were recorded and individuals were analyzed for either vertebral number or muscle fiber composition. Our results indicate that, in both species, small fluctuations in temperature can significantly influence an individual's vertebral development, such that individuals reared in higher temperatures develop a lower number of total vertebrae and a less favorable ratio of pre-caudal to caudal vertebrae for maximum performance. As a result of these morphological discrepancies, the swimming performance of these was significantly impacted and these individuals were found to have decreased burst swimming performance. We are expanding this study to determine whether individuals with decreased burst swimming performance have decreased survival when confronted with a native predator.

23.1 ADDIS, E.A.*; REDING, D.M.; SCHWARTZ, T.S.; PALACIOS, M.G.; BRONIKOWSKI, A.S.; Gonzaga University, Iowa State University, CENPAT-CONICAT; *addis@gonzaga.edu*
Insulin-like signaling and life history trade-offs in garter snakes with divergent life histories
Life history theory, and specifically of the pace of life hypothesis, postulates the existence of trade-offs with organisms falling at the "slow" end of the continuum exhibiting low annual reproduction, slow growth and long lifespan while organisms at the "fast" end have higher reproduction, faster growth and shorter lifespans. While the existence of the pace of life continuum has been documented in a myriad of species, from nematodes to mammals, little is know about the physiological mechanisms underlying these demographic and physiological trade-offs. The insulin-like signaling (IIS) pathway is an evolutionarily conserved molecular network that has been is involved in the pace of life trade-offs in model organisms. Key components of the IIS pathway include insulin-like growth factor 1 and 2 (IGF-1, IGF-2) and associated receptors (IGF-1R, IGF-2R). In this study, we explore the role of these components of the IIS pathway in growth of two genetically divergent ecotypes of the western terrestrial garter snake, *Thamnophis elegans*, which exhibit these slow and fast paces of life. We used a common-garden design in which snakes from each ecotype were placed in one of two daily temperature treatments from birth: 16 hours of voluntary heat exposure with eight hours at 20°C or eight hours of voluntary heat exposure with 16 hours at 20°C. We compare growth rates with plasma levels of IGF-1 and IGF-2 at three time points during rapid juvenile growth and gene expression levels of IGF-1, IGF-2, IGF-1R, and IGF-2R at 1.2 years of age. Lastly, we discuss the relevance of these results in relation to the life history and environmental differences in these divergent ecotypes of the garter snakes.

125.6 ADELMAN, JS*; WILSON, AF; HOPKINS, WA; HAWLEY, DM; Virginia Tech; *adelmanj@vt.edu*
Temperature-induced feeding increases do not augment pathogen deposition on bird feeders: potential consequences for climate-disease relationships
Ambient temperature can play important roles in disease progression and transmission. However, unraveling how temperature influences the links among within- and between-host disease processes remains an important challenge, especially in the face of global climate change. Here, we address this issue in an emerging wildlife disease system: house finches (*Haemorhous mexicanus*) infected with the bacteria *Mycoplasma gallisepticum* (MG). Recent work suggests that bird feeders act as fomites in this system, transmitting MG deposited by one bird to another. We hypothesized that the amount of MG deposited on feeders should increase in response to two, non-exclusive factors: 1) increased MG load in the eye and 2) increased interaction with feeders. We tested how ambient temperature influences these links by housing experimentally infected finches under two thermal regimes: at thermoneutral (TN) and below thermoneutral (sub-TN). As in a prior study, MG load in the eye did not differ between temperature treatments. At the individual level, however, and regardless of temperature treatment, MG load in the eye predicted MG deposition onto feeders in an exponentially increasing manner. With regard to interaction with feeders, we predicted that sub-TN birds would compensate for thermoregulatory costs by increasing food intake, thus interacting with feeders more often and increasing MG deposition. While sub-TN birds consumed more food than TN birds, MG deposition on feeders did not differ between groups. We discuss how nonlinear relationships among feeding efficiency, pathogen load, and pathogen deposition may explain these patterns, contribute to heterogeneous transmission, and buffer the effects of climate on fomite-transmitted diseases.

52.1 ADREANI, M.S.*; STEELE, M.A.; California State University, Northridge; *madreani@csun.edu*
Estimating fecundity, spawning frequency, season length of temperate reef fish; a comparison of natural and artificial reefs
The reproductive output of fishes is often used as a measure of the health and productivity of a given population. This measure may be of particular importance when habitat is altered in some way. Artificial reefs may provide new space for fishes to inhabit, but it is unclear whether fishes reproduce at the same rate on natural and artificial reefs. We tested whether the overall reproductive output on a large artificial reef was similar to nearby natural reefs using three of the most abundant species on rocky reefs in the Southern California Bight (California sheephead, kelp bass and senorita). Fish were collected during their reproductive season and we measured a range of reproductive parameters, including batch fecundity, spawning frequency and the length of the spawning season using visual assessments, gonad histology and egg counts. While there was some variation in the specific measures, our estimates of reproductive output for each of the three species were similar across all of the reefs. These results, along with additional estimates of overall reef productivity, suggest that artificial reefs have the potential to mitigate damages incurred to natural reefs and give us additional insight into the reproductive ecology of these ecologically important species.

72.3 AGUILAR, JA*; LESOV, A; WIESENFELD, K; GOLDMAN, DI; Georgia Tech; *jjaguilar1@gmail.com*

The role of natural frequency in a jumping robot

Many animals and robots jump to reach higher ground, to escape from predators, and even as primary mode of locomotion. At a basic level, jumping involves transient bursts of actuation of a mass coupled with internal elastic elements to generate movement. A hypothesis, then, is that this system's natural frequency, f_0, (from mass and elasticity) should play a crucial role in maximizing jump performance. While there have been many models created to simulate jumping, these often have many parameters and multi-link legs, making it a challenge to analyze the dynamics of such systems. To probe in detail how natural frequency affects jumping performance, we study a simple robot comprising a periodically actuated mass-spring arrangement. The actuator frequency and phase are systematically varied to find optimal performance. If forced for N=2 or more cycles, robot lift-off is achieved optimally at resonance. However, for the fastest lift-off, (N=1), maximal jump heights surprisingly occur above and below (but not at) f_0. A simple model reveals how jumping, which occurs at transient time scales, is optimized less by resonant build up and more by proper timing and phasing. Two distinct jumping modes emerge: a simple jump, which is optimal above f_0, is achievable with a squat maneuver, and a "stutter jump", which is optimal below f_0, is generated with a counter-movement. The stutter jump is slow but uses less power, while the single jump has a fast time to takeoff but requires higher power input. We propose that animal musculoskeletal systems can target these different jumping templates to make situation-appropriate tradeoffs between time-to-takeoff and internal power.

P3.133 AH RAN, K.*; HYUN-WOO, K.; Department of Marine Biology, Pukyong National Univ., Busan 608-737, Rebublic of Korea; *tass5910@gmail.com*

Molecular characterization and expression of crustin-like protein in the Morotoge shrimp, Pandalopsis japonica

Crustin is cationic cysteine-rich antibacterial polypeptides in decapod crustaceans that contain a characteristic four-disulphide core-containing whey acidic protein (WAP) domain at the C-terminus. Crustins are classified under 3 types as domain organization between the signal sequences and the WAP domain. As results of EST sequencing analysis and typical cloning strategy, we obtained total 23 putative crustin-like genes. Based on the structural and phylogenetic analysis, Paj-crustins were further classified into three subgroups. In order to study expression pattern of crustins, end-point RT-PCR was carried out several tissues including hemocyte, gill, epidermis, brain. Recombinat crustins were constructed to compare antimicrobial activity using the prokaryotic expression system. The recombinant crustins were active against Gram-negative bacteria and Gram-positive bacteria. In order to identify the determinant for antimicrobial activity, mutants were constructed and their acitivities were also measured. These results expanded our knowledge about the information of crustacean innate immunity.

S11-2.4 AH-KING, Malin*; GOWATY, Patricia A.; Uppsala University, Univ. of California, Los Angeles; *Malin.Ah-King@gender.uu.se*

A reaction norm perspective on sex and mate choice

Sex is often seen as an essentially discrete trait, ensuing certain characteristics and "roles". However, sex and sexual characters and behaviors are reaction norms, that is all phenotypes emerge out of environmental interactions with pre-existing phenotypes. For example, sex-change may be induced by temperature, body size or social environment. Sex allocation in hermaphrodites is influenced by environmental factors. Though sex is not completely plastic. Reaction norms may be reversible or non-reversible, differ in their amount of plasticity, the rapidity of response to environmental factors and in the responsive time-frame. Also, sex (determination, characters and behavior) changes over evolutionary time, and so does the relative importance of genetic and environmental influence on the expression of a trait. Females are traditionally expected to be generally choosy in their mate choice and males to be indiscriminate. However, accumulating empirical evidence shows that mate choice is flexible in response to environmental, social and internal factors. Both males and females have been shown to shift between choosy and random mating in response to a number of environmental, demographic, social and internal factors. Empirical studies have investigated diverse factors (such as predation risk, density, OSR, encounter rate, chooser condition) causing mate choice flexibility, often as deviations from a general female and male pattern. In contrast, Gowaty and Hubbell (2005, 2009) argued that all individuals are flexible. The dynamic view of sex opens up new directions for future research. We suggest that we need to pay more attention to phenotypes - morphological, physiological, and behavior - as developmentally plastic and/or individually flexible in relation to sex and sex-linked traits.

P3.148 AIDALA, Z.*; HAUBER, M.E.; The Graduate Center, CUNY; Hunter College, CUNY; *zacharyaidala@gmail.com*

Ultraviolet visual sensitivity in avian brood parasites and their hosts

Sensitivity to ultraviolet (UV) light (< 400 nm) mediates a diverse array of avian behaviors including foraging, mate choice, and egg recognition. Among brood parasites (birds which lay their eggs in the nests of others) and their hosts, some host species use differences in UV-reflectance to distinguish between own and foreign eggs. Recent evidence suggests that even seemingly non-mimetic parasitic eggs may be accepted due to color-matching in the UV portion of the avian-visible spectrum. However, the degree of UV-sensitivity of many brood parasite hosts is poorly understood. DNA sequencing of the short wavelength sensitive type 1 (SWS1) opsin gene allows for accurate prediction of a focal species' maximal photoreceptor sensitivity regarding violet sensitivity (VS) at > 400 nm and ultraviolet sensitivity (UVS) at < 400 nm. We report predicted maximal SWS1 opsin sensitivities among Passeriformes hosts of obligate brood parasitic birds: the North American brown-headed cowbird (*Molothrus ater*) as well as the New Zealand shining-bronze cuckoo (*Chrysococcyx lucidus*) and long-tailed cuckoo (*Urodynamis taitensis*). We expected covariation in SWS1 UVS/VS status with rejecter/acceptor behaviors in focal hosts, yet we detected no evidence of such a relationship. Despite the lack of support for the UV-matching hypothesis, these results will allow for more accurate visual modeling analyses within specific parasite-host systems due to the new information regarding predicted SWS1 maximal sensitivities reported here. Future research will investigate full avian-visible spectrum sensitivity differences in hosts using opsin sequencing and microspectrophotometric analyses with the expectation that rejecter hosts will have visual systems that are better able to detect parasitic eggs.

76.4 AIELLO, B.A.*; KING, H.M.; HALE, M.E.; Univ. of Chicago; *braiello@uchicago.edu*

An analysis of neuromuscular control in the pelvic fin of African lungfish (Protopterus annectens).

African lungfish (*Protopterus annectens*) and tetrapods share fundamental features of their limbed locomotion. Previous study of pelvic fin kinematics emphasized the fish's ability to produce rotational movements around the joint between the fin and the pelvis, as well as the ability to lift the body from the substrate, undeterred by the lack of a sacrum and digited limbs. Despite similarities in limb movement, which for sprawling tetrapods, can require nine muscles, the lungfish uses only two muscles that surround the femur and lateral pelvis. These muscles called the pelvic fin protractor and retractor muscle are separated by ventro-medial and dorso-medial running connective tissues. They originate on the medial margin of the pelvis and insert on the distal femur of the fin. The modest morphology of *P. annectens* is strikingly different from the muscles surrounding the pelvic girdle in terrestrial terapods, where they are often robust and span multiple joints. Here we examine the muscular control of lungfish pelvic fin movement *via* EMG and fin kinematics to explore specific functions of the protractor and retractor muscles. We hypothesized that these muscles are functionally subdivided and activate synergistically to generate the range of movements observed. EMG records indicate solitary activation of localized regions of both the retractor and the protractor as well as coordinated activation of regions within these muscles to produce a full range of pelvic fin rotation. Our data suggest that functional subdivision within these muscles is fundamental to pelvic fin rotation, which allows lungfish to produce limb coordination similar to those of tetrapods utilizing only two muscles.

3.5 AKANYETI, O.*; LIAO, J. C.; The Whitney Lab for Marine Bioscience, University of Florida Gainesville; *otar@whitney.ufl.edu*

Modeling midline kinematics of fish swimming in a vortex street

How fish swim in unsteady flows is hardly understood despite its strong ecological relevance. Previous kinematic studies of fish swimming in vortex streets report time-averaged measurements and lack a formal definition to capture motions on a cycle-by-cycle basis. Here we develop a model to describe the continuous body kinematics of rainbow trout (*Oncorhynchus mykiss*) while Kármán gaiting behind a 5 cm diameter D section cylinder. We isolated the body bending kinematics in the fish frame of reference by subtracting the translation and rotation from the original midlines. An analysis of these transformed midlines revealed that the travelling wave equation, which has been traditionally used to model fish swimming in uniform flows, can also describe the bending of the posterior body during Kármán gaiting. We found that wave propagation along the body is a common feature between these two seemingly different behaviors, but have different characteristics. The amplitude and speed of the body wave generated by Kármán gaiting fish was 300% larger and 65% slower than for fish swimming in uniform flows. In Kármán gaiting fish the wave was initiated at the center of mass, 0.2 body lengths posterior to the initiation point for fish in uniform flows. In addition, we measured a high correlation between the lateral translation and the posterior body bending of Kármán gaiting fish (0.89±0.03, $p<0.05$). This suggests that the change in momentum while being buffeted side to side in the vortex street initiates the body wave. Our results show that a simple travelling wave is still a major movement strategy while navigating in unsteady flows. Whether it is generated actively through muscular activity or passively due to flow-induced motions varies depending on the flow regime.

P3.108A AL DAYEH, A.; HERRING, S.W.*; University of Washington, Seattle; *herring@uw.edu*

Mechanical Behavior of the Cartilaginous Nasal Septum

Damage to the nasal septum collapses the snout, perhaps because structural support is lost. During mastication in pigs (*Sus scrofa*), the dorsal septum is compressed anteroposteriorly (A-P) (Al Dayeh et al. 2009). Therefore, the septum is not a dorsoventral (D-V) strut, but it could be resisting dorsal bending of the snout or acting as an A-P strut. Bending predicts dorsal A-P compression and ventral A-P tension. A strut function predicts A-P compression at all levels. These two models were assessed by mechanical testing of porcine septal samples along the A-P or D-V axes in compression and tension (n=13-18). After preloading, specimens were strained non-destructively up to 10% to calculate stiffness; relaxation stress was recorded for 30 (tension) or 120 (compression) sec; finally, specimens were loaded to failure. Overall, the septum was stiffer (3.35 vs. 0.70MPa) and stronger (2.2 vs. 1.4MPa) in compression than tension, but deformed much less at failure (30% vs. 128%). Stress relaxation was greater under compression but took longer. Support for the bending model was poor. A-P compressive stiffness was insignificantly greater dorsally than ventrally; tensile stiffness was not greater ventrally. Support for the strut model was better only if the anteriormost location (tested D-V) was ignored, in which case compressive stiffness and strength were significantly greater A-P than D-V. The anteriormost region was uniquely strong and flexible, presumably because of its connection with the snout disc. Thus, the septum is adapted to receive A-P compression and the anteriormost region is specialized. Nevertheless, the low stiffness and high strain observed throughout the septum imply that it has no important role in structural support of the snout other than as a stress dampener. Its most important function may be growth. Supported by PHS DE08513.

67.7 ALFARO, ME*; FAIRCLOTH, BC; UCLA; *michaelalfaro@ucla.edu*

Using sequence capture of UCEs and flanking regions to resolve phylogenetic relationships within actinopterygian fishes

Ray-finned fishes constitute the dominant radiation of vertebrates with over 30,000 species. Although molecular phylogenetics has begun to disentangle major evolutionary relationships within this vast section of the tree of life there is as yet no widely available approach for efficiently collecting phylogenomic data within fishes, leaving much of the enormous potential of massively parallel sequencing technologies for resolving major radiations in ray-finned fishes unrealized. Here we provide a genomic perspective on longstanding questions regarding the diversification of major groups of ray-finned fishes through targeted enrichment of ultra-conserved nuclear DNA elements (UCEs) and their flanking sequence. Our workflow efficiently and economically generate data sets that are orders of magnitude larger than those produced by traditional approaches. Analysis of the UCE data set recovers a well-supported phylogeny at both shallow and deep time-scales that supports a monophyletic relationship between Amia and gar (Holostei) and reveals elopomorphs and then osteoglossomorphs to be the earliest diverging teleost lineages. We also discuss progress towards developing larger marker sets for major actinopterygian radiations as well as some of the challenges to traditional phylogenetic workflows created by large UCE-based data sets.

29.1 ALLAM, B*; CARDEN, W; WARD, JE; RALPH, GM; WINNICKI, S; PARVEZ, N; PALES ESPINOSA, E; Stony Brook University, Stony Brook, University of Connecticut, Groton, University of Connecticut, Groton;
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Evidence that Perkinsus marinus is acquired by oysters during rejection of waterborne particles as pseudofeces
One of the most common mechanisms for non-vector transmitted parasites to reach the internal host environment is through feeding. In this study, we investigated the mechanisms of oyster host colonization by the Alveolate *Perkinsus marinus* and focused on how oysters process infective waterborne *P. marinus* cells during feeding in an attempt to reveal the portal and mechanisms of entry of this parasite to its host. We also compared the uptake of freely-suspended *P. marinus* with that of aggregated parasite cells to link changes in particle processing by the feeding organs with infection success and route. Finally, we evaluated the effect of oyster secretions (mucus) covering the feeding organs on *P. marinus* physiology because these host factors are involved in the processing of waterborne particles. The ensemble of results shows a unique mechanism for infection by which *P. marinus* is mostly acquired during the feeding process, but not via ingestion. Rather, infection occurs during the rejection of material as pseudofeces before reaching the mouth. The pseudofeces discharge area, a specialized area of the mantle where unwanted particles are accumulated for rejection as pseudofeces, showed significantly higher parasite loads than other host tissues including other parts of the mantle. Aggregated *P. marinus* cells caused significantly higher disease prevalence and infection intensities when compared to freely-suspended parasite cells. Mucus covering the mantle caused a quick and significant increase in parasite replication rates suggesting rapid impact on *P. marinus* physiology. A new model for *P. marinus* acquisition in oysters is proposed.

88.3 ALLEN, V*; NYAKATURA, J; Univ.of Jena;
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Joint contributions to locomotor velocity and power in Iguana iguana
In 'Sprawling' locomotion (e.g. lizards and salamanders), 3D limb kinematics appear more important than the more planar motions of 'upright' animals. In particular, due to the highly abducted proximal limb segment forward motion can be achieved both by its retraction and long-axis rotation (LAR) - the 'double-crank' mechanism. This is observed in both pectoral and pelvic limbs of salamanders, but it's significance in lizards and other 'sprawlers' is not fully known. Here, we use simultaneous measurement of 3D kinematics (XROMM) and limb endpoint forces in a representative lizard (*Iguana iguana*) to quantify joint rotations, torques, powers, and contributions to overall body velocity. In support of previous hypotheses, we find that the importance of the 'double crank' to locomotor progression is much greater in the pectoral than the pelvic limb of *I. iguana*. However, rather than a simple 'double crank', we find complex patterns of 3D pectoral girdle, shoulder and elbow rotations all contribute to forward velocity and power at different points during stance. In contrast, progressive power in the pelvic limb is provided mainly by planar flexion and adduction at the hip and carpal joints - while significant non-planar torques and rotations are found, these appear to be associated with braking and control of ground reaction torques rather than progression. Detailed 3D kinematics for sprawling animals are only recently available via the XROMM method, and so the distribution of such differential mechanisms of pectoral/pelvic limb progression cannot yet be assessed across Lepidosauria. It is possible that this represents a similar fore/hind support/power differentiation to that seen in mammals, although by acting as a 'wheel' rather than a 'strut', the forelimb may be better able to also provide locomotor power.

P3.212 ALLEN, TR*; NGUYEN, JV; FAY, SA; POWER, ME; STILLMAN, JH; Univ. of California, Berkeley;
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The effect of temperature on respiration rates of four key aquatic insect taxa in California riverine food webs.
Predicting changes in trophic ecology of riverine systems in the face of future climate warming requires an understanding of the thermal performance of aquatic insect larvae. Larvae that differ in key trophic traits (i.e., armored vs. unarmored, grazer vs. predator) may also differ in the efficiency with which they use energy under various thermal regimes. Metabolic energy efficiency is maximized at optimal temperatures and declines at higher temperatures due to an increase in fermentative metabolism as metabolic rates outstrip oxygen delivery and an induction of stress responses to cope with thermal or oxidative damage. We compared thermal performance curves of four key aquatic insect taxa (*Pteronarcys californica, Calinueria californica, Hesperoperla pacifica and Dicosmoecus gilvipes*) from the South fork of the Eel River in Mendocino County, CA, by determining their respiration rates over a range of temperatures, 4-40° C using optode spots (PreSens). Respiration rate of P. californica, C. californica, and D. gilvipes peaked near 30°C, while the respiration of H. pacifica peaked near 20°C. Respiration rates among individuals within a species at a given temperature were highly variable. At peak temperature P. californica had an average respiration rate of 330±250 µmolO2/min/g, C. californica, 580±230, D. gilvipes, 250±80, and H. pacifica, 70±10. There was considerable intraspecific variation among individuals of the species tested, which could not be explained by effects of organismal handling or experimental light exposure. Our performance curves will be used to guide further work on molecular mechanisms of thermal response in trophically significant river insect larvae.

9.1 ALLEN, JD*; ARMSTRONG, AF; College of William and Mary, University of California, Davis; *jdallen@wm.edu*
Developmental flexibility in a variable environment: lessons from sand dollars and sea urchins
Despite recent reports of intraspecific developmental plasticity in marine invertebrates, exceptions to the rule of species-specific developmental patterns remain rare. Here we describe unusual intra-clutch variation in the development of an echinoid echinoderm. To generate this variation we exposed sand dollar and sea urchin embryos to increased temperature and low salinity environments. For these types of nearshore animals, the intertidal and shallow subtidal environment is a place of high variability in salinity and temperature. We found that under moderate levels of salinity and temperature stress, the sand dollar, *Echinarachnius parma*, exhibits the unusual developmental pattern of producing multiples (twins, triplets and quadruplets). For echinoderms, this is only the second report of the production of multiples under conditions embryos experience in the real world; the first described briefly by Mortensen 75 years ago. Multiple production is much more frequent in E. parma than in the other nearshore echinoids examined: *Strongylocentrotus droebachiensis* and *Lytechinus variegatus*. We hypothesize that the differences we observed in the propensity to produce multiples are due to differences among echinoids in the strength of the hyaline layer that surrounds blastomeres during early development. We plan to test this hypothesis in other echinoids known to have frail hyaline layers, notably *Eucidaris tribuloides*. Whether the production of multiples is an adaptive response to a variable environment, or simply an interesting developmental aberration remains to be demonstrated. However, novel developmental responses to present-day fluctuations in salinity suggest that ongoing environmental shifts may drive substantial changes in marine invertebrate developmental patterns.

P2.22 ALMEIDA MANSILLA, E*; DYAL, J; LEWIS, JM; BRIM, D; CLYMAN, T; BLANK, JM; California Polytechnic State University; *nerfe_a@hotmail.com*

Influence of Acute Exercise and Ethanol on Mitochondrial Biogenesis Pathways

Acute ethanol exposure inhibits muscle protein synthesis, while chronic ethanol exposure causes muscle wasting in humans and laboratory animals. In contrast, resistance exercise increases protein synthesis and endurance exercise stimulates mitochondrial biosynthesis. Few studies have addressed the interaction of ethanol and exercise. To assess this interaction, Sprague-Dawley rats were familiarized on a treadmill for three weeks and then subjected to an exhaustive acute run. Following the acute bout of exercise, each rat was injected with ethanol (75 mmol/kg) or an equivalent volume of saline. Subjects were sacrificed three hours later and tissues harvested, freeze-clamped, and stored at -80oC. Proteomic techniques were used in order to detect proteins whose phosphorylation state changed due to exercise and/or ethanol exposure. Mass spectrometry was used to identify the proteins that vary in their state. Standard western blot procedures were used to measure phosphorylation state of proteins known to be involved in up-regulation of mitochondrial biosynthesis, such as proliferator-activated receptor -γ coactivator-1α (PGC-1α), cAMP response element-binding (CREB), and p38 MAP Kinase (p38MAPK). These techniques were used to test the hypothesis that alcohol reduces the activation of proteins involved in mitochondrial biogenesis. This work was sponsored by the Department of the Navy, Office of Naval Research, under Award #N00014-11-1-0359.

37.4 ALUPAY, J/S*; CALDWELL, R/L; Univ. of California, Berkeley; *jsalupay@berkeley.edu*

The costs and benefits of losing an arm: autotomy in the octopus Abdopus aculeatus

Animals have evolved a diversity of defense mechanisms including cryptic and startling displays and flight responses to escape their predators. Arguably one of the most extreme tactics is autotomy, the voluntary shedding of a limb or body part. This behavior is beneficial in the immediate escape of the animal and leaves behind a potential distraction for the predator. However, organisms may incur long term costs to activities where the lost limb played a vital role. Reptiles, echinoderms, and arthropods are known to lose specific body parts and provide evidence for increased survival in autotomizing individuals. Several studies in these skeletalized taxa have also shown that autotomy decreases locomotor performance. We studied a soft-bodied organism, *Abdopus aculeatus*, an octopus known to autotomize and regenerate its arms. More than 50% of the 48 individuals observed in the Philippines were found with one or more arms lost or regenerated. Additional arms were autotomized in the lab and were found moving and suctioning to surfaces for up to three minutes without stimulation. Stimulated arms continued to move for more than one hour, attaching to surfaces at the base and repeatedly curling at the tip. These results suggest that autotomized arms have evolved behaviors that distract the predator as the octopus escapes. Preliminary locomotion studies also suggest that there is no difference in the kinetics of how autotomized and intact individuals move. However, the type of locomotion and gait patterns may differ depending on the number of arms that are lost. With these data, more quantitative analyses of the costs and benefits of autotomy may be determined along with a better understanding of the evolution of this mechanism in octopuses.

P1.170 ALVAREZ, MF*; SCHREY, AW; RICHARDS, CL; University of South Florida, Armstrong Atlantic State University; *malvare2@mail.usf.edu*

Trends in Ecological Microarray Studies

Quantification of gene expression on a genome-wide scale can be used to address important questions in ecology and evolution. The regulation of gene expression is directly relevant to ecology because it allows organisms to alter phenotype in response to environmental cues, even in the absence of genetic variation. Because differential gene expression can be labile and responsive to environment, it may drive adaptation and divergence, underlie phenotypic plasticity, and can be used to infer organismal response to a specific event, such as pollution response. Microarrays have become a common tool to quantify gene expression in ecological genomics due to their familiar analysis (ANOVA) and expansive background literature. To assess current trends in microarray studies, we reviewed over fifty ecological microarray studies. We found that many studies have made substantial progress in elucidating the relationship between altered gene expression and adaptation. However, other areas, such as plasticity, remain understudied, despite increasing access to microarray platforms. We also discuss two important design elements that have received attention: the use of sample pooling and heterologous arrays. We summarize the pros and cons of different approaches and make recommendations on the appropriate usage of these methods in ecological settings. We also discuss the persistent problem of expression localization within specific tissues and across time, and suggest methods to minimize the impact of unwanted expression differences due to localization. We conclude with the hope that gene expression can continue to add insight into evolutionary mechanisms as ecologists become more familiar with the technology.

P1.165 ALVES, C; PERRY, E*; CRAIG, C; MILLER-SIMS, V; KIMMERER, W; COHEN, C/S; Connecticut College, Romberg Tiburon Center, Dept. of Biology, San Francisco State University; *eperry09@mail.sfsu.edu*

Wide range of genetic variability of mitochondrial COI in introduced species of copepods in the San Francisco Estuary

The San Francisco Estuary has one of the highest global concentrations of introduced species, including species of Asian copepods that now serve as the main food source for native fishes. Introduced species are often expected to show reduced genetic diversity and it has been hypothesized that high genetic diversity is correlated with invasion success. We examined the genetic diversity of seven introduced copepod species (n=18-33) with the barcoding gene cytochrome *c* oxidase I (COI). Previous work found unusually high haplotype diversity (0.997) the introduced copepod, *Tortanus dextrilobatus*. In this study, a native congener of *T. dextrilobatus*, *T. discaudatus*, was also extremely diverse (1.000, n=14), suggesting that high COI diversity may be characteristic of this genus. Haplotype diversity of the remaining species was widely distributed, ranging from 0.177 to 0.856. Variation in COI diversity may reflect diversity of source populations, invasion history, life history traits such as DNA repair mechanisms, post-arrival demographic variation including responses to selection, or idiosyncrasies in COI evolution. Ongoing work is aimed at comparison of these patterns to other loci in the nuclear genome to test for concordant patterns of variation. The range of variation among these estuarine invaders in a common habitat offers the opportunity for comparative tests of hypotheses on the origin and maintenance of diversity focused on species with extremely high (~10^9) population abundance.

146.3 ALWARD, B.A.*; ROWND, K.R.; BALL, G.F.; Johns Hopkins University; *balward1@jhu.edu*

Time-course of expression of ZENK in auditory brain regions and gonadotropin-releasing hormone—1 cells in starlings in response to song playback

Cues such as day length or social context modulate activity of the hypothalamic-pituitary-gonadal (HPG) axis so it is active at appropriate times. Song has been shown to stimulate luteinizing hormone release. However, the neural pathways mediating connections between auditory areas and the gonadotropin-releasing hormone-1 (GnRH-1) neuronal system and the timing of this stimulation are unclear. Here, we examined the expression of the immediate early gene ZENK in three auditory brain regions--the caudomedial mesopallium (CMM), caudomedial nidopallium (NCM), and nucleus mesencephalicus (MLd)--to understand how activity in these regions relates to the time-course of expression of ZENK in GnRH-1 cells. Birds heard song and we extracted their brains after 1.5, 3, 6 or 27-hrs. A no-song group was also used. We quantified ZENK cells in the CMM, NCM, MLd, and GnRH-1 cells of the POA. As expected, song induced increases in ZENK expression in CMM, NCM, and MLd in the 1.5-hr group as compared to the no-song group. ZENK in NCM of the 1.5-hr group was higher than all other groups and the 3-hr group had more ZENK than the 27-hr and no-song group. In CMM, males had more ZENK at 27-hrs than females, but there was no sex difference at 1.5-hrs. In MLd, the 1.5-hr group had more ZENK than the no-song and 27-hr group. For GnRH-ZENK cells we combined the 1.5, 3 and 6-hr groups into a ‘1st-day’ group as they had almost identical means. The 27-hr group had more GnRH-ZENK compared to the 1st-day and no-song group, which were not different. These results suggest that song continues to affect the HPG axis a day after it is heard. Further analysis is needed to identify areas involved in the transfer of information from auditory brain areas to the GnRH-1 system.

P1.225 AMBARDAR, M.*; GRINDSTAFF, J.L.; Oklahoma State University; *medhavi@okstate.edu*

Testosterone production in response to aggression: physiological or behavioral constraint?

In many animals, the hormone testosterone (T) generally promotes territorial aggression while reducing parental care. This is not always the case, however, and in those circumstances, the physiological mechanisms that mediate these relationships are poorly understood. In male birds, for example, the response of T production following a territorial challenge is variable; some species increase T production while others do not. In species that do not elevate T in response to a social challenge, T levels may already be circulating at maximum levels. Thus, a physiological constraint may be responsible for this discrepancy. Alternatively, males that provide extensive care to young may incur a cost of elevating T because of the suppressive effects of that hormone on parental care. We used a wild population of Eastern bluebirds (*Sialia sialis*) to examine the response of T production following a simulated territorial intrusion (STI), and how this relates to parental care. We quantified parental care by videotaping feeding behavior by adult bluebirds when nestlings were 5-7 days old. To quantify aggression, we performed STIs using a common nest site competitor, the house sparrow (*Passer domesticus*) when nestlings were 7-9 days old. Following parental care and STI trials, we collected a blood sample to determine circulating levels of T. We then performed gonadotropin releasing hormone (GnRH) challenges to test the capability of bluebirds to further increase T levels. The results of this study will provide insight into T production in response to social interactions, and how this relates to the trade-off between aggressive behavior and parental care.

S3-1.2 ANDERSON, P*; FRIEDMAN, M; RUTA, M; Univ. of Massachusetts, Amherst, Univ. of Oxford, UK, Univ. of Lincoln, UK; *panderson@bio.umass.edu*

Diversity and Disparity of the vertebrate feeding apparatus across the invasion of land

When vertebrates first colonized land, about 370 Mya, they encountered a world full of new dietary resources requiring radical changes in feeding mechanisms, not only at the water-land transition but also within the terrestrial realm. However, recent work has indicated that the earliest known limbed vertebrates had mechanical jaw systems similar to their fish relatives. Here, we extend the scope of initial inquiries by examining the functional spectrum of feeding modes in a diverse range of mostly Paleozoic, semi-terrestrial and terrestrial early tetrapods. We collected various biomechanically relevant metrics from the lower jaws of a set of Devonian-Permian taxa: stem-tetrapods (including fishes), stem-amphibians, stem-amniotes, and crown-amniotes. These data were used to construct a morphofunctional space illustrating the variety of biomechanical profiles explored by these early tetrapods. Relative disparity and morphospace occupation across taxonomic groups and stratigraphic bins document a stepwise occupation of various feeding guilds. In terms of mechanical feeding diversity, Devonian and Carboniferous stem tetrapods differ little from lobe-finned fishes. It was not until the appearance of Carboniferous and Permian stem amphibians and amniotes that terrestrial vertebrates began to expand into new regions of biomechanical morphospace. Our data support the hypothesis of a lag in the origin of tetrapod herbivory; the first excursion into herbivore-guild space does not occur until the latest Carboniferous. These results suggest that the conquest of land was a protracted event, lasting 80 My, during which vertebrates developed the repertoire of jaw mechanics necessary to fully exploit available terrestrial resources.

P3.48 ANDERSON, G.E.*; SECOR, S.M.; University of Alabama, Tuscaloosa; *ganderson@crimson.ua.edu*

Developmental shifts in heart position for the diamondback water snake

Heart position in snakes relative to body length has been hypothesized to be adaptively correlated with habitat (aquatic, terrestrial, and arboreal) and shown to be conserved phylogenetically. Among snake species that are phylogenetically diverse, relative heart position shifts with increased length, becoming relatively closer to the head with size. Unknown is whether heart position is fixed to body segment and segments develop differentially with age and size, or if position shifts independently. We examined relative heart position for the diamondback water snakes (*Nerodia rhombifer*) across a 6-fold range in snout vent length (250-fold range in body mass) to demonstrate that the heart moves relatively forward with length (23% to 17% of snout-vent length). We determined that ventral scale number corresponded closely with the number of vertebra. Therefore, ventral scale number was recorded at the anterior edge of the heart to identify the corresponding vertebral segment. Across body lengths, heart position was closely aligned with the 26th – 29th vertebrae with no trend of a more anterior placement of the heart with respect to the vertebrae number. Therefore, heart position appears fixed with respect to body segment. Apparently as water snakes increase in length the seemingly anterior movement of their heart is a function of the differential growth of different body areas. The middle and/or distal portions of the snake’s body experience a greater rate of lengthening compared to the anterior portion.

129.1 ANDERSON, C.V.*; TOLLEY, K.A.; University of South Florida, Tampa, South African National Biodiversity Institute, Cape Town; *cvanders@mail.usf.edu*

Contrasting thermal effects on movements powered by elastic recoil and muscle contraction in chameleons living along a temperature gradient

Temperature has a strong effect on muscle contractile velocity, and thus movement performance, but elastically powered tongue projection in chameleons has been shown to be less thermally dependent than the associated muscle-powered retraction. Adaptation and acclimation to low muscle temperature are known to mitigate thermal effects in muscle-powered movements at low temperature, but natural selection might act differently on movements that benefit from lower thermal dependence (i.e., elastically powered movements). We hypothesize that between closely related chameleon taxa found along an environmental temperature gradient, performance of muscle-powered movements (tongue retraction) will be higher at lower temperatures for taxa found in colder environments than for taxa found in warmer environments. Conversely, performance of elastic recoil powered movements (tongue projection) will vary significantly less between the taxa. We imaged three taxa living along a strong elevation and temperature gradient in South Africa feeding at 15-35°C. We found that tongue projection performance for the taxa from the coldest environment was the most robust between 15 and 25°C (Q_{10} <1.04). Among the examined taxa, however, relative thermal effects on performance did not show altitudinal gradation, with the mid-elevation taxa maintaining the highest degree of performance for both tongue projection and retraction at 25°C. These results indicate that thermal effects on both elastic recoil and muscle-powered movements vary between species living in different thermal environments but that other environmental variables may aid in driving these performance curves.

70.4 ANDERSON, D.A.*; SOUTHWOOD WILLIARD, A.; SCHARF, F.S.; University of North Carolina Wilmington; *daa2211@uncw.edu*

Osmoregulatory disruption due to acute cold stress in a juvenile estuarine fish

Marine fishes rely on active transport of ions to maintain osmotic homeostasis. Impaired function of critical ion pumps, such as Na+/K+ ATPase, at extremely low temperatures may result in a disruption in osmotic and ionic balance that could ultimately lead to death. We tested the temperature sensitivity of Na+/K+ ATPase in red drum (*Sciaenops ocellatus*), a dominant sport fish that encounters extreme cold temperatures during the first winter of life at the northern extent of its range. In a controlled laboratory setting, juvenile red drum were exposed to water temperature treatments of 1, 3, and 5°C, which represented within-range minima, with a 10°C control treatment. Tissue was then collected from cold-stressed and control fish for analysis of enzyme function, water content, and internal ion concentration. We used kinetic assays to compare Na+/K+ ATPase activity in gill tissue with and without ouabain, a Na+/K+ ATPase inhibitor, for each treatment group. Assays were run at both 15 and 25°C to identify enzyme temperature sensitivity within treatments. Results indicate that enzyme activity is positively correlated to the severity of thermal stress (i.e., highest activity at the coldest treatment temperature), and activity increased at the higher assay temperature within each treatment group. In order to complement our assessment of thermal effects on ion transport, we measured water content of muscle tissue and ion concentration of muscle tissue via atomic absorption spectroscopy. Measuring the effects of acute cold stress on osmoregulatory function offers insight to seasonal shifts in physiology and causes of mortality for juvenile red drum.

1.7 ANDERSON, R.A.; Western Washington University; *Roger.Anderson@wwu.edu*

Proximal causes of diet of in the lizard Phrynosoma platyrhinos in a northern desert scrub

Knowing the spatiotemporal patterns, causes, and consequences for both predator and prey has been a persistent challenge for ecologists. Testing hypotheses about prey use and prey availability under field conditions has been problematic. A useful system for such work includes using desert ants as prey and the ant-eating specialist lizard, the Desert Horned Lizard, *Phrynosoma platyrhinos*. The lizard and its prey are abundant in the Great Basin desert scrub in southeastern Oregon, and have been studied for several weeks each summer over the past decade on a 9 ha area in the Alvord Basin. Four species of ants comprise 96% of the diet by number, as analyzed by fecal pellet analyses. These ants tended to be the largest and most common ants captured by pitfall trapping, about 87% of the total ants by number. Annually 10-12 lizards were radiotracked and powdertracked, and were observed to spend most of their activity period in the open and near plant perimeters where the colony entrances to three of the four common prey species were located. Phrynosoma platyrhinos were most active in mid-morning at the same time ants were most abundant near colony entrances. Based on powdertrack trails, we inferred that the lizards knew where the colonies were. These lizards seemed to be relatively efficient foragers, judging from the length of their activity periods and their daily feeding rates.

P1.100 ANDREW, J.L.*; POWERS, D.R.; WETHINGTON, S.M.; George Fox University, Newberg, OR, Hummingbird Monitoring Network, Patagonia, AZ; *jluke11@gmail.com*

Use of Torpor by a High- and Mid-Elevation Hummingbird Species in Southeastern Arizona

Studies have shown that hummingbirds enter nocturnal torpor when energy reserves fall below specific “threshold” levels. The existence of a threshold suggests that it is favorable to remain normothermic, possibly to avoid physiological consequence of prolonged hypothermia. We studied nocturnal torpor use in broad-billed hummingbirds (*Cynanthus latirostris*; mid elevation; n=8) and broad-tailed hummingbirds (*Selasphorus platycerus*; high elevation; n=7) that were free-living during the day to assess the adequacy of available energy resources to allow for maintenance of normothermic metabolism at night. Nocturnal metabolic rate was measured using standard open-flow respirometry, under BMR conditions, at temperatures ranging from 5-38 °C. We found that all individuals of both species entered torpor shortly after the beginning of their nocturnal fast, and did not emerge from torpor until ~1 hour before sunrise. The consistent use of torpor in two species living in distinct ecosystems suggests that these birds might regularly use nocturnal hypothermia to balance their energy budget. If true then these hummingbirds might not experience the physiological consequences of extended hypothermia seen in other animals. Supported by NASA, Richter Scholar Program (George Fox University).

24.4 ANDREW, NR*; HART, RA; JUNG, M-P; TERBLANCHE, JS; University of New England, Australia, National Academy of Agricultural Science,South Korea, Stellenbosch University, South Africa; *nigel.andrew@une.edu.au*

Can temperate insects take the heat? Physiological and behavioural responses suggest high extinction risk with climate change

Insects in temperate regions are predicted to be at low risk of climate change owing to high thermal safety margins (low optimal performance temperature relative to habitat maxima) and/or high warming tolerance (high thermal tolerance relative to habitat maxima) relative to more tropical species. However, these assumptions have been generally poorly examined and such forecasting typically fails to account for microclimatic variation and behavioural optimization of insects. Here, using *Iridomyrmex purpureus* meat ants from Armidale, NSW, we show that ants regularly forage for short periods (minutes) at soil temperatures well above their upper thermal limits determined over slightly longer periods (hours) and do not show any signs of a classic thermal performance curve in voluntary locomotion across 10-55°C. Generally close associations of ant activity and performance with microclimatic conditions, possibly to maximise foraging times, suggest *I. purpureus* display highly opportunistic thermal responses and readily adjust behaviour to cope with extremely high trail temperatures. Increasing frequency or duration of high temperatures is therefore likely to result in an immediate reduction in foraging efficiency. These results for a key functional group suggest that (1) soil-dwelling temperate insects may be at higher risks of extinction with increased frequency or duration of high temperatures resulting from climate change than previously thought; and (2) that indices of climate change-related extinction are strongly influenced by the scale of climate metrics employed.

18.5 ANGIELCZYK, KD*; SCHMITZ, L; Field Museum of Natural History, Claremont McKenna, Pitzer, and Scripps Colleges; *kangielczyk@fieldmuseum.org*

Reconstructing the Diel Activity Patterns of Fossil Nonmammalian Synapsids

The majority of extant mammals are nocturnal, and it has been assumed that this trait characterized the earliest mammals. It also has been hypothesized that the shift to nocturnality caused a fundamental reorganization of the circadian system in mammals. However, the diel activity patterns (DAP) of the nonmammalian synapsid ancestors of mammals have never been examined in detail, even though this could provide insight into whether nocturnality is characteristic of mammals or a deeper lineage, and whether nocturnality evolved multiple times among synapsids. Eye dimensions are correlated with light sensitivity, and eye shape can be used to effectively discriminate amniotes of different DAP. Orbit and scleral ring dimensions are reliable skeletal proxies for eye shape, and can be used to extend reconstructions of DAP into the fossil record. Extant mammals lack scleral rings, but they are present, although infrequently preserved, across much of nonmammalian synapsid diversity. We compiled a data set of 40 specimens from 28 synapsid species. We used previously published data on scleral ring and orbit dimensions of extant squamates and avians with known DAP to establish classification rules with a linear discriminant analysis. Using prior probabilities derived from proportions of DAP among extant amniotes, we classified fossil synapsids (species averages) into diurnal, nocturnal, and cathemeral categories. Our results suggest that diurnality was the most common DAP in the analyzed sample. However, nocturnality was present in several clades, including Varanopidae, Sphenacodontidae, Therocephalia, and Cynodontia. Nocturnality likely evolved multiple times within synapsids, with its earliest appearance in the Permo-Carboniferous.

84.3 ANGILLETTA, MJ*; LEVY, O; SMITH, C; ZELIC, M; ADRIAN, G; KILBY, D; HURLIMAN, A; BORCHERT, J; BUCKLEY, LB; Arizona State Univ., Univ. of North Carolina, Chapel Hill; *angilletta@asu.edu*

Heat tolerance of embryos limits the geographic range of Sceloporus undulatus

To predict how global warming will affect species, ecologists have focused primarily on the increase in mean temperature and its impact on juveniles or adults. Yet, this focus ignores two factors that ecologists must consider to make accurate forecasts. First, future climates will impose acute heat stresses as well as chronic stresses. Second, embryos are most susceptible to acute stress because they cannot behaviorally thermoregulate to the same extent as can juveniles and adults. We quantified the degree to which lizard embryos from four geographically separated populations tolerated acute warming; tolerance was inferred from cardiac performance and survival probability. At a realistic rate of warming, embryos from all populations exhibited cardiac strain at 40°C and experienced cardiac arrest at 45-47°C. By exposing embryos to various diel cycles of temperature, we identified a threshold for survival between 40 and 42°C. In other words, a single brief exposure to 42°C killed all embryos from the four populations, while daily exposures to lower temperatures killed few embryos. Using an individual-based model that considers embryonic survival and development, we predict that environmental warming will affect the distribution of *S. undulatus* in more complex ways than previously predicted.

13.3 APPLEBAUM, S.L.*; LEE, J.W.; MANAHAN, D.T.; Univ. Southern California, Los Angeles; *sappleba@usc.edu*

Global metabolite profiles as predictors of physiological traits in bivalve larvae with genetically-determined differential growth rates

High variance in growth rates is typical for larvae of marine organisms, even when reared under similar environmental conditions. Part of this phenotypic variation within a species can likely be attributed to differential performance of specific genotypes. We conducted factorial crosses using purebred parental lines of the Pacific oyster (*Crassostrea gigas*) to produce larval families with contrasting growth phenotypes. Fast- and slow-growing larvae were analyzed for differences in metabolic rates, protein synthesis rates, and protein content. Additionally, metabolomic analyses were conducted to identify (i) biochemical pathways that contribute to genetically-determined differences in growth rate, and (ii) biomarkers that might predict growth phenotype. Size-specific respiration and protein synthesis rates were similar for contrasting growth phenotypes. Protein growth and depositional efficiency (ratio of protein growth to protein synthesis) were higher in faster-growing larvae. Metabolomic analyses identified over 200 different metabolites in larvae. The amounts of several essential (leucine, methionine, phenyalanine, threonine, valine), and non-essential (tyrosine) amino acids, as well as amino acid derivatives (N6-acetylysine, 5-oxoproline, 5-methylcysteine) were lower in the free amino acid pools of faster-growing phenotypes relative to slower-growing larvae. The lower amounts of proteinogenic amino acids in faster-growing larvae corresponded to lower protein turnover (i.e., higher depositional efficiencies) and support the proposal of differential protein turnover as a mechanistic basis for genetically-determined variance in growth. Further, these metabolites are putative biomarkers with the potential to predict growth phenotype.

9.3 ARMSTRONG, AF*; BLACKBURN, HN; ALLEN, JD; University of California, Davis, College of William and Mary; *frarmstrong@ucdavis.edu*

Delay of hatching in the sand dollar Echinarachnius parma in response to reduced salinity

Hatching plasticity occurs in response to a wide range of stimuli across many animal taxa including annelids, arthropods, flatworms, molluscs, and chordates. Despite the prominence and long history of echinoderms in developmental biology, environmentally-cued hatching plasticity has only been described in a single species: the sand dollar *Echinarachnius parma*. Following our initial observations of hatching plasticity, we conducted detailed experiments on the effects of temperature and salinity on hatching plasticity in three male/female pairs. We tested how temperature, salinity, and their interaction affect time-to and stage-at hatching. While all factors had a significant effect, salinity had the largest effect on hatching plasticity in *E. parma*. Embryos of *E. parma* delayed their time to hatching more than two-fold in response to a salinity reduction from 32 psu to 26 psu while maintaining an otherwise normal developmental schedule. Embryos that experienced the greatest delay in hatching time emerged from the fertilization envelope as 4-arm pluteus larvae rather than hatching as blastulae or early gastrulae. We observed high variability in hatching time and stage both within and among clutches, suggesting intraspecific variation in developmental responses to salinity. A delay in hatching may provide embryos short-term protection from a harmful environment. The simplicity of the manipulation and the reliability of the results suggest that hatching plasticity may be a common occurrence in sand dollar development. The wealth of data on echinoid development, combined with the molecular and genetic tools available, may make sand dollars and sea urchins a valuable model system for future studies of the mechanisms underlying hatching plasticity.

148.6 ARMSTRONG, T E*; LILLIE, M A; SHADWICK, R E; Univ. of British Columbia; *trishaarm@gmail.com*

Stiffness of Mouse Aortic Elastin and its Possible Relation to Aortic Media Structure

Aortic elastin allows arterial expansion on systole and subsequent elastic recoil during diastole, providing crucial capacitance and associated dampening of the cardiac pressure pulses. The structure and mechanical properties of the aortic wall are not uniform along its length due to the varying hemodynamic conditions to which it is exposed, but elastin's contributions to this variation are not well studied. The artery wall is a composite of two main structural proteins: elastin and collagen. Autoclaving an intact aorta removes the collagen and produces a mechanically competent vessel consisting of purified elastin, which can be used to study elastin's contribution to arterial mechanics. Although it is generally assumed that elastin's material stiffness is constant, a recent study in pigs found that it increased 30% along the thoracic aorta. We hypothesize that this increase in elastin stiffness is caused by a difference in the orientation of the elastic lamellae (EL) or in the EL connections to interlamellar elastin fibres (IEL) and smooth muscle cells. Uniaxial tensile testing of autoclaved mouse aortas showed elastin's stiffness also varies along both the thoracic and abdominal aortas in mice, allowing the mouse aorta to be used as a model to investigate this surprising variation in elastin stiffness. Elastin structure within the thin mouse aortic walls is being imaged with multiphoton laser scanning microscopy to identify any variation in the EL or IEL structure that could cause the variation in stiffness.

91.4 ARONOWSKY, A*; ANGIELCZYK, KD; SANZENBACHER, BL; Field Museum of Natural History; *aaronowsky@fieldmuseum.org*

Gamifying comparative anatomy to promote science learning in underserved teens

Motivating underserved urban teens to learn science content can be problematic because many students in this demographic are intimidated by science. The Field Museum of Natural History uses game-based methods to engage students with science content and to encourage them to become active learners. Here, we describe two educational programs, I Dig Science and Game of Bones, that use digital platforms to engage teens and teach them the basics of comparative anatomy through gameplay. I Dig Science (IDSci) is a small intensive summer program run in multiple locations, serving 12 teens per location. IDSci is an innovative combination of gameplay in a virtual world simulating paleontology field work and real world activities with museum specimens. In the virtual world, students are tasked with excavating, re-assembling, and identifying vertebrate fossils from the Permian and Triassic Periods of Earth History. They then compare these virtual fossils to real museum collections to infer the paleobiology of their ancient animal. Game of Bones (GoB) is a video game version of IDSci intended to reach a larger audience and be playable on demand. Both programs are grounded in learning theory and include science content experts in the design process to insure game play mimics an authentic science experience. We will demonstrate the similarities and differences in these two learning programs and discuss evaluation and focus group data that show gamification of science concepts can engage younger audiences and promote science learning. Gamification is an important way to engage learners who may fear or dislike science and aspects of these programs can be used in a spectrum of activities including introductory classes at the university level.

P1.105 ARQUISOLA, B; ALBACH, B; MCCUE, M.D.*; St. Mary's University; *mmccue1@stmarytx.edu*

Egg laying hens produce artificially enriched ^{13C} proteins for tracer studies

Physicians and researchers studying the physiology or pathophysiology of protein metabolism often use ^{13}C-labled free amino acid tracers, which violates the assumption that a tracer molecule undergoes the identical biochemical reactions as the tracee molecule (i.e. proteins). The goal of this study was to investigate ^{13}C-protein synthesis using a hen model (*Gallus domesticus*). Here we characterize the relationship between ^{13}C-1-L-leucine dosing protocols (e.g., ^{13}C-tracer dose response curve and ^{13}C tracer mixed in food or dissolved in drinking water), describe the incorporation and washout kinetics of 13C tracers, and generate highly enriched ^{13}C-egg white proteins (using a uniformly ^{13}C-labeled mixture of amino acids). Recovery of ^{13}C in egg whites ranged from 14% to 21% for the leucine and mixed amino acid tracers, respectively. At the highest leucine doses (434 mg day^{-1}) egg whites were over 150‰ above natural abundance. The cost of isotopic enrichment (δ^{-1}) was lower for the leucine tracer than the mixed amino acid tracers and was lowest at the smallest doses (86 mg day^{-1}). The time required for half maximal ^{13}C enrichment (t_{50}) depended chiefly on the mode of tracer administration and ranged from 2.5 days to 4.9 days for ^{13}C-leucine dissolved in water or mixed in the food, respectively. Uniformly ^{13}C labeled amino acid tracers were lost from the body at a rate (t_{50} = 3.0 days) nearly half of that of the rate of uptake ($_{50}$ = 1.7 days), indicating significant biochemical discrimination of ^{13}C amino acids.

133.3 ARTACHO, P*; LE GALLIARD, JF; Univ. Austral de Chile, Valdivia, Univ. Pierre et Marie Curie, Paris; *paulinaartacho@gmail.com*
Correlational Selection on Resting Metabolic Rate and Body Mass in the Common Lizard
Phenotypic selection, the differential survival or reproduction of individuals with different phenotypic characters, is widely accepted as the primary cause of adaptive evolution in natural populations. Its impact on evolutionary dynamics has been documented profusely during the last decades for both simple morphological characters and life-history traits. Comparatively, the strength and shape of selection acting on more complex functional properties (e.g. physiological traits), still remain poorly investigated. Further, most current studies of phenotypic selection have been performed by analyzing phenotypic traits separately or in a small subset of functional traits. However, behavior, morphology, physiology and performance traits should evolve in concert and their interactions should affect fitness significantly. This study wished to address these issues by performing a field phenotypic selection experiment on locomotor performance, thermal behavior and energy metabolism using as a model the common lizard, *Zootoca vivipara*. We captured 200 individuals (males and females of different ages) in field for measuring body mass (M_b), resting metabolic rate (RMR), maximal sprint speed and preferred body temperature at the laboratory. After measurements, animals were released in outdoor enclosures between the end of one reproductive season and the end of the next one, after which they were recaptured and its survival evaluated. The dataset was analyzed with logistic regression which indicated a complex picture with a combination of positive correlational selection between Mb and RMR, and disruptive selection on RMR. In conclusion individuals that showed high M_b and high RMR were promoted by selection, but also individuals that had low RMR. This is one of the few studies that have demonstrated correlational selection on a proxy of energy expenditure.

P2.174 ARTHUR, L. H.*; VELTEN, B. P.; KINSEY, S. T.; MCLELLAN, W. A.; PABST, D. A.; Univ. of North Carolina Wilmington; *lha8694@uncw.edu*
Oxygen storage capacity of a primary locomotor muscle in two similarly-sized, pelagic dolphins
Diving marine mammals must store oxygen (O_2) within their bodies to power metabolism when submerged. Three body compartments - muscle, blood, and lungs - are sites of O_2 storage. A muscle's O_2 storage capacity is dependent upon its myoglobin concentration ([Mb]) and mass. We compared epaxial locomotor muscle O_2 stores in common (*Delphinus delphis*) (n=8) and striped (*Stenella coeruleoalba*) (n=7) dolphins. These two similarly-sized dolphins have overlapping distributions, but diet analyses suggest striped dolphins are deeper divers. Thus, we hypothesized that striped dolphins would have higher muscle O_2 stores than common dolphins. Striped dolphins possessed higher [Mb], locomotor muscle mass (as % of total body mass) and muscle O_2 capacity than did common dolphins (8.15±0.80 vs. 5.01±0.54 g Mb/100g muscle; 44.82±4.68 vs. 36.26±1.64 %; and 106.75±9.31 vs. 67.1±7.21 ml O_2/ kg muscle). We calculated the aerobic dive limit (cADL) of each species using their muscle O_2 stores, and blood and lung O_2 stores estimated from published, mass-specific relationships. ADL was calculated as total body O_2 stores divided by diving metabolic rate (here assumed to be basal metabolic rate, based upon Kleiber). The cADL of striped dolphins (23.21±0.76 min) was 1.6 times longer than that of common dolphins (14.35±1.34 min). These results support diet analyses and suggest that striped dolphins can dive to greater depths than can common dolphins. The cADL for both species are higher than those measured for common and other similarly-sized dolphins (2-8 min), likely due to the assumed low diving metabolic rate. The difference in cADL suggests that striped dolphins can routinely achieve greater depths, with longer dive duration or higher swim speeds, than can common dolphins.

4.5 ARY, WJ*; CRANFORD, T; BERTA, A; KRYSL, P; San Diego State University, Univ. of California, San Diego; *williamjamesary@gmail.com*
Form and Function of the Odontocete Ear
Toothed whales (odontocetes) have a sound reception apparatus that is specialized for underwater hearing and works in tandem with their biosonar system. The apparatus is composed of the internal acoustic pinnae and the bony tympanoperiotic complex (TPC). The internal pinnae are made of special acoustic fats and other tissues that form a waveguide, bringing sounds from the environment to the TPC, which contains the middle ear bones. The sound reception apparatus functions to filter and/or amplify incoming sounds depending on their utility to the animal. Across species, odontocete TPCs have a variety of shapes. These shapes are linked to function. We CT scanned TPCs from 8 species across the Odontoceti. Geometric Morphometrics techniques characterized the shapes of the TPCs. Vibrational analysis based on finite element models provided a family of "natural" or resonant frequencies for each TPC. These resonant frequencies provide insight into the animals' sense of hearing and the potential effects of anthropogenic sound.

P3.149A ASHLEY, N.T.*; ZHANG, N.; WEIL, Z.M.; MAGALANG, U.J.; NELSON, R.J.; Western Kentucky University, Bowling Green, KY, The Ohio State University, Columbus, OH; *noah.ashley@wku.edu*
Sleeping Dwarfs: Photoperiodic Modulation of Infection-Induced Sleep in Siberian Hamsters (Phodopus sungorus)
Infectious challenge or exposure to inflammatory stimuli, such as bacterial lipopolysaccharide (LPS), suppresses wakefulness and rapid-eye movement sleep (REMS) in favor of increased non-rapid eye movement sleep (NREMS). From a functional standpoint, these changes are hypothesized to conserve energy for immune system activation. Many vertebrates exhibit seasonal changes in sleep-wake cycles and immune function, and photoperiod (day length) serves as a reliable environmental cue to anticipate seasonal stressors in the environment. For example, winter is energetically demanding for most animals and Siberian hamsters (*Phodopus sungorus*) adapted to short winter day lengths display reduced febrile responses after LPS challenge. We hypothesized that short days increase the duration and intensity of NREMS after LPS challenge to create additional energy savings, despite evidence to the contrary that high fever is associated with increased NREMS. Male hamsters were housed under long (16L:8D) or short day lengths (8L:16D), and chronically implanted with transmitters that recorded electroencephalogram (EEG) and electromyogram (EMG) biopotentials simultaneously. After 10 weeks, hamsters received an i.p. injection of LPS or saline (control), and vigilance states (duration and distribution of NREMS, REMS, and wakefulness) and EEG delta power spectra (NREMS intensity) were assessed. Hamsters adapted to short photoperiods displayed cumulatively increased NREMS duration and EEG delta wave amplitude 0-8 h after LPS injection compared to long-day LPS-treated hamsters. These results suggest a seasonal decoupling of LPS-induced fever with sleep to promote energy conservation during predictable energy shortages.

P2.194 ASIMES, A*; ROTH, T.C.; Kenyon College, Franklin and Marshall College; *asimesa@kenyon.edu*

The behavioral and neurological effects of hypoxia during the embryonic development of domestic chicks (Gallus gallus)

Previous research suggests that hypoxia during critical periods of development leads to the impairment of cognitive ability and brain structure. However, it is not clear to what extent hypoxia occurring between critical periods has on both the behavior or brain morphology of chicks. We tested this question in developing chicken embryos by half-wrapping eggs with a membrane impermeable in oxygen. Eggs were forced hypoxic during two periods for 24h at incubation day 9 and 48h at day 13 (n =7; the traditional critical periods) or for 24h at day 11 and 48h at day 15 (n=5; a delayed period) and compared to a control without hypoxia (n=6). The goal was to determine to what degree delaying hypoxic insult eliminates its consequences, in relation to critical period exposure and no hypoxic exposure. Chicks were assessed for spatial, working memory and cognitive function 8 days after hatching using multiple behavioral tests. We also measured differences in brain structure through volumetric analysis of the medial cortex, hippocampus, and amygdaloid complex, which play an important role in memory function and fear. Our results show that chicks exposed to hypoxia during both periods had lower cognitive and spatial memory ability, as well as increased levels of neophobia. We discuss the effect of hypoxic conditions on volumetric changes to the brain. These results suggest that hypoxic insult can have varying and visible consequences depending on the timing of exposure during development.

6.2 ASTLEY, H. C.*; ROBERTS, T. J.; Brown University; *henry_astley@brown.edu*

Where's the catch? Examining the catch mechanism in anuran jumping using inverse dynamics.

Many animals use catapult mechanisms to produce extremely rapid movements for escape or prey capture, resulting in power outputs far beyond the limits of muscle. In these catapults, muscle contraction loads elastic structures, which then recoil to release the stored energy extremely rapidly. Many arthropods employ exoskeletal elements as a "catch mechanism" to lock the joint in place during the loading period, which can then be released to allow joint motion via elastic recoil. However, catapult mechanisms in vertebrates lack a clear anatomical catch. Several vertebrate catch mechanisms have been proposed, including a variable mechanical advantage at the ankle. In this mechanism, the muscle contracts at low mechanical advantage at first, which limits joint motion while the tendon stretches, followed by a transition to high mechanical advantage, which allows the tendon to recoil. To test this hypothesized catch mechanism, we collected simultaneous kinematics via XROMM and single-foot forces during the jumps of three *Rana pipiens*. We calculated joint mechanical advantage, torque, work, and power using inverse dynamics. Preliminary results show an increase in mechanical advantage at the ankle immediately prior to ankle extension, consistent with the variable mechanical advantage catch mechanism.

P3.191 ASTLEY, H. C.*; ROBERTS, T. J.; Brown University; *henry_astley@brown.edu*

The diversity and evolution of locomotor muscle properties in anurans

Anuran jumping is a model system for linking muscle physiology to organismal performance. However, anuran species display substantial diversity in their locomotion and morphology, reflecting their habitats (including aquatic, terrestrial, arboreal, and fossorial environments) as well as other factors (such as protective toxins). Some anurans are renowned for performing powerful leaps from riverbanks or tree branches, but other species move predominantly via burrowing, swimming, short hops, or even diagonal-sequence gaits. Many anurans with similar locomotion and morphology are actually convergent, with "tree frogs" and "walking frogs/toads" both evolving independently several times. On the other hand, closely related species may differ drastically, as with the bullfrog-like Bufo asper compared to other, more typical Bufonid toads. These multiple convergences and divergences allow us to examine the extent to which phylogeny constrains multiple muscle properties linked to locomotor performance, as well as the interdependence of these muscle properties. We hypothesized that traits which must be altered by changes to the muscle proteins (such as maximal shortening speed) would be strongly constrained by ancestry, while traits which can also be altered by changes in expression level (such as relaxation time) would show less constraint. We performed locomotor tests (jumping or running) on 32 total individuals of eight species of anurans, followed by in vitro tests on the semimembranosus and plantaris longus muscles. Preliminary results show significant variation in muscle properties across species, and the ongoing addition of more species to the dataset will allow explicit statistical testing of phylogenetic and functional influences on muscle properties.

P3.100 ATHERTON, S.*; HOCHBERG, R.; University of Massachusetts Lowell; *sarah_atherton@student.uml.edu*

Evolution of the Reproductive System of Urodasys (Gastrotricha, Macrodasyida)

Gastrotrichs are microscopic, hermaphroditic invertebrates with complex reproductive systems. In particular, species of Macrodasyida possess an array of accessory reproductive organs that function in sperm transfer and receival, but homology among the various organs is undetermined. The genus *Urodasys* includes thirteen species that form three "groups" based on the anatomy of their reproductive organs and their reproductive strategies: one group includes four species with paired testes and ovaries but no accessory sexual organs; the second group includes eight species with a single testis, paired ovaries and paired accessory reproductive organs; and the last group includes just a single species that is hypothesized to be parthenogenetic based on the absence of any testes or male reproductive organs. In this study, we investigate the phylogeny of the genus *Urodasys* using partial 28S rDNA sequences to gain insight into the evolution of the three different reproductive strategies.

100.12 ATUKORALLAYA, S; WATERFIELD, V; FRANZ-ODENDAAL, TA*; Mount Saint Vincent Univ; *tamara.franz-odendaal@msvu.ca*

Development of the maxillary dentition in teleost fish

During the vertebrate craniofacial development the first pharyngeal arch forms two prominences which eventually give rise to the maxillary and mandibular bones. In most vertebrates, including humans, maxillary and mandibular bones together with the premaxillary bone have teeth. Usually, odontogenesis in the maxillary and mandibular jaws initiate simultaneously, however in the Mexican tetra (*Astyanax mexicanus*) this process appears to be uncoupled. This small fresh water teleost fish is a good animal model to study the evolutionary development of craniofacial structures. Tetra fish have teeth on the mandibular, maxillary and premaxillary bones. The initiation of oral teeth is first observed at 44 hpf in the mandible and in the premaxilla, and the first oral teeth start to erupt around the 5 dpf. Interestingly, the maxillary teeth erupt much later in life at around 100 dpf. In this study we sought to find the cause for the temporal difference in tooth development in these two bones. Whole mount bone staining and histology were conducted to identify the tooth development stages in M. tetra in selected age groups. The gene regulatory network behind this delay in maxillary tooth development was analysed using in situ hybridization. Our study will shed light on the developmental events leading to odontogenesis in the maxillary bone in this species and will broaden our understanding of tooth development events that occur in the first pharyngeal arch derived bones in vertebrates.

P3.87 AUGUSTIRO, W.*; OCAMPO, G.; University of Hawaii, Manoa, California Academy of Sciences, San Francisco, California; *wendeea@hawaii.edu*

Morphological evolution within Miconieae (Melastomataceae): Insights from the Secundiflorae clade using morphometric data

The Melastomataceae is a large tropical to subtropical family with ca. 5000 species. One of its tribes, Miconieae, includes about 2200 species distributed exclusively in the Neotropics. Within Miconieae, generic circumscription has been problematic and molecular phylogenetic studies have shown that the genera are not monophyletic, suggesting that some characters used for circumscribing the genera are homoplastic. One of the retrieved clades, known as the Secundiflorae clade, has species that are morphologically similar, and the sizes of vegetative and reproductive characters overlap. To study size variation amongst the species of the Secundiflorae clade, DNA and morphometric data were analyzed for 12 taxa. Phylogenetic analyses of nuclear and chloroplast markers showed that the clade is strongly supported as monophyletic. Statistical analyses indicated that the species could not be separated out by morphometric data alone, which suggests a significant degree of overlapping values among species; therefore, morphometric data may not be helpful for segregating species along their entire distribution range. Comparative analyses showed that the morphometric data has no phylogenetic signal, but there is a positive correlation between adaxial leaf hair length and elevation, which suggests that some morphometric variation may have an adaptive component rather than a phylogenetic one. Additional taxa and traits may help to understand the variation within the Secundiflorae clade, which might, at the same time, be a reference for studying the morphological evolution in the highly diverse tribe Miconieae.

P3.136 AVILES, J.*; PENDAR, H.; SOCHA, J.J.; Virginia Tech; *javiles@vt.edu*

Respiratory flow control in darkling beetles: Testing the compartmentalization hypothesis

The tracheal system in some insect species is known to rhythmically collapse and re-inflate, creating bulk flow of air that augments gas exchange in the respiratory system. In darkling beetles, this dynamic compression of tracheal tubes occurs differentially within body regions: more tracheae collapse in the head and thorax than collapse in the abdomen. This pattern of tube collapse may result from the differential application of pressure within the body, enabled by functional compartmentalization of the thorax from the abdomen. Alternatively, if the hemolymph in the coelom is continuous throughout the beetle, the hydrostatic pressure of the hemolymph should be equal throughout, and the coelom can be considered to act as a single compartment. To test if darkling beetles exhibit functional compartmentalization between body regions, we inserted pressure sensors into the third abdominal segment and the thorax of live darkling beetles and recorded changes in pressure at a sampling rate of 100 Hz. Simultaneously, video cameras recorded abdominal pumping and tracheal tube collapse in the outer margins of the thorax. Beetles exhibited significant pressure pulses on the order of 0.2-1.3 kPa roughly every 10 seconds, followed by a period of relatively constant pressure. These pulses occurred simultaneously in both the abdomen and the thorax. However, the peak abdominal pressure was always greater (~30-80%) than that of thoracic pressure, contrary to expectation based on tracheal tube collapse patterns. The concurrency of pressure pulses in different regions of the body suggests that a single mechanism produces tracheal tube collapse, but the differences in peak pressure indicate that the beetle may possess a mechanism that functionally isolates hemolymph between the abdomen and thorax. Support by NSF 0938047 (JJS).

43.1 AZIZI, E.*; ABBOTT, E.M.; Univ. of California, Irvine; *eazizi@uci.edu*

Anticipatory motor patterns limit muscle stretch during landing in toads

To safely land after a jump or hop, muscles must be actively stretched to dissipate mechanical energy. Muscles that dissipate energy can be damaged if stretched to long lengths. The likelihood of damage may be mitigated by the nervous system if anticipatory activation of muscles prior to impact alters the muscle's operating length. Anticipatory motor recruitment is well established in landing studies and motor patterns have been shown to be modulated based on the perceived magnitude of the impact. In this study we examine whether motor recruitment in anticipation of landing can serve a protective function by limiting maximum muscle length during a landing event. We use the anconeus muscle of toads, a landing muscle whose recruitment is modulated in anticipation of landing. We combine *in vivo* muscle length measurements during landing with *in vitro* characterization of the force-length curve to determine the muscle's operating length. We show that muscle shortening prior to impact increases with increasing hop distance. This initial increase in muscle shortening functions to accommodate the larger stretches required when landing after long hops. These predictive motor strategies may function to reduce stretch-induced muscle damage by constraining maximum muscle length despite variation in the magnitude of impact. Supported by NSF grant 1051691.

P3.66 AZOFEIFA, J.G.; CHAPPELL, P.; WEIS, V.M.; SCHWARZ, J.A.*; Vassar College, Oregon State University; *joschwarz@vassar.edu*

Evolution of the LGR hormone receptor gene family in metazoans

Cnidarians exhibit cyclical patterns of gametogenesis and spawning, but it is not clear which genes play roles in establishing and controlling coral reproduction. We hypothesized that selected aspects of the cellular mechanisms used to establish reproductive cycles might be conserved across metazoans. We used a bioinformatic approach to identify cnidarian homologs of a set of vertebrate hormone receptor, hormone synthesis, and circadian and developmental genes. From a set of 15 initial candidate genes we identified unambiguous orthologs of only a handful of genes, with orthology of many of these complicated by gene duplication events through metazoan evolution. For example, the Leucine-Rich Repeat G-Protein Coupled Receptor (LGR) gene family in mammals functions as receptors for the hormones luteinizing hormone (LH) and follicle stimulating hormone (FSH). To get insights into whether cnidarian LGR homologs might play roles in controlling gametogenesis, we aimed to reconstruct the phylogenetic history and structure of the LGR gene family across metazoans. In addition to identifying gene duplication events that produced multiple paralogs of LGR genes in cnidarians, we also report a novel class of LGR from the sea anemone *Aiptasia pallida*. We also determine that unicellular sister taxa of metazoans lack LGR genes, and that they appear for the first time in early branching metazoans, specifially comb jelly (*Mnemiopsis leidyi*) and sponge (*Amphimedon queenslandica*). We have constructed the most comprehensive LGR phylogeny to date, elucidating gene duplication events and selective pressures on the amino acid sequence. Homology modeling of a predicted cnidarian ortholog of the LH/FSH receptor shows a similar protein fold to the human FSH receptor, suggesting a similar function in ligand binding.

71.1 BABONIS, L.S.*; MARTINDALE, M.Q.; Kewalo Marine Lab, Univ of Hawaii; *babonis@hawaii.edu*

Examining a cnidarian novelty: form and function of the nematosomes in Nematostella vectensis

Sea anemones in the genus *Nematostella* are unique among cnidarians in their possession of autonomous, motile, cell masses called nematosomes which circulate throughout the body cavity. Although they were first described many decades ago, neither the form nor the function of nematosomes has been studied in great detail. Using a combination of electron microscopy (TEM and SEM) and molecular biology we build on previous studies to describe the cellular composition of the nematosomes from *Nematostella vectensis*. Although nematosomes are thought to arise from mesenterial tissue, preliminary results suggested that these motile cell masses are composed of several cell types, potentially including cell types found only in the tentacles of *N. vectensis*. In light of these observations, we compared the cellular composition of nematosomes with that of the mesenteries and isolated tentacles. Using EdU (a BrdU analog), we demonstrate that some nematosomes undergo proliferation while inside the gastric cavity. We use the combined results of these studies to develop hypotheses regarding the origin and function of nematosomes in *N. vectensis*.

P1.187 BACHMAN, G; Univ. of Nebraska, Lincoln; *gbachman@unl.edu*

Cooling and Hibernation Effects on Leukocyte Numbers in the Ornate Box Turtle Terrapene ornata ornata.

Changes in circulating leukocyte numbers (heterophils or neutrophils, lymphocytes, and the ratio of these, H/L ratio) reflect immune system activity, stress, and seasonal effects. Winter can elevate the H/L ratio in endotherms due to seasonal increases in glucocorticoids although the H/L ratio decreases in hibernating mammals. In ectotherms, the H/L ratio may be elevated in winter. An elevated H/L in hibernating reptiles has been interpreted as an indication that hibernation is stressful. However the stress response includes changes that support increased metabolic rate, an impossibility in hibernating ectotherms. To begin to understand the functional role and potential causes of changes in leukocyte numbers in response to season and temperature in reptiles, I collected blood smears from active ornate box turtles in the field in summer, in hibernating captive turtles over winter, and from summer-active animals that had been cooled for 5 days to temperatures normally encountered only in winter. Smears were evaluated for the number of leukocytes per erythrocyte and the H/L ratio. Both winter and cold exposure in summer increased heterophil numbers, and because these dominated cell counts, total leukocyte counts were elevated in these samples. Lymphocyte counts are lower in hibernation than in summer , but cooling in summer did not alter lymphocyte numbers. H/L ratios were highest in winter and cooling in summer also significantly increased the ratio. Hematocrit did not differ between active and hibernating turtles. These results suggest that in this species, observed seasonal changes in leukocytes in circulation may be largely due to lowered body temperature, with either extended cold exposure or seasonal cues affecting only part of the leukocyte population.

P3.182 BACHMAN, GC; GIBSON, RM*; VLECK, CM; Univ. of Nebraska-Lincoln, Iowa State University; *rgibson2@unl.edu*

Elevated baseline but lowered stress-induced corticosterone titers during courtship display in a lekking bird

Stress responses of wild birds may be down-regulated if stress-induced re-allocation of energy away from ongoing activities would lower current or future fitness. Well studied contexts include molt, migration, and brood rearing. Energy allocation may also be critical during courtship, particularly if display reduces foraging time and/or elevates energetic expenditure as in lekking species. We investigated the possible modulation of stress responses during courtship in male Sharp-tailed grouse *Tympanuchus phasianellus* by characterizing sex differences and seasonal variation in the capture-induced stress response. We captured birds on leks using walk-in traps. Birds were bled within 3 min of trap entry and after 30 min for RIA of baseline and stress-induced corticosterone (CORT) titers. In mid-April, during the seasonal peak of female attendance and male display, baseline CORT was significantly higher in males than females whereas stress induced CORT was higher in females than males. Females, but not males, significantly elevated CORT in response to capture. Among males trapped throughout April there was no seasonal trend in baseline CORT, but stress-induced CORT titers exhibited a significant U-shaped relationship with date suggesting a reduced male stress response during the seasonal display peak. Stress-induced CORT was also lower in younger males. In the context of elevated baseline CORT, a lowered stress response could reduce allostatic overload in response to stressors such as frequent inter-male aggression and predator attacks. This interpretation implicates allostatic overload as a cost of sexually-selected lek display.

S5-1.5 BADYAEV, A.V.; Univ. Arizona;
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From emergence to evolution: Phenotypic integration of complex offspring sex-bias

Sex-bias in egg-laying order is a seemingly evolutionary impossible combination of precision, complexity, context-dependency, and reversibility. Yet, it is a common occurrence and a frequent starting point for a wide range of adaptive ecological and evolutionary phenomena - from the onset of behavioral strategies to the speed of acquisition of morphological adaptations. Such adaptive sex-bias is unlikely to be a product of coordinated genetic evolution of multiple players in the processes of egg production and sex-determination as this requires unrealistic expectations of evolutionary rates and population sizes and is not a desirable outcome for the process that needs to retain substantial environmental sensitivity. Recurrent deployment of conserved hormonal regulators throughout oogenesis can overcome some of these constraints, but introduces new ones - the necessity to reconcile general effects of hormonal regulation with required directionality and precision during particular stages. I will examine whether self-regulatory and emergent processes that govern the dynamics of oogenesis can produce non-random coordination of oocyte growth, ovulation order, and sex-determination under routine perturbations of shared physiological mechanisms, thereby significantly simplifying the evolutionary pathway to complex, precise, and reversible adaptations in sex-bias.

P2.48 BAETTIG, C. G.*; MILLER, L. B.; HASTINGS, P. A.; MEHTA, R. S.; Univ. of California, Santa Cruz, Scripps Institution of Oceanography, University of California, San Diego; *cbaettig@ucsc.edu*

Kinematics of Feeding in Sarcastic Fringeheads, Neoclinus blanchardi (Teleostei: Blenniiformes)

Suction feeding is the most prevalent mode of prey capture in teleosts. Despite this dominance, suction ability varies greatly among teleosts as a consequence of differences in skull morphology. For example, previous studies have shown that although larger mouths allow predators to take in larger prey, larger gapes generate less force than smaller gapes. We investigated the kinematics of feeding behavior in the sarcastic fringe head, *Neoclinus blanchardi*, a fish with enormous jaws used in dramatic "gaping displays" with conspecifics. Because of their large mouths we hypothesized that *N. blanchardi* uses a strategy of a ram suction feeder, relying on both suction and fast swimming bursts to overtake prey. We find the prey capture kinematics to be quite conserved in this species, with peak lower jaw rotation followed temporally by other peak events such as cranial elevation, hyoid depression, and average time to prey capture. Peak hyoid depression, however, is maintained for a significantly longer period than other kinematic variables. We categorize *N. blanchardi* as a ram suction feeder. Similar to other fishes for which suction feeding kinematics has been studied, the prey item does not move toward the predator's mouth until one gape width from the predator. Interestingly, *N. blanchardi* does not utilize its maximum gape during prey capture. Irrespective of its burst swimming speed, the sarcastic fringe head appears to only use half of its maximum gape to capture prey. This suggests that these fish are capable of modulating their gape size differently when feeding versus displaying to conspecifics.

P2.55 BAGGE, L.E.*; JOHNSEN, S.; Duke University;
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Looking at invisibility: anti-reflective structures and strategies in hyperiid amphipods

Transparency is a common camouflage strategy for animals inhabiting marine pelagic environments. Transparent species are almost perfectly invisible when viewed under ambient light conditions in the mesopelagic zone; however, at shallower depths, and under the bioluminescent searchlights of potential predators, transparent species may become visible due to reflections from their body surface. No study has yet explored whether any pelagic, transparent animals have developed specific adaptations to minimize surface reflections, though anti-reflection cuticular nanoprotuberances, which optically function as a gradient refractive index material, have been found in the eyes of butterflies and moths, and in transparent wings of moths. Our study uses scanning electron (SEM) and transmission electron (TEM) microscopy to investigate the cuticle of several species of pelagic, transparent hyperiid amphipods, *Phronima* spp. and *Cystisoma* spp. Preliminary results show that the appendages of *Cystisoma* spp. (n=2) are covered with an ordered array of papillae, 200-300nm in height. Interestingly, the dorsal surfaces of *Phronima sedentaria* (n=4) and *Cystisoma* spp. (n=2) are covered with a biofilm of densely aggregated sphere-shaped bacteria. Preliminary analysis suggests that the biofilm could effectively function to reduce reflectance of 500nm blue-green bioluminescent light, though future work is needed to further characterize and determine the refractive index of the biofilm.

28.6 BAHLMAN, JW*; SWARTZ, SM; BREUER, KS; Brown University; *joseph_bahlman@brown.edu*

The cost of performance: power cost and aerodynamic force generated by varying wingbeat kinematics

Bats display a wide range of flight behaviors, including steady flight, rapid acceleration, sharp turns, and load carrying. These behaviors require different combinations of lift and thrust, which are achieved by varying wing kinematics. Although the kinematics associated with different flight behaviors have been studied, it has not been possible to directly relate specific kinematic parameters to force production because flapping animals change multiple parameters simultaneously. To isolate the effect of specific kinematic parameters on aerodynamic force, and measure the energetic cost associated with each flapping motion, we designed, built, and tested a multi-articulated robotic bat wing that was instrumented to measure net lift, thrust, and mechanical power. During testing in a wind tunnel, we varied five kinematic parameters: four affecting wing motion (wingbeat frequency, wingbeat amplitude, stroke plane, downstroke ratio), and one affecting dynamic morphology (wing folding on upstroke). For each kinematic parameter, we described its relationship with net lift, net thrust, and mechanical power as the parameter varied across most of the range observed in the model bat species, *Cynopterus brachyotis* . Each parameter affected lift, thrust, and power in a different manner. For example, increasing amplitude produced additional force at a lower power cost than increasing frequency. Wing folding on the upstroke increased net lift and decreased power cost albeit with reduced thrust. The different relationships between kinematic parameters with lift, thrust, and power can inform modeling of how all the kinematic parameters can collectively be varied to produce the combination of forces required for different flight behaviors.

P1.213 BAILEY, A.M.*; LONG, K.L.; GREIVES, T.J.; ZHAO, S.; KRIEGSFELD, L.J.; DEMAS, G.E.; Indiana Univ., Bloomington, Univ. of California, Berkeley; *allibail@indiana.edu*

Seasonal Differences in RFamide Peptide Regulation of the Reproductive Endocrine Axis in Siberian Hamsters

Seasonally breeding animals use photoperiod to limit reproduction to favorable conditions. Changes in day length cause neuroendocrine adjustments in the reproductive endocrine axis, resulting in activation or suppression of reproduction. Recently, two RFamide neuropeptides, kisspeptin and RFamide related peptide 3 (RFRP-3) have been characterized as seasonal stimulatory and inhibitory regulators of the axis, respectively. We examined seasonal differences in gene expression of these peptides in the gonads and hypothalamus in Siberian hamsters (*Phodopus sungorus*). In long-day (LD) reproductively active males, expression of kisspeptin in the testes is constant over 30 weeks, whereas RFRP-3 expression increases over time. In short-day (SD) reproductively regressed males, kisspeptin expression similarly remains constant over 30 weeks, while RFRP-3 shows an initial maximum expression during reproductive regression and subsequently decreases. We assessed functional endocrine responses to kisspeptin and RFRP-3 by administering exogenous peptides in combination. In LD males, kisspeptin consistently stimulates the reproductive axis except when combined with a high dose of RFRP-3. In SD reproductively active males (i.e., SD non-responders), RFRP-3 appears to have a dose-response-like stimulatory effect on the axis, which is enhanced when combined with kisspeptin. These effects will subsequently be assessed in females. Collectively, these results will show the differential role of RFamides in regulating seasonal reproductive function and will broaden our understanding of the neuroendocrinology of seasonal breeding.

40.4 BAIRD, A.J.*; MILLER, L.A.; Univ. of North Carolina, Chapel Hill; *ajbaird86@gmail.com*

Tubular heart pumping in tunicates and other invertebrates.

Valveless tubular hearts transport hemolymph in many invertebrates with open circulatory systems. Tunicates such as Ciona intestinalis rely on bidirectional valveless pumping through a U-shaped heart tube. Research related to valveless fluid transport has described pumping in tubular hearts as either peristalsis (characterized by a linear frequency-flow relationship and active contractions down the length of the tube) or dynamic suction pumping (characterized by a nonlinear frequency-flow relationship and a localized region of active contraction). The immersed boundary method will be used to simulate the fully-coupled fluid-structure interaction problem. Corresponding experiments will be performed using dynamically scaled physical models of peristalsis and dynamic suction pumping. Womersley number and other parameters will be matched to the heart tube of Ciona intestinalis and other tunicates. The fluid transport efficiencies of each mechanism will be described over this parameter space. A new pumping mechanism that includes features of both traditional peristalsis and dynamic suction pumping will be introduced that incorporates the electrophysiology of the tubular heart.

4.1 BALABAN, JB*; SUMMERS, AP; WILGA, CAD; University of Rhode Island, University of Washington; *jbalaban@my.uri.edu*

Mechanical Properties of a Shark Jaw Support Structure

The upper jaws of elasmobranchs (sharks, skates, and rays) are not fused to the cranium as they are in tetrapods. Instead, they are suspended by 0-3 ligaments (none in skates and rays) anteriorly and a skeletal element, the hyomandibula (HY) posteriorly. The HY connects the cranium to the jaw joint and can have many orientations, shapes, and sizes depending on the clade. We know how the HY moves during feeding and, from bite force estimates and measurements we can estimate the forces acting on the HY. Here we present data on how well these elements withstand the stresses associated with the loads seen during feeding. We determined the mechanical properties of the HY of four species of sharks with different jaw orientations and feeding styles (bamboo shark, a suction feeder; smoothhound shark, a biter; sandbar shark, a biter; and dogfish, both suction feeder and biter. We used sonomicrometry to track local strain in the direction of loading and at 90 degrees to the loading direction. This allowed us to estimate both the stiffness of the material and its Poisson’s ratio. We also measured the cross sectional shape and the percent area of calcified cartilage to predict how well the element handles force in different directions. Our results show that despite large differences in size and shape, there is little difference between the effective mechanical properties of the HY in different species. It appears that to withstand larger forces the HYs increase in size without a changing in mechanical properties. This is in contrast to analogous results from the pelvic girdles of cartilaginous fishes. However, differences in the shape of the cross-sectional area and relative mineralization levels among species may lead to differences in the response among species to bending or tensile load.

P3.115 BALIGA, VB; Univ. of California, Santa Cruz; *vbaliga@ucsc.edu*

The Morphology and Ontogeny of Cleaning Behavior in Labrid Fishes

In fishes, cleaning is a mutualistic service whereby one species consumes the ectoparasites or diseased tissues of another species. Cleaners may be categorized as obligate or facultative. The vast majority of fishes are facultative cleaners: they clean mainly as juveniles, switching to another diet as adults. Using Labrid fishes, a clade containing both obligate and facultative cleaners, this study seeks to identify whether there are specific morphological adaptations associated with cleaning behavior in juvenile fishes and how these traits may change over ontogeny. I measured 6 characters describing body shape in obligate cleaners, facultative cleaners, and their non-cleaning relatives across ontogeny. I find that obligate and facultative cleaners do not separate from their non-cleaning relatives in morphospace as juveniles or adults. However, when examining ontogenetic scaling patterns of body shape, I find that cleaners, both facultative and obligate, undergo a larger number of allometric changes over ontogeny than non-cleaners. Most notably, the elongation ratio, (a ratio of total length to maximum body depth) of facultative cleaner species as juveniles overlaps in range with that of obligate cleaners. As these facultative cleaner species grow, their body shape becomes less elongate and there is little overlap with obligate cleaners, which maintain the same elongate body shape across ontogeny. This result indicates that a decrease in body elongation, which results in a deeper, less fusiform body, coincides with the transition away from cleaning behavior in facultative species. Adults with deeper and larger bodies may no longer be able to dart continuously along the bodies of potential clients as they clean ectoparasites, forcing the adults to change their diets.

P3.13 BALLI, S. *; DREW, R. E. ; University of Massachusetts Dartmouth; *sballi@umassd.edu*

Effect of aggression and social status on gene expression in rainbow trout

Aggression is an agonistic and costly behavior by which individuals compete for better resources and social status. This study examined the modulation of aggressive behavior in the establishment of social status in rainbow trout (*Oncorhynchus mykiss*). Subsequently, gene expression in the brain as a result of aggression and social status was also examined using quantitative polymerase chain reaction (qPCR). The behavior study was conducted on 12 dyads of juvenile rainbow trout from two inbred domesticated strains, Hot Creek and Arlee. The fish were allowed to compete for food and social status for 9 days and were sacrificed to analyze gene expression in the brain. Nine of the twelve dyads developed a clear dominant and subordinate relationship. During the establishment of social status, the overall frequency of aggressive encounters decreased. However, the aggressive interactions progressed from simple chase-away to physical harm. Corticotrophin-releasing hormone (*crh*) and neuropeptide Y (*npy*) genes were differentially expressed with respect to brain region and social status. From previous studies, these genes are known to influence food intake, stress and aggression. Region-specific expression of additional genes involved in aggression and social status are currently being analyzed by qPCR and *in situ* hybridization. This research will aid the understanding of possible genetic variation involved in modulation of aggressive behavior social status in fish and other vertebrates.

P2.68 BALUCH, DP; TRAYNOR, K; CEASE, AJ*; COLOUMBE, M; STOUT, V; SWEAZEA, K; Arizona State University, University of Sydney; *arianne.cease@sydney.edu.au*

Jumpstarting STEM Careers

A successful career in STEM (science, technology, engineering, mathematics) requires not only great classroom education and research experiences but also extensive training and preparation via great mentors and role models. To help promote this preparation, initiatives by the NSF, NIH and other funding institutions now require that post-doctoral mentoring plans be incorporated into funded research proposals to maintain a pipeline of future professionals. Women and minorities are especially affected by low rates of career advancement. Recent statistics show that women received over 40 percent of all BA/BS degrees awarded by U.S. 4-year colleges and universities in the life sciences. However, in the basic science departments of most medical schools and universities, the proportion of women associate professors is still below 30 percent, and the proportion with rank of full professor is only 20 percent. In an effort to address these concerns, the Central Arizona Chapter of the Association for Women in Science (AWIS), based at Arizona State University, in collaboration with colleagues from George Washington, Gallaudet and Ottawa Universities, has developed a program to help prepare graduate students, post docs and early faculty for a career in STEM. This NSF ADVANCE funded program tackles the problem of low career advancement of women and minorities by hosting a series of career development seminars and workshops to provide training, mentoring and networking opportunities to graduate students and post docs as they progress through their program of study. Such career training programs that include mentoring and networking will help address the complex problem encountered by women and minorities and thus will aid in restoring a pipeline of diverse STEM professionals.

126.4 BARAK, V*; BROWN, C; FASSBINDER-ORTH, C; Creighton University, University of Tulsa; *virginiabarak@creighton.edu*

Avian Adaptive Immune Responses to Buggy Creek Virus (Togaviridae: Alphavirus) and its Arthropod Vector, the Swallow Bug (Oeciacus vicarius)

Life history decisions such as reproduction, growth, and development result in variability in physiological responses among avian species and likely impact a bird's immune response to both macro and microparasites. Here we examine the adaptive, humoral immune responses of a native bird and an invasive bird to an arbovirus (Buggy Creek virus; Togaviridae: *Alphavirus*), and its ectoparasitic arthropod vector (swallow bug; *Oeciacus vicarius*). Swallow bugs are closely associated with the native, colonially nesting cliff swallow (*Petrochelidon pyrrhonota*) and the introduced house sparrow (*Passer domesticus*) that occupies nests in cliff swallow colonies. We measured levels of BCRV-specific and swallow bug-specific IgY levels before nesting (prior to swallow exposure) and after nesting (after swallow bug exposure) in house sparrows and cliff swallows in western Nebraska. Levels of BCRV-specific IgY increased significantly following nesting in the house sparrow, but not in the cliff swallow. Additionally, house sparrows displayed consistently higher levels of swallow-bug specific antibodies both before and after nesting compared to cliff swallows. These results indicate that significant differences in the immune response to this arbovirus and its arthropod vector exist between these two avian species. These immune response differences may be influenced by the life history characteristics of these avian hosts, and may help to explain the differences in disease susceptibility that exist between these two species.

S1-1.2 BARBER, Jesse/R*; KAWAHARA, Akito/Y; Boise State University, University of Florida; *jessebarber@boisestate.edu*

Anti-bat behavioral strategies and evolutionary routes in the escalation of the bat-moth arms race

Bat-insect interactions date back millions of years, and the shared evolutionary history between echolocating bats and nocturnal insects have resulted in a suite of unique defensive strategies. Tiger moths have escalated the arms race by beaming ultrasonic response signals back at bats. In tiger moths, these sounds have been shown to warn bats of bad taste, function in acoustic mimicry complexes and jam bat biosonar. We will discuss our recent discovery that hawkmoths also produce ultrasound in response to bat attack. Unlike tiger moths, hawkmoths are not chemically defended, only males produce ultrasound and the structure of the sound-producing organ varies greatly across the family. This raises the prospect that anti-bat ultrasound production may be linked to multiple additional behavioral strategies, including cross-family acoustic mimicry, advertisement of physical defenses and/or evasive flight; and that hawkmoth ultrasonic reply to bat attack has multiple independent evolutionary origins. We will consider data from three main technical approaches: 1) high-speed filming experiments of bat-moth interactions in the lab, 2) playback of bat echolocation attacks to moths in the field and 3) construction of an evolutionary tree built on molecular (DNA) data that we are using to examine the historical transitions of anti-bat ultrasound production.

48.5 BARIS, T.Z.*; OLEKSIAK, M.F.; CRAWFORD, D.L.; University of Miami/Rosenstiel School of Marine and Atmospheric Science; *tbaris@rsmas.miami.edu*

Evolution of Two Genomes: Impact of Sequence Divergence on Mitochondrial Function

We are investigating the divergence in oxidative phosphorylation (OxPhos) metabolism among populations of *Fundulus heteroclitus*. The OxPhos pathway occurs in mitochondria and uses oxygen to produce the majority of ATP in a cell. This pathway consists of 5 large enzyme complexes with 45 to 4 proteins per complex and is the only pathway in which the proteins involved are coded by both mitochondrial and nuclear genomes. *F. heteroclitus* populations have sequence divergence in OxPhos genes in both mitochondrial and nuclear genomes. These populations are distributed along a steep thermal cline on the east coast of the United States and have evolved by natural selection to adapt to this clinal variation in temperature. Thus, *F. heteroclitus* serve as a model species to enhance our understanding of the impact of nucleotide divergence on physiological function. The initial studies of OxPhos function used 96 individuals from six different populations of *F. heteroclitus*, and differences in mitochondrial respiration were measured using a high-resolution respirometer (Oxygraph-2k, Oroboros Instruments, Innsbruck, Austria). The fish from each population were acclimated to both 12°C and 28°C. Hearts were isolated from each individual, permeabilized, and assayed at 3 different temperatures (12°C, 20°C, and 28°C). Total mitochondrial respiration and individual enzyme complexes of oxidative phosphorylation were measured by addition of complex specific substrates and poisons. Differences among populations and temperatures will provide insights into the evolution and adaptation of natural populations.

104.2 BARNES, B.M.*; WILLIAMS, C.T.; BUCK, C.L.; Univ. of Alaska Fairbanks, Univ. of Alaska Anchorage; *bmbarnes@alaska.edu*

Circadian rhythms in free-living arctic ground squirrels.

In indigenous arctic reindeer and ptarmigan, circadian rhythms are not expressed during the constant light of summer or constant dark of winter, and it has been hypothesized that a seasonal absence of circadian rhythms is common to all vertebrate residents of polar regions. Here we show that, while free-living arctic ground squirrels do not express circadian rhythms during the heterothermic and pre-emergent euthermic intervals of hibernation, they display entrained daily rhythms of body temperature (Tb) throughout their active season which includes six weeks of constant sun. In winter, ground squirrels are arrhythmic and regulate core body temperatures to within +/-0.2 C for up to 18 days during steady-state torpor. In spring, after use of torpor ends, male but not female ground squirrels, resume euthermic levels of Tb in their dark burrows but remain arrhythmic for up to 27 days. However, once activity on the surface begins, both sexes exhibit robust 24-h cycles of body temperature. We suggest that persistence of daily rhythms through the polar summer enables ground squirrels to minimize thermoregulatory costs. However, the environmental cues (zeitgebers) used to entrain rhythms during the constant light of the arctic summer in these semi-fossorial rodents are unknown.

59.3 BARNETT, AA*; THOMAS, RH; Southern Illinois University; *abarnett@siu.edu*

The delineation of the fourth walking leg segment is temporally linked to posterior segmentation in the mite Archegozetes longisetosus (Acari: Oribatida, Trhypochthoniidae)

Acari (mites and ticks) lack external segmentation, with the only indication of segmentation being the appendages of the prosoma (chelicerae, pedipalps, and four pairs of walking legs). Acari also have a mode of development in which the formation of the fourth walking leg is suppressed until the nymphal stages, following a hexapodal larva. To determine the number of segments in the posterior body region (opisthosoma) of mites, and to also determine when the fourth walking leg segment is delineated during embryogenesis, we followed the development of segmentation in the oribatid mite *Archegozetes longisetosus* using time-lapse and scanning electron microscopy, as well as in situ hybridizations of the *A. longisetosus* orthologues of the segmentation genes *engrailed* and *hedgehog*. Our data show that *A. longisetosus* patterns only two opisthosomal segments, indicating a large degree of segmental fusion or loss. Also, we show that the formation of the fourth walking leg segment is temporally tied to opisthosomal segmentation, the first such observation in any arachnid.

P1.66 BARNETT, AA*; SCHMIDT-OTT, U; Southern Illinois University, University of Chicago; *abarnett@siu.edu*

Developing an RNA Interference Protocol for the Mite Archegozetes longisetosus

The establishment of methodologies that reveal the functions of genes and their products are necessary for understanding the evolution of developmental regulation and morphological novelties. RNA interference (RNAi) is one such method as it reveals a gene's function by disrupting its translation. Recent phylogenetic studies place the chelicerates as the most basally branching arthropod group, making developmental studies of chelicerates essential to understand arthropod evolution. Despite this, RNAi has been developed for only three chelicerate species, the spiders *Parasteotoda tepidariorum* and *Cuppiennius salei*, and the mite *Tetranychus urticae*. Acari (mites and ticks) are the most morphologically diverse and speciose chelicerate clade with over 55,000 nominal taxa and many as yet unnamed species, making Acari species an ideal choice for comparative studies. Besides *T. urticae*, the only other mite used for gene expression studies is *Archegozetes longisetosus*. However, RNAi protocols for this species are currently unavailable. *T. urticae* and *A. longisetosus* represent disparate mite lineages, which diverged prior to the mid-Devonian. This long period of independent evolution has resulted in drastically different body morphologies (e.g. the absence of genital papillae in *T. urticae*), feeding behaviors (particulate vs. fluid feeding), and life history strategies, (i.e., *A. longisetosus* maintains the pleisiomorphic Acari life cycle of a prelarva, larva, three nymphal stages, and the adult). Therefore, the morphological differences and similarities between these two species provide an excellent opportunity to study developmental plasticity and evolutionary novelty in Acari in particular, and arthropods in general. The objective of the research proposed is to develop an RNAi protocol for use on the mite Archegozetes longisetosus. Here we highlight the outcomes emerging from this work.

P2.101 BARRILE, G.M.*; BOWER, C.D.; DOWNS, L.K.; KLINGER, J.M.; MOORE, J.T.; KLINGER, T.S.; HRANITZ, J.M.; Bloomsburg University, Bloomsburg; *gmb98296@huskies.bloomu.edu*

A comparison of larval and post-metamorphic growth and development between island and mainland populations of Fowler's toad

Previous research documents island dwarfism in Fowler's Toad, *Anaxyrus* (formerly *Bufo*) *fowleri*, persists on Assateague Island for at least 22 years. Because of the scarcity of freshwater habitats on Atlantic Coast barrier islands, only a subset of the mainland amphibian communities inhabits these islands. Life history traits often adapt to local conditions within the range of the species. In 2011, we conducted pilot studies of several life history traits, including larval and post-metamorphic growth rates. We continued these studies of life history traits of *A. fowleri* in 2012, conducting a common garden experiment to investigate island and mainland larval growth rates under common conditions. We monitored tadpoles for growth rate, developmental rate, size at developmental stage, time to metamorphosis, and size at metamorphosis. Island and mainland tadpoles raised primarily in June did not show differences in growth and development. However, mainland tadpoles reared primarily in July significantly differed from the island and mainland tadpoles reared in June. We believe the temperature differences between June and July influenced tadpole growth and development. Since island and mainland eggs did not differ in size after fertilization, maternal effects were not coincident with source population. Since island and mainland toadlets grow and develop similarly to metamorphosis, we conclude that environmental factors contribute strongly to the dwarf body size in island toads. Toadlet post-metamorphic body sizes support this finding because body size differences are already apparent by July of the post-metamorphic growth season. Factors in either the larval or post-metamorphic environments may be responsible for the smaller body sizes of island toads.

P1.24 BARTHELL, J. F.*; HRANITZ, J. M.; REDD, J. R.; BREWSTER, T. N.; CHICAS-MOSIER, A. M.; DINGES, C. W.; HAYES, C. A.; RIVERA-VEGA, K. M.; WILLIAMS, M. I.; PETANIDOU, T.; WELLS, H.; University of Central Oklahoma, Bloomsburg University of Pennsylvania , Clarkson University, Oklahoma State University, Bowdoin College, Fordham University, College of New Jersey, University of the Aegean, University of Tulsa; *jbarthell@uco.edu*

Plant Competition in a Greek Island Ecosystem: A Perturbation Experiment

Flowering plants use nectar and other rewards to compete for pollinators. It is known, for example, that the ability to consistently attract large-bodied and strong-flying bees can be mediated by nectar standing crop levels within and between species. Yellow star-thistle, *Centaurea solstitialis*, is an effective competitor for pollinators in the western USA where it has realized an extensive native range expansion during the last century. However, in its native range, *C. solstitialis* occurs in relatively low densities and fails on average to attract large-bodied bee species like honey bees. Using a perturbation experiment to explore this phenomenon, visitation rates by flying Hymenoptera (bees, wasps, etc.) were observed in plots of *C. solstitialis* within an island ecosystem on Lesvos, Greece, after introducing flowers of the sympatric competitor, *Vitex agnus-castus*. The results indicate that even a short-term introduction of the competing *V. agnus-castus* (with its relatively high standing crop nectar volumes) can disrupt visitation patterns within pollinator guilds of *C. solstitialis*. Although mediated by densities of *C. solstitialis* in the study plots, this effect suggests that the range expansion of newly introduced flowering plant species, especially those requiring outcrossing, may be directly related to the competitive landscape these species encounter upon arriving in new environments.

P3.25 BARTLOW, C.*; LAMOREAUX, N.; STANTON, R.; PARIKH, N.; PERO, A.; RAUSCHMEIER, K.; HOFFMAN, T.; MARX, J.; PATEL, S.; SCEIA, K.; BIGGERS, W.J.; STRATFORD, J.; Wilkes University; *william.biggers@wilkes.edu*

GST Levels in Terrestrial Birds Show No Evidence of Contamination From Natural Gas Drilling

In 2011 and 2012, we captured nearly 500 birds of 20 species along streams in watersheds with and without active gas drilling. Glutathione s-transferase (GST) enzyme activity in animal tissues has been demonstrated to serve as a good indicator of oxidative stress as a result of exposure to environmental toxins. GST levels were not influenced by sex (Wilcoxon sign rank test, $W = 38$, $p = 0.89$) or mass (Spearman rank correlation, correlation = 0.38, df = 15, $p = 0.14$). Watershed type did not influence GST levels when all species were pooled together (Wilcoxon signed rank test, $W=62$, $p = 0.52$). When species that were unlikely involved in the stream food web were excluded, there was no effect of watershed type (Wilcoxon signed rank test, $W=20$, $p=0.82$). Our study focused on five species most likely to be exposed to any contaminants if present: common yellowthroats *Geothypis trichas* , grey catbirds *Dumetella carolinensis*, red-eyed vireos *Vireo olivaceus* , song sparrows *Melospiza melodia*, and tree swallows *Tachycineta bicolor*. What we have found thus far is primarly based upon data collected during 2011 and spring of 2012. At the present time we are continuing to analyze data that has been collected in the summer of 2012.

81.4 BARTOL, I.K.*; KRUEGER, P.S.; THOMPSON, J.T.; Old Dominion University, Norfolk, VA, Southern Methodist University, Dallas, TX, Franklin and Marshall College, Lancaster, PA; *ibartol@odu.edu*

Hydrodynamic gait identification in squid using volumetric flow imaging

Squids employ two fundamentally distinct mechanisms of propulsion, pulsed jetting and fin oscillations. Simultaneously quantifying complex wake vortex flows from these two systems and identifying coordinated gaits with speed related propulsive performance benefits is a significant challenge, requiring new technologies and approaches. With the goal of identifying coordinated hydrodynamic gaits, flows around brief squid *Lolliguncula brevis* swimming against a current in a water tunnel were visualized and quantified using a volumetric (3D) approach, known as defocusing digital particle tracking velocimetry (DDPTV). The 3D flows generated by the jet and fins were complex, with multiple vortex wake patterns being detected for both the jet and fins, ranging from isolated to interconnected vortex structures. To help identify distinct wake patterns, quantitative tools, including proper orthogonal decomposition (POD) and topological techniques using critical point properties, were used to analyze the wake measurements, and propulsive performance metrics were calculated. While significant variability was observed, especially for fin flows, several distinct wake patterns were identified, suggesting that our approach has potential for (a) assigning quantitatively meaningful metrics to qualitatively observable differences in wake features and (b) identifying true hydrodynamic gaits in swimmers with multiple propulsive systems. Funded by NSF grant IOS-1115110.

P2.148 BASHEVKIN, S*; GEORGE, S; Tufts University, Medford, Massachusetts, Georgia Southern University, Statesboro, Georgia; *georges@georgiasouthern.edu*

The ups and downs of life in a halocline: The behavior of P. ochraceus larvae after prior exposure to low salinity

The vertical distribution of planktonic larvae in the water column determines their horizontal displacement by currents. In recent years, the salinity in the Salish Sea has periodically dropped during summer months due to increased freshwater input from the Fraser River. Larvae of the sea star *Pisaster ochraceus*, a keystone predator of the intertidal zone, are especially vulnerable to these changes since they lack the ability to ion- or osmo-regulate. We examined the impact of prior exposure to low salinity on the behavior of *P. ochraceus* larvae in a halocline. We reared larvae in 20-22 (low salinity) or 30-32ppt (control) filtered seawater. At the bipinnaria stage, we introduced them into the top or bottom of haloclines comprised of 20ppt at the top and 30ppt at the bottom. Very few bipinnariae introduced either above or below the halocline were able to pass through to the other side, indicating that the halocline posed a major barrier to larval movement. In addition, low salinity larvae introduced above the halocline were trapped in the upper region of the column. Low salinity larvae changed their distribution in the water column at a much slower rate than control larvae, possibly indicating impaired swimming abilities. Reduced salinity in the Salish Sea could result in larvae arriving in unsuitable habitats since larvae developing in surface waters with lower salinity would be distributed differently in the water column and therefore carried elsewhere by currents. Due to impaired swimming abilities, they may be unable to pass through the halocline in search of food or to evade predators. Smaller *P. ochraceus* populations in the rocky intertidal could result in drastic changes to the ecosystem including a reduction in species diversity.

P2.149 BASHEVKIN, S*; DRIVER, P; GEORGE, S; Tufts University, Medford, Massachusetts, Georgia Southern University, Statesboro; *georges@georgiasouthern.edu*

Is the upward migration of Pisaster ochraceus larvae motivated by the presence of food at the halocline or the salinity they are acclimated to?

Salinity fluctuations are expected to become increasingly frequent in the Salish Sea in the Pacific Northwest due to glacial melting caused by global warming. The Salish Sea is characterized by a distinct stratified upper layer between 5 and 20 m depth with salinities of 20 to 30ppt at the surface. Thin phytoplankton layers are common in these stratified regions of the water column and have the potential to induce predator aggregation and increase trophic transfer. The present study addressed how brachiolaria larvae of *Pisaster ochraceus* respond to low salinity and the presence of a thin phytoplankton layer at the halocline. Four treatments with 2 replicates were set up: larvae reared in 20 and 30ppt were introduced into control columns and haloclines with and without the alga *Isochrysis galbana*. Brachiolariae reared in 30ppt aggregated in the halocline when food was present but those in 20ppt swam through the food patch to the top of the column. Brachiolariae from both salinity treatments remained lower in control water columns when food was present than when absent. These results indicate that the upward migration of *P. ochraceus* larvae may be primarily motivated by the search for food. The presence of algae in the water column can affect the vertical distribution of *P. ochraceus* larvae and therefore their horizontal displacement by currents. However, low salinity larvae swam through the food patch to reach their preferred salinity. These larvae might not benefit from thin phytoplankton layers situated in regions of high salinity. They might spend a longer time in the plankton, less time feeding, with a greater possibility of either being eaten or carried away from favorable sites to settle.

15.5 BASTIAANS, E*; MARSHALL, J; SITES, J; MORINAGA, G; SINERVO, B; Univ. of California, Santa Cruz, Weber State University, Brigham Young University, Clark University; *ejbastiaans@gmail.com*

Interpopulation variation in throat color morphs in an incipiently speciating lizard: From blue to white and back again?

Both color polymorphism and alternative reproductive tactics are associated with accelerated rates of speciation in several taxa. We document discrete variation in throat color, an important sexual signal, in the mesquite lizard (*Sceloporus grammicus*) species complex. Some populations within this complex exhibit orange, yellow, and blue color morphs in males, which are similar to color morphs that are associated with alternative reproductive tactics in related lizard species. However, several other populations of the *S. grammicus* species complex instead exhibit orange, yellow, and white throat color morphs in males. We previously found both types of color variation to be associated with variation in male aggressiveness, but the effects of blue and white coloration are opposite. Here, we place this interpopulation color variation into a phylogeographic context and discuss how it relates to previous hypotheses regarding speciation processes within the *S. grammicus* complex.

104.3 BATAVIA, M; University of California, Berkeley; *mbatavia@berkeley.edu*

The effects of day length, hibernation, and hibernaculum temperature on tooth morphology in the Turkish hamster (Mesocricetus brandti)

Ever-growing rodent incisors deposit dentin – one of the tissues comprising mammalian teeth – on a circadian basis; these daily dentin layers are visible both in histological cross section and on the medial surfaces of incisors. Hibernation disrupts the normal pattern of dentin deposition, and distinct hibernation marks have been documented in the incisor dentin of several rodent species. Little, however, is understood about the factors that influence hibernation mark morphology. We tested the effects of day length, hibernation, and hibernaculum temperature on incisor surface morphology in Turkish hamsters housed in one of four conditions: long days (LD) at 22°C, short days (SD) at 22°C, SD at 5°C, and SD at 13°C. Body temperature and torpor use were monitored with implanted radio transmitters, and teeth were examined postmortem. Teeth of SD hamsters had narrower, less distinct circadian increments than teeth of LD hamsters, and hibernation at both 5°C and 13°C was associated with very narrow, sharply defined increments. At 5°C the number and cumulative width of hibernation increments were related to number and cumulative duration of periodic arousals, although this relationship was not detected at 13°C. This investigation adds to a growing body of work on the effects of hibernation on hard tissue morphology, and has implications for the study of hibernation behavior in evolutionary and historical contexts.

S7-1.5 BATTELLE, Barbara-Anne; Univ, of FL, Whitney Laboratory for Marine Bioscience; *Battelle@whitney.ufl.edu*

What the clock tells the eye: Lessons from an ancient arthropod

Eyes are major targets for regulation by circadian clocks, but effects of circadian clocks on vision are not fully understood in any system. Among invertebrates, effects of circadian rhythms on eyes are perhaps best understood in the American horseshoe crab *Limulus polyphemus*. This animal uses its compound lateral eyes (LEs) to find mates, and it spawns at night and during the day. Behavioral studies suggest *Limulus* see at night nearly as well as during the day, and electrophysiological studies show that its LEs are dramatically more sensitive to light at night than during the day. Half the nighttime increase in LE sensitivity can be attributed to signals from central circadian clocks. Circadian signals reach the eyes via axons from central, clock-driven, efferent neurons that project through the optic nerves. These efferent neurons are active at night and silent during the day. When active, they release the biogenic amine octopamine which elevates cAMP in post synaptic cells. The effects of clock input on LEs are diverse. Clock input at night drives changes in LE structure that increase photon catch and electrophysiological properties of photoreceptors such that their signal to noise ratio increases. Recent evidence shows that clock input also influences the dark-adaptive biochemistry of photoreceptors. Rhabdomeral concentrations of several proteins critical for the photoresponse change significantly day to night. At night, the levels of opsin (Ops), the protein moiety of visual pigment, and the alpha subunit of the G protein activated by the visual pigment (Gqalpha), increase, and arrestin, the protein that quenches the photoresponse, decreases. Clock input is required for normal nighttime increases in rhabdomeral concentrations of Ops and Gqalpha and these effects are mediated by octopamine and activation of the cAMP cascade.

P1.171 BAUMGARTNER, MF; TARRANT, AM*; LYSIAK, NSJ; HANSEN, BH; ARUDA, AM; ALTIN, D; NORDTUG, T; OLSEN, AJ; Woods Hole Oceanographic Institution, SINTEF, Trondheim Norway, BioTrix, Trondheim Norway, Norwegian Univ. Science and Tech., Trondheim Norway; *atarrant@whoi.edu*

Identifying markers of preparation for dormancy and the terminal molt in Calanus finmarchicus

Calanus finmarchicus is an oceanic calanoid copepod that can enter dormancy during the last juvenile stage (fifth copepodid, C5) of development. In many locations, a portion of the population enters dormancy, while the remainder skips dormancy and molts into adults. Regulation of *Calanus* dormancy is poorly understood, and dormancy cannot be initiated reliably in the laboratory. To gain insight into *Calanus* dormancy, we sampled C5 copepodids from Trondheim Fjord, Norway every other day from May 1 to June 11, 2012. Unlike many heterogeneous oceanic populations, most individuals from this high-latitude fjord population are predicted to enter dormancy with relative synchronicity. As expected, we primarily observed early-stage individuals (C2-C4) during early May and C4-C5 individuals during June. The C5 copepodids were overwhelmingly in pre-apolysis molt phases, consistent with animals preparing for dormancy rather than proceeding directly toward the terminal molt and adulthood. We are using Illumina-based transcriptional profiling to compare gene expression patterns between early- and late-developing C5 copepodids with the goal of identifying a molecular signature of preparation for dormancy. We also collected laboratory-reared copepods on the day of molting from the C4 to the C5 stage. We sampled these animals daily throughout the C5 stage and monitored their within-stage molt phase, gonad maturation, and oil sac size. Transcriptional profiling is also being conducted on these cultured animals to identify genes that are diagnostic of progression toward the terminal molt and adulthood.

P1.19 BEAUCHAMP, K. A.*; CADIEN, D. B.; DUGGAN, R. M.; PILGRIM, E. M.; City of San Diego , County Sanitation District of Los Angeles County, City and County of San Francisco Department of Water, Power and Sewer, U.S. Environmental Protection Agency; *kbeauchamp@sandiego.gov*

Morphological and molecular investigation of species in the family Leptocheliidae (Crustacea: Peracarida: Tanaidacea) from the Northeastern Pacific Ocean

Crustaceans of the order Tanaidacea are abundant in soft bottom habitats in the Northeastern Pacific and measures of species diversity within this group are ecologically significant to ocean monitoring programs. Identification of species within the family Leptocheliidae is problematic due to their small size (1-3mm) and unresolved species concepts. For example, although <1>Leptochelia dubia1> has been identified worldwide the cosmopolitan distribution of this species is questionable. Specimens identified as <1>L. dubia1> are common in our samples along the California coast, however, limitations of current taxonomy only allow classification to a species complex level that may include several different species. In this study, we use a combination of traditional taxonomic procedures and molecular techniques to explore the systematic relationships of species in the genus <1>Leptochelia1> and related taxa. Specimens of <1>L. dubia1> Cmplx were collected at three sites: San Francisco Bay, Los Angeles Harbor and offshore of San Diego. Key morphological characters were analyzed for each individual using light and scanning microscopy. Phylogenetic analyses using the mitochondrial COI gene on the morphologically identified specimens are underway and will be compared with GenBank sequences of <1>Leptochelia1> species and other taxa in the family Leptocheliidae. In the future, we plan to add the nuclear histone 3 gene to the molecular analyses and include specimens from additional sites along the Northeastern Pacific and other geographic regions.

56.4 BEBUS, SE*; SMALL, TW; SCHOECH, SJ; University of Memphis; *sebebus@memphis.edu*

Developmental corticosterone exposure is correlated with exploratory behavior and learning flexibility in Florida scrub-jays (Aphelocoma coerulescens)

The level of corticosterone (CORT, the avian glucocorticoid), to which an individual is exposed during development can have long-term effects on personality and cognitive abilities. We quantified cognitive abilities and exploratory behavior of fourteen Florida scrub-jays (*Aphelocoma coerulescens*), 10-11 months of age, in a controlled, captive setting. We recorded exploratory behavior upon introduction to the test cage. Additionally, we tested each bird with a color association and a reversal learning task. These tasks required birds to locate food rewards buried in sand-filled wells of a particular color. Scrub-jays relied on color cues rather than location to find food rewards. Birds showed little variation in their ability to learn the color association. However, some birds more often visited empty wells after visiting reward wells, which may be indicative of increased exploratory behavior. Subsequently, we switched the reward color to evaluate reversal learning capability. Preliminary results show that the ability of birds to learn the color reversal was positively correlated with their baseline CORT levels as nestlings (i.e., taken at 11 days of age, n=10). Nestling baseline CORT levels also were positively correlated with both the latency to explore the floor of the cage and the time to first take food. Further measures of exploratory behavior are currently being analyzed. Plasma samples were also taken for baseline and stress responsiveness at capture and post-testing and these data will be presented as assays are currently underway.

128.4 BECK, M. L.*; HOPKINS, W. A.; HAWLEY, D. M.; Virginia Tech; *beckmic@vt.edu*

The effects of trace element exposure on tree swallow reproductive success and stress response following remediation of a coal-fly ash spill

Coal combustion waste contains elevated concentrations of numerous trace elements that pose health risks to humans and wildlife. Exposure to elevated concentrations of these elements can cause teratogenic effects, reproductive failure, altered hormonal responses, and aberrant reproductive behavior in wildlife. We examined the reproductive success of adult tree swallows and the morphology and stress response of their nestlings following remediation of a large coal-fly ash spill in TN, USA. Most eggs and nestlings in the remediated colonies had element concentrations below levels that cause adverse physiological and developmental effects in other species. Exposure to these low concentrations of trace elements did not affect clutch size and fledging success and did not affect nestling body size and body condition prior to fledging. Exposure to a period of unseasonably cold weather negatively affected reproductive success across colonies but these effects were greatest at two remediated and one reference colony that was disturbed by a nearby marina. We found that basal corticosterone concentrations of nestlings did not differ among reference and contaminated colonies but that following handling restraint the induced and fold-increase in corticosterone concentrations was suppressed in nestlings from some contaminated colonies. Taken together, our results suggest that exposure to residual trace elements following remediation efforts may have subtle physiological effects on nestlings but that reproductive success of swallows is not being adversely affected.

P3.106 BECKER, EA*; SCOTT, R; WEBB, JF; University of Rhode Island, URI; *emily_becker@my.uri.edu*

Diversity of Adult Lateral Line Morphologies is not Explained by Differences in Neuromast Patterning in Two Lake Malawi Cichlids

The diversity found in the lateral line (LL) system of fishes has been attributed to differences in the pattern and timing of development. However, few studies have compared LL development in closely related species characterized by divergent adult morphologies. LL development occurs in three phases: neuromast differentiation and patterning, neuromast maturation (changes in size, shape), and canal morphogenesis. Thus, we asked - during which phase(s) of LL development do interspecific differences in adult lateral line morphology become apparent? We used fluorescent mitochondrial dyes to visualize hair cells in order to describe cranial neuromast distributions in ontogenetic series (hatch through >100 dpf) of two Lake Malawi cichlids, *Aulonocara stuartgranti* (widened canals) and *Tramitichromis* sp. (narrow canals). *Aulonocara* grows faster and hatches with more canal and superficial neuromasts than *Tramitichromis*. *Aulonocara* has a full set of mandibular (MD) canal neuromasts well before they appear in *Tramitichromis*, but a full complement of neuromasts in the other cranial canals are present at an earlier age in *Tramitichromis* than in *Aulonocara*. Early appearance of MD neuromasts in *Aulonocara* may be related to their role in prey detection (Schwalbe, et al., 2012). Despite differences in adult LL morphology, larval *Tramitichromis* and *Aulonocara* have the same number and distribution of canal neuromasts, but *Tramitichromis* has more superficial neuromasts, which are found in the same linear series or clusters as in *Aulonocara*. Thus, these two species demonstrate the same initial patterning of neuromasts, but differences in adult LL morphology are due to the subsequent processes of superficial neuromast proliferation, canal neuromast maturation, and LL canal morphogenesis. Supported by NSF grant IOS-0843307 to JFW and NSF EPSCoR Cooperative Agreement #EPS-1004057.

145.3 BEDORE, CN*; MCCOMB, DM; FRANK, TF; HUETER, RE; KAJIURA, SM; Florida Atlantic University, Ocean Classrooms, Nova Southeastern University, Mote Marine Laboratory; *cbedore@fau.edu*

Effects of temperature and anesthesia on visual temporal resolution in elasmobranch fishes

An organism's ability to track moving objects, or temporal resolution, has been correlated to habitat and lifestyle, and can be further modulated by temperature and light intensity fluctuations within the environment. Photopic (bright-light/day time) vision is typically faster than scotopic (dim-light/night time) because visual sensitivity is greater in dim light and integration time must be slowed to allow for capture of the maximum number of photons. Higher temperatures result in increased temporal resolution in both endothermic and non-endothermic fishes. Previous studies have used either anesthetized or paralyzed fishes to determine temporal resolution, measured as the maximum critical flicker fusion frequency (CFF_{max}). However, sedation with the anesthetic, tricaine methanesulfonate (MS-222), is thought to suppress sensory system responses, although empirical evidence is lacking. Therefore, we quantified scotopic and photopic CFF_{max} in the yellow stingray, *Urobatis jamaicensis*, at the extremes of its temperature range, 20°C and 30°C, and immobilized with anesthesia, MS-222, or a paralytic, Pavulon. Both low temperature and anesthesia (MS-222) reduced CFF_{max}. With an increase of 10°C, CFF_{max} doubled from 12Hz to 25.3Hz (photopic) under Pavulon, whereas CFF_{max} increased by only 4Hz, from 6.7Hz to 10.7Hz (photopic) under MS-222 anesthesia. In general, MS-222 anesthesia minimized the effects of both temperature and light-adaptation compared to Pavulon. Yellow stingray CFF_{max} was similar to the skate, another benthic batoid, but slower than shark species studied with the same technique. These results illustrate the effects of light adaptation, temperature, and anesthesia on visual function within the elasmobranch fishes.

69.6 BEERS, J.M.; Stanford University; *jbeers@stanford.edu*

Relationships between hemoprotein expression and cardiovascular physiology of Antarctic notothenioids: form, function, and future implications.

Antarctic notothenioid fishes have been exploited by scientists for decades as classic Krogh-style models with which to study cold-adapted physiological traits. Some of the most fascinating discoveries have come from studies focused on one particular group of notothenioids, the white-blooded icefishes (Family: Channichthyidae). Noted for their complete lack of hemoglobin, and also myoglobin in some species, these animals have partially compensated for the loss of oxygen-binding proteins by utilizing several enhanced cardiovascular features. One such characteristic is the presence of vast blood vessel networks, evidenced most strikingly in the eyes. Findings have shown that retinal vascular densities are inversely correlated to the amount of hemoglobin in the blood, thus suggesting a relationship between heme protein expression and oxygen supply/demand in the highly aerobic retina. Interestingly, data indicate that the development of the elaborate vascular patterns that we see in the eyes of present day icefishes may have arisen via a cellular route of nitric oxide-mediated angiogenesis. Implications for this finding hold importance because this cell signaling pathway is fundamental to most, if not all, vertebrate animals, and thereby allows us to explore questions that may have potential biomedical applications. Furthermore, the unique cardiovascular physiology of icefishes may prove costly because the adaptations for life in the stably cold, well-oxygenated waters of the Southern Ocean might reduce the tolerance of these fish to high temperature. Indeed, icefish have significantly lower thermal tolerance than their red-blooded counterparts, which could place these animals in a precarious position with regard to future climatic warming.

P1.108 BELANICH, J.R.*; SECOR, S.M.; University of Alabama, Tuscaloosa; *jrbelanich@crimson.ua.edu*

Postprandial metabolic response and specific dynamic action of scorpions

A mandatory physiological response to meal digestion and assimilation is an increase in metabolic rate; the accumulative cost of which is referred to as specific dynamic action (SDA). Whereas SDA has been examined for a wide spectrum of invertebrate and vertebrate groups, there has been relatively little attention paid to the postprandial metabolic responses of arachnids. In this study we characterize the postprandial metabolic profile of six scorpion species, (*Centruroides sculpturatus, Hadrurus arizonensis, Heterometrus longimanus, Hottentota trilineatus, Opistophthalmus whalbergi,* and *Pandinus imperator*) representing three families following their consumption of crickets. Body mass of scorpions ranged 0.8 g for *C. sculpturatus* to 17.5 for *P. imperator* and meal sizes ranged from 4.6 to 19.5% of scorpion body mass. All scorpion species responded with a rapid increase in metabolic rate that peaked at six hours after feeding before declining and returning to prefeeding rates within three days. Postprandial metabolic peaks ranged from 1.8 to 5.3-fold of SMR and did not necessarily correlate with relative meal size. SDA ranged from 15 – 297 J and was largely determined in magnitude by body mass, however mass specific SDA was significantly greater for the smaller species. The SDA coefficient (percentage of meal energy equivalent to SDA) ranged from 2.4 for *O. whalbergi* to 11.4 for *C. sculpturatus*.

119.4 BEN-HAMO, M*; BURNS, DJ; BAUCHINGER, U; MUKHERJEE, S; EMBAR , K; PINSHOW, B; Ben-Gurion University of the Negev, University of KwaZulu-Natal; *miri.benhamo@mail.huji.ac.il*

Behavioral and Physiological Responses during Feather Replacement in House Sparrows

All birds lose feathers, whether during molt or by accident, and replace them by processes that are energetically demanding. We hypothesized that house sparrows, *Passer domesticus biblicus*, use both physiological and behavioral mechanisms to reapportion their resources among competing functions that change when feathers are lost. We tested two predictions: 1) Sparrows growing new feathers adjust their behavior to minimize the energy costs of foraging and to increase net energy gain from their food; and 2) since house sparrows are known to carry limited energy reserves, when regrowing lost feathers they use facultative nocturnal hypothermia to save energy. To test these predictions we divided sparrows into three groups: 1) Plucked - sparrows from which we plucked 15 specific feathers; 2) cut - sparrows in which the same 15 feathers were cut off at the calamus below the barbs; and 3) control - unmanipulated sparrows with plumage intact. We recorded the amount of seeds the sparrows ate when they foraged in artificial food patches, and continuously recorded their body temperatures (T_b) by telemetry. We found that plucked sparrows growing new feathers adjust their foraging behavior by decreasing vigilance and increasing their effective encounter rate with seeds. However, these sparrows did not use facultative nocturnal hypothermia. In fact, their nighttime T_b increased significantly compared to the cut and control groups. We attribute the increase in nighttime T_b to increased metabolism during feather regrowth.

P1.76 BENDRICK-CHARTIER, E.M.*; LEUNG, N.Y.; OAKLEY, T.H.; Univ. of California, Santa Barbara, UCSB; *ellabc@gmail.com*

Localized inhibition of cnidocyte firing by light in the sea anemone Anthopleura sola

Firing of complex, engergetically expensive cnidocytes is influenced by chemosensory and photosensory cues in cnidarians, but the organismal function of the light behavior remains unknown. As previously shown in *Hydra magnipapillata*, we demonstrate that light environment affects cnidocyte firing behavior in the sea anemone *Anthopleura sola*. When mechanically stimulated, bright light inhibits firing compared to dim light. We illuminated half of each anemone with various LEDs (470, 510, 600, and 635 nm) and quantified the microbasic p-mastigophore (mpm) cnidocyte firing response in illuminated and shaded regions of the animal. We captured more mpm nematocysts from shaded regions of the animal than from illuminated regions. Therefore light inhibition of cnidocyte firing is a localized response that can differ among regions of the anemone. This photosensory response differs from chemosensory responses, which were shown previously in *Haliplanella luciae* to be integrated systemically. The absence of an integrated light response may inform the organismal function of the light behavior. First, a localized response would be unnecessary if light is being used as a diurnal signal to maximize firing during night time, when zooplankton prey are likely to be more abundant. Second, even though some genetic components of phototransduction and chemotransduction are shared in Cnidaria, the differing organismal responses suggest the genetic cascades are decoupled. Third, a localized light response is consistent with local shadows cast by prey increasing firing propensity. Fourth, a localized light response could mediate differential investment in "hunting" for regions of the animal in dim light that cannot make strong use of photosynthetic symbionts. Firmly establishing the organismal function of light-mediated cnidocyte firing will require further experimentation.

36.2 BENNETT, MM*; OWINGS, A; YOCUM, G; RINEHART, J; GREENLEE, K; North Dakota State University, Fargo, United States Dept. of Agriculture, Fargo, United States Dept. of Agriculture, Fargo; *meghan.bennett@ndsu.edu*

Flight metabolic rate as an expression of quality in temperature stressed alfalfa leafcutting bees, Megachile rotundata

The alfalfa leafcutting bee,*Megachile rotundata* F.(Hymenoptera: Megachilidae)is a solitary species that develops inside a maternally constructed brood cell. Pre-pupal *M. rotundata* diapause over winter and resume development as ambient temperatures increase. Environmental cues are known to initiate biological processes in many insects, allowing better survival of anticipated stressors, such as temperature fluctuations. However, insects are limited in their ability to deal with extreme temperature fluctuations when not in a diapausing state. To better understand how temperature fluctuations during juvenile development affect adult physiology, we exposed pupal *M. rotundata* to one of three temperature treatments and assessed changes in adult flight physiology. Pre-pupae were reared normally at 29°C for 14 days. At that point, some insect development was interrupted for 1 week by placement in either constant 6°C or 6°C with a 1h daily pulse of 20°C (FTR). Pupae were returned to 29°C and allowed to develop to adulthood. Because insect flight is metabolically expensive and is essential for success for the next generation, flight metabolism was used to indicate quality. Flight metabolic rates were measured using flow through respirometry. When compared to uninterrupted or FTR development, females from constant 6°C had higher metabolic rates, while males from constant 6°C had lower metabolic rates. Surprisingly, 53% of bees from the 6°C group were unable to fly and had morphological defects. These data suggest that interrupting bee development with placement in a constant 6°C, a common rearing method, negatively affects adult bee physiology.

62.1 BENTLAGE, B; University of Maryland; *bastian.bentlage@gmail.com*
Species distributions in the open oceans: integrating distribution models and population genomics
Population genetic and phylogeographic studies have uncovered strong population structuring and previously unrecognized amounts of cryptic sibling species in many marine habitats. In the open oceans, most studies have investigated patterns of population structuring and species diversity for the uppermost parts of the water column. These patterns can be explained using present-day environmental discontinuities of water masses. The deeper parts of the open ocean water column (the mid-water) have been largely neglected due to the difficulties of sampling this environment. I present a case-study integrating three-dimensional correlative ecological niche modeling with population genomics that investigates population genetics of hydrozoan jellyfish (Cnidaria: Medusozoa) that inhabit the open oceans, in particular mid-water habitats. Ecological niche modeling was employed to predict the ranges of suitable habitat in the open oceans to make predictions about present-day geographic distributions of hydrozoan jellyfish and the sub-structuring of their populations. Population genomic data are then used to test these geographically explicit hypotheses of population structure. Preliminary results suggest that species inhabiting deep waters display little genetic differentiation among distant populations while shallow water inhabiting species display strong population genetic structuring.

146.1 BENTLEY, GE*; PERFITO, N; CALISI, RM; UC Berkeley; *gb7@berkeley.edu*
Season- and context-dependent sex differences in melatonin receptor activity in a forebrain song control nucleus: comparison of data from the laboratory and a semi-natural environment
There are dense populations of melatonin receptors in large areas of the songbird brain, in particular in the visual system and the song control system. Melatonin has therefore been implicated in neuroplasticity of the song control system. Previously we demonstrated extremely large changes in activity of melatonin receptor in Area X, a forebrain song control nucleus that is important for song learning and production. In a laboratory environment, melatonin receptor activity was drastically down-regulated in male and female European starlings during photostimulation (a simulated breeding season). The functional significance of this large change in Area X is unclear, so we sought to elucidate it by tracking melatonin receptor activity in male and female starlings housed in a semi-natural environment and permitted to breed. Males and females all exhibited high melatonin receptor activity in Area X during short days at the start of the breeding season, and maintained this high activity during photostimulation until females laid eggs. At this point the females down-regulated melatonin receptor activity in Area X, whereas the males maintained high activity until later on in the breeding season. Overall, we observed a gradual termination of melatonin receptor activity in Area X as the breeding season progressed, but the timing of the termination was different between the sexes. Our data contrast with those collected in a laboratory environment, and highlight the need for studying brain and behavior of wild species in as natural an environment as possible if we are to understand the significance of any observed effects.

P2.211 BERESIC-PERRINS, R.K.*; GOVEDICH, F.; ROSE, D.; SHUSTER, S.M.; Northern Arizona Univ., Southern Utah Univ.; *rkb32@nau.edu*
A description of a new Helobdella (Hirudinoidea: Glossiphoniidae) species, Helobdella blinnii found in Montezuma Well, Arizona
A new leech species of the genus *Helobdella* has been recorded within Montezuma Well, an isolated travertine well found in central Arizona. *Helobdella blinnii* was first described as *Helobdella stagnalis*, which is a common leech found in lakes and streams in Europe and North America. *H. blinnii* morphology includes: six pair of testisacs, five pair of smooth crop caeca,one lobed pair of caeca posteriorly directed, one pair of eyes, a nuchal scute, diffused salivary glands, and their color ranges from light to dark brown, whereas. *H. stagnalis* have 6 smooth crop cacea and are transparent to a light grey color. They have 1 to 11 offspring from 7 to 11 white eggs per brood, which differs from *H. stagnalis*, which, on average, have twice as many offspring and the eggs are pink in color. *H. blinnii* breed year-round, with peak breeding bouts in the fall and spring. *H. stagnalis* breeds only in the summer months. Molecular analysis was performed by sequencing the cytochrome c oxidase subunit I (COI) and nicotinamide adenine dinucleotide dehydrogenase subunit I (NDI) mtDNA gene regions to investigate whether *H. blinnii* differs genetically from other *Helobdella* species (collected from GenBank) and close known populations of *H. stagnalis* located within the same region as Montezuma Well. We concluded that *H. blinnii* differs morphologically, behaviorally and genetically from other *Helobdella* species and is endemic to the unique environment of Montezuma Well.

129.5 BERG, O*; HOLZMAN, R; BROWN, M D; OLAIVAR, A F; MULLER, U K; California State University, Fresno, Tel Aviv University; *umuller@csufresno.edu*
Fluid mechanics of the bladderwort feeding strike: 0 to 60 mph in 1 millisecond
The aquatic bladderwort *Utricularia gibba* captures zooplankton in mechanically triggered underwater traps. With characteristic dimensions less than 1 mm, the trapping structures are among the smallest known that work by suction—a mechanism that would not be effective in the creeping-flow regime. In order to understand the adaptations that make suction feeding possible on this small scale, we have measured several dozen *U. gibba* suction events by digital Particle Image Velocimetry. The spatial distribution of fluid speed identifies the external flow as inviscid, as generally observed for adult fish. We have furthermore characterized the internal flows by tracking particles at frame rates up to 50 000 per second. These results diverge from observations in fish: the fluid is accelerated from rest at an extraordinarily rate (up to 25 000 m/s^2) to reach a peak speed of 5 m/s, ensuring that the internal flow is also inviscid. Thus the short duration of the strike out-paces the development of a boundary layer, creating a fast and energy-efficient inward jet. The dynamics are well described by a time-dependent Bernoulli equation in which the action of the trap door is represented by a step increase in driving pressure. The limiting flow speed is shown to depend only on this pressure, while the initial acceleration is determined by pressure and channel length. The flow is effectively inviscid because less than 20% of steady-state power is lost to friction. Frictional losses increase rapidly with decreasing channel diameter, setting a lower limit on practical bladderwort size.

P1.98 BERG, CL*; CHOW, JS; MCGEE, MD; WAINWRIGHT, PC; University of California, Davis; *clberg@ucdavis.edu*
Divergent feeding kinematics in two Amazonian cichlids
The Amazon Basin represents a hotspot of fish diversity and contains the largest number of freshwater species in the world. In this study, we examine the kinematics of feeding in two Amazonian cichlids with similar habitats but divergent morphology, *Pterophyllum scalare* and *Crenicichla strigata*. *P. scalare* have deep heads with small mouths suitable for picking prey off the underside of floating vegetation. In contrast, *C. strigata* have elongate heads and large mouths, and are ambush predators that typically dart out from vegetation to strike at passing prey. Using a Fastec HiSpec 1 camera system, we recorded video at 2000 frames per second of multiple *P. scalare* and *C. strigata,* capturing small fish (*Danio rerio*, *Tanichthys albonubes*) introduced individually via a feeding tube. We then digitized each video with a custom modification of the program Dltdv3 in MATLAB, tracking eleven points on the fish and prey item throughout the duration of the strike. We analyzed kinematic patterns using mixed models and generated p-values for the fixed effects of size (head length) and species using 10,000 Markov Chain Monte Carlo samples in R. With the exception of a higher maximum jaw protrusion, *P. scalare* displayed less cranial kinesis than *C. strigata*, including smaller maximum gape, head elevation, and jaw rotation. However, *P. scalare* possessed both shorter timings and higher velocity movements for gape, head elevation, jaw protrusion, and lower jaw rotation. Our data suggests that despite their similar habitats, these cichlids exhibit extreme kinematic divergence.

P3.10 BERGMAN, D.A.*; SLIGH, S.; GOOTE, P.; Grand Valley State University; *bergmand@gvsu.edu*
Crayfish Feeding on Zebra Mussels: An Assessment of Feeding Efficiency Related to Cluster Size
The expansion of zebra mussel distribution into inland waterways of North America has created significant abiotic and biotic challenges. Zebra mussels foul a wide array of submerged substrates including rock surfaces, plants, native bivalves, dock walls, and watercraft. Fouling of water intake pipes and associated installations can severely impair water delivery to hydroelectric, municipal and industrial users making proactive or reactive control measures necessary. Mussels increase water clarity by removing suspended clay, silt, bacteria, phytoplankton, and small zooplankton. This focuses nutrients into the bottom of lakes away from much of the food chain and also causes increases in cyanobacterial toxins due to increased growth of blue-green algae. However, mussels are exploited by a host of predators, most notably waterfowl, fish, and crayfish. They can return some of the nutrients to the food chain, but unfortunately even with predation much of the nutrients remain at the bottoms of lakes. We have tested one native Michigan crayfish species (*Orconectes propinquus*) for feeding responses when given an opportunity to interact with clusters of zebra mussels to ascertain their abilities in handling and consuming invasive mussels.

112.3 BERGMANN, P.J.*; MCELROY, E.J.; Clark University, College of Charleston; *pbergmann@clarku.edu*
Many-to-many mapping of phenotype on function, and the F-array
Relationships between phenotype and function are often complex, involving trade-offs, facilitations, redundancies, and traits that influence only one aspect of function. In systems with multiple phenotypic parts and multiple functional capacities, phenotype-function relationships are frequently very complex. For example, trade-offs, facilitations, redundancies, and unique relationships can interact with one another, influencing the rate of evolution of the various phenotypic and functional traits, and creating “functional lines of least resistance” to evolution. Although it is well known that trade-offs limit the rate of functional and phenotypic evolution, and it has been shown that redundancy can ameliorate these trade-offs, we find that facilitations and unique phenotype-function relationships also play roles in ameliorating trade-offs, sometimes more effectively than redundancy. We term the complex relationships between multiple aspects of phenotype and multiple aspects of function many-to-many mapping. We apply the F-matrix approach for relating basic limb morphology to locomotor performance in a series of Phrynosomatine lizards to illustrate this concept. We also make suggestions for dealing with the problem of multicollinearity in functional morphology datasets, and for placing the F-matrix approach in a comparative context.

28.3 BERGOU, A; FRANCK, J; TAUBIN, G; SWARTZ, S; BREUER, K*; Brown University; *abergou@gmail.com*
How do bats turn?
An animal's ability to effectively maneuver is crucial to its survival. The importance of maneuvering is especially evident amongst flying animals, which have evolved a particularly impressive collection strategies. One of the simplest, yet most important, maneuvers amongst flyers is their ability to reorient their heading - or body yaw - in flight. Recently this mode of maneuvering has been investigated for several species of insects and birds showing a diverse array of evolved mechanisms to perform this simple maneuver. Here, we revisit this classical maneuver and investigate how bats perform low velocity turns. We use a model-based tracking framework to reconstruct detailed wing and body kinematics of maneuvering bats from high-speed video. Using this data, we simulate the aerodynamic forces on the wings of bats using both quasi-steady and direct numerical simulations. In turn, we use these aerodynamic models to construct integrated simulations of a bat to discern the mechanism that bats use to turn.

2.4 BERGSTROM, C.A.*; PACHECO, J.; FRITZ, T.; University of Alaska Southeast; *cabergstrom@uas.alaska.edu*

Functional morphology and swimming performance in flounder: are left-sided fish faster?

Performance consequences of morphological variation within species set the stage for ecological selection to occur. In fishes, variation in body shape is known to affect swimming performance, leading to changes in ecological interactions such as predator avoidance and prey capture. However, performance consequences of one of the most conspicuous forms of body shape variation, direction of asymmetry in flatfishes, are poorly understood. Starry flounder (*Platichthys stellatus*), is a flatfish species that is polymorphic for asymmetry direction. The proportion of sinistral (left-sided) and dextral (right-sided) morphs exhibits a geographical cline across the species range. Differences in morphology (head shape, tail size, body depth) and stable isotope signatures between sinistral and dextral morphs suggest that they may differ in locomotor performance as well as prey acquisition. Here we tested if there were also differences between morphs in prolonged swimming endurance and fast-start velocity and acceleration. Two categories of swimming performance were tested: endurance was measured as the amount of time required to exhaust a fish swimming at constant speed in a flow chamber, and fast-start performance was measured from video of fish stimulated to induce a startle response in still water. Sinistral fish had superior performance over dextral fish in both categories, and preliminary data suggests they may also have an elevated metabolic rate. These data add to evidence of ecological segregation between asymmetry flounder morphs, implicating selection as a potential mechanism maintaining the geographical cline in their distribution.

P3.170 BERLIN, J/C*; KIRK, E/C; RODGERS, M/C; ROWE, T/B; HULLAR, T/E; University of Texas, Austin, Washington University in St. Louis School of Medicine ; *JeriCR55@aol.com*

Global Sensitivity of the Mammalian Head to Rotation: Importance of Semicircular Canal Orientation for Locomotor Agility in Therian Mammals

Determining locomotor abilities of extinct mammals is difficult in the absence of postcranial fossil elements. Previous methods compared the radius of curvature (R) of semicircular canals with qualitative assessments of locomotor agility in extant taxa. This approach ignores the effects of canal orientation on vestibular sensitivity, and how deviations of canal orientations from orthogonality influence the location of global maximum rotational sensitivity. We present a program that estimates vestibular sensitivity in 3 dimensions using measurements of the orientation and the R for all six semicircular canals. This represents a significant advance over prior methods that focus on canal radius of curvature only. We quantified semicircular canal size and orientation in a comparative sample of 40 therian mammals. Phylogenetically-informed statistical comparisons of this sample reveal that gliding and saltatory species have relatively high global maximum sensitivity to angular head accelerations. By contrast, fossorial species have relatively low global maximum sensitivity to angular head accelerations. These analyses indicate that locomotor mode in mammals is correlated with vestibular sensitivity, suggesting that CT data on semicircular canals may be used to test locomotor hypotheses for fossil species.

112.2 BERMAN, G.J.*; CHOI, D.; BIALEK, W.; SHAEVITZ, J.W.; Princeton University; *gberman@princeton.edu*

Quantifying inter-specific variations through the automated discovery of stereotyped behaviors

In recent years, the scientific community has learned a great deal about morphological evolution through making comparisons between closely-related species, discovering, for instance, that significant physical alterations between species can occur through a potentially reversible accumulation of single nucleotide substitutions. Applying these ideas towards the evolution of behavioral traits, however, has proven much more challenging. Much of this difficulty arises as a result of our inability to quantify behavior with the same fidelity and richness that exists in the study of morphology. In this talk, I will describe the novel metrics we have developed to quantify stereotyped movements -- behaviors that an animal performs frequently and with great similarly. Using the fruit flies of the *Drosophila melanogaster* species subgroup as model organisms, we find that it is possible to mine high-speed movies of an animal moving in a structureless environment for such behaviors. This is achieved using a novel method that draws from ideas in information theory, non-linear dynamics, and unsupervised learning. Our method creates a well-defined statistical definition of what it means for an animal to perform a stereotyped motion, allowing for the rigorous construction of new behavioral metrics. Moreover, we show that using these quantifications, it is possible to make meaningful comparisons between these species' behaviors, thus opening the door for further insight into the interplay between genes, neurons, and behavior.

24.5 BERNARDO, J.*; SPOTILA, J.R.; AGOSTA, S.; Texas A&M Univ., Drexel Univ., VA Commonwealth Univ.; *jbernardo@tamu.edu*

Thermal sensitivity of metabolic rates explains range properties: towards a cause-and-effect understanding of climate change vulnerability

Understanding causes of species distributions has been a central goal of ecology for more than a century, but our current understanding is surprisingly unsophisticated. Most current evidence is based on correlations between abiotic factors and range properties (limits, extents) but does not examine species biology directly. Macroecological, and macrophysiological approaches do consider correlations between species traits and range properties, but they are often weak and lack a concrete mechanistic, cause-and-effect explanation. Here we test macro-scale predictions of The Oxygen- and Capacity-Limitation of Thermal Tolerance Model (OCLM), a mechanistic model based on detailed analysis of cellular and sub-cellular processes assayed in vivo as organisms are thermally challenged. The OCLM, developed using marine animals, finds that deterioration of whole organism performance with increasing temperature past optimal performance reflects an inability to satisfy oxygen demands of metabolism, and the concomitant onset of anaerobisis. Using a salamander model system, we show that the rate at which metabolic performance deteriorates with increasing temperature explains a substantial amount of interspecific variance in lower elevational limits and in the latitudinal extent of geographic ranges. These results provide (1) one of the strongest empirical explanations of interspecific variance in range properties in any system, (2) the first interspecific comparative support of the predictions of the OCLM, and (3) the first demonstration of the relevance of the OCLM to terrestrial organisms. Our results also have important implications for evolutionary models of species range determination.

P3.19 BESPALOVA, IOULIA*; HELMS, KEN; Arizona State University, University of Vermont; *ibespalo@asu.edu*

Meathead queens: Lethal fighting linked to larger heads in Messor pergandei

In certain populations of *Messor pergandei*, colony foundation entails obligate lethal fighting between queens. In such populations, queens cooperate with each other in digging nests and rearing the first brood, but reduce to one queen through lethal fighting shortly after workers emerge (secondary monogyny). This fighting behavior is not present in other populations of the same species, where queens either cooperate for the entire life of the colony (primary polygyny) or remain solitary (haplometrosis). We examined whether the necessity of fighting resulted in differences in head width, a proxy for mandible strength, in queens from these three behavioral regions. Workers and newly-mated queens were collected from two sites exhibiting primary polygyny, two sites exhibiting secondary monogyny, and one site exhibiting haplometrosis. Log of head width and hind femur, alinotum and first gaster segment length were measured and regressed against each other using Standard Major Axis (SMA) regression, then linear slopes and elevations were compared among sites. Queens from sites exhibiting lethal fighting were found to have wider heads at a particular alinotum, hind femur, and first gaster segment length, while workers did not show a clear or significant distinction in regression lines between populations with fighting and non-fighting queens. This trend indicates that *M. pergandei* queens in populations which exhibit secondary monogyny have evolved stronger mandibles in response to the necessity of lethal fighting during colony founding.

118.6 BEZAULT, E*; RENN, S; Reed College, Portland (OR); *ebezault@reed.edu*

ANALYSIS OF COPY NUMBER VARIATION ACROSS AFRICAN CICHLID GENOMES

Structural variation has been shown to be a major source of evolutionary novelty. The African cichlids, known as one of the most explosive example of adaptive radiations, offer an excellent model to study the genetics of adaptation and diversification in Vertebrates. The sequencing of the genome of 5 species and their annotation (Cichlid Genome Consortium & Broad Institute) provide key genomic resources to study their evolution. The interest of array-based Comparative Genomic Hybridization (aCGH) to study Copy Number Variation (CNV) is widely accepted, yet challenging when conducted across distantly related taxa. To analyze CNV at the whole genome level across African cichlids lineages, we have developed a high-density multi-species microarray platform (12plex 135K NimbleGen array). To ensure high hybridization efficiency at a wide phylogenetic level among African cichlids, the probes have been selected based on the consensus sequence from the multiple genome alignment of the 5 cichlid species sequenced. Furthermore this exon-focus array includes 70K probes targeted on the EnsEMBL tilapia genome annotation, specifically representing ~24K predicted-genes. At the overall genome level, this array presents an average probe interval of 6Kb, which could expectedly allow the detection of structural variation of 30-60Kb. We first used this array to analyze CNV among the 5 species previously sequenced, representing 3 major evolutionary lineages of African Cichlids: Oreochromines, Neolamprologines and Haplochromines, with representatives of 2 different lake radiations and 1 non-radiating riverine species. We therefore compared the results obtained from aCGH with the ones derived from genome sequencing. The aCGH approach will be extended at population level as well as broader phylogenetic scale within African cichlids, to identify CNV associated with adaptation and diversification.

110.4 BHULLAR, B.-A.S*; MARUGAN-LOBON, J.; RACIMO, F.; BEVER, G.S.; ROWE, T.B.; NORELL, M.A.; ABZHANOV, A.; Harvard, Univ. Auton. de Madrid, Max Planck Inst. Evol. Anthro., NYCOM, Univ. Tex, Aus., Amer. Mus. Nat. Hist., Harvard ; *bbhullar@fas.harvard.edu*

The evolution and development of the archosaurian head and the origin of the bird skull

The bird skull is a highly specialized structure that has diverged considerably from the ancestral cranial plan of the archosaurian "ruling reptiles," whose modern representatives are birds and crocodilians. We investigated the developmental mechanisms underlying this divergence on several scales. On a broad scale, we propose that the heterochronic mechanism of progenetic paedomorphosis explains many seemingly disparate transitions from a more ancestral archosaurian skull to an avian skull. The bird lineage was juvenilized in several steps relative to ancestral forms, an insight obtained using a geometric morphometric analysis that included both phylogenetic and ontogenetic breadth. Early avialans in particular clustered with the juveniles and embryos of other archosaurs, with more crownward taxa moving farther and farther backward along a trajectory corresponding to ontogenetic progression. Definitionally, these results describe paedomorphosis, but the particular mechanism of progenesis was strongly supported by corresponding decreases in body size and in time to sexual and somatic maturity. Furthermore, some modularity exists in the heterochronic transformations here identified, notably in that the premaxilla, which forms the distinctive bird bill, grows peramorphically against a global paedomorphic background in which the orbits and brain become relatively larger and the maxillary region smaller. Given a broad evolutionary developmental mechanism for major changes in skull form toward birds, we have subsequently undertaken investigations of the specific molecular mechanisms behind the transformations elucidated by our phylogenetic/ontogenetic morphometric work, with some success in testing hypotheses of gene function using manipulation of model organisms.

P2.94 BICKEL, R.; CLEVELAND, H.; BARKAS, J.; BELLETIER, N.; STERN, D.L.; DAVIS, G.K.*; University of Nebraska, Lincoln, Bryn Mawr College, Janelia Farm, HHMI; *gdavis@brynmawr.edu*

Potential Patterning Differences Underlying Oviparous and Viviparous Development in the Pea Aphid

The pea aphid, *Acyrthosiphon pisum*, exhibits several environmentally cued, discrete, alternate phenotypes (polyphenisms) during its life cycle. In the case of the reproductive polyphenism, differences in day length determine whether mothers will produce daughters that reproduce either sexually by laying fertilized eggs (oviparous sexual reproduction), or asexually by allowing oocytes to complete embryogenesis within the mother without fertilization (viviparous parthenogenesis). Oocytes and embryos that are produced asexually develop more rapidly, are yolk-free, and much smaller than oocytes and embryos that are produced sexually. Perhaps most striking, the process of oocyte differentiation is truncated in the case of asexual/viviparous development, potentially precluding interactions between the oocyte and surrounding follicle cells that might take place during sexual/oviparous development. Given the important patterning roles that oocyte-follicle cell interactions play in Drosophila, these overt differences suggest that there may be underlying differences in the molecular mechanisms of pattern formation. We have found differences in the expression of homologs of *torso-like* and *tailless*, as well as activated MAP kinase, suggesting that there are important differences in the hemipteran version of the terminal patterning system between viviparous and oviparous development. Establishing such differences in the expression of patterning genes between these developmental modes is a first step toward understanding how a single genome manages to direct patterning events in such different embryological contexts.

P1.55 BICUDO, J.E.; University of São Paulo;
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Metabolic rates and phenotypic flexibility in indigenous populations of the Upper Rio Negro, Amazon, Brazil

Energy restriction leads to reduction in energy expenditure to maintain proper energy homeostasis. A change in the energy metabolism of the individual may be an important component of this adaptive response. Indigenous people living in the upper Amazon, Brazil, have been exposed to chronic parasite infestations. Children growth is severely impaired, and adults show reduced body mass, imbalance in body composition and low stature. These are not linked to shortage of food or poor quality diet. Rather, it is the outcome of chronic parasite infestations. The parasites compete for the energy resources available. I propose that survival of these populations has been facilitated due to phenotypic flexibility. Measurements of the Indian subjects (experimental) were taken in the field. Oxygen uptake to estimate basal metabolic rate (BMR) and peak metabolic rate (PMR) was determined by collecting respiratory expired air in a Douglas bag, which was then connected to an open flow system for O2 and CO2 analysis. To estimate BMR, samples were taken throughout the night, with the individuals laying in their hammocks. The same procedures were applied to the control group (a sample of the Brazilian standard population). To estimate PMR, individuals (experimental and controls) pedaled on a cycle ergometer until reaching a plateau. The experimental group BMR was statistically different and four times lower than the control group BMR. The PMR of both experimental and control groups were not statistically different. I hypothesize that the indigenous people may save available energy resources by lowering their BMR, but are able to work as hard as the controls when challenged, as shown by their equal PMRs. It seems that a larger metabolic scope of the indigenous people give them some advantage to cope with the parasites.

P3.139 BIDDULPH, T.A.*; KOVACEVIC, S; WATERS, J.S.; HARRSION, J.F.; Arizona State University;
Taylor.Biddulph@asu.edu

Trachea and Flight Muscle Volumes of Adult Drosophila melanogaster Reared in Hypoxia, Normoxia, and Hyperoxia Using Synchrotron X-Ray Phase Contrast Microtomography

Investigation of the structural response of the tracheal system in *Drosophila melanogaster* to varying atmospheric oxygen levels allows for a better understanding of insect adaptation to hypoxia and hyperoxia. *Drosophila melanogaster*, more commonly known as the fruit fly, has been used as a model organism in scientific experiments for many years but only little is known about the organism in respect to the adult tracheal system. In this study, a sample of male flies were reared for one generation in 10, 21, or 40 kPa oxygen from egg to adult, and were then taken to the Advanced Photon Source at Argonne National Lab where synchrotron x-ray phase contrast microtomography (SR-µCT) was conducted on the freshly euthanized specimens. Highly detailed visual reconstructions of the x-ray images were produced on-site and then later used to make measurements and collect quantitative data. The tracheal branch under investigation is located adjacent to the second spiracle, towards the posterior end of the thorax, and supplies oxygen to approximately 25% of the dorsal longitudinal flight muscles. By calculating trachea to longitudinal flight muscle volume ratios in the thorax, we hope to gain some insight on how the tracheal system changes in hypoxic and hyperoxic conditions. This data will help us better understand how oxygen delivery systems are constructed in insects. This research was partially funded by NSF EFRI BSBA 0938047 to Jake Socha and Jon F. Harrison.

108.2 BIELECKI, J*; GARM , A; University of Copenhagen;
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Fixational eye movements in the earliest stage of metazoan evolution

Fixational eye movements in vertebrate vision prevent sensory adaptation by refreshing the retinal image. Without fixational eye movements an animal would be rendered blind during visual fixation until the time when the eyes were moved voluntarily or the world moved in front of them. Box jellyfish face the same sensory adaptation problem as vertebrates and a counter strategy is necessary to prevent image fading, but unlike vertebrates these animals do not have motor control of their eyes. Here we present the first evidence that vertebrate fixational eye movements have evolutionary parallels in Cnidarians, the first phylum to develop a central nervous system. We have proven that the bell contractions in the box jellyfish Tripedalia cystophora induce a swinging of the eye-carrying rhopalia which, in amplitude and duration, matches the spatio-temporal resolution of the lens eyes. Video recordings of free swimming and tethered animals determined the spatio-temporal relationship between the rhopalial swinging and the visual physiology of T. cystophora, and the findings were further confirmed by performing extracellular electrophysiological recordings on transected rhopalia exposed to comparable visual stimuli in vitro.

146.6 BIGA, PR*; FROEHLICH, JM; University of Alabama at Birmingham ; *pegbiga@uab.edu*

Epigenetic regulation of myogenesis in a growth paradigm-specific manner.

Piscine growth is unique in that many species exhibit patterns of muscle growth opposite that of mammalian species. Many teleosts exhibit hyperplastic muscle growth throughout their lives, while most mammals only exhibit hyperplasia during fetal growth or following trauma. Recently, we have characterized closely related fish species that exhibit different growth types: zebrafish (determinate-like) and giant danio (indeterminate). The zebrafish (*Danio rerio*) has been used extensively as a model system for developmental studies but, unlike most teleost fish, it grows more determinately. A close relative, the giant danio (*Devario cf. aequipinnatus*), grows indeterminately, displaying both hyperplasia and hypertrophy in muscle as an adult. Interestingly, the adult giant danio exhibits a significant increase in body mass following growth hormone treatment, while the adult zebrafish fails to respond with more than a 10% increase in growth. To better understand the underlying mechanisms of growth paradigm differentiation, we have begun to characterize potential methods of epigenetic regulation of myogenic regulating factors between these two opposing growth types. Methylation of lysine residues on histone 3 (H3) has been shown to repress muscle-differentiation-specific gene promoters in mammals. Here we demonstrate differential patterns of epigenetic regulation between closely-related fish species exhibiting opposing growth paradigms, where hypermethylation of several lysine residues is associated with the Myf5 promoter in myogenic precursor cells (MPCs) from adult giant danio myotomal tissue. Giant danio MPCs do not express Myf5 protein during *in vitro* myogenesis, suggesting that epigenetic regulation may play a pivotal role in growth paradigm potential.

P3.108 BIRD, AM; VON DASSOW, G; MASLAKOVA, SA*; Oregon Institute of Marine Biology, Univ. of Oregon; *svetlana@uoregon.edu*

How the pilidium larva grows

Many benthic marine invertebrates have ciliated planktonic larvae which must feed and grow in order to reach metamorphosis. The fact that ciliated cells in animals are apparently unable to divide while in possession of a cilium implies possible constraints on how ciliated larvae can grow. Monociliated cells may lose their cilium, divide, and regrow the cilium, but cells that develop multiple cilia can no longer divide. The planktotrophic pilidium larva of nemertean worms grows considerably during its long pelagic life (weeks to months), and its overall size and the length of its ciliary bands has likely consequences for its feeding efficiency. The epidermis of the pilidium consists of multiciliated cells. Do these cells simply stretch to accommodate an increase in size, or are there non-ciliated or monociliated cells that contribute to the growing larval body? By using an anti-phosphohistone antibody, BrdU labeling and confocal microscopy, we detected dividing cells in the pilidium of *Micrura alaskensis*. They are restricted to several discrete regions of the larval body, most notably in the pits between the larval lobes and lappets. We refer to these regions as “axils” (Latin “pits”). We show with BrdU pulse-chase that proliferating cells in the axils contribute both to the larval body (including the ciliary band), as well as the imaginal discs from which the juvenile worm develops. We also located the putative growth zones in the pilidial axils by scanning electron microscopy - the cells in the growth zones are smaller than the neighboring cells, and have a single rudimentary cilium each, as opposed to multiple well-developed cilia. These findings not only illustrate how this multiciliated body can grow, they also suggest a mechanism by which growth of larval and juvenile bodies could be coupled.

P2.46 BIRD, DJ*; DAVYDOV, Y; AMIRKHANIAN, A; VAN VALKENBURGH, B; Univ. of California Los Angeles, Univ. of California Los Angeles ; *dbirdseed@gmail.com*

Cribriform plate morphology as proxy for olfactory innervation in felids and canids

In general, carnivorans are considered to possess a keen sense of smell. The two most studied groups of the carnivorans, the felids and canids, differ in their relative reliance on olfaction versus vision in foraging. Canids tend to rely more on olfaction and possess relatively large olfactory bulbs, while felids are considered more visual predators and have smaller olfactory bulbs. Using computed tomography scans and 3-D imaging software, this study examines one feature of the mammalian olfactory apparatus, the cribriform plate, to ask whether olfactory innervation is smaller in felids than canids. The cribriform plate (CP) is a bony cup that separates the nasal chamber from the brain case and houses the olfactory bulb. The CP is perforated with foramina that surround the olfactory nerve fibers traveling from snout to brain. CP morphology varies across mammalian species and likely reflects aspects of olfactory function. Specifically, the size and number of CP foramina vary, and cumulative foramina area may be viewed as a proxy for relative olfactory innervation. Novel spline technology has made it possible to quantify the total cross-sectional area of CP foramina for the first time and to compare this metric across species. Preliminary results reveal that the total area of cribriform plate foramina, and thus olfactory innervation, is smaller in felids than in canids. These results suggest there may be a trade-off between the enhanced visual anatomy (large, frontally directed orbits and high binocularity) and olfactory innervation among felids. In the future, these methods will be applied to fossils, in which the CP with its osseous imprints of olfactory innervation may hold promising clues to the olfactory ecology of extinct felid and canid species.

72.4 BIRKMEYER, P. M.*; GILLIES, A. G.; FEARING, R. S.; Univ. of California, Berkeley; *paulb@eecs.berkeley.edu*

Dynamic climbing of near-vertical surfaces with a legged robot

Geckos are able to ascend challenging, smooth vertical surfaces with speed and robustness to perturbations that robot designs have yet to match. Studies of these animals reveal that they have fluid, efficient body dynamics during climbing as well as adhesives that are capable of providing very large adhesive forces relative to body mass. We have developed a 10 cm, 19 gram legged robot that we are using to study the effects of foot design, adhesion, and body dynamics on climbing ability on smooth, hard surfaces. The robot uses a microstructured rubber adhesive with shear-induced adhesion qualitatively comparable to that seen in geckos. A bio-inspired ankle and tendon system is used to promote conformation with a surface as well as engagement without generating peeling moments. Automated foot testing shows the feet are capable of normal adhesive loads of 0.37N with a shear load of 1N with only minor performance degradation when the feet are significantly misaligned with the climbing surface. Early climbing trials on a hard near-vertical surface show that the maximum velocity possible while climbing decreases as the incline increases. The robot demonstrated climbing speeds of 10 cm per second on 70-degree inclines and was limited to inclines of 75 degrees and below. A fundamental model describes the effect of incline on climbing speed. Other evidence also shows that this performance limit is due to body dynamics and adhesive limitations. New models and system modifications, and engagement methods are leading to improved climbing performance and robustness of the robotic platform.

114.1 BIRN-JEFFERY, AV*; HUBICKI, C; BLUM, Y; HURST, J; DALEY, MA; Royal Veterinary College, UK, OSU, Oregon; *abirnjeffery@rvc.ac.uk*

Don’t break a leg: injury prevention, robustness and stability of legged locomotion

In uneven terrain, legged animals must avoid falling and exceeding tissue safety factors to prevent injury. Simple models of locomotion highlight a potential trade-off between stability and injury avoidance as some control strategies for stability require large leg forces. To investigate scaling effects on leg control for stability, we studied obstacle negotiation in ground birds spanning a 50-fold body mass range. We expected larger, straight-legged animals to prioritise reduction of peak forces, leading to lower robustness and stability compared to smaller species. Unexpectedly, we observed that body and leg dynamics during obstacle negotiation are similar. Furthermore, force trajectories remained similar to level terrain across species. These results suggest a common control policy, regardless of body size. We noted an asymmetry in the stance force trajectory across birds, with peak force around 30-40% of stance, which is not predicted by current models. We demonstrate that minimum-work actuation applied to an intrinsically damped leg model correctly predicts these force characteristics and suggests higher intrinsic damping in smaller species. Despite similar peak forces across terrains, the birds achieve remarkably high robustness and stability, negotiate 50% leg length obstacles with little variation in speed, and limit fall risks to only 8 in 10,000. Animals prioritise injury and fall avoidance over steady dynamics. The experimental data is consistent with a control policy involving feed-forward swing-leg control to minimise changes in passive-dynamics of stance phase. Consistent trends across a 50-fold range in body size suggest general principles which may be useful for the control of legged robots.

51.5 BISHOP, C.D.*; KRUG, P.J.; St. Francis-Xavier Univ. Nova Scotia, Cal. State Univ. L.A.; *cbishop@stfx.ca*

Differential use of nitric oxide to regulate metamorphosis is related to larval selectivity: an eco-devo test using the sea slug Alderia willowi, a species with a settlement dimorphism.

Settlement and metamorphosis among marine larvae is often environmentally mediated. Larvae competent to initiate this transformation display intra- and interspecific variation in habitat selectivity as a function of time in the competent state, and consequently, variation in the overall timing of settlement and metamorphosis. Theoretical work has modeled the kind of behavior that should maximize recruitment to the adult population. However, this approach does not inform the nature and dynamic behavior of the endogenous regulatory mechanisms that must operate downstream of environmental cues. In turn, research focused upon elucidating such mechanisms has documented variation in their function among taxa, yet suffers from the lack of a conceptual framework for interpreting that variation. The sea slug Alderia willowi produces non-selective and selective larvae in the same clutch. These two larval types approximate ecologically generalist and specialist larvae, thereby allowing comparative tests of the function of signaling systems while removing phylogenetic effects. By pharmacologically manipulating nitric oxide/cyclic GMP (NO/cGMP), serotonin and dopamine signaling systems in both classes of larvae, we show that among these three systems, NO signaling differs uniquely and categorically in its influence upon the “decision” of a larva to initiate the irreversible events of metamorphosis. We propose a model in which the degree of influence NO exerts on metamorphic “decisions” relates to larval selectivity.

88.1 BISHOP, K.L.*; O'NEILL, M.; SCHMITT, D.; Florida International University, Stony Brook University, Duke University; *kristin.bishop@fiu.edu*

Comparison of walking mechanics in an arboreal and a terrestrial primate

Animals have several mechanisms available that may reduce their muscular effort while walking. One is to adopt an inverted pendulum movement of center of mass to exchange potential and kinetic energy needed to lift and accelerate the center of mass. Alternatively, animals can reduce the energy lost through redirecting the path of the center of mass, known as collisional energy loss. Previous work has shown that some animals use the inverted pendulum mechanism less effectively than others, but it is not known whether those animals accept a higher cost for locomotion or compensate by using other energy saving mechanisms such as reducing collisional energy loss. Arboreal animals may be unable to use the inverted pendulum mechanism, and if so, they may compensate by reducing collisional losses. In this study we compare the walking mechanics of two species of lemurs, *Lemur catta*, the most terrestrial of the lemurs, and *Eulemur fulvus*, an exclusively arboreal species. Individuals of both species were videorecorded while walking across a force plate that was either flat or had a pole attached, simulating arboreal locomotion, to record the kinematics and kinetics of their locomotion. We found that *L. catta* was capable of having very high energy recovery, with a maximum energy recovery of 71%, comparable to that found in dogs and humans. Recovery values were high in this species for both ground and pole. *E. fulvus* had lower energy recovery on both ground and pole, with a maximum recovery below 50%. Thus the use of an arboreal support does not drive mechanical patterns, but arboreal adaptations appear to have an import effect suggesting that effective arboreal movement may be inconsistent with energy recovery. Kinematic analysis and comparisons of collision fraction were used to explain the differences in energy recovery between the terrestrial and arboreal species.

P2.29 BJELDE, B.E.*; MILLER, N.A.; TODGHAM, A.E.; San Francisco State University; *bbjelde@mail.sfsu.edu*

The role of oxygen in determining upper temperature tolerance in the fingered limpet under emersed and immersed conditions

Predicting an organism’s vulnerability to future increases in temperature requires an understanding of the factors that set their upper temperature tolerance. Previous investigations of cardiac performance and thermal tolerance limits in the fingered limpet, *Lottia digitalis*, have shown that limpets exposed to a thermal ramp under emersed conditions maintained heart function to a higher temperature than limpets exposed to the same heating while immersed. Here we examined whether differences in O_2 concentration in air and water could explain reduced cardiac thermal tolerance under immersed conditions. Limpets were heated at a rate of 6°C/h under hyperoxic (35%), normoxic (21%), or hypoxic (5%) O_2 conditions in both emersed and immersed conditions. Thermal limits of heart function were calculated as break point temperatures (BPT). Similar to previous work, emersed limpets were significantly more thermally tolerant than immersed limpets under all O_2 exposures. BPTs of emersed limpets were roughly 2-3°C higher than immersed limpets under normoxic and hyperoxic conditions and almost 5°C higher under hypoxic conditions. Thermal tolerance was not increased in either immersed or emersed limpets exposed to 35% O_2 suggesting that in both air and water the ability to supply O_2 to tissues at high temperatures is already maximized under normoxia. However, under hypoxic conditions both groups of limpets exhibited significantly reduced thermal tolerance providing evidence of O_2 limited thermal tolerance at low environmental PO_2s. Given the consistent differences in thermal tolerance in emersed and immersed limpets across all O_2 concentrations, reduced O_2 availability in water is not sufficient to explain air/water thermal tolerance differences.

144.5 BLACK, C.R.*; BERENDZEN, P.B.; Univ. of Northern Iowa; *corinthi@uni.edu*

The Effect of Phylogeny on Morphological Characteristics of the Skeleton in Pleuronectiformes

Pleuronectiformes, commonly known as flatfishes, are a highly specialized order of fishes displaying obvious asymmetrical morphology. When flatfish hatch, they are symmetrical. As development continues, one eye migrates dorsally to the other side of the head. This causes morphological changes to occur simultaneously, resulting in an asymmetric fish. These changes include asymmetry of paired fins, dentition, and pigmentation of the body. The skeletal structure undergoes morphological changes as development continues. Of these skeletal structures, the frontal complex of the skull illustrates the greatest transformation. Although all Pleuronectiformes undergo similar developmental changes, there are significant differences in morphology of these characters across the phylogeny. This study focuses on examining the morphological diversity of several skeletal characteristics including the shape of the frontal complex, fin insertion points, and the spinal flexure using geometric morphometrics. Radiographic images of at least one representative of every genus available, in the order of Pleuronectiformes, were digitized by placing 32 landmarks across the skeleton. Landmarks were standardized, a principal component analysis was performed, and the ancestral phylomorphospace was reconstructed using the most recently published molecular phylogeny. Preliminary results will be presented.

111.2 BLACKBURN, HN*; ALLEN, JD; College of William and Mary; *hnblackburn@email.wm.edu*

Maternal effects on cloning frequency, larval development and juvenile size in the sea star Asterias forbesi

A fundamental life-history trade-off occurs between the size and number of offspring that a female produces. Traditionally, biologists have assumed that there is a species-specific optimal egg size, the value of which can fluctuate with changing environmental parameters. However, in unpredictable environments a bet-hedging strategy resulting in variable offspring sizes may be favored. The sea star *Asterias forbesi* produces eggs that vary more than two-fold in volume within a single clutch (110µm - 150µm diameter). In addition, the larvae derived from these eggs have frequently been observed to produce clones. To test for maternal effects on cloning frequency and larval development we sorted sibling embryos at the blastula stage into large (190µm mean diameter) or small (140µm mean diameter) size classes. Previous studies have shown that exogenous cues can alter the frequency of cloning, but it is unclear whether endogenous reserves might also influence the asexual production of larvae. Our results suggest that despite an initial disadvantage in energy reserves, small treatments produced clones at frequencies similar to their large siblings. Since little is known how maternal investment affects juvenile quality in sea stars, we continued to follow these larvae and examined the effect of maternal investment on time to and size at metamorphosis. Small treatments took about 2 additional days compared to large treatments before settling as juveniles, a 6.3% increase in developmental time. Because the experiment ended early, our estimate of the developmental period for larvae from small eggs is highly conservative. Size at metamorphosis did not appear to be affected by maternal investment and varied greatly within treatments.

67.6 BLACKBURN, DC*; CANNATELLA, DC; SUKUMARAN, J; WAKE, DB; California Academy of Sciences, University of Texas, Austin, Duke University, University of California, Berkeley; *david.c.blackburn@gmail.com*

The impact of taxonomic progress on knowing the Tree of Life: an example from amphibians

Since 1985, taxonomic research on the diversity of living amphibians has increased species diversity by ~60% (from 4014 in 1985 to 7000+ in late 2012). We evaluate the impact of nearly thirty years of species-level taxonomy on our knowledge of the Amphibian Tree of Life. Using a recently published study based on DNA sequence data for nearly 2900 amphibian species, we explore the impact of post-1985 taxonomy (i.e., after the 1985 publication of *Amphibian Species of the World*, ed. D.R. Frost) on our present-day knowledge of evolutionary relationships and patterns of diversification. We present both qualitative and quantitative comparisons based on phylogenies generated by (1) pruning recently published trees to circa 1985 taxonomy and by (2) reanalyzing matrices in which "post-1985 taxa" are removed from the analysis. We ask to what extent our knowledge of the Amphibian Tree of Life is dependent on taxonomic research and species discovery since 1985. In a general sense, would we have known then what we know now if only we had DNA sequence data in 1985? We highlight analyses based on tree shape statistics that reveal general themes likely true for our present-day understanding of other organisms.

P3.218 BLACKMON, T.N.*; JOHNSON, M.A.; Trinity University, San Antonio; *tblackmo@trinity.edu*

Temperature-dependent behaviors in the Texas spiny lizard (Sceloporus olivaceus)

The maintenance of body temperature is a critical task for ectotherms, which rely largely on the temperature of their environment for thermoregulation. In reptiles in particular, many animals use behavioral mechanisms to control their thermal exposure; however, relatively little is known about variation in natural behaviors as a function of body temperature. In this study, we examined *Sceloporus olivaceus* (the Texas spiny lizard) in the field to determine the relationship between temperature and natural behavior in this species. We measured the internal body temperature and external perch temperature of 42 adult lizards, and found that internal body temperatures at the time of capture ranged from 26° to 41°C, with the average body temperature 34.5°C. We found no difference between the average temperature of males and females. As expected, our results also showed a strong positive correlation between the internal and external temperatures. In addition, we collected 33 hours of behavioral observations for 56 *S. olivaceus*, recording the frequency of two common behaviors (locomotion and push-up displays) performed by the lizards in full sun, partial sun, and full shade. These data suggest that males perform more locomotion behaviors and pushup displays while in the shade, while females have a higher rate of locomotion in full sun. Taken together, our findings suggest that though the sexes do not differ in average temperature, there may be sex-specific differences in the temperatures at which certain behaviors are exhibited.

P2.70 BLACQUIERE, L.D.*; HOESE, W.J.; California State University, Fullerton; *lblacquiere@csu.fullerton.edu*

Assessment of student conceptions of evolutionary trees

Biologists use evolutionary trees to depict hypotheses about the relationships among taxa. Trees possess lines that represent lineages, internal nodes that represent where lineages become evolutionarily isolated from one another and terminal nodes that represent the taxa under consideration. Interpreting a tree (i.e., "tree-thinking") is an important skill for biologists yet many students struggle when reading evolutionary trees. Common documented misconceptions include using morphological similarity, internal node counting or terminal node proximity, instead of identifying internal node that represents the most recent common ancestor, to determine relationships among taxa. We developed an assessment that tested whether students were using common ancestry or one of the other, non-scientific, strategies to determine relationships among taxa. We interviewed 12 students in introductory biology following instruction on evolutionary trees, verified common problems students had interpreting trees, and developed a diagnostic test that we used to determine whether students consistently employed one strategy to interpret evolutionary trees. We found that a minority of students used tree-thinking when interpreting trees. Those students who used alternative strategies to interpret trees did not consistently use a single alternate strategy; alternate strategies of all types were used preferentially to tree-thinking strategies by these students. This study provides instructors with a tool with which they can determine how well students understand how to interpret evolutionary trees.

P2.218 BLAIR, P. B.*; FREEMAN, C. F.; THACKER, R. W.; Univ. of Alabama at Birmingham; *pbblair@uab.edu*

Distinguishing clades of the sponge-specific cyanobacterial symbiont Synechococcus spongiarum through high-resolution melting analysis and denaturing/temperature gradient gel electrophoresis

Approximately one-third of coral reef sponges in the nutrient poor Caribbean host photosynthetic cyanobacterial symbionts classified as *Synechococcus spongiarum*. The diverse *S. spongiarum* group consists of multiple, diverse clades that are distinguished using DNA sequences of the 16S-23S ribosomal RNA internal transcribed spacer (ITS) region. Since this task requires labor-intensive PCR-based amplification, bacterial plasmid cloning, and DNA sequencing, we developed high-throughput methods to rapidly screen sponge hosts for the presence of particular *S. spongiarum* genotypes. For these genotyping trials we generated a series of standard clones for each major clade based on previously identified and sequenced specimens. High-resolution melting (HRM) and Denaturing/Temperature Gradient Gel Electrophoresis (D/TGGE) was carried out using specifically designed primers to amplify a variable portion of the ITS region from these clade standards. Clade profiling using HRM and DGGE techniques failed to resolve the clade standards as well as TGGE. It was also found that TGGE analysis could be used to resolve individual clades amplified from whole genomic DNA, even when these samples included mixes of multiple clades within a sample. Thus, we suggest that TGGE is the most appropriate method for rapid and accurate genotyping to discriminate mixtures of symbionts within a single host. These methods of genotyping *S. spongiarum* will facilitate future work with these symbionts and can be applied to a broad range of other ecological interactions.

P2.43 BLEICHER, S.S*; KOTLER, B.P; BROWN, J.S; University of Illinois at Chicago, Ben-Gurion University of the Negev; *bleicher.s.s@gmail.com*

Response of Prey to Evolutionarily Novel Predators with a Constraint-Breaking Adaptation: What do gerbils think of sidewinder rattlesnakes?

We investigated three evolutionary concepts: 1.Convergent evolution between North American and Middle Eastern desert vertebrates. 2.Constraint breaking adaptations in invasive species, and 3.Prey species acclimation to an evolutionarily novel predator? In an aviary we exposed Allenby's gerbils (*Gerbillus andersoni allenbyi) to known predators: red foxes, barn owls and Saharan horned vipers (Cerastes cerastes). We also exposed the gerbils to an evolutionarily novel predator, the Sidewinder Rattlesnakes (Crotalus cerastes) from North America. In addition to being novel, they possess heat sensory pits, a potentially constraint breaking adaptation over the native predator. Using optimal patch use theory, we quantified the gerbils' responses to each of the snake species prior to, during, and immediately after spending time in the aviary. At "entry" and "exit" the gerbils were exposed non-lethally to the snakes to measure instinctive fear. During the 60 day trial in the aviary the predators were not restrained. At entry, the gerbils recognized the evolutionarily novel rattlesnake as lesser a threat than the native horned viper. During the two months of experiments in the vivarium the gerbils learned to assess the risks posed by the novel predator. The gerbils showed a stronger response to the sidewinders at exit. Our experiment suggests that in the case of the horned viper versus the pit-viper rattlesnake, the gerbils learned how to behave in the presence of the evolutionarily novel predator. The gerbils assessed the behavior of the snake. This was shown by change in behavior between moon phases. Our observations showed that the constraint breaking adaptation does not give the sidewinder a clear advantage against the gerbils as a pray species.*

2.1 BLEVINS, E.L.; Harvard University; *eblevins@fas.harvard.edu*

Structure-function relationships in the pectoral fin of freshwater stingray Potamotrygon orbignyi

To achieve the characteristic undulations of rajiform locomotion, the pectoral fins of batoid fishes must be flexible and well-controlled, to generate, accommodate, and modulate the propulsive wave. Batoids have dramatically diverged from their shark-like ancestors in both fin use and structure, but lack the mechanical linkages that provide control in the pectoral fins of actinopterygian fishes. By integrating an understanding of 3-D swimming kinematics with the pectoral fin morphology of freshwater stingray *Potamotrygon orbignyi*, I connect aspects of structure and function in the fin of an undulatory rajiform swimmer. The morphology of skeletal and muscular fin elements differs across fin chord and span, creating regional variations that correlate with the swimming kinematics of *P. orbignyi*. Anterior regions of the pectoral fin, which form a stable leading edge during swimming, are structurally stiffened by a more robust fin skeleton, with the potential for active stiffening from a pennate arrangement of muscle fibers. Structure predisposes mid-disc and posterior regions of the fin to greater flexibility; these same regions show the greatest amplitudes during undulation. Comparisons with the fins of a representative actinopterygian fish (bluegill sunfish *Lepomis macrochirus*) and shark (dogfish *Squalus acanthias*), reveal structural convergence between stingrays and actinopterygians in fin ray branching and segmentation. The repetition of fin elements during the evolution of batoid pectoral fins created the potential for this convergence, as well as for regional specialization within the fin, with structural features connecting pectoral fin morphology and undulatory performance.

P3.164 BLIAMPTIS, J.P.*; HALE, M.E.; University of Chicago; *jpbliamptis@gmail.com*

Finding balance in an unstable world: the neural control and kinematics of larval zebrafish pectoral fins in response to roll

While the pectoral fins of larval zebrafish (*Danio rerio*) beat regularly and in coordination with axial undulations during steady forward swimming, experimental work indicates that they do not serve a propulsive or stabilizing role in this behavior but appear to have a respiratory function, mixing fluid near the body. Beyond steady swimming, the question of whether larval pectoral fins are used in movement systems remains unanswered. As adult fish use pectoral fins in a diverse set of behaviors, including for stability, maneuvering, forward propulsion and braking, the pectoral fins of larval may also function in these contexts. We hypothesized that the fins are active in response to environmental perturbations that destabilize the animal, and we focused on their response to roll. We partially embedded larval zebrafish so that the fins were free to move and tipped the fish, generating roll to right and left side. As a control, we also moved the tank without roll. The fish reacted consistently with alternating pectoral fin movement in response to roll but not to non-roll movement. We compared fin kinematics between left and right side rolls and found no consistent difference in the pattern of fin movement associated with roll direction. To begin to understand how this response is neurologically controlled, we examined the role of the vestibular region in the response. We embedded zebrafish with cranial transections that either retained or eliminated vestibular input to the fin motor pool. When the vestibular system was ablated, the behavior was no longer observed indicating the presence of circuit connections between the vestibular nerve and fins. We have yet to determine the effect of pectoral fin movement on body roll but hypothesize that they generate force to correct for the perturbation.

P3.199 BLUM, Y*; BIRN-JEFFERY, AV; VEJDANI, HR; HURST, JW; DALEY, MA; Royal Veterinary College, London, UK, Oregon State University, Corvallis, Oregon, Oregon State University, Corvallis, Oregon; *yblum@rvc.ac.uk*

Swing Leg Control: Disturbance rejection versus injury avoidance

We seek to understand the strategies used by animals to achieve stable and robust locomotion in uneven terrain. As stance dynamics are strongly influenced by the landing conditions, a critical transition occurs between the swing and stance phase of the leg. We therefore hypothesize that animals use a simple swing leg control policy to target landing conditions that achieve specific performance goals. In several studies, we investigated the dynamics and kinematics of different bird species (quail, pheasants, guinea fowl, and turkeys) while running over level ground and negotiating a ground height disturbance (such as a step up, step down, or an obstacle). It appears that swing leg control, namely the time-dependent adjustment of leg angle and leg length in anticipation of ground contact, affects the initial conditions of the following stance phase, and therefore, controls the stance phase as well. Especially the angle between the center of mass' velocity vector and the virtual leg, which determines the amount of leg loading during stance, seems to be critical for stance dynamics. To evaluate the observed behavior, we then developed and analyzed potential swing leg control policies based on principles of disturbance rejection and injury avoidance, applied these control policies to a simple model with a passive stance phase, and compared the predictions to the experimental data. The results suggest a compromise between disturbance rejection and injury avoidance, as birds do not achieve perfect disturbance rejection, but the strategies they use do result in very impressive robust locomotion without exceeding peak forces or impulses that could lead to musculo-skeletal damage. This work was funded by BBSRC and HFSP.

46.2 BOARDMAN, L*; SØRENSEN , JG; GROUT, TG; TERBLANCHE, JS; Stellenbosch University, South Africa, Aarhus University, Silkeborg, Denmark, Citrus Research International, Nelspruit, South Africa; *lboardman@sun.ac.za*

Cross tolerance between modified atmospheres and low temperature in insects

Insect tolerance to low temperature treatments for post-harvest disinfestation of crops depends on the insects' basal ability to withstand or repair the stress associated with long-term low temperature exposure, or the ability to rapidly develop biochemical protection. Changes may be induced at the whole animal level (e.g. respiration rate, water balance), or at the molecular level (e.g. induction of cryoprotective metabolites and proteins). Post-harvest disinfestation treatments can be augmented with modified atmospheres (e.g. high carbon dioxide and/or low oxygen) to improve their efficacy. Theoretically, the potential overlaps in the mechanisms which insects can use to counteract low temperature and modified atmosphere stressors may result in cross tolerance. Here, we examine different levels of responses after exposure to temperature and/or gas stress in larvae of the false codling moth, *Thaumatotibia leucotreta*, an agricultural pest of southern Africa. Larvae were exposed to a range of temperature conditions (0°C, 25°C, 35°C), high carbon dioxide (6% CO_2) and low oxygen (2% O_2) treatments, both separately, as well as in various combinations, for different durations prior to a standard post-harvest disinfestation exposure at -1°C. During these experiments, larvae were assayed for mortality, body water content, body lipid content, cell viability, membrane lipid composition, heat shock protein 70 and cryoprotectant expression levels. The results from these experiments will be discussed in the context of a range of mechanistic hypotheses proposed to explain insect low temperature tolerance and cross tolerance.

P3.12 BOBEK, JE*; HRANITZ, JM; BARTHELL, JF; CLEMENT, M; APTED, T; BATES, L; HALL, N; CAKMAK, I; WELLS, H; Bloomsburg University, University of Central Oklahoma, University of Central Oklahoma, American Samoa Community College, Loyola Marymount University, Uludag University, Tulsa University; *jonathan.bobek@asu.edu*

Senescence Marker Expression is Linked to Foraging Decisions in Honey Bees

Foraging behavior differs among individual honey bees, indicating a genetic basis to foraging decisions by these globally important pollinators. Many bees exhibit flower constancy during foraging, where individuals faithfully return to a specific flower color. Since developmental gene expression produces age-dependent behaviors in hive castes, we studied how gene expression affects decision-making during foraging. During June-July 2010 at Uludag University (Turkey), we monitored honey bee foraging in a 60-minute behavioral assay to categorize foraging patterns of free-flying Anatolian honey bees (*Apis mellifera anatolica*). Bees selected from alternative reward conditions, high reward quality versus low reward quality, randomized in artificial blue and yellow flowers. Blue or yellow "constant" bees rarely visited opposing color flowers, while "undecided" bees readily switched to the higher reward flower quality. We compared brain mRNA of three groups (Blue Constant (BCF), Yellow Constant (YCF), Undecided (UF) foragers) on Agilent bee arrays, using a one-way ANOVA with pairwise contrasts. Only regucalcin-like protein differed between groups ($F = 30.39508$, $p = 0.001855$), with two-fold lower expression in YCF versus UF and BCF bees. No difference in regucalcin expression was found between BCF versus UF bees. Since regucalcin is linked to aging in animals, flower color choice and responsiveness to floral rewards by foraging honey bees may be an age- or development-dependent behavior, similar to other behaviors within the hive.

26.2 BOGGS, C.L.*; NIITEPOLD, K.; PEREZ, A.; Stanford University; *cboggs@stanford.edu*

Comparative Effects of Adult Food Limitation on Butterfly Life Histories

Change in resource allocation patterns in response to variation in food acquisition provides a mechanistic basis for understanding observed life history responses to variation in food availability. Organisms respond differently to changes in food quantity vs. quality, as demonstrated empirically and theoretically, using conceptual structures such as resource congruence, stoichiometry and the geometric framework. Here we examine the life history effects of realistic changes in the quantity of food available and connect lab experiments to field observations, using butterflies as a model system. Variance in per capita flower availability results from weather and land use patterns, and can lead to prolonged nectar limitation. In butterflies, adult food limitation generally doesn't affect lifespan, but can lead to reduced fecundity. We extend work on allocation to reproduction under nutrient stress by asking how such stress affects fecundity, egg mass and composition as a function of age in two species with contrasting life histories, hence physiological demands. The larvae of *Speyeria mormonia* diapause without feeding and hence the eggs are expected to have a greater energetic provisioning requirement than eggs of *Colias eurytheme*. Likewise *S. mormonia* has a higher use of adult food in egg production. Consistent with these traits, under laboratory conditions, *S. mormonia*'s eggs are heavier, and fecundity decreases to a greater extent under nutrient stress. Nonetheless, *S. mormonia* does not defend egg mass or egg energy stores under nutrient stress, although *C. eurytheme* does. We also compare female performance under stress in the lab with that in the field for *S. mormonia*.

108.4 BOK, MJ*; PORTER, ML; CRONIN, TW; University of Maryland, Baltimore County; *mikebok@gmail.com*
The physiological basis of polychromatic ultraviolet vision in mantis shrimp
Stomatopods, or mantis shrimps, possess the most spectrally diverse retinal photoreceptor array yet described. Their photoreceptors are maximally sensitive to sixteen discrete wavelengths of light between 310 and 700 nm, as well as to linearly and circularly polarized light. The spectral tuning mechanisms at work in these photoreceptors have been well described within the human visible range, above 400 nm, showing that this surprising diversity of photoreceptor types is achieved through unique arrangements of visual pigments and long-pass optical filters in receptor sets of reticular cells 1 to 7 (R1-R7). However, stomatopods also have R8 photoreceptors sensitive to at least five different wavelength ranges of ultraviolet (UV) light, but little is known about their spectral tuning. Here we present molecular and physiological evidence that polychromatic UV vision in the stomatopod *Neogonodactylus oerstedii* is achieved by the elegant pairwise combinations of one of typically two visual pigments, absorbing at 330 nm and 380 nm respectively, with four novel UV-specific short- and long-pass optical filters. Modeling of photoreceptor spectral sensitivity from the absorbance spectra of these filters and pigments closely matches previous electrophysiological recordings from the R8 receptor cells. Furthermore, various species of stomatopods utilize different complements of these components, producing a diversity of UV receptor suites throughout the order. The sophisticated composition of stomatopod UV photoreceptors suggests an essential role for this capacity in their visual ecology.

P2.24 BOLES, S.E*; HETTINGER, A; GAYLORD, B; SANFORD, E; TODGHAM, A.E; San Francisco State University, Bodega Marine Laboratory, Univ. of California, Davis, San Francisco State University ; *ponettie@mail.sfsu.edu*
Physiological cost of future ocean conditions on larval development in the native Olympia oyster, Ostrea lurida.
Since the Industrial Revolution, roughly 48% of anthropogenic CO_2 has been absorbed by the oceans, causing a reduction in pH of 0.1 units, and a further decrease of 0.3-0.4 pH units is expected by the end of this century. A great deal of research has been done to predict the future impacts of ocean acidification (OA) on calcifying organisms; however, studies examining the synergistic effects of OA and global warming on the physiological and biochemical processes during early development of calcifying animals are unclear and require further analysis. We reared larvae of the native Olympia oyster, *Ostrea lurida*, under a factorial combination of CO_2 (control, 385ppm vs. elevated, 1000ppm) and water temperature (control, 20°C vs elevated, 24°C). To evaluate the energetic costs associated with growth and development under these treatments, we assessed enzyme activity of the Krebs cycle, a proxy for aerobic metabolism. To further investigate cellular transcriptional activity under experimental conditions, RNA to DNA ratios were measured. Larvae reared under conditions of elevated CO_2 could face higher energetic demands, leaving less energy available for biomineralization and growth. This in turn could leave less energy available for coping with thermal stress (e.g. ocean warming as well as highly variable thermal habitat of the intertidal zone), possibly impeding survival and settlement of *O. lurida*. With global climate change, a plethora of environmental factors are predicted to undergo relatively rapid changes; therefore it is pertinent to understand the impacts of climate change from a multi-stressor perspective.

116.9 BOND, C; Greensboro College, North Carolina; *bondc@greensboro.edu*
Comparative Time-Lapse Studies of Coughing Calcareous Sponges
Despite their lack of muscles and neurons, sponges are capable of propagated contractile events, known as contractile waves. These contractions have been studied mostly in demosponges with the typical leuconoid canal design. This present study presents novel time-lapse examinations of contractions in live calcareous sponges with simpler canals: *Leucosolenia botryoides* (asconoid canals) and *Sycon clliata* (syconoid canals). Particular attention was paid to contractile events here termed "debris coughs", in which clouds of debris were ejected from excurrent oscules during a contractile wave. Debris coughs occurred in both asconoid and syconoid sponges: syconoid sponges were observed to cough more frequently and in apparently greater volumes than was seen in asconoid sponges. Debris fields (presumably ejected by a cough) also were seen occasionally with *Sycon* sponges: these deposits were composed of small round cells of uncertain nature, but they were in the same size range as choanocytes. Putative ingredients of the ejected debris clouds could be sponge cells and/or the residue of organisms (victims of predation and filtration) trapped and consumed in the canals of these highly spiculose sponges.

62.2 BONETT, RM*; TRUJANO-ALVAREZ, AL; WILLIAMS, MJ; TIMPE, EK; University of Tulsa, Louisiana State University, University of Connecticut; *ron-bonett@utulsa.edu*
Biogeography and body size shuffling of aquatic salamander communities on a shifting refuge
The Southeastern Coastal Plain of North America is a refuge for many divergent lineages of freshwater vertebrates. However, this region was submerged by a marine transgression throughout the Eocene, so the modern Southeastern Coastal Plain and its communities are relatively young. Using the fossil record and a multi-locus nuclear phylogeny, we examine divergence times and body size evolution of aquatic salamanders from North American coastal plains since the Mesozoic. At least five salamander families occurred on the extensive Western Interior Coastal Plain, which existed from the Upper Cretaceous through the Eocene. Four of these families subsequently colonized the Southeastern Coastal Plain by the early Oligocene to late Miocene. The oldest divergences among extant species from Southeastern Coastal Plain endemic clades occurred during the Miocene, indicating that most of the current diversity arose from a single lineage of each family that colonized the Southeastern Coastal Plain after the Eocene marine regression. Body size is highly labile in these four families, which show at least one or more major size shifts since the early Cenozoic, including two recent size reversals in endemic Southeastern Coastal Plain clades. This has resulted in continuous shuffling of the size order of aquatic salamander lineages on this shifting refuge since the Late Cretaceous. Therefore, while the environmental niche parameters of these aquatic salamanders may be highly conserved, size related ecological factors (eg. trophic interactions) have likely been highly labile across space and time.

S6-1.5 BOONSTRA, R.; University of Toronto Scarborough; *boonstra@utsc.utoronto.ca*

The role of the stress axis in coping with chronic uncertainty

The adaptations animals have in the natural world are solutions to ecological problems to which they have a long evolutionary history. The stress axis is a vital regulator of that adaptation. Animals in nature experience periods of long-term uncertainty because of lack of food, severe weather, high predator threat, social conflict, and so on. However, only some species are chronically stressed by these factors – showing chronic changes in their physiology, reproduction, and condition; others deal with a stressor acutely and then go back to the business of living. I will present evidence that the stress axis in the first group continues to function remarkably well. The difference between chronic and acute responses of the two groups may be related to their life history. Though the biomedical literature and most of the literature on natural populations regard chronic stress-induced changes as pathological, I will argue that these changes are adaptive and ultimately promote an animal's survival and reproductive success.

P3.132 BOOTH, KK*; GREENLEE, KJ; North Dakota State University , North Dakota State University; *kimberly.booth@my.ndsu.edu*

Hormonal Control of Developmental Effects on Immunity in the Caterpillar, Manduca sexta

Insect immunity is innate immunity and can be classified as humoral, such as the production of anti-microbial peptides (AMPs) and phenoloxidase (PO), or cell-mediated. Cell-mediated immunity includes encapsulation, nodulation, and phagocytosis. Previous research has shown that insect immune responses change within an instar, or developmental stage. *Manduca sexta* larvae (tobacco hornworm) early in the 5th and final instar have more robust cell-mediated and humoral immune responses to bacterial infections when compared to animals later within that instar. However, it is unclear how immunity varies within other instars. Before we can compare the immune response in 3rd and 4th instars, we validated the effect of development on immunity in 5th instar *M. sexta*. AMP and PO activity of hemolymph from *M. sexta* did not vary within the first four days of the 5th instar. However, hemolymph from *M. sexta* injected with vehicle had statistically higher levels of PO activity compared to caterpillars injected with *Micrococcus lysodeikticus* regardless of age, indicating that bacterial injection depletes PO stores. Other research has shown that juvenile hormone (JH), which regulates development and peaks at the beginning of an instar, may be immunostimulatory. To test the hypothesis that JH drives developmental-dependent changes in immunity, we will apply JH inhibitor to caterpillars early in the 5th instar and JH analog in late 5th instar caterpillars, and measure AMP and PO activity as an index of immune function. These data highlight the need for accounting for within-instar age in experimental design.

104.6 BORCHERT, JD*; ANGILLETTA, MJ; Arizona State University; *jdborche@asu.edu*

The younger games: flies compete for oviposition sites that benefit their young

We used game theory to predict how fruit flies (*Drosophila melanogaster*) should compete for oviposition sites. Although flies prefer to lay their eggs within a particular range of temperatures, the potential for competition among offspring should cause females to accept warmer or cooler sites when preferred sites become crowded. To look at this problem, I observed where flies chose to lay eggs under various densities of competing females. In each trial, 1, 5, 10, or 20 flies were placed within a thermal gradient of potential oviposition sites, (a grape agar media ranging from 21°C to 37°C). Additionally, I also ran a trial where I added a single fly at a time to the thermal gradient to see if effects on behavior resulted from the presence of other females or the presence of eggs on the media. After 9 hours, I counted the eggs laid in each portion of the gradient and analyzed how the distribution of eggs was affected by the density of females. By drawing on game theory to make quantitative predictions, this research builds on previous empirical studies of competition between thermoregulating animals.

P2.125 BORSTEIN, SR*; MCGEE, MD; WAINWRIGHT, PC; California State University, Sacramento, University of California, Davis; *sam@borstein.com*

Mouthbrooding does not constrain craniofacial diversity in Lake Tanganyika cichlids

Mouthbrooding, the parental care strategy in which the eggs or larvae are incubated in the mouth, may constrain craniofacial diversity in teleost fishes. In this study, we examined mouthbrooding and morphological diversity in cichlid fishes from East Africa's Lake Tanganyika. This radiation is approximately 5-6 million years old and consists of nearly 200 species. Ancestral state reconstruction reveals that there is a deep split between a clade of substrate-spawning cichlids (Lamprologini) and a clade of mouthbrooding cichlids. We used geometric morphometric methods with the TPS family of programs to digitize a set of 25 sliding semi-landmarks along the dorsal and ventral outline of the head for every described cichlid species endemic to Lake Tanganyika. We generated a morphospace of relative warps, retaining three axes that explained more variation than would be expected by chance. Head elongation or deepening was the major axis of diversity and accounted for 60 percent of variation. The other two axes explained 16 and 12 percent of variation and were driven by mouth angle and mouth size, respectively. We then examined patterns of diversity in the mouthbrooding and non-mouthbrooding sister lineages using the program Morphospace Disparity Analysis to generate 10,000 bootstrapped samples of the mean Euclidean pairwise distance, a common measure of morphological diversity. Surprisingly, mouthbrooding species exhibit nearly three times the average pairwise distance of non-mouthbrooders (3.1 in mouthbrooders vs 1.3 in non-mouthbrooders, $p<0.01$). Our results demonstrate that, contrary to expectations, mouthbrooding does not constrain craniofacial diversity in Tanganyikan cichlids.

P3.75 BOSTWICK, C.J.*; WINTERS, G.C.; DABE, E.C.; BOBKOVA, Y.; CITARELLA, M.R.; KOHN, A.B.; SWALLA, B.J.; MOROZ, L.L.; University of Florida, University of Washington ; *bostwick@ufl.edu*

Piwi genes and their expression in the ctenophore Pleurobrachia bachei: Quest for ancestral master regulators of non-coding RNAs in animals.

In the short time since their discovery, the function and properties of non-coding RNAs (ncRNAs) have been the subject of intense research focus. These species of RNAs are not translated into protein, but serve other roles in the development and regulation of an organism's genome. Piwi proteins are a subfamily of the Argonaute family of proteins, which bind small ncRNAs and have been implicated as being one of the chief protein components of transcriptional and post-transcriptional gene silencing. Moreover, Piwi proteins and their ncRNAs (known as piRNAs) have also been shown to play a role in the epigenetic modification of the genome. We have discovered two Piwi genes in the genome of the pelagic ctenophore, *Pleurobrachia bachei*. Comparative genomic analysis to a variety of metazoan Piwi sequences provided evidence that the *P. bachei* Piwi genes are indeed homologous to those of other metazoans. The Piwi mRNA was expressed in the tentacle bulbs, comb tips, aboral organ, and gonads of *P. bachei*. However, the expression of each Piwi within these body structures differed slightly. We also found both Piwi transcripts expressed in the embryonic stages of *P. bachei* in transcriptome sequencing projects, indicating a role for Piwi during the development and maturation of *P. bachei*. Further experiments utilizing RT-PCR showed both Piwi RNAs being transcribed in the majority of embryonic stages from one cell to twenty-four hour old embryos. This suggests that, in ctenophores, Piwi is expressed in both the germline and in stem cells and is likely involved in the process of cellular differentiation.

137.1 BOUILLIART, M.*; TOMKIEWICZ, J.; LAUESEN, P.; ADRIAENS, D.; Ghent University, Belgium, Denmark Technical University Aqua, Charlottenlund, Billund Aquakultur, Denmark; *mathias.bouilliart@ugent.be*

The feeding apparatus of first feeding European eel (Anguilla anguilla) larvae: a functional morphological approach

The European eel (*Anguilla anguilla* Linnaeus 1758; Actinopterygii, Anguillidae) is faced with a severe decline (up to 99%) in its natural populations over the last 40 years. Due to the absence of knowledge regarding the exact cause for this decline, a lot of effort is recently put in obtaining a complete artificial breeding program for this endangered, but still globally traded species. Unfortunately, the artificially reared eel larvae are, at present, unable to stay alive for more than three weeks after hatching. Since the larval mortality rate peaks at the onset of active food uptake, and literature regarding the larval feeding capacities, strategies and natural prey preferences is rather scarce, a functional morphological analysis of the feeding apparatus of first feeding larvae is performed. This analysis includes modeling the theoretical bite force by using a graphical 3D-reconstruction of the musculoskeletal system of these extremely small organisms (< 1cm). Based on the acquired 3D data of joints, levers and muscle insertions, as well as muscle data, very small bite forces (10^{-5} N) are obtained for these European eel larvae. Additionally, preliminary data on kinematics (from video recordings) of jaw and hyoid movements in pre-feeding larvae demonstrates a rather limited ability of jaw movement by both ligaments and muscles. Combining both results, rather small and soft food items are suggested to be preferable in both natural and artificial environments, which appears to be in line with the existing hypothesis that these larvae feed on either small and/or gelatinous prey items in nature (Hydrozoa, Thaliacea, Ctenophora, Polycystenia) and, additionally, may be useful information to optimize the artificial breeding program.

S8-1.3 BOURY-ESNAULT, N.*; LAVROV, D.; PéREZ, T.; IMBE-UMR7263, CNRS, Université d'Aix-Marseille, Station Marine d'Endoume, Marseille, France, Department of Ecology, Evolution, and Organismal Biology, Iowa State University, Ames, IA, USA, IMBE-UMR7263 CNRS, Université d'Aix-Marseille, Station Marine d'Endoume, Marseille, France; *nicole.boury-esnault@orange.fr*

The integrative phylogeny approach applied to Porifera: a case-study the Homoscleromorpha

The two main scientific tasks of taxonomy are species'delineating and classification. These two tasks are often treated differently, with species classification accomplished by newly-developed phylogenetic methods, often based on molecular sequences, while species delimitation is conducted by what is often considered as an "old-fashioned" typological approach based on a morphological description. A new "integrative taxonomy" approach has been recently proposed (Dayrat, 2005) maintaining that species delimitation should be a multidisciplinary undertaking combining several independent datasets. Here we argue that the same principle is relevant to species classification. In the last 20 years we assembled various datasets based on external morphology, anatomy, cytology, spicule shapes, geography, reproduction, genetic sequences and metabolomics of homoscleromorph sponges. We show how we used these datasets to describe new species of homoscleromorph sponges and to elucidate their phylogenetic relationships and their phylogenetic position within the phylum Porifera.

P1.32 BOVERY, CM*; WYNEKEN, J; Florida Atlantic University; *cbovery@fau.edu*

Spatial and Temporal Distributions of Sea Turtles in the Florida Gulf Stream

An understanding of the spatial and temporal distributions of a species is essential to understanding its basic habitat needs including large-scale movements and seasonal changes in behavior. Such basic information for large pelagic vertebrate is often restricted to satellite tag data or coastal observation. For species that undergo spatially discrete habitat shifts through their various life stages, such information is often incomplete. Sea turtles are migratory throughout their lives. Their habitats range from coastal foraging grounds to pelagic fronts and are linked by migratory corridors. We conducted approximately monthly aerial surveys of the Florida Current between the southeast coast of Florida and the Bahamas banks to establish when and where sea turtles used this fast moving component of the Gulfstream Current. The initial year of surveys identified loggerhead (*Caretta caretta*) and green (*Chelonia mydas*) turtles as the most frequently observed species. Leatherback (*Dermochelys coriacea*) and other sea turtles not identified to species were also observed. Locations of sea turtle sightings suggest presence along the western edge of the Florida Current peaks in the spring and early summer during breeding season. Additionally, few to no sightings in areas farther offshore (20-60nm) suggest either turtles seldom use these waters or water speeds are fast enough to exceed our resolution. These data both expand our understanding of current use by migratory turtles and bolster spatially and temporally explicit conservation strategies that emerge with growing utilization of oceanic resources.

S5-1.2 BOWDEN, R.M.*; CLAIRARDIN, S.G.; PAITZ, R.T.; Il. St. Univ.; *rmbowde@ilstu.edu*

Early hormonal influences on temperature dependent sex determination in turtles

In reptiles with temperature dependent sex determination (TSD), treatment with exogenous steroids, particularly estrogens, during the middle third of development have well documented effects on sex determination. Less well understood are the effects of maternal or endogenous steroids on development, despite the fact that eggs have a rich supply of maternal steroids at oviposition. Because embryos are exposed to steroids very early in development, understanding the fate of those compounds, and potential effects on development are critical to revealing the link between early exposure to steroids and steroid effects. To this end, we have been investigating embryonic metabolism of maternal steroids, how timing of exposure influences steroid effects, and more recently, the effects of endocrine disrupting compounds during early development in the red-eared slider turtle *Trachemys scripta*. We have found that the embryo and its associated membranes are responsible for the metabolism of maternal steroids, and that estradiol is converted to several estrogen sulfates that are present in both the yolk and albumen egg compartments. Interestingly, at least some of these sulfonated products are capable of influencing sex determination, as we have demonstrated with exogenously applied estradiol sulfate. When the endocrine disruptor Bisphenol-A is applied to eggs, the rate and end products of estrogen metabolism, and sex determination are altered. The metabolism of maternal estrogens is important to modulating the influence of steroids on development, and disruption of this process may help explain how the estrogenic effects chemicals such as Bisphenol-A are elicited.

P2.96 BOWER, C.D.*; BARRILE, G.M.; DOWNS, L.K.; KLINGER, J.M.; MOORE, J.T.; Bloomsburg University, Bloomsburg; *cdb84667@huskies.bloomu.edu*

Investigation of the Island Rule in Anurans: A Comparative Study of Hyla cinerea and Anaxyrus fowleri

Studies of body size evolution disagree on evolutionary and ecological mechanisms of body size in island populations. The Island Rule hypothesis predicts that small insular vertebrate carnivores evolve to display gigantism. We studied a case of island dwarfism in anurans, small vertebrate carnivores, comparing Fowler's toads and green tree frogs on barrier islands to nearby mainland populations on the eastern shore of Virginia. In contrast to the Island Rule, island toads (*Anaxyrus fowleri*) display a significant body reduction (about 20%) compared to their mainland counterparts. Is this due to evolution or environmental stresses on the island? Evidence from a common garden experiment investigating Fowler's toads suggests similar larval growth rates, development, and size at metamorphosis of island and mainland tadpoles. We decided to conduct a comparative study to better understand if insular dwarfism in anurans is unique to Fowler's toads, or if other anuran species inhabiting the islands show similar differences to mainland conspecifics. We collected mature male green tree frogs (*Hyla cinerea*) from four different habitats (two island, two mainland) and characterized the snout to vent lengths of each population. Results suggest that, similar to the Fowler's toads, green tree frogs also display a reduction in body size (about 6%) from their mainland counterparts. These results suggest that barrier island environments strongly influence the growth and body size of anurans.

22.3 BOWERS, E.K.*; SAKALUK, S.K.; THOMPSON, C.F.; Illinois St. Univ.; *ekbowers@ilstu.edu*

Immune challenge and terminal investment in female house wrens (Troglodytes aedon)

The reproductive costs associated with up-regulation of the immune system have been well-documented and arise from a trade-off between reproductive effort and self-maintenance. However, some recent studies that activated the immune system of breeding individuals found that parents actually increased, rather than decreased, reproductive effort following immunostimulation, suggesting terminal parental investment as prospects for future reproduction declined. We tested the trade-off and terminal investment hypotheses in a free-living population of house wrens (*Troglodytes aedon*) by challenging the immune system of breeding females with an antigen, lipopolysaccharide. Immunized females showed no evidence of subsequent reproductive costs associated with the immunostimulation; instead, they produced offspring of higher phenotypic quality, but in a sex-specific manner. Relative to control offspring, sons of immunized females had increased body mass and their sisters enhanced cutaneous immune responsiveness to phytohaemagglutinin injection. Further study suggests that immunostimulation leads to an increase in both pre-hatching resource allocation to eggs and post-hatching maternal effort when provisioning live young.

99.1 BOWSHER, J H*; ANG, Y; FERDERER, T; MEIER, R; North Dakota State University, National University of Singapore; *julia.bowsher@ndsu.edu*

Deciphering the evolutionary history and developmental mechanisms of a complex sexual ornament: the abdominal appendages of Sepsidae (Diptera)

Male abdomen appendages are a novel trait found within Sepsidae (Diptera). Here we demonstrate that they are likely to have evolved once, were lost three times, and then secondarily gained in one lineage. In order to establish the developmental mechanism for appendage formation, we studied the development of the sternites in males and females for three species with and one species without the appendages. For each species and sex the number of cells in the ventral histoblast nests was counted. The species without appendages has similar cell counts in all sternites regardless of sex. All species with appendages have elevated cell counts for the fourth segment, which gives rise to the appendages. In *Perochaeta dikowi*, which reacquired the trait, the female also has an elevated cell count on the fourth segment despite the fact that females do not develop appendages. This difference suggests that *P. dikowi* has evolved a different developmental mechanism for appendage formation.

62.3 BOYER, SL*; BAKER, CM; POPKIN-HALL, ZR; LAUKO, DI; WIESNER, HA; KOZAK, KH; LUXBACHER, AE; Macalester College, University of Minnesota; *boyer@macalester.edu*

Historical biogeography of mite harvestmen from the Wet Tropics of Australia

The Wet Tropics of Queensland, Australia have emerged as a model system for understanding the evolutionary effects of climate change on rainforest animals. In vertebrates whose species distributions span the Wet Tropics, contraction and fragmentation of forest habitats during the Last Glacial Maximum has resulted in population-level divergences whose genetic signatures are apparent today. In contrast to vagile vertebrate species, the dispersal-limited leaf litter-dwelling mite harvestmen (Arachnida, Opiliones, Cyphophthalmi) have tiny species distributions (~50km in diameter). As a result, the consequences of habitat fragmentation and contraction are expected to differ from what has been documented in vertebrates. Currently, our knowledge of the diversity and distribution of mite harvestmen across the Wet Tropics is in its infancy, but significant progress has been made and historical biogeographic patterns have begun to emerge. We present new species and new locality data, ecological niche models and hindcasting, and a preliminary phylogeny for the mite harvestman genus *Austropurcellia*.

22.1 BOYLE, W.A.*; WINKLER, D.W.; GUGLIELMO, C.G.; Kansas State U., Cornell, U. Western Ontario; *aboyle7@mail.ubc.ca*

When and how do Tree Swallow chicks die during cold weather?

Temperate-breeding altricial birds face strong selection to breed early with the consequence that chicks experience periods of inclement weather that both increase thermogenic stressors and reduce their food supply. Tree Swallows (*Tachycineta bicolor*) are aerially-foraging cavity-nesting insectivores that frequently suffer complete or partial nest failure during cold weather. We studied individual-level chick mortality risk in a population of Tree Swallows near Ithaca, NY during 2010. Using weather and food data collected locally, we measured environmental conditions chicks experienced between hatching and fledging. We also characterized the development of chicks at days 3, 6, 9, and 12 by weighing, measuring feather cover, capacity for endothermy, and body composition using quantitative magnetic resonance (QMR). During periods of cold weather, we weighed and conducted additional QMR scans daily, and determined chick fate. Two cold snaps occurred during the study, and due to nesting asynchrony, cold weather affected chicks at all stages of development. Of the 140 chicks we followed (32 nests), 65 (from 19 nests) died during or immediately following periods of cold weather. Mortality risk was highest for 6-9 day-old-chicks. At this age chicks have a moderate capacity for endothermy but have incomplete insulation from growing feathers. Chicks died with on average 9.6% fat which is 3.6% more fat than lean females carry at the end of the breeding. After controlling for body composition change with chick age (linear decrease in proportion of mass accounted for by fat), the last measurements prior to death revealed slightly higher fat loads than on chicks that survived. Our data suggest that chicks are most vulnerable midway through development, and that they do not die because they have exhausted their energy stores.

P3.131 BRACE, A.J.*; COON, C.A.C.; MCCUE, M.D.; MCWILLIAMS, S.R.; MARTIN, L.B.; University of South Florida, St. Mary's University, University of Rhode Island; *abrace@mail.usf.edu*

Critical amino acid allocation as a mediator of range expansion in an introduced species

The spread of introduced species into new territory can cause economic damage and disrupt native ecosystems. However, little is known about how some populations shift their ranges following an introduction. One hypothesis proposes that individuals that invest less in immune defenses than other processes, such as reproduction and growth are the most likely to successfully colonize new areas. This hypothesis rests on the assumption that investments in immunity and reproduction trade-off, though almost all support for this is indirect. To directly discern the significance of resource allocation in animal range expansions, we compared investments in immune versus reproductive and somatic tissues between house sparrows (*Passer domesticus*), currently undergoing range expansion in Kenya and grey-headed sparrows (*Passer griseus*), a native congener. We directly measured allocation of an isotope-labeled critical amino acid (13C-labeled leucine) among gonads, liver, spleen, intestines and pectoral muscle after individuals from both populations were experimentally infected with a naturally occurring intestinal (coccidian) parasite. We hypothesized that house sparrows would allocate more resources to gonads and pectoral muscle than liver and spleen compared to grey-headed sparrows. Analyses are underway but our results will provide one of the first direct studies of the role of resource allocation in range expansion.

P1.78 BRADY, P/C*; TRAVIS, K/A; MAGINNIS, T; CUMMINGS, M/E; University of Texas at Austin, University of Portland; *pbrady@physics.utexas.edu*

The polaro-cryptic mirror: a biological adaptation for open-ocean camouflage

With no object to hide behind in 3D-space, the open ocean represents a challenging environment for camouflage. Camouflaging to solar illumination poses particular problems due to the dynamic polarization aspect of the light field. Near the water surface, the degree of polarization can be up to ~70%, and the complex polarization distribution changes throughout the day. Polarization vision research predicts the importance of polarized light in predator-prey interactions. Presently understood underwater crypsis strategies (e.g. vertically held mirror-like surfaces) are effective against axially-symmetric spectral irradiance fields present in high solar elevation conditions (noon), yet ineffective against asymmetric polarized light fields present at lower solar elevation conditions (sunrise, sunset) in the first 15 meters of the open ocean. Here, we evaluated polarization camouflage strategies by measuring the Mueller matrix (a mathematical description of a surfaces polarization reflection property) of an open-ocean mirror-like fish, the Lookdown (*Selene vomer*). We calculated the range of Mueller matrix values that would maximize crypsis by approximating a fish as a vertically held plate and summing the polarization contrast values for all other predator-prey viewing angles. Our results show that the Lookdown's Mueller matrix values occupy the minimization basin of the calculated polarization-contrast space, and suggest an evolutionary adaptation for polaro-crypsis. Lookdown reflectance properties exhibit significant gains in polaro-crypsis (up to 80%) from other reflective crypsis strategies by incorporating angle-specific depolarization and transformation of incident polarization.

54.2 BRAMANTI, L*; EDMUNDS, PJ; California State Univ Northridge; *philebo@gmail.com*
Demographic models can forecast climate change effects on scleractinian corals: the Pocillopora damicornis case study
Climate change and ocean acidification (OA) are large-scale threats for coral reefs, yet despite a growing literature on the effects of temperature and pCO_2 on reef corals, few studies have attempted to forecast the effects at a population level. According to projections, seawater pH will decrease 0.3 to 0.4 by the end of the 21st Century, and temperature in tropical seas will be 3.2°C warmer. Using empirical analyses of the effects on respiration, survival, and calcification of early life stages of *Pocillopora damicornis*, we employed a demographic approach to forecast the consequences of climate change and OA on the population dynamics of this coral. Such approach can supply useful tools to forecast population dynamics under different environmental conditions. We constructed a size-based demographic model using life-history tables and transition probabilities for a population of P. damicornis in southern Taiwan and projected the population structure over 100 y under differing scenarios. The simulations incorporated a decline of larval survival due to increases in temperature and pCO_2, with the results suggesting that an increase of pCO_2 from 380 to 900 ppm could lead to a non-linear reduction in population density from 11.6 to 2.3 colonies m^{-2} in 150 y. In the first 130 y population density remains 10.6 colonies m^{-2}, but thereafter declines quickly to 2.3 colonies m^{-2} by 2162. A temperature increase from 26.4°C to 29.6°C could further reduce density to 2.1 colonies m^{-2}. The drastic decrease happens when larval survival reduce to 80%, suggesting early life stages can play an important role in the population dynamics of this species. Our model can be expanded to a metapopulation approach linking multiple populations using a connectivity matrix including empirical estimates of larval dispersal under future climate conditions

134.3 BRANDLEY, NC*; JOHNSON, MG; JOHNSEN, S; Duke University; *ncb9@duke.edu*
Reduction of an aposematic signal: the role of microhabitat in North American black widows (Latrodectus)
An aposematic signal may warn a predator of the signaler's dangerous capabilities. While much work has focused on the evolution and form of aposematic signals, few studies have examines why they may be lost or reduced. Ancestral trait reconstruction suggests that two species of North American black widows (*Latrodectus mactans* and *L. hesperus*) exhibit a reduction of aposematic coloration. While these species still possess the black widow's iconic ventral red hourglass, they usually lack the dorsal coloration seen in congeners. To examine why *L. mactans* may have reduced its coloration, we present microhabitat comparisons between it and a sympatric black widow, *L. variolus*, that has retained its dorsal coloration. We found that the dorsally all-black *L. mactans* (N=21) tends to prefer lower microhabitats than that the dorsally colored *L. variolus* (N=27, p<.05). We suggest that when considering microhabitats, the differences in coloration between the species may represent a cost-benefit tradeoff between signaling to predators and avoiding presenting a queue to eavesdroppers. Because *L. mactans* is found close to the ground with its hourglass pointed upwards, it is less likely that a predator will view its dorsal side than for *L. variolus*. However many prey still approach from below, and reducing dorsal coloration may improve *L. mactans'* foraging ability.

132.2 BRASCHAYKO, E.B.*; RILEY, L.G.; Fresno State Univ.; *ebrasch45@mail.fresnostate.edu*
The Effects of Chronic Cortisol on Appetite in Tilapia Oreochromis mossambicus
Stress in fish has been shown to impair growth, reproduction, immune function and overall health. Stress is managed along the hypothalamic-pituitary-interrenal axis resulting in the release of cortisol. In the brain, appetite regulating hormones include ghrelin, neuropeptide Y (NPY) which both stimulate appetite and corticotropin releasing hormone (CRH) which acts to decrease appetite. Cortisol has been shown to decrease food intake and growth in several species of fish. Whether cortisol is altering the neuroendocrine regulators of food intake is poorly understood in fish. The current study was designed to investigate the effect of chronic cortisol treatment on food intake and the endocrine regulators of appetite in tilapia. Tilapia were fed one of the following treatments: 0 mg/kg (control), 50 mg/kg, and 500 mg/kg cortisol-laden feed. For 32 days fish were fed a known amount of excess feed twice a day, at 0900 and 1600h, and allowed to feed for 1h at which point remaining food was collected to determine food consumption. At 32 days fish were sacrificed and brain and stomach were collected. The high cortisol dose significantly reduced food intake and growth compared to controls. In both the telencephalon and hypothalamus regions of the brain, there was a significant decrease in NPY expression in both the low and high cortisol dose treated fish compared to controls. Interestingly, there was no change in ghrelin expression in the hypothalamus and stomach but ghrelin expression in the telencephalon was significantly decreased in the low cortisol dose. There was no change in CRH levels across treatments in the telencephalon or hypothalamus regions. These data suggest that chronic exposure to cortisol may decrease appetite by decreasing expression of appetite stimulating hormones in the brain.

P3.183 BRASHEARS, J.A.*; FOKIDIS, H.B.; DENARDO, D.F.; Colgate University, University of British Colombia, Arizona State University; *jbrashears@colgate.edu*
Defense behavior and the stress response in three species of python
Previous research has focused on correlating an animal's type of defense behavior with its stress response. Proactive defense behaviors (fighting or fleeing)have been associated with high baseline plasma glucocorticoid concentrations and low hormone stress responses, while reactive defense behaviors (freezing or hiding) have been associated with high hormone stress responses. This paradigm has been fruitful in understanding the behavior of many organisms, particularly mammals and birds, but it is unknown how broadly this paradigm can be extended to other taxa. We tested the relationship between defense behavior and the stress response in three species of python (*Antaresia childreni*, *Python regius*, *Bothrochilus boa*) with qualitatively different defense behaviors. We measured defense behavior both pre- and post-stressing, and compared the results to plasma corticosterone concentrations. We also measured maximum corticosterone production in each species using intracardiac injection of adrenocorticopric hormone (ACTH). Contrary to our predictions, we found that species with proactive defense behavior had a higher hormone stress response than the species with reactive defense behavior. Although the most aggressive species, *B. boa*, has high baseline levels of corticosterone, they were not high in the other proactive species, *A. childreni*. We conclude that the proactive/reactive dichotomy may not be sufficient to explain the relationship between the stress response and defense behavior in pythons and that further research in this area should focus on identifying broad trends across diverse species.

68.2 BRAZEAL, KR*; HAHN, TP; UC Davis; *krbrazeal@ucdavis.edu*

Comparing the effects of testosterone treatment on onset and continuity of plumage molt between two species of cardueline finch

All birds must replace their feathers each year in order to survive, but species vary in their flexibility of timing the transition from breeding to molt. Past studies have established that high levels of sex steroids (e.g. estradiol and testosterone associated with breeding) can delay the onset of molt. Differing responsiveness to sex steroids may be responsible for variation in molt timing among species. This study compared the role of testosterone in regulating molt timing in two species of cardueline finches. House finches and pine siskins are both seasonal breeders, but the latter are considered more flexible in their reproductive timing because they will sometimes arrest their molt if conditions become favorable for late summer breeding. Wild caught birds of both species were brought into captivity and treated with testosterone via silastic implants administered either prior to molt or during the middle of molt. We found that pine siskins were more sensitive to testosterone than house finches; testosterone completely prohibited molt in the siskins until the implants were removed, while many of the house finches were able to slowly molt a limited number of feathers during the treatment period. However, house finches given testosterone during the middle of molt arrested molt more abruptly than did pine siskins. These results help to clarify mechanisms by which different species coordinate transitions from one life cycle stage to the next.

67.1 BRAZEAU, M.D.; Naturalis Biodiversity Center; *martin.brazeau@gmail.com*

Taking a step back: computational problems for morphological data revisited

Although no longer as prevalent as molecular sequence data, morphological data remain an important source of phylogenetic and comparative data. Without them, it is impossible to place fossils in the tree of life or have a complete picture of the evolution of phenotypes. However, morphological characters are hierarchical, violating the assumptions of character independence in popular phylogenetic algorithms. Morphological character datasets may thus contain characters that are inapplicable to a subset of the taxa. Existing algorithms and software do not account for this, forcing researchers to develop workarounds at the level of character matrix construction. All these workarounds present computational problems. Possibly the most widely accepted approach to dealing with character inapplicability in morphological datasets is to score inapplicable taxa as missing data. However, it is well known that this approach may artificially add steps to tree scores, potentially discarding optimal solutions during the search process. Here I show modifications to the Fitch parsimony procedure that returns correct counts when non-applicable data are distinguished from missing data, but not considered a separate character state. A preliminary implementation examining published datasets shows that considerable resolution of published morphological trees may owe to computational artefacts owing to non-applicable data. The problem is further explored in light of parametric methods, such as maximum likelihood and Bayesian posterior probability, and possibilities for improving their applicability to morphological data. It is hoped that these considerations and developments can lead to improved algorithms for handling morphological data.

20.6 BRIGHT, J.A.*; COBB, S.N.; MARUGAN-LOBON, J.; RAYFIELD, E.J.; University of Bristol, Hull York Medical School, Universidad Autonoma de Madrid; *j.bright@bristol.ac.uk*

Morphological, dietary and phylogenetic convergence in the diurnal birds of prey

Birds are one of the most diverse clades of modern vertebrates, and have historically been regarded as a classic group in which to study adaptation through evolution. Different lineages of birds often display remarkable convergence in their cranial and beak morphologies, frequently presumed to be associated with similarity in dietary niche. We tested this assumption by performing Geometric Morphometric (GMM) analyses within a subset of neognathous birds, the diurnal birds of prey. Recent molecular phylogenies have classified this group as polyphyletic. There are therefore multiple examples of convergence within this subset of birds, for instance between the falcons (Falconidae) and hawks (Accipitridae), or between the Old World vultures (Accipitridae) and New World vultures (Cathartidae). Three-dimensional landmarks and semi-landmarks were collected from the beaks and skulls of diurnal raptors. Principle Components Analysis shows that carrion feeders (the Old and New World vultures) tend to cluster together in morphospace regardless of phylogeny, indicating strong morphological as well as dietary convergence. However, despite obvious dietary convergences, Falconids plot separately to all other Accipitrids. Thus it seems that although dietary niche may be predicted based on cranial morphology in some families, ecology alone is insufficient to explain the variety of forms seen in the diurnal birds of prey. This may reflect the fact that many raptors hunt and kill with the talons not the beak, meaning that talon morphology may additionally predict dietary ecology. Further functional analysis of the range of talon and beak forms will aim to test this.

P2.182 BRIM, D.L.*; TADROS, A.K.; TOMLINSON, V.E.; KENNETT, K.M.; BLANK, J.M.; California Polytechnic State University, San Luis Obispo; *douglas_brim@cuesta.edu*

Influence of Ethanol Ingestion on Overload-induced Muscular Hypertrophy in the Rat

Ethanol consumption is known to cause muscle atrophy in humans and rodent models. Numerous studies have characterized the changes in skeletal muscle associated with chronic ethanol ingestion and identified signaling pathways related to intracellular protein synthesis that are inhibited by acute ethanol consumption. However, these studies have been done primarily in sedentary animals. Since protein synthesis in muscle is increased by chronic resistance exercise, we performed an experiment assessing the interaction between ethanol consumption and resistance training in a hind limb muscle of the rat. We overloaded the right plantaris of male Sprague-Dawley rats (n=14) by surgical excision of the gastrocnemius and soleus. The animals were fed either an ethanol or maltodextrin containing liquid diet. After five weeks the plantaris was harvested from both the unaltered and overloaded legs and the muscle masses were compared. Surgical overload significantly increased plantaris mass ($p<0.0001$), and an ethanol diet tended to decrease plantaris mass ($p=0.0697$). In both the overloaded and unaltered legs, the mass of the plantaris was reduced by 12% in rats fed an ethanol containing diet. These results suggest that while ethanol does not prevent hypertrophy induced by chronic resistance exercise, the additive effects of ethanol and exercise are to diminish the hypertrophy induced by exercise. This work was sponsored by the Department of the Navy, Office of Naval Research, under Award # N00014-11-1-359 to the California Central Coast Research Partnership (C3RP).

S10-1.7 BRISCOE, Adriana*; YUAN, Furong; University of California, Irvine; *abriscoe@uci.edu*

Physiological genomics of color vision in butterflies

Butterflies evolve mimetic wing coloration under selection from predators. Unless butterfly eyes have adaptations for discriminating mimetic color variation there is a risk of confusing mimics from potential mates for the butterflies themselves. The genus Heliconius, composed of 43 species, is of particular interest because unpalatable species form Müllerian mimicry rings throughout the Neotropics. We have discovered that Heliconius eyes express recently duplicated ultraviolet (UV) opsin mRNAs, and provided evidence that this gene duplication may be an adaptation for species recognition of mimetic colors, via enhanced UV color vision. Little is known, however, about the correlated changes in vision gene expression accompanying the evolution of a new UV-photoreceptor type. We report the results of a large-scale visual transcriptome study. Our results suggest that natural and sexual selection on the compound eye has varied considerably over the evolutionary history of the genus and that tradeoffs exist in evolving increased visual complexity.

66.3 BROTHERS, J.R.*; ERNST, D.A.; HANKINS, K.; LOHMANN, K.J.; University of North Carolina, Chapel Hill; *brotherj@live.unc.edu*

Ontogeny of navigational responses to regional magnetic fields in loggerhead sea turtle hatchlings

Hatchling loggerhead sea turtles (*Caretta caretta*) from the east coast of Florida enter the ocean and immediately begin a long distance migration lasting several years. During this time, many of the turtles circle the Sargasso Sea before eventually returning to the North American coast. Young loggerheads are known to begin their migration with a “magnetic map” in which regional magnetic fields existing along the migratory route serve as open-sea navigational markers and elicit changes in swimming direction at critical points in the migration. Little is known, however, about whether the magnetic fields turtles experience early in their migration influence orientation responses to subsequent regional magnetic fields. As a first step toward investigating, we tested the orientation responses of two groups of turtles with different “magnetic histories” to a field that exists near northern Portugal (north of the normal migratory route). Turtles that had previously swum only in the magnetic field of their home beach failed to show a consistent directional preference when tested in the north Portugal field. In contrast, turtles that had previously swum in a magnetic field that exists near South Carolina (a location along the early migratory pathway) responded to the same north Portugal field by swimming approximately southwest, a direction that might help them remain within the warm-water migratory pathway. These results suggest that experience with magnetic fields that exist along the migratory route can influence subsequent responses to regional magnetic fields under at least some conditions.

124.1 BROWN, AC*; MCGRAW, KJ; CLOTFELTER, ED; Univ. of Massachusetts Amherst, Amherst College, Arizona State Univ.; *acbro0@cns.umass.edu*

Dietary carotenoids increase non-carotenoid coloration of female convict cichlids (Amantitlania nigrofasciata).

The carotenoid tradeoff hypothesis states that carotenoids must be traded-off among competing demands, but this is rarely tested in ornamented females. We used the reverse sexually dimorphic convict cichlid (*Amantitlania nigrofasciata*) to test whether the ornament could contain information about female fitness. Fish were supplemented with 3 levels of carotenoids, and then both spectral and chemical analyses on integument, and chemical analyses on ovaries, were performed. Dietary carotenoid supplementation increased the yellow coloration of the integument, but not actual carotenoid content of the skin. In fact, we found that the yellow patch is produced through a combination of carotenoid pigment and light-reflecting microstructures. Although only behavioral observations can determine the functional significance of the yellow ventral patch, our results indicate that ventral patches contain information about bearers’ carotenoid status. Future research on pigment-based signaling, particularly in fish, should consider the presence and role of structural coloration, in addition to the evolutionary pressures that reinforce honesty in intrasexual signaling.

P1.184 BROWN, T.K.*; MERSCHEIM, M.; DAVIDSON, E.; CSU San Marcos; *traceyb@csusm.edu*

Energetics of Blainville's Horned Lizards, Phrynosoma blainvillii, in Disturbed and Undisturbed Habitats

Blainville’s Horned Lizard, *Phrynosoma blainvillii*, is considered a California state species of special concern. The distribution of this species has declined dramatically in so. Cal. largely because of habitat disturbance, human development, and the introduced Argentine ant. Previous work indicated that the body size, diet, and movements of this species living in disturbed (long-term grazing & fire) habitats were adversely affected. These findings suggest that anthropogenic disturbance may result in higher energy expenditure in the lizards stemming from increased foraging costs. The present study was aimed at estimating the energetics of individual Blainville’s horned lizards to help elucidate the physiological mechanisms driving population decline in suboptimal habitats. Twelve horned lizards (six each in undisturbed and disturbed CSS/chaparral habitat) were captured and fitted with radio-transmitters in Riverside Co., CA. Doubly labeled water was used to study the field metabolic rates (FMR) during two, two-week periods representing late spring and early summer; data on growth, habitat use and movements were also collected. Overall, season had a significant effect on FMR ($P = 0.006$), but there was also a significant season-site interaction ($P = 0.002$) and nearly a season-sex-site interaction ($P = 0.057$). At the undisturbed site, female FMRs increased 13 to 27% while male FMRs decreased by 9 to 40% between the first and second study period. At the disturbed site, all lizard FMRs decreased 20 to 76%. Overall, FMR at the disturbed site appeared to be lower than at the undisturbed site, but this tendency was overshadowed by the large proportion of study animals who were male (only one female followed there) and beginning aestivation. Mean FMR for both sexes combined in the late spring was 0.158 ml CO_2 per gram hour for lizards with a mean body mass of 42.8 g.

P2.165 BROWN, J.M.*; CHUGHTAI, A.; WALKER, R.A.; DEAROLF, J.L.; Hendrix College, Conway, AR; *brownjm@hendrix.edu*

Effects of prenatal steroids on the fetal rectus thoracis

Glucocorticoids accelerate lung development in premature infants and are used in clinical medicine to improve their chances of survival. However, the effects of these steroids on breathing muscle development are undetermined. When glucocorticoids are given to mothers going into premature labor, they cause cell differentiation in tissues to occur sooner than it would during normal development. This switch to differentiation means that cellular proliferation is halted prematurely. We hypothesize that exposure to prenatal steroids will cause IIA fast-twitch fibers in the rectus thoracis, an accessory inspiratory muscle, to be reduced in number. Also, since other studies have shown that steroids lead to muscle fiber atrophy, we hypothesize that exposure to prenatal steroids will result in a decrease in muscle fiber size. To test these hypotheses, the glucocorticoid, betamethasone (0.05 mg/kg), or sterile water, was injected into pregnant guinea pigs twice a week at 65%, 75%, and 85% gestation. Samples of the fetal rectus thoracis muscle were collected 24-hours after the last steroid or water injection. Samples were sectioned and stained with antibodies to differentiate between slow (A4.951) and IIA fast-twitch (2F7) fibers. Digital images of the antibody-stained muscles were taken, and fibers were circled in Scion Image, which measured their mean 2F7 staining densities and diameters. Z-scores were calculated and used to group fast-twitch fibers staining lightly (IIX) or darkly (IIA) for 2F7. The mean proportions and diameters of these fibers were then calculated. If our hypothesis is supported, then infants exposed to glucocorticoids will have smaller and fewer IIA fast-twitch muscle fibers. As a result, the breathing muscles of these infants will be more prone to fatigue from ventilatory activity.

P3.24 BROWNE, D. E.*; LEWIS, K. R.; BAKER, D. M.; University of Mary Washington, Fredericksburg, VA, University of Mary Washington; *dbaker2@umw.edu*

Effects of the herbicide atrazine on gene expression in the zebrafish, Danio rerio: a microarray analysis

Atrazine has been the most widely used conventional herbicide in the United States for many years, and consequently is one of the most common pollutants in American groundwater. Previous research has shown that atrazine exposure negatively affects growth and development, metabolism, and immune function in a variety of vertebrates. In order to identify the molecular pathways underlying these effects, we used whole-transcriptome microarray analysis to test for changes in gene expression in the brain of the zebrafish (*Danio rerio*) after atrazine exposure. We exposed juvenile zebrafish to environmentally relevant levels of atrazine (400 ppb) for 15 days, beginning at 35 days post fertilization. RNA was isolated from whole heads immediately after exposure and at maturity (35 weeks) and cDNA levels from atrazine-treated fish were compared to those from control fish using a zebrafish 12x135K array. We identified 62 differentially regulated genes ($p \leq 0.05$, fold change ≥ 2 or ≤ 0.5) in the juvenile fish and 57 differentially regulated genes in the adults, indicating that exposure to atrazine during development has both acute and long-term effects on gene expression. The affected genes encode peptides that function in development (regulators of cell growth, differentiation, proliferation, and apoptosis); intercellular signaling (receptors, ligands, and transducers); as well as transcription factors, membrane transporters, and metabolic enzymes.

P1.130 BRUCE, HS*; EISEN, MB; PATEL, MB; University of California, Berkeley; *hbruce@berkeley.edu*

The topology of Hox gene networks during limb morphogenesis of the crustacean Parhyale hawaiensis

Generating a multicellular animal from a single-celled zygote requires the coordinated spatiotemporal expression of thousands of genes. Members of the Hox family of transcription factors, expressed in different domains along the anterior-posterior axis of Bilaterian embryos, are well known for their role in determining regional identity. The Hox proteins, however, only regulate the process as transcription factors; it is the hundreds of downstream genes they mobilize that physically construct the embryo. This downstream network that builds each unique region of an embryo is largely a black box. The goal of my project is to systematically identify the genes regulated by Hox proteins in a model crustacean, *Parhyale hawaiensis*, and to begin to dissect their role in segment construction and evolution. I will generate expression profiles from individual segments from single embryos at time points throughout appendage morphogenesis, using Illumina's Tru-Seq platform. This will give me snapshots of only those genes associated with each appendage type, and at progressive stages of morphogenesis. By comparing and contrasting this set of time- and segment-specific expression profiles, I will generate candidate genes with which to perform follow-up functional studies. One question I will address is whether maxillipeds, feeding appendages that evolved independently in at least two crustacean lineages, have co-opted the same genetic pathways to arrive at a similar morphology. This work will provide a detailed picture of the molecular network that connects Hox genes to the structures they pattern in a crustacean model organism, which is necessary for a holistic understanding of morphogenesis and morphological evolution.

P3.76 BRUDERS, R.L.*; MOROZ, L.L.; SWALLA, B.J.; KOHN, A.B.; University of Washington, Friday Harbor Labs, University of Florida, The Whitney Laboratory for Marine Bioscience; *bruder2@uw.edu*

The Wnt pathway in the ctenophore Pleurobrachia bachei

Wnt signaling is known to be critical for proper embryonic development in most animals studied to date (DeSalle and Schierwater, 2008). Still key evolutionary questions on the origin and evolution of this pathway in the metazoan common ancestor remain unresolved. Recently, the genome of *Pleurobrachia bachei*, a member of the early branching metazoan linage ctenophora, has been sequenced. Insights into the function of the *Wnt* pathway in P. bachei will provide information on early evolution of this key pathway. Three *Wnt* ligand genes were identified in *P. bachei* and cloned for *in situ* hybridization. These genes showed expression in the combs, tentacles, mouth, ciliated grooves and polar fields of the adult *P. bachei*. In a genomic search for other members of the canonical *Wnt* pathway, components of the destruction complex and antagonists were incomplete or missing from the genome. *Wnt* expression in the adult *P. bachei* indicates that *Wnt* could also be playing a role in neurotransmission in the adult.

33.5 BRUDERS, R*; KOHN, A.B.; KOCOT, K.M.; SWALLA, B.J.; NOREKIAN, T; MOROZ, L.L.; Univ of Washington, Univ of Florida, Auburn Univ; *rebeccabruders@gmail.com*

Gone with the Wnts: Genomic insights into Wnt signaling in the ctenophore, Pleurobrachia bachei

Wnt signaling is known to be critical for proper embryonic development in most animals studied to date. Still, a key evolutionary question involves the origin and evolution of this pathway in the last common ancestor of metazoan. Recently, the genome of *Pleurobrachia bachei*, a member of the early branching metazoan linage Ctenophora, has been sequenced. Insights into the function of the Wnt pathway in *P. bachei* will provide information on early evolution of this key pathway. *First*, only three Wnt ligand genes (*PbWnt6*, *PbWnt9*, and *PbWntX*) were identified and cloned in *P. bachei* compared the ctenophore *Mnemiopsis leidyi* which has 4 Wnt ligand genes. *Second*, using *in situ* hybridization these genes showed differential expression in the combs, tentacles, mouth, ciliated grooves and polar fields of the adult *P. bachei*. However, surprisingly there were very low levels of expression in all the Wnt ligands in the *P. bachei* embryos. A genomic survey for other members of the canonical Wnt pathway revealed components of the destruction complex and antagonists were incomplete or missing from the genome as was also in *Mnemiopsis*. The extensive expression of Wnt ligands in the adult *P. bachei* indicates that Wnt could also be playing a role in neurotransmission in the adult.

P3.150 BRUMLOW, C*; ROSE, V; ROWE, A; ROWE, M; , ; , ; , ; , ; , ; , ; , ; , ; Sam Houston State, Huntsville High School, TX, Univ. Texas, Austin; *ceg012@shsu.edu*

Topographical variability of pain sensitivity in grasshopper mice: a preliminary analysis.

Bark scorpions (*Centruroides* spp.) are known for possessing extremely painful, neurotoxic venom that can be lethal to vertebrates, including humans. Grasshopper mice (*Onychomys* spp.) feed readily on bark scorpions, protected by structural changes in the voltage-gated sodium channels in the mice's peripheral nerves and muscles that are the targets of bark scorpion toxins. These structural changes include mutations in the mice's nociceptors (i.e., pain-sensing neurons), resulting in stings that are briefly irritating to the mice but do not lead to aversive conditioning. Anecdotal observations from previous feeding studies suggest an additional adaptation enabling the mice to feed on bark scorpions – stings delivered to the facial region of a mouse appear to induce less grooming than stings landing elsewhere on the mouse's body. These observations suggest there are topographical differences in the expression of the structurally modified sodium channels responsible for the mice's resistance to the scorpion's pain-inducing toxins. For example, nociceptors in the face of the mouse (trigeminal ganglia neurons) may express more of the resistant channels than nociceptors innervating tissue from the rest of the body (dorsal root ganglia neurons). We are currently re-examining videotapes from our earlier feeding trials. For each mouse, we are recording the topographical location of each sting (face vs. body), as well as the amount of time the mouse grooms the site of the sting. Results showing that the mice receive most of the stings to the face, and that such stings are less irritating than stings to the body, would provide preliminary evidence suggesting adaptive topographical differences in pain sensitivity in grasshopper mice.

S9-1.3 BUCKLEY, Lauren B.; Univ. of North Carolina, Chapel Hill; *buckley@bio.unc.edu*

Body temperatures along altitudinal and latitudinal gradients: interactions between phenotypes and multiple environmental stressors

The divergence between body and air temperatures is central to patterns of thermal stress associated with climate change. We use biophysical models to estimate body temperatures as a function of an organism's phenotype and environmental conditions (air and surface temperatures and radiation). Using alpine butterflies as a case study, we compare mean body temperatures and the incidence of thermal extremes along altitudinal gradients in both past and current climates. Organisms at higher elevation can experience more frequent thermal stress events despite generally cooler air temperatures due to high levels of solar radiation. Incidences of thermal stress events have increased more rapidly than increases in mean conditions due to recent climate change. Increases in air temperature have coincided with increased cloudiness with complex consequences for altitudinal patterns of thermal stress. We compare altitudinal trends, including seasonal overlap, between tropical and temperate mountains to ask whether mountain passes are higher in the tropics (Janzen's hypothesis) when considering body rather than air temperatures. Our analysis highlights the potential fallacy of predicting thermal stress based solely on air temperatures and the importance of considering phenotype-environment interactions.

P2.215 BUCKNER, JC*; LYNCH ALFARO, JW; RYLANDS, AB; ALFARO, ME; Univ. of California, Los Angeles, Conservation International; *jcharrayb@ucla.edu*

Statistical Biogeography of the Marmosets and Tamarins

The Callitrichidae are a family of Platyrrhine monkeys with greater than 50 taxa with distributions in Central and South America. Previous phylogenetic studies of the group have neglected to consider the species relationships within a geographic context. Here we consider the phylogenetic relationships and biogeography of the family using a species tree constructed from a concatenation of ten genes. We implemented a Bayesian discrete-states model of diffusion in BEAST for 40 taxa to determine the most likely pattern of invasion across South America. Our data show that sister taxa are grouping geographically within the same or in adjacent subregions. Also, our study supports an origin of the Callitrichid ancestor in the western Amazon and two major invasions of the Atlantic forest region from the Amazon at approximately 13MYA and 6MYA. We have also found that multiple instances of re-invasion and counter-invasion throughout the group's history explain current patterns of sympatry among species. Finally, our geographic data, along with morphological and phylogenetic data, lends support to certain taxonomic delineations including the splitting of the genus *Saguinus* into two genera.

P1.43 BUEHLER, DM; University of Toronto;
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Applying animal eco-physiological techniques in urban ecosystems: Mini review

We are living in an urban century. For the first time more than 50% of the world's human population lives in towns and cities. As a result, understanding how people influence the 'green' component of urban environments is of great significance. The study of urban ecosystems is an interdisciplinary field requiring input from geographers, planners, engineers, ecologists, sociologists, political scientists, psychologists and economists to name a only a few. Integrative biologists have a role to play since life in urban ecosystems requires that animals use novel food, water, and living habitats; and interact with constant anthropogenic disturbances and highly diverse stimuli and stressors, including vehicles, humans, pets, lights, and noises associated with urban environments. All of these may have profound effects on multiple aspects of their physiology including stress responses, metabolism, immune function and exposure to disease. This poster is meant to be a "getting started guide" based on an integrative biologist's interest in applying animal eco-physiological techniques to birds in urban areas.

100.4 BUMP, P.A.K.*; VETTER, K.M.S.; University of Hawaii at Mānoa, Denison University; *paulbump@hawaii.edu*

The Synergistic Nature of the Behaviors and Mechanisms that Support Effective Burrowing in the Mantis Shrimp Squilla empusa

The mantis shrimp *Squilla empusa* is a charismatic marine crustacean known for its powerful strike, keen sense of vision, and chemosensory abilities. These benthic creatures create extensive burrows that are important in feeding, reproduction, and protection from predation. Through field observations of a population located in Great Harbor in Woods Hole, MA this species of mantis shrimp has been observed to construct burrows faster and makes more alterations than previously recorded. To understand the mechanics of these burrowing behaviors, mantis shrimp were filmed making burrows in the lab using high-speed videography. *S. empusa* used two markedly distinct methods of burrowing: pleopod fanning and maxilliped bulldozing. Pleopod fanning consists of a swift posterior power stroke, followed by a slower recovery motion towards the anterior. During the power stroke the pleopods are fully extended, while during the recovery phase the pleopods curl up, reducing drag. In the other form of burrowing, the maxillipeds dig into the substrate, rotate to hold the sediment in a basket, and then deposit the contents outside of the burrow. To understand the fine structure of the mantis shrimp's pleopods and maxillipeds, analysis of the appendages was performed using a Zeiss dissecting microscope. Through this series of observations and analyses we are starting to understand how pleopod anatomy and kinematics work synergistically to create an effective burrowing system. This work was supported by NSF DBI-1005378 "REU Site:Biological Discovery in Woods Hole," the Lucy B. Lemann Fellowship Fund Award, and the Laura and Arthur Colwin Endowed Summer Research Fellowship Fund Award

114.5 BURDEN, S.A.*; REVZEN, S.; MOORE, T.Y.; SASTRY, S.S.; FULL, R.J.; Univ. of California, Berkeley, Univ. of Michigan, Harvard Univ.; *sam.burden@berkeley.edu*

Using reduced-order models to study dynamic legged locomotion: Parameter identification and model validation

Generating testable hypotheses for dynamic legged locomotion is challenging because motion imposes a continually-changing reference frame, and perturbations typically induce nonlinear effects. Fortunately, rhythmic biological motion is often highly stereotyped and low-dimensional, suggesting amenability to description by reduced-order dynamical models as proposed by the Templates and Anchors Hypothesis (TAH). Such models can predict experimental outcomes that cannot otherwise be quantified. For instance, during perturbations from the environment, purely mechanical self-stabilizing behavior can be defined, so that deviations resulting from neural feedback can be explored. However, given a candidate reduced-order model, there is seldom a direct method to measure free parameters and validate the model. Operationalizing TAH requires statistical tools to estimate parameters and select models using data collected within experimental paradigms. We propose a computationally-tractable method for applying nonlinear regression to the piecewise-defined dynamical models that naturally describe terrestrial locomotion. We illustrate the technique using data from an experiment involving center of mass (COM) perturbations and mass distribution manipulations applied to running cockroaches. Preliminary results corroborated our initial finding that neural feedback could be delayed by 1-2 strides after perturbation onset and demonstrated that a parsimonious spring-mass model for horizontal plane dynamics of sprawled running animals (Lateral Leg Spring) provides an accurate quantitative prediction of the animal's COM dynamics during this interval. Our approach can be applied more generally to dynamical systems ranging from muscles to swarm coordination.

P3.65 BURGESS, S.A.*; EISENLORD, M.E.; GALLOWAY, A.W.E.; DETHIER, M.N.; University of Michigan, University of Washington, Friday Harbor Laboratories; *shelbyab@umich.edu*

Food choices and values for a benthic herbivore, Idotea wosnesenskii

Spatial subsidies of aged detrital seaweed from habitats of high primary production may provide a significant source of energy to adjacent food webs. Previous studies indicate nearshore consumers use aged algal material as a food source. As aging occurs, algae are thought to increase in food value due to bacterial colonization. To test this, two experiments were conducted. The first examined preference of aged versus fresh thalli of two different kelp species, *Nereocystis luetkeana* and *Agarum fimbriatum*, in laboratory feeding experiments. Adults of *Idotea wosnesenskii*, an intertidal isopod common to the Pacific Northwest, were given four treatments of aged and fresh kelp of both species. Significantly more *N. luetkeana* was consumed than *A. fimbriatum*, but contrary to expectations, there were no significant differences in consumption of fresh versus aged tissue for either species. The second experiment was a 10 week long feeding trial with newly hatched *I. wosnesenskii* to determine growth rates on five different diets: aged *N. luetkeana*, fresh *N. luetkeana*, and fresh *Ulva* spp., *Fucus gardneri*, and *Mazzaella splendens*. Diets of algae with anti- herbivore defenses, one chemical (*F. gardneri*) and one mechanical (*M. splendens*), resulted in significantly lower growth rates than algae without these defenses. There was not a significant difference in growth rates between aged and fresh *N. luetkeana*. Our results suggest the species of algae may be more important in providing useful subsidies to benthic grazers than the degree of aging. The effects of aging on the nutritional value of algal blades needs further investigation.

59.5 BURGGREN, W. W.; University of North Texas; *burggren@unt.edu*
Transgenerational Effects of Parental Hypoxia on Vertebrate and Invertebrate Larvae
Non-genetic transgenerational modifications of offspring phenotype are increasingly evident in physiological studies. Indeed, this phenomenon is emerging as a potential source of variation in comparative physiology. Here we focus on non-genetic transgenerational transfer of morphological, physiological and behavioral traits in the zebrafish (*Danio rerio*) and the water flea (*Daphnia magna*). The experimental design was similar in both studies (Ho and Burggren, 2012; Andrewartha and Burggren, 2012). Essentially, parents were chronically exposed to hypoxia and then returned to normoxia for breeding and reproduction. A control population stayed in normoxia. The subsequently produced offspring (6-18 day old zebrafish larvae; 0-18 day old *Daphnia* larvae) were then exposed to severe hypoxia and their responses recorded. Additionally, physiological and metabolic traits of the larvae whose parents were exposed to hypoxia were assessed and compared with control populations. In *Danio*, larval offspring had longer body length when derived from adults that had been exposed to hypoxia for 2, 3 or 4 weeks. Hypoxic resistance (measured by time to loss of equilibrium) 6-18 dpf was ~15% lower in those larvae from parents that had been exposed to 1 week of chronic hypoxia, but longer exposures (2,3 or 4 weeks) significantly increased larval resistance by ~24-30%. CTMin (~39.5°C) and CTMax (~10-12 °C) were unchanged by parental hypoxic exposure. Neonatal *Daphnia* from hypoxic-exposed adults had a significantly smaller body mass and higher metabolic rate. These effects dissipated with further development within a brood and with subsequent broods. Parental hypoxic exposure thus can be revealed as a factor in larval phenotype through non-genetic transgenerational mechanisms.

129.3 BURLE, M.H.; RICO-GUEVARA, A.; RUBEGA, M.A.*; LANK, D.; Simon Fraser University, University of Connecticut; *margaret.rubega@uconn.edu*
A hummingbird tongue in a shorebird head: Tuamoto sandpipers are nectar-feeders
Nectarivory has evolved repeatedly, and avian lineages that have adapted to floral nectars as a food source exhibit convergence on characteristic modifications of the beak and tongue. The Tuamotu sandpiper (*Prosobonia cancellata*) is an endangered Scolopacid sandpiper endemic to the Tuamotu Archipelago in French Polynesia. We document here evidence that Tuamotu sandpipers are nectarivores, with adaptations of morphology, feeding mechanics, and behavior reflecting a commitment to nectarivory that is not merely facultative. Previous investigators (Pierce & Blanvillain 2004) noted that Tuamotu sandpipers visit flowers, but could not confirm that they were consuming nectar. Our field observations revealed that adult and juvenile Tuamotu sandpipers visit nectar-producing flowers of the shrub *Scaevola taccada* and the tree *Cordia subcordata* frequently, probing deep into corollas. Examination of specimens showed that their tongue tip is bifurcated, a morphological modification unknown from other charadriiforms, but common in known nectarivores (e.g., hummingbirds and sunbirds). The hyobranchial apparatus of Tuamoto sandpipers is also modified in a manner consistent with nectarivory, with epibranchials that are elongated in comparison to other scolopacid sandpipers. We used high-speed video (up to 240 f/s) to film free-living Tuamotu sandpipers feeding at flat-sided nectar feeders; our videos demonstrate that the birds use cyclic tongue protrusion to extract nectar; no other sandpiper is known to, or is likely to be able to, protrude its tongue as far past the bill tip as do Tuamotu Sandpipers. Collectively, these lines of evidence demonstrate conclusively that Tuamotu Sandpipers represent a previously unappreciated independent evolution of nectarivory in shorebirds.

52.2 BURNETT, NP*; HELMUTH, B; VILLARTA, K; WILLIAMS, GA; Univ. of California, Berkeley, Univ. of South Carolina, Hong Kong Univ., Hong Kong Univ.; *burnettnp@gmail.com*
Feeding patterns and their implications for energy budgets in tropical limpets
Energy budget models are often used to understand and predict the metabolic responses of species to environmental variation, such as global warming. The robustness of these models is based on an understanding of patterns of energy gain and expenditure of the modeled organisms, but such measurements can be imprecise for species with complex or poorly understood behavior patterns. Applying these models to keystone species can help predict community-wide responses to environmental variation, especially in the intertidal zone, where many species live near lethal limits of stress. Limpets (*Cellana* spp.) are keystone grazers in the high intertidal zones of the tropics. Most intertidal grazers forage while submerged or splashed, so their activity patterns are closely limited by the tidal cycle. These constraints have been incorporated into behavior models of *Cellana*, but little is known of their feeding rates and ingestion, remaining a 'blackbox' in the models. Using an accelerometer-based contact microphone, we recorded the feeding patterns (rasping sounds) of *Cellana* on the shore over several tidal cycles. Limpets fed at a rate of 80 – 100 rasps per minute (rpm) while moving up with the flooding tide, became inactive near slack tide, and then fed again at 80 – 100 rpm while moving down the shore with the ebbing tide. These data are consistent with the prediction of a model of digestion mechanics that limpets are volume-limited grazers, rather than energy-limited foragers. Refining estimates of energy intake using field-based measurements of foraging can help tailor energy budget models, such as Dynamic Energy Budget Models (DEBM), to specific species and improve our ability to forecast energetic consequences of environmental change.

78.2 BURNETTE, MF*; ASHLEY-ROSS, MA; Wake Forest University; *burnmf0@wfu.edu*
Will spit for food: role of target height in the spitting force of hunting archer fish.
Archer fishes (Toxotidae) are famous for their method of hunting terrestrial insects: the fish fires a stream of water from its mouth, which will dislodge a potential prey item from a leaf or branch overhead. Archer fish in the lab are known to shoot as far as one meter and wild archer fish are expected to encounter terrestrial prey at many different heights. It is known from previous studies that firing the stream of water is energetically costly and that tuning the shot accordingly will help keep these costs to a minimum. It is also known that archer fish tune the stream of water to prey size, such that larger prey are hit with shots that have more kinetic energy. To do this, the fish tunes the mass of the fired shot, but not its velocity. However, it is not known how target height influences shot force. If the fish fired a shot that was not tuned to height, a low target may be hit with more force than necessary to dislodge it, while a target further away might not be hit hard enough. The goal of the present investigation is to determine how the force of an archer fish's shot varies with target height. Using a paper cricket silhouette as a target and a force transducer, we measured the force of the shot on the target at four different heights (0.2 to 0.8 meters elevation, in 0.2 meter increments). Our results suggest that targets presented closer to the water surface are hit with more force while targets further away are hit with less force. High-speed video of the stream of water shows that velocity remains consistent, even between shots fired at targets that differ in height, but the shape of the shot changes with target height. At lower elevations, the shot appears more stream-like in its shape, while at high elevations, the shot breaks up into smaller droplets that strike the target.

2.3 BURTON, L.J.*; GUASTO, J.S.; STOCKER, R.; HOSOI, A.E.; Massachusetts Institute of Technology; *lisab@mit.edu*

Different strokes for different folks: Comparing motion across and within swimming species

Modeling swimming biological systems hinges on accurately representing the shape of the system in time. We present a method of describing the complex kinematics of an organism using only a few parameters. This low-order representation of the organism's stroke is suitable for fast and effective comparison of different motions performed by the individual, by other individuals and by other species. Using images from videos, we extract optimal basis modes in the curvature space for various species. We use this characterization of the swimmer's shape to model and predict the swimming speed and trajectory. For a given species, we use the optimal set of basis modes to model the system in an idealized fluid environment. We find the maximum efficiency stroke for the model system and compare it to the stroke observed in situ. Studying basis modes across species allows us to rationalize biological kinematics and draw conclusions about how different organisms interact with their environment.

P2.116 BUSTAMANTE, JR., J.*; LOUDON, C.; Univ. of California, Irvine; *cloudon@uci.edu*

Cricket antennae shorten when bending (Acheta domesticus (L.))

Insect antennae are important mechanosensory and chemosensory organs. Insect appendages, such as antennae, are encased in a cuticular exoskeleton and are thought to bend only between segments or subsegments where the cuticle is thinner and more flexible (intersegmental membrane). Antennae will bend or deflect in response to forces, and the resulting bending behavior will affect the sensory input of the antennae. In some cricket antennae, such as in *Acheta domesticus*, there are a large number (>100) of subsegments of variable length, and yet these antennae bend in a continuous smooth curve without kinks. We evaluated whether these antennae bend only at the joints between subsegments, which has always been assumed but not tested. In addition we questioned whether an antenna undergoes a length change as it bends, which could result from some patterns of joint deformation. Using constrained live crickets and a high-magnification dissecting microscope, we took photos of antennal flagella when straight and when bent, and digitized the images to analyze the morphological reconfiguration. Measurements were conducted with both male and female adult crickets (*Acheta domesticus*) with bending in four different directions: dorsal, ventral, medial, and lateral. Bending did occur only at the joints between subsegments, and antennae shortened during bending, regardless of gender or bending direction. Antennal shortening during bending would prevent stretching of antennal nerves and may promote hemolymph exchange between the antenna and head.

P3.112 BUSTIILLO, SN*; HELM, BR; DAVIDOWITZ, G; University of Arizona, Tucson; *bhelm@email.arizona.edu*

Growth, chemical and caloric composition of the fat body during metamorphic commitment in 5th instar Manduca sexta

The onset of metamorphosis in insects occurs in close correlation with the attainment of a critical weight late in larval growth. At this size, time to metamorphosis becomes fixed irrespective of continued feeding and growth because the hormonal signaling that commits the larva to metamorphosis is irreversibly initiated. Larval resource acquisition and storage are an important component of successful metamorphosis and reproductive provisioning in the adult stage of life. This suggests that resource accumulation during the larval phase should be a critical factor in determining when, and at what size, commitment to metamorphosis occurs. Our study addresses the question, "What role does larval resource storage play in attainment of the critical weight?" We examine resource accumulation by quantifying the growth, chemical composition, and caloric content of the fat body in growth-phase 5^{th} instar *Manduca sexta* larvae reared on five environmental treatments of diet quality and temperature. We summarize our findings within the context of attainment of the critical weight.

148.5 BUTLER, M.R.*; DEAROLF, J.L.; RICHMOND, J.P.; Hendrix College, Conway, AR, Univ. of North Florida, Jacksonville, FL; *butlermr@hendrix.edu*

The effect of prenatal steroids on citrate synthase activity in the fetal guinea pig scalenus muscle

Glucocorticoids are commonly administered to women considered at risk for premature birth to speed up fetal lung development and reduce infant mortality. Although these steroids aid lung development in preterm infants, their effects on ventilatory muscles are not well documented. In this study, the effect of betamethasone, a glucocorticoid, on the activity of the oxidative enzyme citrate synthase (CS) in the scalenus muscle of fetal guinea pigs will be examined. Previous histological research demonstrated that NADH (oxidative enzyme) concentrations were greater in the scalenus muscles of betamethasone-treated guinea pig fetuses. Thus, we hypothesize that CS activity will be greater in the muscles of fetal guinea pigs treated with betamethasone compared with control fetuses. Pregnant guinea pigs were injected with either betamethasone (0.5 mg/kg) or sterile water twice a week, 24-hours apart, at 65%, 75%, and 85% gestation. Muscles samples were collected, homogenized, and diluted to a predetermined optimal dilution factor with buffer. A reaction mixture (50 mM imidazole, 0.25 mM DTNB, 0.4 mM acetyl CoA, and 0.5 mM oxaloacetate, pH 7.5 at 37˚C) was added, and the maximum reaction rate (Vmax) of CS was measured with a microplate reader at 412nm. The Vmax values were converted to units of enzyme activity (μmol/min·g wet muscle mass), and the average CS activities of the control and treated muscles were compared. If our hypothesis is supported, infants treated with glucocorticoids could potentially have higher oxidative capacities in their ventilatory muscles than their untreated counterparts. This change would lead to greater fatigue resistance and allow treated infants to better respond to ventilatory challenges.

78.4 BUXMAN, C.L.*; WESTNEAT, M.W.; University of Chicago, Field Museum of Natural History; *cmccord@uchicago.edu*

How do triggerfish eat? The evolution of variable feeding behavior in balistid fishes

Muscles in many vertebrates have become repeatedly subdivided, yielding multiple actuators for biomechanical systems. Muscle subdivisions may, with evolutionary change in origin, insertion, or contractile physiology, increase the potential range of behavioral repertoires. The highly subdivided adductor mandibulae muscles of triggerfishes (Teleostei: Balistidae) are an ideal system for investigating the functional significance of a subdivided musculature. Here, we investigated the behavioral consequences of multiply subdivided jaw closing muscles through a series of feeding experiments. Feeding sequences from several morphologically and phylogenetically disparate species were filmed during bouts with different prey items of dissimilar material properties. Video sequences were digitized using 14 landmarks to assess the biomechanically relevant kinematics of the cranium. Kinematic variables were calculated from landmark data, phylogenetically corrected, statistically analyzed and compared across treatments and taxa, and mapped onto the balistid phylogeny in order to identify potential patterns of evolutionary change in feeding behavior. Our results indicate that triggerfishes modulate feeding behavior (low stereotypy and high flexibility). Furthermore, variation in kinematic profiles is only somewhat consistent with phylogenetic disparity. Taken together, our results suggest multiple independent origins of feeding behavior strategies in the triggerfish lineage. Future work will add *in vitro* and *in vivo* muscle properties, and several measures of triggerfish jaw performance that, along with the behavioral analyses discussed here, will provide insight into the evolutionary relationship of form and function in this group. Supported by NSF IGERT No. DGE-0903637 and DEB- 0844745.

145.1 BYERS, K.J.; RIFFELL, J.A.*; BRADSHAW, H.D.; Univesity of Washington, Seattle; *jriffell@uw.edu*

Differential pollinator attraction and processing of flower scent by bumblebees

Flowering plants attract the attention of insect pollinators using a wide variety of signals, including scent, which can recruit pollinators at a distance and draw them into visual range. We have investigated the role of floral scent in mediating differential attraction between two species of monkeyflowers (*Mimulus*) reproductively isolated by pollinator preference. The bumblebee-pollinated *Mimulus lewisii* and the hummingbird-pollinated *M. cardinalis* are significantly different both in the chemical composition of the volatile bouquet and in the rate of scent production. *M. lewisii* flowers produce a bouquet of at least 11 monoterpenes, dominated by limonene, β-myrcene, and cis-β-ocimene. Of these 11 monoterpenes, *M. cardinalis* flowers produce only limonene, released at just ~1% the rate of M. lewisii flowers. Bumblebees respond more strongly to *M. lewisii* as measured by gas-chromatograph-coupled multi-unit recording from antennal lobe (AL) neurons, and by wind tunnel and two-choice behavioral assays. Three monoterpenes – limonene, β-myrcene, and cis-β-ocimene – are necessary and sufficient to ensure the neural and behavioral response of bumblebees to *M. lewisii*. These volatiles are also found in the tergal gland of bumblebees, which mediates recruitment and foraging activation of worker bees. Indeed, AL recordings reveal that the *M. lewisii* floral scent and tergal gland extracts are represented similarly in the bee AL, hinting at a possible signaling co-option between the recruitment pheromone in bumblebees and floral scent in *M. lewisii*. In this system, floral scent alone is sufficient to elicit differential visitation, implying a strong role of scent in the origin and maintenance of reproductive isolation between *M. lewisii* and *M. cardinalis*.

S9-1.4 BYRNE, M; Univ. of Sydney, Australia; *mbyrne@anatomy.usyd.edu.au*

Impacts of warming and ocean acidification on growth of larval and juvenile sea urchins - from the poles to the tropics

The Temperature Size Rule states that temperature increases development rates of ectotherms faster than growth rates, resulting in smaller body sizes at life history transitions. Thus a decline in body size is predicted to be a response to global warming. Ocean acidification reduces body size in marine ectotherms as growth rates decrease with reduced carbonate availability and physiological hypercapnia. Ocean warming and acidification covary, but it is not known how they will interact to affect development, growth, size at maturity and other proxies of fitness. To address these issues, the response of sea urchin life histories from across world latitudes to warming and acidification was investigated. Exposure to stress early in development can have negative downstream effects because performance of later ontogeny depends on success of early stages. Embryos generated on ocean change conditions are sensitive to warming and may not reach the calcifying stage in the absence of parental acclimation and adaptation. Larvae are sensitive to warming and acidification. The effects of acidification in echinoplutei indicate that the stunting effect of pH/pCO2 is influenced by physiological hypercapnia and teratogenic effects. In long-term rearing of juveniles to maturation acidification reduced body size and warming mitigated this effect. Sea urchins were larger at maturity under projected warming and acidification scenarios suggesting that body size will not necessarily decrease with climate change. Reproductive potential showed a negative response to acidification with varying levels of mitigation by warming. It may be too early to make firm predictions on the effect of marine climate change on body size. The data highlight the need to examine how covarying stressors interact in long term studies.

P1.118 BYSTRIANSKY, J.S.*; SACKVILLE, M.; YOO, J.; TATTERSALL, K.; ALONGE, M.M.; JUDD, S.M.; FARRELL, A.P.; BRAUNER, C.J.; DePaul University, University of British Columbia; *jbystria@depaul.edu*

Preparation for freshwater migration in adult pink salmon (Oncorhynchus gorbuscha)

Despite decades of research on smoltification of salmon during their seaward migration, very little is understood about whether salmon undergo a similar physiological preparation for freshwater re-entry during their spawning migration. Pink salmon reach maturity and return to freshwater at two years of age. Exceptions to this rule are very rare making pinks the ideal species to study seasonal changes in osmoregulatory capacity. This study examined the expression and activity of gill H+-ATPase and several isoforms of Na+K+-ATPase in lab-reared pink salmon held in seawater over an 19 week period coinciding with the period prior to, during and after the timing of their natural freshwater migration. Muscle water content and plasma sodium and chloride concentrations were determined to assess the osmoregulatory status of pink salmon throughout the study period and discussed in relation to observed changes in gill ion transporter expression and activity.

111.3 CAHILL, AE; Stony Brook University; *acahill@life.bio.sunysb.edu*
Metamorphosis of Crepidula larvae in response to varying conspecific densities and settlement cue concentrations
It is known that larvae of *Crepidula* spp., like many other marine invertebrate larvae, metamorphose in response to a cue from conspecific adults. However, the relationship between adult density and larval metamorphosis is not well-characterized in *C. fornicata* or *C. plana*. On Long Island, *C. fornicata* occurs at much higher densities than *C. plana*, which has a patchier habitat. *C. fornicata* may therefore be less sensitive to conspecific cue than *C. plana*. Here, I performed a bioassay using adult-conditioned water to examine metamorphosis in both *Crepidula* spp. in response to cue from conspecific and heterospecific adults. Because metamorphosis in still water rarely mimics field conditions, I varied adult density and measured settlement of *C. fornicata* larvae in the field. Larvae in both the lab and the field metamorphosed at higher rates with increasing adult density. These results indicate that recruitment in small populations of *Crepidula* may be limited by the ability of larvae to detect conspecific adults, which in turn has implications for population dynamics at range edges.

106.4 CAI, J*; HEINEY, P.A.; SWEENEY, A.M.; University of Pennsylvania; *caij@sas.upenn.edu*
Building a Lens from a Single Protein: Small Angle X-ray Scattering on Squid Eyes
Throughout evolution, camera-type animal eyes developed spherical, graded refractive index lenses which eliminate spherical aberration. The graded refractive index is achieved by changing the density of proteins within the lens. To reduce unwanted scattering of light, the protein density fluctuations in the lens must be small. This effect becomes more significant in the periphery of the lens, where the protein density is lower than in the center. Squid lens material is dominated by only one protein isoform, making it a tractable system to understand how changes in protein biophysical properties contribute to bulk lens optical and material properties -- in contrast, vertebrate lenses are an experimentally intractable mix of multiple, polydisperse isoforms. Our previous work has shown that the isoforms in the periphery of the lens have a more positive surface charge, implying that Coulomb interaction assembles the protein in repulsive glass phase, with lower surface charges mediating assembly of progressively higher index lens regions. Here, we perform small angle x-ray scattering experiments on squid lenses. Each lens sample is separated into four concentric layers based on radius. Experiments show that the packing properties change gradually from the central core of the lens to the periphery. We also discuss how squid lens proteins interact with each other and how they are packed to form graded index glass. Future studies will apply the lessons learned from squid lens materials to manufacturing artificial self-assembling lenses with graded refractive index, which can be applied widely in industry.

P1.8 CAIN, PW*; GARDNER, B; THAKER, M; HEWS, DK; Indiana State University, Indian Institute of Science; *pcain1@sycamores.indstate.edu*
Fluctuating asymmetry in visual signals of male Sceloporus undulatus lizards
Fluctuating asymmetries (FA) are small deviations from bilateral symmetry in morphological traits resulting from suboptimal developmental conditions. Trait FA may be a measure of "quality" used by receivers. We asked if FA of three paired colored signaling patches differed in adult male *Sceloporus undulatus* lizards from a logged (n=12) and unlogged (n=30) site. Patch areas for each trait were calculated from digital images using Image-J. FA was significant for each trait, but sites did not differ in FA for any trait. Body-mass residuals differed significantly between logged (mean=-0.269) and unlogged sites (mean=0.108). We also asked if residual patch size (from regression of average patch size on snout-vent length) could convey information about relative body mass (a short-term "quality" measure). Patch size residuals significantly and positively correlated with residual body mass for abdominal blue patches only; relatively heavier males had relatively larger blue patches. Although FA for each trait did not differ between sites, stress effects from disturbance may be delayed and future generations may exhibit higher FA. Body-mass residuals differed between logged and unlogged sites, consistent with stress from disturbance. Disturbance may have been recent because an effect was detected in a "short-term" quality measure (body-mass residuals) and not a "long-term" measure (FA). We detected significant FA in the three traits, hence future work should determine if conspecific receivers assess FA in patch size, and whether conspecifics use body mass-residuals when assessing opponents.

P1.177 CAIN, SD; ZUNGUL-HASTY, LS; KELSEY, P*; Eastern Oregon University; *shaun.cain@eou.edu*
The Distrubution of GABAergic Neurons in The CNS of Nudibranch Molluscs
The neurotransmitter GABA is known to play a role in the transmission of information in the central nervous systems of many animals, including molluscs. GABA can function as an inhibitory transmitter both at metabotropic and ionotropic synapses, activating either chloride or potassium conductances. Therefore, it is thought that this neurotransmitter is typically inhibitory at GABAergic synapses. Indeed, GABA plays an inhibitory role in interactions between the visual and vestibular system in the nudibranch *Hermissenda crassicornis*. However, GABA can also play an excitatory role mediated by sodium conducting channels as shown in the feeding circuit of *Clione limacina* or through reduction of a potassium current in photoreceptors in *Hermissenda*. Given the different roles GABA plays in the neural circuits underlying behavior in molluscs, we investigated the distribution of GABAergic neurons in the monophyletic clade Nudibranchia. Neurons both within the brain and buccal ganglia that contain GABA were identified using immunohistochemistry. In all species we investigated, GABA-like immunoreactive neurons were found in both the brain and buccal ganglia. The distribution in the brain was variable while the number and distribution in the buccal was similar in all species (4-6 neurons per gangion). This might indicate that the role of GABA in the feeding rhythm is more highly conserved then that in other parts of the nervous system of nudibranchs.

P2.142 CALE, K.M*; DAVIS, J.E; Radford University; *kmcale@radford.edu*
Developmental Investigation of Juvenile Hormone and Royal Jelly in Madagascar Hissing Cockroaches (Gromphadorhina portentosa)
Growth, maturation, and stress are closely related systems in the physiology of insects as in vertebrates. Changes in these systems are regulated in part by juvenile hormone (JH); high levels of JH pre-maturation generally prevent a nymph from maturing into an adult state. While JH has been found to be primarily responsible for adult maturation in many species of insects, the complete mechanistic relationship between the hormone and development remains unclear. Previous findings from research done in our laboratory motivated us to examine the impact of agonistic juvenile hormone modulation; using Madagascar hissing cockroaches (*Gromphadorhina portentosa*) as a model. Taking the modulation one step further, we added the newly studied hormone royalactin, a protein present in honeybee royal jelly, to the food source of some treatment groups. Recent studies on drosophila have suggested that royalactin, which was thought only to be responsible for queen bee morphogenesis, may also have a significant impact on maturation in other insects. Using this new discovery, we investigated the impact of royal jelly supplementation on MHC development in parallel to our studies on JH. Exploration of hormonal interactions on development includes analyzing correlations of individual's developmental track, adult weight, and sex.

48.4 CALHOON, E.A.*; JIMENEZ, A.G.; HARPER, J.M.; JURKOWITZ , M.S.; WILLIAMS, J.B.; Ohio State University, University of Michigan; *calhoon.18@osu.edu*
The relationship between life history in temperate and tropical bird species and lipids in fibroblast mitochondrial membranes
Temperate birds are thought to have a fast pace of life, having a shorter life-span with high reproductive output, whereas tropical birds are thought to have a slow pace of life. In support of this idea, tropical birds have lower metabolic rate, invest fewer resources in reproduction, and have higher adult survival rates compared with temperate birds. How these differences in life-history at the organismal level may be rooted in differences at the cellular level remains unknown. Here, we cultured fibroblasts of phylogenetically-paired tropical and temperate species, isolated mitochondria from each, and compared their mitochondrial membrane lipids. We found that temperate bird species tended to have more mitochondrial lipids than tropical species, especially cardiolipin, but that temperate species did not have significantly more mitochondrial protein and lipids in their cells. Since cardiolipin is highly localized to the inner mitochondrial membrane, this could indicate that temperate birds have more inner mitochondrial membrane, but not a higher amount of mitochondria. We also found that mitochondria from tropical species had higher amounts of plasmalogens, a lipid that could serve as an antioxidant. Overall, our findings are consistent with the idea that there are underlying cellular physiological traits which could account for the differences in whole animal physiology between animals with different life histories.

146.4 CALISI, R.M.*; KRAUSE, J.S.; PERFITO, N.; BENTLEY, G.E.; WINGFIELD, J.C.; Univ. of California, Davis, Univ. of California, Berkeley, Univ. of California, Berkeley; *beccacalisi@gmail.com*
Transitions in avian parental care: a role for hypothalamic gonadotropin inhibitory hormone (GnIH)
The discovery of GnIH is changing the way we view the regulation of sexual behavior and reproductive function in general. GnIH inhibits gonadotropin synthesis and release *in vitro* and *in vivo* in both birds and mammals, resulting in a decrease in circulating sex steroids as well as a decrease in sexual behavior. However, the role of GnIH, if any, during the time of parental care is unknown. The transition from sexual and aggressive behaviors to parental care often involves a decrease in circulating testosterone levels that otherwise can interfere with parental care. Based on preliminary results and the negative effects of GnIH on androgen circulation, we characterized hypothalamic GnIH in male and female European starlings (*Sturnus vulgaris*) over the parental care phase of the breeding season. We found that GnIH-ir peptide expression changes with the first day of incubation and first day of chick care. We conducted an egg removal experiment to examine how unpredictable events (i.e. nest predation) can affect this relationship. Results revealed that GnIH-ir expression changes in response to egg loss. Thus, changes in GnIH-ir expression during these important transitions in parental care may implicate it in the mediation of such behaviors. Finally, we attempted to block GnIH expression *in vivo* using a recently discovered RFRP (GnIH mammalian homolog) receptor antagonist, RF9, and found that both systemic and central administration in birds does not alter LH circulation as it does in mammals, nor does systemic administration alter parental behavior, as measured by visits to nests. Thus, while RF9 may serve as a potent RFRP receptor antagonist in mammals, its actions do not appear to function similarly in birds.

70.6 CALOSI, P*; TURNER, LM; HAWKINS, M; NIGHTINGALE, G; BERTOLINI, C; TRUEBANO-GARCIA, M; FORD, A; SPICER, JI; Plymouth University, University of Portsmouth; *piero.calosi@plymouth.ac.uk*
The effect of exposure to multiple environmental challenges on multiple physiological responses: an inter-individual approach
Continuing increase in atmospheric CO_2 anthropogenic emissions will lead to an increase in ocean-surface temperature of 3-5&degC, and a decrease in pH of 0.3-0.4 units by 2100. Whilst marine intertidal organisms already experience periodical environmental fluctuations that exceed these values, and are believed to be adapted to these conditions, actual data on how they respond to chronic exposure is limited. Moreover, investigations to date have typically employed independent sample analysis (ITSA), which is a powerful tool for the detection of significant alterations of biological responses. However, ITSA does not take into account inter-individual variation and relationships between traits. Here, we investigated individuals' metabolic rate (MR), gill Na^+ / K^+-ATPase activity and upper thermal tolerance (UTT) in adults of the amphipod *Gammarus marinus* exposed for 15 days to combined elevated temperature and CO_2. Briefly, ITSA detected significant up-regulation in gill Na^+/K^+-ATPase activity in individuals exposed to elevated temperature and CO2 and a significant decrease in upper thermal tolerance (UTT) in the high-CO_2 treatment. ITSA revealed that UTT responses are largely but weakly MR-dependent, and that sUTT response to CO_2 and temperature exposure depended also on individuals' MR. We will discuss the advantages and disadvantages of integrating ITSA and ILSA when interpreting organisms' biological responses within the context of global change.

P1.192 CAM, S; EVANGELISTA, D*; HO, M; HUYNH, T; KRIVITSKIY, I; LIN, Y; STEVENSON, R; DUDLEY, R; Univ. of California, Berkley, Univ. of California, Berkeley; *devangel77b@gmail.com*

Cute baby birds and flight control: a coming of age story of intrigue, flips, falls from great heights, and high speed cameras

"There is an art to flying, or rather a knack; the knack lies in learning how to throw yourself at the ground and miss." We dropped baby Chukar Partridge (*Alectoris chukar*, *n*=31) and Mallard Ducks (*Anas platyrhynchos*, *n*=5) from 1 day post hatching through fledging, to observe use of the wings during aerial challenges over ontogeny. Birds initially used an asymmetric flapping motion to right by rolling; this was followed by symmetric flapping motions which achieved righting more rapidly by pitching. The switch also corresponded to the first detectable instances of directed aerial descent in which the trajectories deviated from simple ballistics. Analysis of the high speed video allows examination of the details of the righting maneuvers and computation of the relative contributions of inertia and aerodynamics. The results will guide understanding of how maneuvering may shape the development or evolution of aerial behaviours in general.

118.4 CAMERON, CB*; BISHOP, C; Univ. de Montreal, St. Francis-Xavier Univ.; *c.cameron@umontreal.ca*

Biomineral ultrastructure, elemental constitution and genomic analysis of biomineralization-related proteins in hemichordates

Here, we report the discovery and characterization of biominerals in the acorn worms *Saccoglossus bromophenolosus* and *Ptychodera flava galapagos* (Phylum: Hemichordata). Using electron microscopy, X-ray microprobe analyses and confocal Raman spectroscopy, we show that hemichordate biominerals are small $CaCO_3$ aragonitic elements restricted to specialized epidermal structures, and in *S. bromophenolosus*, are apparently secreted by sclerocytes. Investigation of urchin biomineralizing proteins in the translated genome and expressed sequence tag (EST) libraries of *Saccoglossus kowalevskii* indicates that three members of the urchin MSP-130 family, a carbonic anhydrase and a matrix metaloprotease are present and transcribed during the development of *S. kowalevskii*. The SM family of proteins is absent from the hemichordate genome. We will present corresponding results from the crinoid *Florometra serratissima*. These results increase the number of phyla known to biomineralize and suggest that some of the gene-regulatory 'toolkit', if not mineralized tissue themselves, may have been present in the common ancestor to hemichordates and echinoderms.

112.4 CAMERON, S.F.*; WILSON, R.S.; Uni of QLD, Australia; *s.cameron3@uq.edu.au*

Sexual dimorphism of Hemidactylus frenatus along a latitudinal cline: testing Rench's rule in an ectotherm with intense male-male competition in lower latitudes

Rench's rule predicts that animal populations with greater average body sizes should exhibit higher magnitudes of sexual dimorphism. As higher latitudes are commonly associated with greater average body sizes, a latitudinal cline in sexual dimorphism is also expected to follow suit. However, given sexual dimorphism is driven by gender differences in reproductive fitness, any increases in male-male competition in lower latitude populations could counteract Rench's rule. To investigate this idea it is necessary to examine a species with intense male-male competition and quantify inter-sexual differences in both morphological and whole-animal performance traits. We used *Hemidactylus frenatus* as they are found along a large latitudinal range across Australia and are likely to experience intense male-male competition in lower latitudes due to a warmer climate and higher densities. We predicted the magnitude of sexual dimorphism would be stabilized along their latitudinal range due to the interacting effects of Rench's rule at higher latitudes and increasing male-male competition in lower latitudes. We found greater average body sizes for populations from higher latitudes, however no evidence for Rench's rule as there was no associated increase in sexual dimorphism with latitude. In contrast, whole-animal performance exhibited a negative correlation with latitude, where individuals from populations from lower latitudes had greater relative biting performances than those from higher latitudes, although no latitudinal variation in inter-sexual differences in performance was found.

P3.214 CAMP, N*; MARTINEZ, E; PHILLIPS, C; PORCERRA, A; TORRES, J; COLOMBO, R; MENZE, MA; Eastern Illinois University, University of South Florida; *mmenze@eiu.edu*

Life in Hot Waters: Live Fast and Die Young

Thermal variation has profound implications for the physiology and life histories of ectotherms, influencing individual performance and population dynamics. Aquatic ecosystems are especially strongly affected by alterations in the thermal environment. Coffeen Lake, a cooling source for a central Illinois coal-power plant, has temperatures in excess of 35°C during the summer months due to discharge of thermal effluent. Lake Mattoon is a comparable lake system that is not impacted by thermal discharge. Previous studies demonstrated the average length and weight of *Lepomis macrochirus* in Lake Mattoon (132 ± 2 mm, 59.9 ± 2 g; $p < 0.05$) to be greater than Coffeen Lake (75.1 ± 1.1mm, 9.4 ± 0.51g; $p < 0.05$), and the average age to be significantly younger in Coffeen Lake (1 year) than in Lake Mattoon (2.3 years). However, the molecular, cellular, and whole-organism aspects of thermal adaptation in Coffeen Lake bluegill remain uncharacterized. We captured *L. macrochirus* from Coffeen Lake and Lake Mattoon and adapted the animals to two different temperatures (15° C and 30 °C) for two weeks in laboratory tanks. No significant difference was found between the upper thermal maximum of either population, adapted to 30 ˚C, after two weeks of acclimation [Mattoon = 39.7 ± 0.1 ˚C, Coffeen = 41± 0.1 ˚C, n = 6-9 ± SE; $p > 0.05$). Additionally, no differences were observed among oxygen consumption rates of animals adapted at 15 °C or 30 °C captured from either lake system. However, acute exposure of 15 °C adapted animals to 30 °C from both lakes led to a 1.7-fold increase in oxygen consumption rates. These results indicate broad plasticity in temperature tolerance for *L. macrochirus* , and oxidative stress will be discussed as possible factor in the reduced life span in Coffeen Lake.

78.5 CAMP, A.L.*; BRAINERD, E.L.; Brown University, Providence RI; *ariel_camp@brown.edu*
Hyoid kinematics and hypaxial muscle strain during suction feeding in largemouth bass (Micropterus salmoides)
To capture food, suction feeding fishes use their kinetic skulls to rapidly expand the mouth cavity both laterally and dorsoventrally. Ventrally, mouth volume is increased by depression and retraction of the hyoid, but the muscular cause of this motion is unclear. This ventral expansion could be produced by the sternohyoid muscle, which attaches directly to the hyoid apparatus at the urohyal. If this is true, sternohyoid muscle shortening should equal urohyal retraction. The ventral body muscles, the hypaxials, could also retract the hyoid by rotating the cleithrum of the pectoral girdle, which is linked to the urohyal by the sternohyoid muscle. In this case, hypaxial muscle shortening should equal urohyal retraction. We tested these hypotheses by measuring urohyal and cleithrum kinematics, as well as sternohyoid and hypaxial muscle shortening, during suction strikes in 3 largemouth bass (*Micropterus salmoides*). Bone kinematics were measured relative to a body axis plane using X-ray Reconstruction of Moving Morphology. This technique combines bone models with motion recorded from bilateral x-ray video to create 3D animations of bone kinematics. Muscle shortening was measured with fluoromicrometry, which uses x-ray videos to measure distance changes between intramuscular markers. The urohyal moved both caudally (retraction) and ventrally (depression) relative to the body axis, and the cleithrum was retracted. Hypaxial muscle shortening was similar to urohyal retraction distance, with means of 6.2mm and 8.5mm, respectively, whereas mean sternohyoid muscle shortening was only 0.5mm. The hypaxial muscles generated hyoid depression, via cleithrum retraction, while the sternohyoid muscle acted like a ligament to transmit hypaxial shortening to the urohyal.

P1.25 CAMPBELL, D.G.*; JACOBS, M.W.; McDaniel College, Friday Harbor Laboratories; *dgc003@mcdaniel.edu*
Home harbor advantage? Local adaptation of Botrylloides violaceus populations in the San Juan Islands
Botrylloides violaceus is a relatively recent invader of the United States coastlines. It grows quickly and is a strong competitor, which causes problems for native species and aquaculture. In the San Juan Islands *B. violaceus* has been present for several decades and is found in some harbors, but not all. *B. violaceus* larvae are non-feeding and are short-lived, suggesting that dispersal limitations could decrease gene flow between populations resulting in local adaptation. We performed a reciprocal transplant of *B. violaceus* juveniles between two harbors that varied in environmental conditions such as temperature, salinity, and food availability. Juveniles explanted to the warmer harbor had greater growth and survival, but population of origin had no effect, suggesting that local adaptation has not occurred. Variation in growth and survival was higher within populations than between populations, which suggests that genetic variation for those traits exists in the populations and that local adaptation could still occur in the future. Alternatively, there may be sufficient gene flow occurring between populations to prevent local adaptation from occurring.

P1.107 CAMPBELL, JB*; DUELL, ME; KLOK, CJ; HARRISON, JF; Arizona State University; *jacob.campbell.1@asu.edu*
Water loss, respiration, and critical PO_2 in Cetoniinae
Observations indicate that as insect size increases, ventilation and metabolic rates scale allometrically, while some studies indicate that critical PO_2 is mass-independent. This has not been confirmed in entirety. Scarab fruit chafer beetles in subfamily Cetoniinae were chosen for this investigation because species vary in mass by several orders of magnitude, therefore representing an excellent model taxon for mass-scaling comparisons. By slowly decreasing oxygen from 21% to 0% we found critical PO_2 simultaneously with water loss, CO_2 emission, and activity in six species of Cetoniinae beetles (*Euphoria fulgida holochloris, Dicronorrhina derbyana, Coelorrhina hornimani, Mecynorrhina torquata, Trypoxylus dichotomus, Goliathus goliathus*) ranging in size from 0.1-14g. While manipulating oxygen concentrations we observed patterns that allowed us to quantify cuticular, trans-spiracular, and ventilatory respiration and water loss. Cuticular water loss and respiration were measured during periods of discontinuous gas exchange to ensure full spiracular closure; ventilatory water loss was measured in normoxia; trans-spiracular water loss was quantified during anoxia, assuming that as individuals became unresponsive, spiracles remained open throughout the duration of anoxia. Preliminary data suggest that critical PO_2 does not vary by species and is mass-independent. However, species do show differences in water loss rates during different levels of hypoxia indicating various strategies of water conservation. Our quantifications of cuticular, ventilatory, and trans-spiracular water loss will allow us to better explain physiological events in respiration and make further predictions about ventilatory responses to oxygen variation.

P2.178 CAMPION, A*; HWEE, D; BAEHR, L; NEMETH, Z; BODINE, S; RAMENOFSKY, M; Univ. of California, Davis; *awcampion@ucdavis.edu*
Comparative study of the oxidative metabolism in skeletal muscle of migratory and nonmigratory White-crowned Sparrows
The annual cycle of many long distance migrants is characterized by dramatic changes in behavior and physiology or phenotypic flexibility. Such alterations serve to match individuals with the energetic demands of each life history stage. Yet, it is unknown whether traits attributed to migrants are expressed also in nonmigratory congeners. We present data comparing the oxidative capacity of skeletal muscle of the long distance migrant, *Zonotrichia leucophrys gambelii* with its nonmigratory congener *Z.l. nutttalli* both within and across their life history stages. Owing to the reliance on efficient energy utilization for migration, we measured enzyme concentration of succinate dehydrogenase and citrate synthase in the flight and gastrocnemius muscles of both subspecies using western blot analysis. We predicted upregulation of enzymes in flight muscle during migration that would be absent in the nonmigrant's flight muscle and absent in both subspecies' gastrocnemius muscle. Seasonally, the flight muscle of the two subspecies had elevated enzyme concentrations during both the post breeding and fall stages. Specifically, in the migrant, both enzymes were elevated in flight muscle when birds departed from the breeding grounds in fall but had decreased upon arrival to the wintering site ($P<0.05$). As predicted, enzyme concentrations in flight muscle of *Gambelii* exceeded those of *Nuttalli* during the post breeding and fall stages ($P<0.05$) but were comparable during winter, a stage when the congeners are most similar. Our results reveal dynamic changes in the oxidative capacity of the flight muscle of *Gambelii* that contribute to phenotypic flexibility attributed to the migratory life history.

35.5 CAMPOS, E.O.*; BRADSHAW, H.D.; DANIEL, T.L.; University of Washington, Seattle; *eocampos@uw.edu*

Exploring plant-pollinator interactions using 3D printed flowers

Pollination syndromes are suites of floral traits postulated to reflect convergent evolution among distantly related species due to selection by a shared guild of pollinators. We used a four-parameter geometric model of flower shape to construct artificial flowers using computer-aided design software and a 3D printer. The four shape parameters describe corolla curvature, corolla width, flower length, and nectary radius. Our goal is to use these flowers to test whether the shape of artificial flower populations can evolve in response to selective pressures induced by real flower-foraging animals in an experimental evolution study. To assess whether pollinator foraging performance is affected by variation in "floral" shape, we allowed individuals of the hawk moth *Manduca sexta* to forage freely on dimorphic arrays of 16 artificial flowers. The two morphs in an array differed in only one of the four shape parameters. We find that if the nectary radius is too large (2.5 mm), *M. sexta* is able to exploit artificial flowers equally well regardless of the values of other shape parameters (mean number of flowers of each morph emptied per foraging trial: 6.0 ± 0.8 SE; 4.9 ± 0.9 SE; $p > 0.34$). But if nectary radius is reduced to 1 mm, then flower curvature has a significant effect on foraging performance (7.6 ± 0.2; 2.1 ± 0.4; $p < 0.01$). These results suggest that artificial flowers could experience a selection differential based on shape as a result of visitation by moths.

P3.222 CAPPER, RL*; MEYER, E; MATZ, MV; Univ. of Texas at Austin, Oregon State University; *roxana.capper@gmail.com*

Discovering the genes contributing to thermal stress survival in the coral Acropora millepora

The rate at which corals can adapt to changing environments is paramount to understanding how reef ecosystems will shift in the face of global climate change. In order to determine the potential response repertoire of corals to elevated heat stress, we performed an experiment to reveal the genetic basis of mortality under heat stress with the goal of locating regions of the genome that contribute to survival when exposed to high temperatures. First, 30 directed, non-selfing and genetically distinct families of the scleractinian coral *Acropora millepora* were cultured to uncover the heritability of heat stress survival. Then, each culture was split with half of the larvae subjected to prolonged heat stress (12 hr 32°C) and the other half placed into control temperature conditions. Survivors of all treatment and control samples were collected. We then used the novel technique of quantitative high resolution melting (qHRM) to scan the genomes of each family at 96 SNP loci to determine which regions of the genome correlate with post-heat stress survival. Using this method, we found multiple loci that are associated both within reciprocal crosses and between unrelated crosses. Ongoing analyses of these loci will potentially elucidate the genetic mechanisms that contribute to survival under thermal stress.

P2.26 CAREY, N; SIGWART, JD*; Queen's Univeriity Belfast; *j.sigwart@qub.ac.uk*

Environmentally-driven changes to metabolic scaling relationships in grazing mollusks

Scaling of metabolic rate with organismal body mass shows significant natural variation within certain boundaries associated with ecology and activity patterns, not following traditional 2/3 or 3/4 scaling. Chitons (polyplacophoran mollusks) exhibit natural variation in both basal metabolic rates and scaling relationships, with differences linked to lifestyle and natural history. The magnitude of the scaling exponent can describe relationships between organisms of different sizes, so this has broad scale implications for the dynamics and composition of natural communities. If metabolic scaling exponents are plastic to extrinsic factors, they may be altered under conditions of environmental change, such as future warming and ocean acidification. To test this, we acclimated three species of chiton from the north-eastern Pacific (*Katharina tunicata*, *Tonicella lineata*, *Mopalia muscosa*) to conditions from future climate change scenarios. Three temperatures and two pH conditions were examined in a factorial design, to determine the synergistic and antagonistic effects of these factors on both basal metabolism and the scaling of metabolism. Thirty specimens of each species, representing full ontogenetic series were acclimated to treatment for one week (i.e. 540 specimens in total), and then examined for changes to basal metabolic rate (respiration). Acclimation to higher temperature, as expected, caused metabolic rate to increase; however, the effect of increased pCO_2 was less pronounced. The combined effects of increased temperature and pCO_2 were erratic, and not simply additive. These data suggest species' physiology will show complex, unpredictable reactions to multiple stressors under future climate change scenarios, and this may have similarly unpredictable and complex effects on community composition.

90.3 CARLSON, BE*; LANGKILDE, T; The Pennsylvania State University; *bec169@psu.edu*

Behavioral variation among tadpole populations: ecological causes and consequences

Theory predicts that intraspecific trait variation can have important ecological impacts, yet we have a poor understanding of the causes and consequences of trait variation in natural systems. Local adaptation can generate among-population trait differences, and these adaptive variants may have cascading effects on the rest of the ecosystem through interactions of these organisms with other species. Wood frog tadpoles inhabit ponds that range from 'low-risk' (few predators) to 'high-risk' (many predators). 'High-risk' ponds are expected to favor lower activity levels and greater responsiveness of tadpoles to predator cues than do 'low-risk' ponds. We reared tadpoles from a variety of ponds in mesocosms, both with and without caged predators. We measured the behavior of the tadpoles and the predator density in the source ponds. We found that responsiveness to predators increased with predation risk in source ponds while overall activity rate was unaffected. More active tadpoles should have stronger negative effects on periphyton and zooplankton (due to increased foraging), and less responsive tadpoles would result in smaller indirect effects of predators on these lower trophic levels. Preliminary evidence suggests that increased tadpole activity was associated with reductions in periphyton and increases in zooplankton. Behavior in this system varied predictably along an ecological gradient, with apparent consequences for interacting species. This work highlights the potentially important role of ecological differences among communities in shaping, and being reciprocally shaped by, intraspecific behavioral variation.

P2.100 CARLSON, BE*; MCGINLEY, S; ROWE, MP; The Pennsylvania State University, Sam Houston State University; *bec169@psu.edu*

Morphological and behavioral sexual dimorphism in scorpions as compensation for locomotor costs of reproduction

Sexual dimorphism can result from sexual or ecological selective pressures, but the importance of alternative reproductive roles and trait compensation are poorly understood. We evaluated an enigmatic morphological sexual dimorphism in the metasoma ('tail') of striped bark scorpions, which we propose is a compensatory coadaptation to increase the efficacy of escalatory defensive behavior (stinging) in females. Sex differences in evasive locomotor performance due to costs of reproduction would favor greater aggression in females and the development of structures to support this defensive tactic. We tested the effects of sex and morphology on stinging and sprinting performance and characterized overall differences between the sexes in aggressiveness towards perceived threats. Female scorpions stung at a higher rate than males, and greater body mass (which often occurs in females) was associated with higher sting rates. While females were more aggressive overall, we found no evidence that the shape of the metasoma supports stinging performance, though the males' heavier metasomas curiously appeared to enhance locomotion. Males sprinted faster than females, partly explained by the fact that lighter bodies and heavier metasomas increased sprint speed. Although sexual dimorphism in these scorpions may be best explained by other undocumented differences in niche or behavior or by sexual selection, these results suggest the larger metasoma of males may indeed have evolved to increase running speed as they rely on evasion to escape predation, while relatively inactive and aggressive females may conserve resources by producing smaller metasomas.

125.5 CARLTON, E.D.*; COOPER, C.L.; DEMAS, G.E.; Indiana Univ., Bloomington, Claflin Univ., Orangeburg, SC; *elcarlto@indiana.edu*

Metabolic signals differentially regulate trade-offs between the reproductive and immune systems in female Siberian hamsters

Most free-living animals have finite energy stores that they must allocate to different physiological processes. As such, when energy is limited, energetic trade-offs among these physiological systems may occur. In our study, we experimentally limited energy availability to female Siberian hamsters (*Phodopus sungorus*) with 2-Deoxy-D-glucose (2-DG), a non-metabolizable glucose analog that disrupts cellular utilization of glucose. We observed how treatment with a low or high dose of 2-DG affected energy allocation to the reproductive and immune systems. We predicted that limiting energy availability via 2-DG treatment would decrease reproductive and immune functions. In addition, a subset of hamsters was treated with leptin, an adipose hormone that provides a direct signal of available fat stores. We predicted that leptin treatment would provide a "false signal" of energy reserves and would reduce the energetic constraints imposed by 2-DG. We found that 2 -DG treatment reduced, but leptin did not restore, reproductive tissue mass. Additionally, leptin treatment enhanced innate immunity, as measured by a bacterial killing assay, although 2-DG treatment had no effect on this measure. In contrast, the high dose of 2-DG decreased immunoglobulin G (IgG) production in response to a foreign antigen; however, leptin treatment did not counteract the 2-DG induced decrease in IgG levels. Rather, leptin appeared to enhance the negative effects of 2-DG on IgG levels. Collectively, these findings suggest that an animal's current energy balance can affect both reproductive and immune responses but that different metabolic fuels affect energy allocation to the reproductive and immune systems in dissimilar ways.

25.1 CARNEY, R.M.*; AHEARN, S.C.; MCCONCHIE, A; GLASER, C; JEAN, C; BARKER, C; PARK, B; PADGETT, K; PARKER, E; AQUINO, E; KRAMER, V; Brown University, City University of New York, University of British Columbia, California Dept of Public Health, Univ of California, Davis; *ryan_carney@brown.edu*

A biologically-based GIS model for predicting outbreaks of mosquito-borne viral diseases

The Dynamic Continuous-Area Space-Time (DYCAST) system is a biologically-based spatiotemporal model that uses public reports of dead birds to identify areas at high risk for West Nile virus (WNV) transmission to humans. We implemented this model prospectively using geographic information system (GIS) software during an unprecedented outbreak in California; daily risk maps were made available online and used by local agencies to target public education campaigns, surveillance, and mosquito control. DYCAST proved to be a timely and effective early warning system, with 80.8% sensitivity, 90.6% specificity, and identification of high-risk areas an average of 37.2 days prior to onset of illness. In subsequent years the model was implemented throughout the entire state of California. Additionally, we modified the model's biological parameters based on the dengue infection cycle, and implemented an open-source version of the software retrospectively during a dengue epidemic in Riberão Preto, Brazil. Results indicate that the model provided early and accurate identification of high-risk areas, including the detection of cryptic interepidemic foci of transmission critical to efficacious control efforts. DYCAST predicted up to 90.3% (4,234/4,690) of cases, at a maximum mean of 66.3 days prior to onset of illness; sensitivity and specificity were 83.8% and 78.8%, respectively. Ultimately, this biological modeling approach has been shown to be an effective, inexpensive, and scalable solution for the surveillance and control of zoonotic diseases such as dengue and WNV, and has potential for further adaptation to model other ecological phenomena that cluster in space and time.

P3.113 CARRILLO, A.*; BANSUAN, H.; MIRANDA, A.; DICKSON, K.; Cal. State Univ., Fullerton; *andresc2@uci.edu*

Effects of Extended Incubation on Post-Hatching Growth of Larval California Grunion

In previous studies of extended embryonic incubation in *Leuresthes tenuis*, we found that larvae that hatched after extended incubation (at 28 days post-fertilization, dpf) had more skeletal development in the jaws and caudal fin and greater feeding rates than those hatched at 10 dpf (normal incubation), suggesting that the 28-dpf larvae would feed and grow faster after hatching. In this study we measured the same characteristics in grunion incubated at 20°C, hatched at 10 dpf or 28 dpf, and cultured at 20°C for up to 40 days after hatching (dah). We hypothesized that (a) larvae hatched at 10 dpf and grown for 18 dah have greater body length and skeletal development in the jaws and caudal fin than larvae that hatch at 28 dpf (same age post-fertilization), and (b) the post-hatching rate of growth in length and skeletal development of the caudal fin and jaws are greater in *L. tenuis* hatched at 28 dpf compared to those hatched at 10 dpf. From each of the two incubation groups, five grunion were sampled periodically at 0-40 dah. In each individual, length was measured and skeletal elements were examined in cleared-and-stained fish. Body length was greater and skeletal development was more advanced in larvae hatched at 10 dpf and grown to 18 dah, compared to 28-dpf larvae at hatching. Post-hatching growth in body length and the length of hypural 1 did not differ as a result of extended incubation, whereas the number of dentary teeth and caudal skeletal elements differed only at 0-4 dah. Thus, we conclude that the previously measured increases in feeding rate and skeletal morphology at hatching do not result in higher post-hatching growth, and that grunion that extend incubation do not reach the size of those that hatch earlier, at least within 40 days after hatching.

P1.54 CARRILLO-BALTODANO, A*; COLLIN, R; Smithsonian Tropical Research Institute, Panama City; *carbalallan@gmail.com*

Sex-change in Crepidula cf. marginalis (Gastropoda: Calyptraeidae) is a response to physical contact with conspecifics

Interactions with conspecifics commonly influence sex allocation in sequential hermaphrodites, but the cues that trigger sex change in invertebrates have not been examined in detail. In the marine environment waterborne compounds seem the most obvious pathway to established intraspecific communication, but at least in fishes behavioral interactions also play an important role. Previous experiments with several *Crepidula* species have shown that growth and subsequent sex change of small males appears to be inhibited by association with females or with larger males. When males are raised alone size at sex change was smaller and the time to sex change was faster than males paired with a female. To determine if water-borne cues trigger sex change, pairs of small *Crepidula* cf. *marginalis* from Veracruz, Panama, were raised in cups in the laboratory. Thirty replicate males were raised in a cup separated from a female by a 350-micron mesh, to prevent physical interaction but allow food and water to flow between the sides. As a control, males were raised with a female without any obstacle. We found no difference in size or growth rate between males in the two treatments. However, males in the mesh-separated treatment changed sex more quickly than those in the control. More than 50% of these males had changed before any of the individuals in the control began to change. This suggests that physical contact and not water-born cues mediate the effect of conspecifics on sex change in this species.

P2.67 CARROLL, M.A.*; SKEETE, D.; CATAPANE, E.J.; Medgar Evers College; *catapane@mec.cuny.edu*

STEP into Science at Medgar Evers College, a Successful Strategic Plan

STEP into Science was designed to increase the number of students earning BS degrees in Biology and Environmental Science. The program goals are to: recruit new students and non-STEM students into Biology or Environmental Sciences; improve retention by providing academic, financial and mentoring support; foster integration of research and technology to better equip majors to be successful applicants to graduate/professional programs; and increase the number of students graduating with BS degrees. Now in our fifth year the program has had great success. We use peer recruiters to attract more high school, transfer, and non-science college students into STEM majors and place emphasis on undergraduate research experiences to increase the quality and retention of science majors through their BS degree. Since the inception of the program, STEM enrollment more than doubled and the number of majors actively engaged in research has risen more than 90% with a concurrent increase in student research presentations at scientific conference, and an 87% increase in the number of students receiving external research internships and travel awards to attend national conferences. STEM graduates have also increased and the program anticipates that these and future STEP into Science graduates will continue on to Masters and Doctoral programs in STEM and ultimately enter rewarding careers in the science enterprise.

56.3 CARRUTH, L.L.*; SHAHBAZI, M.; Georgia State University; *lcarruth@gsu.edu*

Early Developmental Stress Alters HVC but not RA size in Male Zebra Finches

Stress has long lasting effects on animal physiology, development, behavior, reproductive success and survival. The effects of stress are mediated by glucocorticoids, such as corticosterone (Cort), via membrane-bound or intracellular glucocorticoid receptors (GR). When an organism is exposed to repeated stressors early in life this can alter stress-responsive neurobiological systems persisting across all life history stages. Early developmental stress affects the size of the avian song control nuclei and song quality in many songbirds, suggesting a direct link between brain and behavior. Song nuclei including HVC (proper name) and RA (nucleus robustus arcopallii) are required for song learning and production, and the complexity of the male zebra finch (*Taeniopygia guttata*) courtship song is important in female mate choice. Early Cort treatment differentially reduced the HVC size, but not RA, in juvenile and adult male zebra finches. This suggests that the effect of developmental stress on the HVC size may be mediated through Cort via activation of GR within HVC. This may be a specific mechanism by which HVC size and song quality are altered in developmentally stressed birds. Taken together, this suggests a potential role for Cort in mediating adverse effects of developmental stress in adult male zebra finches and highlights the developmental plasticity of the zebra finch brain.

78.3 CARTER, C.B.*; RICE, A.N.; WESTNEAT, M.W.; COOPER, W.J.; Washington State University, Cornell University, The Field Museum of Natural History; *casey.carter@email.wsu.edu*

Feeding kinematics in damselfishes (Pomacentridae): ecological diversity and repeated trophic convergence

The damselfishes represent a species-rich lineage that forms a major component of the fish fauna on all coral reefs, and as such they represent an important part of the vertebrate trophic diversity present in these communities. The evolution of the functional morphology of damselfish skulls is characterized by rapid and repeated shifts between a limited number of trophic niches, such that the adaptive diversification of their trophic ecology has primarily consisted of multiple shifts between three primary feeding niches: herbivory, planktivory and a limited type of omnivory. This pattern of evolution has resulted in repeated convergence on skull shapes that are associated with either primarily benthic-feeding niches (herbivory and omnivory) or pelagic-feeding niches (planktivory). Whether or not the skull kinematics of damselfishes in separate feeding guilds exhibit similar patterns of movement has not been previously studied. Here we examined the feeding kinematics of 5 damselfish species that represent wide coverage of the pomacentrid lineage, and which include an herbivorous species, an omnivore, and three convergently evolved planktivores. We used high-speed video recordings of feeding events from wild-caught fishes captured in the waters around Lizard Island on the Great Barrier Reef. We compare the feeding performance of damselfishes that are both trophically and morphologically diverse, as well as those that are trophically divergent, but distantly related.

P3.26 CARY, TL*; PASK, JD; ROLLINS-SMITH, LA; KARASOV, WH; Univ. of Wisconsin, Madison, WI, Vanderbilt Univ. Medical Center, Nashville, TN; *tcary@wisc.edu*

PCB-126 exposure lowered antimicrobial peptide secretion in juvenile northern leopard frogs

Two factors threatening global amphibian populations are disease and environmental contamination. Chytridiomycosis is an amphibian disease caused by the fungus *Batrachochytrium dendrobatidis (Bd)*; antimicrobial peptides (AMPs) secreted onto the skin of amphibians are thought to defend against *Bd*, providing a first-line innate immune strategy. We hypothesized that larval exposure to PCB-126, an organic contaminant, would decrease AMPs secreted by post-metamorphic *Lithobates pipiens*. Tadpoles were fed a control diet or a diet with 0.37, 1.2, or 5.0 ng PCB-126/g until metamorphosis. Juvenile frogs were injected with saline or norepinephrine-HCl dissolved in saline and placed in buffer to collect secreted skin peptides. The peptides were enriched to obtain hydrophobic peptides which include the AMPs and quantified using a bradykinin based peptide assay. Skin peptides were also analyzed using matrix-assisted laser desorption time-of-flight mass spectrometry. Control frogs secreted 593 ±101 µg/g body weight (BW) skin peptides, while frogs exposed to 0.37, 1.2, or 5.0 ng PCB-126/g had 336 ±43, 378 ±62, and 365 ±56 µg/g BW skin peptides, respectively. One-way ANOVA determined no significant difference (p= 0.077), however, post-hoc Dunnet's test determined that 0.37 ng PCB/g signficantly lowered skin peptide secretion (p= 0.047). Furthermore, when the control group was compared against all PCB-treated animals, PCB-126 significantly lowered skin peptide secretion (p= 0.004). In all treatment groups the suite of AMPs secreted by frogs was similar, indicating that AMP type was not affected by PCB exposure. If a minimum threshold of AMPs is needed to be protective, lowered AMP levels due to contaminant exposure may increase frog susceptibility to *Bd*.

S1-1.1 CASAS, Jerome; University of Tours (FRANCE); *casas@univ-tours.fr*

SEARCH GAMES IN REALISTIC PREDATOR-PREY INTERACTIONS

I will present two cases of predator-prey search games, wolf-spiders and wood crickets on one hand and a microlepidopteron leafminer and its parasitoid on the other hand. Much is known about the sensory ecology background as well as the role of the arena, the physical environment in which the game is played, for these two systems. Air flow sensing in crickets and vibration perception in the microlepidopteron larvae enable prey to escape. These are unintended cues left by the foraging predators. Both the litter structure as well as the exact pattern of the mine both also determine the outcome. I end the talk by describing a highly simplified model of search games with incomplete information for which the leafminer-parasitoid interaction was a motivating example. A healthy dose of randomness in the chosen paths is beneficial both for the prey and the predator. Further progress in modelling realistic search games between predator and prey requires (i) joint information about both trajectories, so far seldom recorded together, and (ii) a theoretical development of combined pursuit-evasion and search games models, two kinds of models which so far live their own lives without interaction. However, most observed predator-prey close range interactions contain elements of both.

S11-2.3 CASE, A.L.; Kent State University; *acase@kent.edu*

The advantages of gynodioecy vs. dioecy in plants

Plants exhibit the full spectrum of variation in both gender expression and sexual systems. Individuals can be male, female, simultaneous hermaphrodites, or sequential hermaphrodites. Populations can be comprised of any combination of these sexes, making plants an ideal system in which to study the relative advantages and disadvantages of each alternative strategy. Indeed, evolutionary transitions between sexual systems have received more attention in plants compared to other eukaryotes, both because of their extensive sexual variability and because several features of plant life histories--including immobility and modularity--make them remarkable subjects for evolutionary and ecological research. In this talk, I summarize over a century of research on the adaptive significance of gender variation in plants. I place particular emphasis on the repeated evolution of gynodioecy and dioecy, the stability and maintenance of these two sexual systems, and the important role of phenotypic plasticity in transitions between them. Dioecy (=gonochorism) is the predominant sexual system in the animal kingdom, far exceeding any other, while gynodioecy is almost unheard of among animals. In plants, gynodioecy and dioecy are both relatively common and frequently derived, often co-occurring within plant genera. Perspectives on dioecy as a recently derived state can improve understanding of its adaptive significance. To do so in a broad context that allows for cross-kingdom comparisons, I address how predominant theories of the evolution of dioecy might be applied uniquely to plants vs. applied generally across eukaryotes.

135.6 CASS, AN*; MCCUNE, AR; Cornell University; *anc24@cornell.edu*

Are swimbladders inverted lungs? Evidence from developmental genetics

The homology of lungs and swimbladders has been accepted to varying degrees by the great morphologists of the 19th and 20th centuries. We have recently shown that a shared developmental regulatory network underlies the early development of tetrapod lungs and the zebrafish swimbladder. This is the first genetic evidence supporting this proposed structural homology. One major unresolved incongruity regarding lung and swimbladder homology is that lungs bud ventrally from the gut while swimbladders bud dorsally, leading some to the conclusion that lungs and swimbladders are not structurally homologous, but rather independent modifications of the posterior pharynx. However, comparative developmental biology has shown that a seeming structural inversion, such as the ventral to dorsal inversion of the nervous system in bilaterian invertebrates and chordates, can be due to an inversion of the ancestral patterning mechanism and not an independent structural origin. The developmental genetic mechanism specifying the ventral location of the tetrapod lung bud is well understood, and involves the mutual antagonism of the lung-specifying gene *Nkx2.1* and its mutual antagonist *Sox2*. Our study examines the expression pattern of these two genes in the posterior pharynx and swimbladder bud in zebrafish. An inversion of the ancestral lung patterning mechanism would be strong evidence for the structural homology of these two structures and addresses a longstanding and controversial issue in comparative anatomy.

P1.99 CASTELLANOS, L*; SILVERBERG, R; MORGAN, T; WILLIAMS, CM; HAHN, DA; University of Florida, Gainesville, Kansas State University, Manhattan; *carolinewilliams@ufl.edu*

Evolution of energy metabolism in cold-adapted Drosophila melanogaster.

In ectotherms, the time to recovery following cold exposure (chill coma recovery time, CCR) is an ecologically-important phenotype, yet the mechanisms underlying variation in CCR are not well-understood. One hypothesis is that animals showing fast CCR times have higher rates of aerobic metabolism during cold exposure, allowing them to regulate metabolic homeostasis more effectively. This may result in selection to increase rates of metabolism in organisms with greater cold tolerance. We tested this hypothesis using replicate lines of *Drosophila melanogaster* that have been selected for fast and slow chill coma recovery times, and also in lines originating from a wild-caught population with naturally segregating variation in cold tolerance (the Drosophila Genetic Reference Panel, DGRP), using stop-flow respirometry at a range of temperatures. We present evidence that metabolic rates become elevated as a consequence of selection for fast CCR, and in addition that metabolic rates are positively correlated with CCR times in the DGRP. This is strong evidence that evolution of energy metabolism is an important component of cold adaptation, and has implications for metabolic cold adaptation theory. In addition, we present a novel method of accounting for the influence of activity in stop-flow respirometry.

P1.222 CASTRO, DJ*; ROBINSON, CD; JOHNSON, MA; Trinity University; *dcastro1@trinity.edu*

The effect of variation in endocrine mechanisms on natural display behavior in Caribbean Anolis lizards

Sexual display behaviors often consist of elaborate performances designed to attract potential mates. In *Anolis* lizard species, display behaviors consist of dewlap (i.e., throat fan) extensions and pushups, and species can vary dramatically in their patterns of display. In this study we observed the natural behavior of adult males of three sympatric species of *Anolis* lizards from the Barahona region in southwestern Dominican Republic. We found that *A. coelestinus* and *A. cybotes* generally perform few dewlap extensions and many pushups in each display bout, while *A. brevirostris* performs similar numbers of both display behaviors in each bout. We also conducted controlled arena trials in order to provoke aggressive displays between pairs of conspecific males, and we found display patterns consistent with the natural behavior of the species. Because previous studies have shown that an increase in circulating androgens is associated with an increase in sexual display behavior, we aimed to test whether differences in androgen receptors in the muscles controlling dewlap extension and pushups are associated with the frequency of use of that particular muscle during displays. We quantified the concentration of androgen receptors in the muscles through immunocytochemistry, and found species-specific variation in androgen receptor expression across tissue types. This study will allow us to determine how variation in endocrine mechanisms can lead to variation in social display behavior in anoles.

8.4 CASTRO, D.A.*; PODOLSKY, R.D.; College of Charleston; *diegocastro90@gmail.com*

Effects of Elevated Oceanic CO_2 and Temperature on Sperm Motility and Swimming Speed in Northern and Southern Populations of the Sea Urchin Arbacia punctulata

Increases in atmospheric CO_2 are raising CO_2 levels in the ocean, driving a decrease in oceanic pH through the process of ocean acidification. Several key biological processes, including calcification and cellular metabolism, are sensitive to small changes in pH. Little is known, however, about how populations evolving under different conditions have responded to variation in CO_2 or to the synergistic effects of CO_2 and other environmental parameters like temperature. Latitudinal comparisons are a powerful way to address such questions. We examined the swimming performance of sperm cells under different CO_2 and temperature conditions for sea urchins (*Arbacia punctulata*) collected from northern and southern populations in the western Atlantic. Prior work found that increases in CO_2 through about 2.5 times current levels, corresponding to 100 years in the future based on climate models, led to significant linear declines in both sperm motility and swimming speed. We exposed sperm from each population to each of the two respective collection temperatures (14 and 24C) under a range of CO_2 concentrations (pre-industrial, current, 1.75 times current, and 2.5 times current). We predicted that sperm of northern and southern populations would show differences in the degree of sensitivity to CO_2 at a common temperature. Sperm from southern urchins likely show greater sensitivity because a given CO_2 change leads to smaller pH changes in southern waters compared to the same CO_2 change and associated pH change in northern waters. Our results will be discussed in terms of differences expected in the solubility of CO_2, in oceanic upwelling, and in aragonite saturation levels between northern and southern latitudes.

S5-1.7 CATALANO, R. A.*; SAXTON, K; BRUCKNER, T; PEARL, M; ANDERSON, E; GOLDMAN-MELLOR, S; MARGERISON-ZILKO, C; SUBBARAMAN, M; CURRIER, R; KHARRAZI, M; Univ. of California, Berkeley, California Department of Public Health; *rayc@berkeley.edu*

Hormonal Evidence Supports the Theory of Selection in Utero

ABSTRACT Objectives: Antagonists in the debate over whether the maternal stress response during pregnancy damages or culls fetuses have invoked the theory of selection in utero to support opposing positions. We describe how these opposing arguments arise from the same theory and offer a novel test to discriminate between them. Our test, rooted in reports from population endocrinology that human chorionic gonadotropin (hCG) signals fetal fitness, contributes not only to the debate over the fetal origins of illness, but also to the more basic literature concerned with whether and how natural selection in utero affects contemporary human populations. Methods: We linked maternal serum hCG measurements from prenatal screening tests with data from the California Department of Public Health birth registry for the years 2001-2007. We used time series analysis to test the association between the number of live born male singletons and median hCG concentration among males in monthly gestational cohorts. Results: Among the 1.56 million gestations in our analysis, we find that median hCG levels among male survivors of monthly conception cohorts rise as the number of male survivors falls. Conclusions: Elevated median hCG among relatively small male birth cohorts supports the theory of selection in utero and suggests that the maternal stress response culls cohorts in gestation by raising the fitness criterion for survival to birth.

63.3 CAUSEY, D.R.*; REYES, J.A.; WAGGONER, C.M.; HAMILTON, A.W.; ARMSTRONG, J.L.; KELLEY, K.M.; California State Univ. Long Beach, Pacific Coast Environmental Conservancy, Orange County Sanitation District; *dwight.causey@gmail.com*

PROTEIN EXPRESSION SCREENING IN ENDOCRINE-DISRUPTED, CORTISOL-PRODUCING INTERRENAL TISSUE OF URBAN OCEAN FISH

Wild fish residing near wastewater treatment plants (WWTPs) in coastal southern California have previously been demonstrated to exhibit an endocrine-disrupted condition affecting function of the cortisol-producing interrenal, which is correlated with exposures of the fish to specific classes of environmental contaminants. Fish exhibiting this form of endocrine disruption do not activate a normal neuroendocrine response to stress. Studies of English sole indicate that interrenal response to ACTH is impaired when tested in vitro, and interrenal from these fish exhibit corresponding decreases in expression of steroidogenic mRNAs including steroidogenesis-activation regulator (StAR) and P450-11β hydroxylase. Using proteomics-based screening, interrenal proteomes were compared between control and endocrine-disrupted English sole captured from reference and WWTP locations, respectively. Analyses thus far reveal that nine proteins were negatively correlated with cortisol response ($p<0.05$), while twenty proteins were positively correlated ($p<0.05$). Identification of some of these proteins indicate alterations in expression of heat-shock protein 60 (HSP60), aldehyde dehydrogenase, peroxiredoxin, and malate dehydrogenase, suggesting responses including oxidative and cellular stress and altered cellular metabolism. Proteins were also identified that significantly correlated with cortisol response, which are candidate players in the disrupted interrenal condition. (Support from NOAA/USC Sea Grant Program in California).

P3.79 CAVACO, N*; DE JONG, D; SEAVER, E; Kewalo Marine Laboratory; *naneac@hawaii.edu*

Understanding regeneration through an annelid worm

Regeneration, the ability to re-grow a missing body part after it has been removed, is seen in many phyla across the animal kingdom. However, the degree to which regeneration occurs varies. For example, some amphibians can regenerate limbs while some fish can regenerate fins. In addition, the mechanisms for regeneration differ. In some planarians, stem cells are readily available to differentiate into needed cell types while Hydra can regenerate without cell division. An essential question of regeneration studies is what is the origin of the regenerative tissue? Though many annelids can regenerate following transverse body amputation, the cellular mechanisms of regeneration in this phylum are poorly studied. The purpose of my project is to describe what happens in regenerating juveniles of the annelid Capitella teleta. Juveniles are more transparent and regenerate faster than adults. This study aims to characterize the cellular events during posterior regeneration. EdU, a modified nucleotide, is incorporated to visualize cell division patterns. By two days post-amputation, positive labeling in the posterior of the animal marks the onset of cell division. Cell division in the regenerating juvenile is detected in all three germ layers, but not all germ layers are required to regenerate. New segments reform and normal development is re-established by seven days post-amputation. DiI, a vital marker, aids in visualizing cell behavior. Adjusting DiI techniques will lead to demarcating the amputation site and capturing cell movement. A detailed understanding of cellular patterns seen in regenerating juveniles sets the foundation for future studies on determining the origin of the regenerative tissue in this system.

P1.134 CAVE, E.J. *; GUNN, T.; BEDORE, C.; KAJIURA, S.; KERSTETTER, D.; Florida Atlantic University, Nova Southeastern University; *ecave@fau.edu*

Sexual dimorphism in the dentition of pelagic stingrays, Pteroplatytrygon violacea

The elasmobranch fishes are a group of vertebrates that have evolved a multi-functional mouth that is involved in mating behavior. Sexually dimorphic changes have been observed, which include epidermal thickening in females and seasonal changes in male dentition. Male Atlantic stingray (Dasyatis sabina) dentition changes from molariform to pointed during the mating season, which allows them to better grasp the females to successfully mate. Pelagic stingrays (Pteroplatytrygon violacea) are in the same family (Dasyatidae) as Atlantic stingrays and are likely to undergo seasonal changes in dentition as well. However, pelagic stingrays possess pointed symphyseal teeth to aid in feeding on teleosts and squid. Therefore, it is unknown if pelagic stingrays also undergo seasonal changes in dentition to aid in mating. Pelagic stingray jaws were collected from commercial fisherman. Tissue was dissected from each jaw and the number of teeth in the files and rows was recorded. The tooth next to the symphyseal tooth in the second row of the upper jaw was extracted and photographed. Photographs were digitized and analyzed for shape with various software programs. Results show that sexual dimorphism in pelagic stingrays is seen between male and female teeth ($P=0.01$). There were no significant differences in males and females between mating and non-mating seasons ($P=0.06$, $P=0.55$). The number of tooth rows increased significantly according to disc width in upper jaws in both sexes. The number of tooth rows in the lower jaws of males also increased significantly. There is no significant difference in tooth files in upper or lower jaws in both sexes. However, number of tooth files are significantly different between males and females.

P3.123 CAVIEDES-VIDAL, E*; LOPEZ-CATIVA, L; MOLINA-MARINO, L; Univ Nac de San Luis - Consejo Nac de Inv Científicas y Técnicas, Univ Nac de San Luis; *enrique.caviedes@gmail.com*

CHARACTERIZATION OF COMPLEMENT-SYSTEM ACTIVITY OF COMMON PIGEON PLASMA (Columba livia)

The complement system (CS) is an important component of the innate immune system of vertebrates that protects against infectious agents. We used the rabbit red blood cell (RRBC) hemolysis assay to assess and characterize the activity of CS in pigeon plasma (pool). Immediately before the assay, plasma was treated with two inhibitors (EDTA and heat) to make sure that hemolysis was due to CS activity. Plasma samples were preincubated in a thermoregulated water bath, then a solution of RRBC (2% v/v) was added and the mix incubated again at selected temperature. After the incubation, samples were centrifuged, supernatant was loaded on a plate and the released hemoglobin was read at 540 nm. We evaluated: A) the effect of the temperature on CS activity by incubating the reaction mix at different temperatures. B) the kinetics of hemolysis by incubating plasma samples with RRBC and stopping the reaction at different times. C) the effects of the plasma concentration on RRBC lysis, a series of assays with increased concentrations of plasma was performed. The reaction showed a positive relationship between incubation temperature and hemolysis reaching a maximum at 41°C. Hemolytic activity was detected with a concentration of 10 % pigeon plasma and was total at 20 %. RRBC lysis was apparent after 2.5 min of incubation and increased steadily until 25 min, when it became constant. Considering that pigeons are an extremely successful species that has been widely spread in rural and urban areas, that they harbor a diverse parasite fauna and are potentially associated with zoonotic events, to assay the complement system as an innate immune component in the resistance to disease may be an important tool. Funded by PICT 97-01320 to EC-V

P1.143 CAVIERES, G*; NUñEZ-VILLEGAS, M; SABAT, P; Universidad de Chile; *griselcavieres@gmail.com*

Can the thermal conditions experienced during ontogeny have consequences on phenotypic flexibility in Phyllotis darwini?

We studied the putative effect of thermal history experienced during development on physiological flexibility of energetic traits (basal metabolic rate (BMR), thermal conductance (Ct) and body mass) in an altricial rodent, the leaf-eared mouse (Phyllotis darwini). Adults individuals were trapped in central Chile and maintained in pairs for breed. Pups were isolated after weaning and acclimated to either cold or warm conditions (15 and 30° C) until adulthood. Subsequently, individuals were acclimated to opposite thermal treatment. The results revealed a significant effect of the ontogenetic history on adult's thermoregulatory capacities. Individuals developed at 15°C showed a significant increase in BMR. Additionally, individuals reared at 30 ° C exhibited lower BMR, and a Ct significantly higher, which in turn was correlated with an increase in morphometrics traits related to heat loss (foot and ear length). Adults acclimated at 30°C decreased BMR; however those reared at 30°C and then acclimated to 15°C did not increased BMR. Furthermore, the Ct in animals developed at 30 ° C changed when they were re-acclimated at 15 ° C, but not in the opposite direction. Therefore, morphometric traits showed inflexible reaction norms. The results suggest the existence of ontogenetic dependence on the ability of change on metabolic attributes in Phyllotis darwini.

73.2 CEASE, AJ*; ELSER, JJ; HAO, S; HARRISON, JH; University of Sydney, Arizona State University, Institute of Zoolog, Chinese Academy of Sciences; *arianne.cease@sydney.edu.au*

Low plant nitrogen content and high population density enhance migratory characters in a polyphenic locust

Locusts present an impressive and well-studied example of phenotypic plasticity in which population density regulates a variety of behavioral, morphological, and physiological traits that often culminate in migratory swarms. *Oedaleus asiaticus*, a north Asian locust, has outbreaks and migratory swarms comprised predominantly of brown morphs. Heavy livestock grazing promotes outbreaks by lowering plant nitrogen content and likely lowering the protein:carbohydrate ratio to the optimal range for this locust. However, it is unclear if a change in plant quality can modulate the effect of density on phase characteristics. We found that locusts reared at high population density and fed low-N plants (i.e. plants that are high quality for *O. asiaticus*) had the most enhanced migratory characteristics while locusts fed high-N plants (i.e. deleterious for this locust) consistently had decreased expression of migratory characters. These results do not support existing paradigms that poor-quality resources increase the expression of migratory phenotypes. We then compared feeding habits of the brown (outbreak) and green (non-outbreak) morphs. There was no difference in plant preference nor protein:carbohydrate intake target ratio; however, when confined to diets extreme in their protein:carbohydrate ratios, green locusts decreased consumption and brown locusts maintained a similar consumption rate on all diets. From these results we infer that the green morph strategy may be most beneficial for sedentary insects confined to limited food choices to avoid long-term deleterious effects of consuming an unbalanced diet, while the brown morph strategy of being more willing to consume suboptimal foods may be most beneficial for roaming insects.

P3.188 CHABY, L.E.*; CAVIGELLI, S.A.; WANG, K.; WHITE, A.; BRAITHWAITE, V.A.; Pennsylvania State University, University of Pittsburg; *Lec5252@psu.edu*

The effects of adolescent stress on adult behavior

Animals that experience stressors in early life often have modified stress responsivity and associated changes in behavior as adults, leading to long term depressed-like states. Unlike early life stages, relatively less attention has been paid to exposure to stress soley during the adolescent phase, yet this is an inherently plastic time where specific neural regions in the brain undergo considerable change. Here we investigated the development of adult rat behavior in animals that experienced chronic mild stress throughout the adolescent phase. Once the rats reached maturity, both control and chronic mild stress exposed animals were returned to standard housing for 13 weeks before they were tested in successive negative contrast trials (SNC). SNC is a technique used to gauge the emotional state of frustration; it does this by quantifying the sensitivity of an animal to an unexpected downshift in reward value. For this study, the rats were trained to expect 5 minutes of access to a 32% sucrose solution daily, and their lick rate to this high level reward was monitored over 12 days. On the 13th day (and for the next 7 days) the concentration of the sucrose solution was unexpectedly decreased to a 4% sucrose solution. The lick rate of the rats exposed to chronic mild stress during adolescence dropped almost 3 times more than control rats, indicating that they more easily gave up this challenge. This suggests that exposure to mild but prolonged stress during adolescence significantly increased the susceptibility to frustration and impairs coping ability in these animals.

74.3 CHADWELL, BA*; YOUNG, JW; SHAPIRO, LJ; NEOMED, Rootstown, OH, Univ. of Texas, Austin; *bchadwell@neomed.edu*

A Comparative Look at Tail Movement During Narrow Branch Locomotion.

Tails have been suggested to act as either counterweights or dynamic stabilizers to maintain balance during locomotion, functions that should be especially important on narrow substrates, e.g. branches. Most tests of these assertions have been based on mathematical modeling, purely morphological studies, or qualitative observation. Few empirical data exist with which to test tail function during narrow branch locomotion. We present kinematic data on tail movements in two primates, squirrel monkeys (*Saimiri*) and tamarins (*Saguinus*), during quadrupedal locomotion on a 3.2cm diameter pole. Ongoing studies are focused on describing locomotor tail movements in other arboreal animals as well (e.g., *Petaurus*). Morphological data suggest that *Saguinus* has reduced power-grasping abilities relative to *Saimiri*, perhaps necessitating compensatory means of maintaining balance on narrow substrates. To test this hypothesis, we used video analyses to document tail angular kinematics throughout strides. We predicted that tails used as effective balancing organs, whether as counterweights or dynamic stabilizers, should be held at elevated angles with respect to the substrate, thus maximizing rotational inertia and resistance to movement. Additionally, tails used as dynamic stabilizers should exhibit exaggerated movement over a stride. Controlling for variation in speed and body mass, we found that *Saguinus* holds the tail at more elevated angles (mean angular position: *Saguinus* 7.1 deg; *Saimiri* -15.5 deg; $p<0.05$) and moves the tail through wider ranges of motion (amplitude: *Saguinus* 26.1 deg; *Saimiri* 13.7 deg; $p<0.05$). These preliminary data suggest that tamarins are more reliant on using their tails as balancing organs. Supported by NSF BCS-1126790 and NSF BCS-0647402.

P3.27 CHALLENER, R.*; MCCLINTOCK, J.B.; MAKOWSKY, R.; Univ. of Alabama at Birmingham; *rchallen@uab.edu*

Effects of reduced carbonate saturation state on early development in the edible sea urchin Lytechinus variegatus

Land-based aquaculture facilities often utilize additional bicarbonate sources to boost alkalinity in order to buffer seawater against reductions in pH. Despite these preventative measures, many facilities are likely to face periodic reductions in pH and corresponding reductions in carbonate saturation states due to the accumulation of metabolic waste products. We investigated the impact of reduced carbonate saturation states (Ω_{Ca}, Ω_{Ar}) on embryonic developmental rates, larval developmental rates, and echinoplutei skeletal morphometrics in the common edible sea urchin *Lytechinus variegatus* under high alkalinity conditions. Fertilized sea urchin eggs pooled from several adults were distributed among 5 x 1 liter glass beakers per treatment and maintained for 5 days without food. Rates of embryonic and larval development were significantly delayed in both the low and extreme low carbonate saturation state treatments relative to the control at a given time. Larvae reared under ambient control conditions had significantly greater skeletal postoral arm lengths and overall skeletal body lengths relative to skeletal body lengths than larvae grown under extreme low carbonate saturation state conditions, indicating that changes in the carbonate system can impact not only developmental rates but also larval skeletal morphology. Reduced rates of embryonic development and delayed and altered larval skeletal growth are likely to negatively impact larval culturing of *L. variegatus* in land-based, intensive culture conditions where calcite and aragonite saturation states are lowered by the accumulation of metabolic waste products.

P2.19 CHAMPAGNE, AM*; ALLEN, HC; WILLIAMS, JB; Ohio State University; *champagne.7@osu.edu*

Tests on the organization of lipids in the avian stratum corneum

Cutaneous water loss (CWL) accounts for over half of all evaporative water loss in birds. The barrier to water loss through the skin is the stratum corneum (SC), the outermost layer of the epidermis, composed of corneocytes embedded in a lipid matrix of cholesterol esters, fatty acid methyl esters, triacylglycerides, free fatty acids, cholesterol, ceramides, and cerebrosides. The relative abundance of these lipid classes may affect the barrier properties of the lipid matrix by affecting the ability of the lipid molecules to pack together or interact with water molecules to prevent CWL. In this study, we acclimated House Sparrows (*Passer domesticus*) to different temperature and humidity regimes and measured their CWL at different ambient temperatures. We then used infrared (IR) spectroscopy to measure lipid-lipid and lipid-water interactions in extracted SC of these birds at different temperatures and hydration levels. We found that in all groups, CWL increased at higher temperatures, and these changes were associated with a disordering of lipid hydrocarbon chains. Furthermore, as the SC was hydrated, lipid chain order did not change, suggesting that hygroscopic lipid moieties lie outside of lipid lamellae, rather than inside as has previously been suggested.

111.4 CHAN, KYK*; GRUNBAUM, D; Univ. of Washington; *kychan@uw.edu*

Assessing effects of starvation-induced morphological variations on swimming of larval sand dollars with a novel biomechanical model and video motion analysis

Morphologies of planktonic larvae of many marine invertebrates are complex and highly variable. Larval morphologies impose biomechanical constraints on vital ecological functions, including swimming. Earlier modeling studies suggest slight changes in larval morphology could compromise swimming performance. However, environmental variables such as food availability and ambient pH often induce morphological changes in larvae. These natural variations suggest the general hypothesis that environmentally-induced morphological changes are coordinated such that larval abilities to perform ecological functions are conserved. To test this hypothesis, we developed a novel protocol to extract geometric meshes representing detailed 3-dimensional larval morphologies from confocal micrographs and used this model to assess the impacts of morphological variations on larval swimming. Larval sand dollars (*Dendraster excentricus*) are known to be phenotypically plastic and develop longer ciliated extensions “arms” under food-limited conditions to enhance feeding. In this case study, using non-invasive video motion analysis and the biomechanical model, we tested the specific hypothesis that the starvation-induced morphological changes alter larval swimming. Video analysis results showed that 4-arm larval sand dollars swam in wider helices and had higher oscillatory speeds when starved. In still water, the model larvae had different passive sinking behaviors, suggesting the observed morphological variations had biomechanical implications. The observed differences in larval swimming could be a result of both changes in biomechanics and behaviors. Our results support the general hypothesis that environmentally-induced morphological variations, including starvation, are coordinated to balance ecological functions tradeoffs.

P1.210 CHAN, H*; DEMATHIEU, SL; LOPES, PC; JOHNSTON, N; KRAUSE, JS; BENTLEY, GE; Univ. of California, Berkeley, Univ. of California, Berkeley and GABBA, Univ. of Porto, Univ. of California, Davis, Univ. of California, Berkeley and Helen Wills Neuroscience Institute; *hilarychan@berkeley.edu*

Neuroendocrine basis of cooperative breeding in the sociable weaver

Cooperative breeding is one of Nature’s enigmas. Why would individuals delay reproduction to help care for young that are not their own? Primarily studied from an ecological and evolutionary perspective, essentially nothing is known about the neuroendocrine control of cooperative breeding in birds. Gonadotropin-releasing hormone (GnRH) and gonadotropin-inhibiting hormone (GnIH), key neuropeptides in regulating reproductive physiology, are logical candidates for the regulation of cooperative breeding. While GnRH activates reproductive physiology and behavior, GnIH inhibits them. To explore differences in these neuropeptides associated with being a breeder or a non-breeding “helper”, we studied the sociable weaver (*Philetairus socius*). These birds live in large communal nests in semi-arid regions of southern Africa and breeding is linked to rainfall. From behavioral observations during the rainy season, we established the identity of individuals visiting each chamber containing offspring. We captured the birds and collected their blood and brains. The brains were processed via immunohistochemistry for the presence of GnRH and GnIH. Blood was used to examine steroid concentrations and determine paternity. By exploring a role for GnRH and GnIH in mediating the different behavioral phenotypes found in cooperative breeding species, our findings help us gain insight into the mechanisms controlling reproductive inactivity in helpers and contribute to further our understanding of the neural basis of cooperative breeding.

P1.125 CHANG, E*; YANG, M; SHERWOOD, DR; MATUS, DQ; Duke University; *emily.chang@duke.edu*
The evolution of anchor cell invasion during rhabditid nematode vulval development
Cell invasion through basement membrane (BM) is a complex yet fundamental phenomenon essential for biological processes such as mammalian embryo implantation, leukocyte migration, and tumor metastasis. To understand the mechanisms guiding BM invasion we are using a simple model of cell invasion that occurs during the larval development of the nematode, *Caenorhabditis elegans*. To form the uterine-vulval connection, a specialized somatic gonadal cell, the anchor cell (AC), invades through the underlying uterine and ventral epidermal BM to contact the vulval precursor cells (VPCs). Like many developmental events in *C. elegans*, AC invasion is a tightly regulated process with little intra-specific variation. Despite the extensive work on vulval development in other non-model nematode species, little is known about how or whether the AC connects the developing uterine and vulval tissues in other species. We are interested in determining if the role of the AC in initiating the uterine-vulval connection is conserved across nematode species. Using DIC optics and laser ablation we have examined AC invasion in 16 nematode species representing several hundred million years of rhabditid nematode evolution. We find little morphological diversity in the timing and requirement of the AC to initiate the uterine-vulval connection, with one notable exception; during *Oscheius tipulae* vulval development, the AC invades one VPC division earlier. Given the plasticity of other aspects of nematode vulval development (*e.g.*, induction, cell fate and patterning), it appears that AC invasion is under strong selective pressure to ensure a stable uterine-vulval connection.

P3.117 CHANG, C; FRANZ-ODENDAAL, TA*; Saint Mary's University, Mount Saint Vincent University; *tamara.franz-odendaal@msvu.ca*
Condensations to Mineralizations: The Development of the Zebrafish (Danio rerio) Infraorbital Bones
The infraorbital bones make up five of the eight dermal bones found in the orbital region of the zebrafish skull. This series of bones ossifies in a consistent sequence starting with infraorbital one, and then infraorbitals three and five. Infraorbital four ossifies next and finally, infraorbital two, which is the last bone in this series and also the last bone in the zebrafish skull to ossify. We conducted a detailed analysis of the condensation to ossification phases of development of these bones. Our analyses involved both bone and osteoblast staining of zebrafish at twenty different time-points. Infraorbital bone condensations are shaped as templates of the final bone shape, and they mineralize at one or more centers of ossification. Initially mineralization is closely associated with the lateral line canals and/or foramen. Our comprehensive growth series detailing the ossification of each infraorbital bone provides important insight into how the bones in this series achieve their shape and paves the way for future studies in teleost skeletal biology.

11.2 CHANG, E.S.*; SHCHEGLOVITOVA, M.; CARTWRIGHT, P.; University of Kansas; *eschang1@gmail.com*
Comparative transcriptomics of cnidarian freshwater parasites
The myxozoan *Myxobolus cerebralis* and the enigmatic *Polypodium hydriforme* are both parasites with extremely unique life cycles and aberrant body plans specialized to parasitize certain economically relevant fish species. Both have been suggested to have phylogenetic affinity with cnidarians because of the similarity of their polar capsules to nematocysts. This has been supported by some molecular analyses. However, because they are morphologically distinct from each other and any other cnidarian, their phylogenetic placement within Cnidaria is unresolved. The large scale of information provided by next generation sequencing appears promising for shedding light on some of these questions. We have sequenced, assembled, and are characterizing the transcriptomes from both of these species, in the hopes of refining the phylogenetic placement of these organisms and investigating developmental and morphological transitions which occurred in their evolution. Because these are both parasites that live among host tissue, the analysis of these transcriptomes involved the development of a post-sequencing contamination filtering method based on a series of hierarchical BLAST searches, which could be applied to other situations in which contamination before sequencing cannot be avoided. As part of this effort, we have isolated genes that appear to be homologous to nematocyst-specific genes. Obtaining transcriptomes allowed for the rapid discovery of potentially informative candidate genes for future phylogenomic and developmental studies, that will yield insight into the evolution of these highly divergent life cycles and morphologies.

90.2 CHANG, J.*; EASTMAN, J.M.; ALFARO, M.E.; University of California, Los Angeles, University of Idaho; *jonathan.chang@ucla.edu*
Family-level analysis of exploited and at-risk ray-finned fish species shows high potential loss of biodiversity
Commercial harvesting of ray-finned fishes is both intense and widespread. The distribution of this pervasive exploitation and its attendant risk of extinction with respect to phylogeny is not currently well-understood. Previous studies have shown that clustered extinction increases the loss of trait diversity, which have both short-term (lower yield, reduced ecosystem services) and long-term effects (lost evolutionary history, biodiversity). We used several previously published phylogenies of families with exploited species and constructed additional phylogenies using *phlawd*. Species on these phylogenies were matched to exploitation and extinction risk data collected from fishbase.org, the IUCN Red List, and the Sea Around Us Project. Our results show a highly significant clustering of extinction risk and exploitation among many of the fish clades examined. Additionally, the pattern of these clustered extinction risks would lead to a significantly increased loss of evolutionary history compared to a pattern of random extinction, maximizing the potential threat to biodiversity. We also analyzed the rate of body size evolution using *auteur*, and found that in some families species that are at risk for extinction or are experiencing exploitation pressure tend to enjoy a significantly faster rate of body size evolution. This finding, in conjunction with the threat of a high loss in evolutionary history, suggests that commercial harvesting of fish is pruning away particularly exceptional branches on the fish tree of life.

19.5 CHAPPELL, M.A.*; LONDONO, G.; JANKOWSKI, J.; ROBINSON, S.; RINCON, D.; CHINOME, A.; RIVERA, S.; RINCONGUARIN, D.; FLOREZ, C.; Univ. of California, Riverside, Univ. of Florida, Gainesville, Univ. of British Columbia, Vancouver, Univ. de Antioquia, Columbia, Univ. Tecnologia y Pedagogica de Tunja, Columbia, Univ. Industrial d Santander, Columbia; *chappell@ucr.edu*

Do Tropical Birds From Andean Forests Have Low Basal Metabolism?

Recent studies by Joe Williams, Popko Wiersma, and colleagues indicate that tropical forest birds from Panama have significantly lower basal metabolic rates (BMR) compared to birds from higher latitudes. This finding was attributed to the slow 'pace of life' of tropical species (e.g., life history characterized by long lifespan, delayed maturation, low reproductive investment). To expand these results with data from a geographically distant tropical region, we measured BMR in 120 bird species from three field stations along the eastern Andean slope in Peru. The stations (400 m, 1400 m, and 3000 m elevation) include habitats ranging from hot, humid lowland Amazon forest to cool, high-altitude cloud forest. Birds were mist-netted and measured at night under conditions appropriate for determining BMR (ambient temperature 30-34 °C, fasted for > 5 h, stable and low metabolic rate, body temperature > 35 °C). We compared our BMR results to the data in Wiersma et al. (2007), and to the stringent BMR allometry generated by McKechnie and Wolf (2004). Both of the latter datasets include temperate as well as tropical species. We also tested for effects of altitude on the BMR of Andean birds, as there are substantial environmental temperature differences between the stations.

P2.147 CHARPENTIER, C.L.*; COHEN, J.H.; University of Delaware; *charpecl@udel.edu*

Fish kairomone-induced defenses during larval development of an estuarine crab

Zooplankton in marine, estuarine, and freshwater environments exhibit diel vertical migrations, descending during the higher light conditions of daytime to avoid visual predators and ascending at night to feed. Fish kairomones have been shown to increase zooplankton behavioral response to light, which would enhance the timing and magnitude of vertical movement. Freshwater zooplankton have also been shown to display pronounced morphological and developmental changes upon fish kairomone exposure; such morphological effects are less clear for marine species. We examined the photobehavior and morphology of *Rhithropanopeus harrisii* throughout its zoeal larval stages, comparing individuals reared in odor-free control seawater to those reared in the presence of odor from a predatory fish, *Fundulus heteroclitus*. Larvae exposed to either control seawater or fish kairomones throughout larval development had a similar lower light intensity threshold (3.64 $\times$ 10 ^{12} photons m^{-2} s^{-1}) for a light-mediated descent response when tested in a simulated underwater angular light distribution. However, kairomone-reared zoea exhibited a greater proportion of descending individuals, most pronounced in stage 3 zoea. Morphological effects were only evident in stage 3 larvae with increased lateral spine length in those reared in fish kairomones. These data show that chemosensory inputs such as fish odor increase both morphological and behavioral predator-avoidance strategies in *R. harrisii* larvae. Further study is required to better understand the specific neural processes that contribute to the phenotypic plasticity of these sensory responses.

99.3 CHAVEZ, A.A.*; GORMAN, C.; ERKEN, M.; MCDOUGALD, D.; STEINBERG, P.D.; NISHIGUCHI, M.K.; New Mexico State University, University of New South Wales, University of New South Wales; *nish@nmsu.edu*

Predation response of Vibrio fischeri biofilms to protozoan bacteriovores

Vibrio fischeri is a bioluminescent marine bacterium found worldwide, an active member of the bacterioplankton community, and has been used as a model system to study their beneficial associations with sepiolid squids. *V. fischeri* also proliferates in a sessile, stable, community known as a biofilm, which is one alternative survival strategy of its life cycle. Although this survival strategy is adequate protection from abiotic factors, marine biofilms are still susceptible to grazing by bacteria-consuming protozoa. Subsequently, grazing pressure can be controlled by certain defense mechanisms that confer higher biofilm-anti-predator fitness. In the present work, we hypothesize that *V. fischeri* exhibit an anti-predator fitness behavior while forming biofilms. Different predators, representing commonly found species in aquatic communities were examined, including the flagellates *Rhynchomonas nasuta* and *Neobodo designis* (early-biofilm feeders), and the ciliate *Tetrahymena pyriformis* (late-biofilm grazer). *V. fischeri* biofilms included isolates from both seawater and squid hosts (*Euprymna* and *Sepiola*). Our results demonstrate inhibition of predation by biofilms, specifically isolates formed from seawater strains. Additionally, anti-protozoan behavior was observed to be higher in late biofilms, particularly from the ciliate *T. pyriformis*; however, inhibitory effects were found to be widespread among all isolates tested. These results provide an alternative explanation for the adaptive advantage and persistence of *V. fischeri* biofilms and provide an important contribution in the understanding of defensive mechanisms that exist in the out-of-host environment.

50.5 CHAVEZ, A.A.; GORMAN, C.*; LOSTROH, C.P.; NISHIGUCHI, M.K.; New Mexico State University, Colorado College; *nish@nmsu.edu*

Genetic switches control host specificity in a squid-Vibrio symbiosis

Gap repair is a technique that has historically been used to clone entire operons by using the natural recombinant homologous cloning mechanism in *Saccharomyces cerevisiae*. By using *S. cerevisiae in vivo* recombination, we can manipulate and express operons from different *Vibrio fischeri* strains from geographically distinct squid host populations to determine if suites of genes are responsible for the specificity observed among closely related host-symbiont pairs. *V. fischeri* ES114 genomic DNA (isolated from *Euprymna scolopes*, a Hawaiian squid host) was then used as the nucleotide template; the targeted operon and the gapped vector was digested and simultaneously introduced into yeast cells allowing recombination. *V. fischeri* can then be transformed with the new vector by tri-parental mating to contain entire operons/regulons from the other strain, in this case *V. fischeri* ETJB1H (isolated from *E. tasmanica*, an Australian squid host). This technique allowed us to execute a detailed investigation of the importance in strain-specificity of these gene operons *in vivo*. Subsequently, two different squid host species (*E. scolopes* and *E. tasmanica*) were used to test colonization abilities and competition of the constructed strains. Results indicate that after mobilizing *lux* and *pil* operons from ETJB1H to ES114, colonization of the constructed strain was equivalent to the efficiency observed for the native strain; the same was observed for the *msh* operon, but in this case after mobilization from ES114 to ETJB1H. Thus, competitive ability based on symbiotic loci is not equal among closely related strains of *Vibrio*. Deciphering how the evolutionary history of specificity between closely related *Vibrio* strains occurred may give insight to the function of competence and inter-strain genetic specificity.

P2.134 CHEN, H.-Y.*; ROER, R.D.; WATSON, R.D.; University of Alabama at Birmingham, University of North Carolina at Wilmington; *elgase@uab.edu*

Molecular Cloning of a cDNA Encoding a Putative Plasma Membrane Calcium ATPase from Y-Organs of the Blue Crab (Callinectes sapidus)

Existing data indicate that a stage-specific increase in intracellular free Ca^{++} is involved in regulating (stimulating) ecdysteroid production by crustacean molting glands (Y-organs). The concentration of Ca^{++} in cytosol is controlled mainly by proteins intrinsic to the plasma membrane and to the membranes of organelles. Several families of proteins are involved, including Ca^{++} channels, Ca^{++} pumps (ATPases), and Ca^{++} exchangers. The family of Ca^{++} pumps includes plasma membrane calcium ATPases (PMCAs). As a step toward understanding the involvement of calcium signaling in regulation of ecdysteroidogenesis, we have used a PCR-based cloning strategy (RT-PCR followed by 3'- and 5'-RACE) to clone from Y-organs of the blue crab (*Callinectes sapidus*) a cDNA encoding a putative PMCA. The 4292 base pair (bp) cDNA includes a 3510 bp open reading frame encoding a 1170-residue protein (Cas-PMCA). The conceptually translated protein has an estimated molecular weight of 128.8 and contains all signature domains of an authentic PMCA, including phosphorylation, ATP-binding, and calmodulin-binding domains. An analysis of membrane topography predicted Cas-PMCA to have ten transmembrane domains and two large intracellular loops, a pattern consistent with the structure of known PMCA proteins. An assessment of tissue distribution showed the Cas-PMCA transcript to be broadly distributed in both neural and non-neural tissues. We anticipate that using quantitative real-time PCR to measure the abundance of the Cas-PMCA transcript in Y-organs during a molting cycle will provide insight into the possible involvement of PMCA in Ca^{++}-mediated regulation of ecdysteroidogenesis.

28.4 CHENEY, JA*; MIDDLETON, KM; KONOW, N; GIBLIN, EL; BREUER, KS; SWARTZ, SM; Brown University, Providence, RI, University of Missouri, Columbia; *Jorn_Cheney@Brown.edu*

Electromyography of bat wing membrane muscles

Bat wing membranes consist of a double layer of skin, and this architecture makes them thin, lightweight, and compliant. A number of small muscles, the plagiopatagiales, are embedded in the membrane, oriented approximately along the chord of the wing. These muscles both originate from and insert into this membrane. It has been hypothesized that the plagiopatagiales function to tense the membrane, which would reduce wing compliance and decrease wing camber. For this hypothesis to be correct, the plagiopatagiales must be active during flight. Further, we predict that if these muscles function to reduce wing camber by increasing membrane tension, their activity should occur during downstroke, when the membrane is cambered due to significant load. This activity pattern should only hold during steady flight. However, when a flight behavior must maximize lift, such as during landing, we expect that the muscle activity and intensity would change in order to maximize wing camber. To determine when these muscles are active during flight, if at all, we used fine-wire electromyography. We implanted sew-through electrodes in a single plagiopatagialis muscle in four individuals of the Jamaican fruit bat (*Artibeus jamaicensis*). Using a lightweight cable, we recorded electromyograms from the muscle during both steady flight and landing maneuvers in a wind tunnel. Consistent with our hypotheses, we found that, during steady flight, the plagiopatagiales were active during the downstroke, and during landing events, the periodic pattern of activity and recruitment changed. Overall, our results are consistent with the idea that the plagiopatagiales modulate wing camber during flight.

8.1 CHENG, B*; BIBLE, J; TODGHAM, A; MILLER, N; CHANG, A; FERNER, M; WASSON, K; DECK, A; ZABIN, C; LATTA, M; GROSHOLZ, E; Univ. of California, Davis, San Francisco State University, San Francisco State University, Smithsonian Environmental Research Center, San Francisco Bay National Estuarine Research Reserve, Elkhorn Slough National Estuarine Research Reserve, State Coastal Conservancy; *bscheng@ucdavis.edu*

A test of multiple stressors and latent effects on a foundational estuarine species, the Olympia oyster (Ostrea lurida)

In natural systems, stressor events often occur in tandem, with the potential to produce interactive responses that are not predicted by the effect of each stressor alone (i.e. synergistically). In addition, there has been increasing recognition that stressors that occur in early life stages may have effects that manifest at later life stages (latent effects). However, lab experiments seeking to understand the effects of climate change and other anthropogenic stressors often only manipulate one stressor with only one life stage. Understandably, this is most often due to logistical constraints. Here, we report data from a multiple stressor and latent effects experiment on newly settled Olympia oysters (*Ostrea lurida*) that were subjected to varying levels of dissolved oxygen and temperature. We found significant differences in performance (growth) that suggest that multiple stressor effects may commonly result in synergistic negative effects in Olympia oysters. Finally, we describe our ongoing experiment, which tests for latent effects from these early life stage stressors (temperature and DO) and the ability of oysters to tolerate an additional stress that occurs later in life (low salinity events). A strength of this experimental approach is that it parallels the timing of natural stressors as they occur in the field. For California Olympia oysters, new recruits that settle in the summer will most likely experience thermal and hypoxic stress. In contrast, juveniles (3-6 months post settlement) are most likely to experience low salinity events that occur during the winter.

P2.83 CHENG, C.*; KO, A.; SUZUKI, Y.; Wellesley College; *ysuzuki@wellesley.edu*

A potential novel factor involved in the regulation of metamorphosis onset in the red flour beetle, Tribolium castaneum.

Postembryonic development, such as metamorphosis, is characterized by major morphological and physiological changes. This process relies on the interactions between many hormonal and neuroendocrine factors. Of particular interest is the POU domain transcription factor, *ventral veins lacking (vvl)*, which has been shown to be important in regulating neuronal development. This study aimed to examine the role of *vvl* in the red flour beetle, *Tribolium castaneum*, and to elucidate its potential interactions with neuroendocrine factors, such as juvenile hormone (JH) and ecdysone. RNA interference-mediated silencing of *vvl* expression was found to induce precocious metamorphosis. Furthermore, ectopic application of JH or methoprene, a JH analog, prolonged the larval stage. Together with the inhibition of molting, these results indicate that Vvl might act to repress neuroendocrine changes associated with metamorphosis. A model of how Vvl interacts with JH and ecdysone will be presented.

P3.104 CHEW, A.E.; Western University of Health Sciences, Pomona, CA; *achew@westernu.edu*

Measuring fossil diversity and its relationship to climate change in deep time: a case study from the early Eocene

Densely distributed mammal samples from the early Eocene in Wyoming's Bighorn Basin span episodes of major climate change over nearly 3 Myr and provide one of the best opportunities to study community response to climate change in deep time. Diversity, including evenness and richness, is a basic indicator of community structure. However, the measurement of diversity in fossil communities is complicated by sampling and preservation gaps, limited exposure and methods of fossil collection, which can produce patterns in biotic data that are difficult to distinguish from actual community response. This project tests the utility of several modern ecological parameters (evenness: probability of interspecific encounter index, trendlines fitted to rank-abundance curves; richness: individual- and sample-based rarefaction) for fossil applications, using Geographic Information Systems to limit and explore the effects of outcrop variation. Diversity trends are compared for a ~1 Myr period of relatively static cool temperatures and a subsequent 1.2 Myr period of warming that led to the Early Eocene Climatic Optimum (EECO) in which the Earth reached the hottest temperatures of the Cenozoic. Results demonstrate previously unrecognized spatial bias that complicates interpretation of faunal response to the EECO. Alpha and beta richness were comparatively static and depressed during the cool period, but entered an alternative, significantly elevated and fluctuant semi-stable state during warming. Evenness also increased during warming, whereas the dominance of the fauna by two abundant lineages escalated consistently regardless of temperature. A previously identified short-term faunal event is shown to be part of the long-term warming fluctuations.

P3.34 CHIANG, S.*; BELANGER, C.L.; BERKE, S.K.; JABLONSKI, D.; Univ. of Chicago, South Dakota School of Mines and Technology, Siena College; *schiang@uchicago.edu*

Does oceanography constrain marine bivalve invasions?

Invasive species can detrimentally impact marine systems via competition, predation, and other interactions. Understanding the mechanisms behind successful introductions can help reduce the frequency and ameliorate the effects of further invasions as the Earth grows warmer and human-mediated transport intensifies. Here we present preliminary results on the most influential environmental factors in the success of 42 invasive marine bivalves using a database of occurrences and remote-sensing data for both native and and invasive habitats at 1° resolution. Invasive marine bivalves appear to be less tightly restricted to the temperature ranges of their native habitat than are terrestrial plants (see Petipierre et al. 2012); only 31% of invasive bivalves occupy ranges with median temperatures within the interquartile range of their native ranges and 15% of invasive bivalves are able to succeed in areas with temperatures outside their native range. In contrast, invasive bivalves conform more closely to the net primary productivity (NPP) of their native ranges with 56% occupying areas whose NPP falls within their native range(significantly more than for temperature; Fisher's Exact Test) and less than 5% succeeding in areas with NPP outside their native range. Unsurprisingly, failed invasions are often outside or near the extremes of their observed native ranges for both temperature and NPP. However, our data show a slight trend for some species to occupy increasingly different thermal regimes as the invasion progresses over time.

P3.22 CHICOLI, A.*; BAEDER, M.; PALEY, D. A.; University of Maryland, College Park, MD, 20742, Harvey Mudd College, Claremont, California, 91711; *achicoli@umd.edu*

Collective anti-predator behavior due to individual-based rules and social information transmission

We present a self-organizing model of group startle response behavior in two dimensions, and use it to investigate decision-making in fish schools. By overlaying probabilistic, and stochastic startle response behaviors onto a model of collective sorting in animal groups, we provide a mechanism by which group members can identify, and rapidly respond to, a potential threat. We also demonstrate a variety of startle response behaviors that can emerge from changes in individual-level interactions and threat parameters. While the model is focused on fish schools, the theoretical interpretation can be extended to other animal groups. The results from our model are considered in the context of the evolution and ecological importance of animal groups and are used to make testable predictions about startle responses and decision-making in animal groups.

P1.159 CHILTON, H*; TOMANEK, L; ZUZOW, M; California Polytechnic State University, San Luis Obispo; *hchilton@calpoly.edu*

The Proteomic Response of Mytilus galloprovincialis and Mytilus trossulus to Acute Oxidative Stress in the Presence of Sirtuin Inhibitors

Global climate change imposes physiological constraints on marine ecosystems that can alter the distribution of intertidal organisms. In one such instance, the native cold-adapted *Mytilus trossulus* has been replaced along its southern range by the invasive warm-adapted *Mytilus galloprovincialis*. These blue mussels occur throughout rocky intertidal zones where they are subjected to greatly varying environmental conditions in terms of temperature and hypoxia, stressors that are known to induce oxidative stress. It has been hypothesized that while under acute heat stress, related Mytilus congeners undergo a shift in redox potential through the reduction of NADH fueled respiration pathways to the production of the reducing agent NADPH as a potential defensive mechanism against the production of reactive oxygen species. In addition, it has been hypothesized that sirtuins (a family of NAD-dependent deacetylases) might be involved in the regulation of this metabolic transition. To test the latter hypothesis, a discovery approach was used to analyze the proteomic response of these species to varying concentrations of the pro-oxidant menadione, and the sirtuin-inhibitors nicotinamide and suramin. Menadione can induce apoptosis through the elevated production of peroxide and superoxide radicals, while suramin and nicotinamde both inhibit sirtuin activity. Organisms were exposed to these compounds in filtered seawater for 8 h, followed by a 24 h recovery period under constant aeration. Tissues were then prepared for 2D-gel electrophoresis and proteins were identified with tandem mass spectrometry. Observed results characterize the role of deacetylation of the two *Mytilus* congeners to responding to stressful conditions.

137.2 CHINA, V*; HOLZMAN, R; Tel Aviv University, The Interuniversity Institute for Marine Sciences in Eilat ; *victor.china@gmail.com*

The crucial effect of hydrodynamics on feeding efficiency during the "critical period" of fish larvae.

Survival of the larval stage of marine fishes has far-reaching consequences in determining their rates of settlement, population size and stability. While feeding performance is known to play a central role in determining survival, there is little information on the mechanisms of prey capture by fish larvae. The hydrodynamic forces that govern suction feeding performance are expected to change through the larvae's ontogeny, as the larvae transition from a viscous-dominated regime to a realm of higher Reynolds numbers. We used numerical simulations, feeding experiments and hi-speed video observations to test the direct effect of viscosity on larval feeding performance. Computational fluid dynamic (CFD) simulations revealed that the flow generated at small mouth sizes is characterized by shallow spatial gradients compared to that measured for high Reynolds numbers. Prey-capture rates were positively correlated with larval size and negatively correlated with viscosity; primarily due to mechanistic effects of the suction flow and reduced capture success. High-speed photography indicated that in order to feed successfully under conditions of increasing viscosity, the larvae had to open their mouths faster and wider. Starvation is considered a primary cause of mortality in the early stages of larval fishes, as suggested a decade ago in Hjort's "critical period" hypothesis. Our findings indicate severe hydrodynamic constraints on the efficiency of suction-feeding at the size range typically associated with that "critical period". These constraints could explain starvation and low survival of larval fish and also imply an evolutionary constraint on the minimal larval size at hatching.

P2.74 CHO, S.-J.*; TIMBANG, L.; AHN, A.; REGALADO, S.G.; WEISBLAT, D.A.; Univ. of California, Berkeley; *sjcho71_cns@calmail.berkeley.edu*

Gene loss, gene duplication and Hox cluster fragmentation in the leech Helobdella

Studies in vertebrates (superphylum Deuterostomia) and insects (superphylum Ecdysozoa) have led to the generalizations that: 1) Hox genes usually occur as an ordered cluster along the chromosome; 2) the spatiotemporal order of their expression corresponds to their order within the cluster, with genes at the 3' end of the cluster expressed more anteriorly in the embryo; 3) they function to provide regional or segment-specific identities to tissues along the anteroposterior (AP) axis. Previous studies have shown that Hox genes in annelids show these general patterns of expression as well. Genomic analyses have shown that the eleven Hox genes in the polychaete annelid *Capitella telata* and the mollusc *Lottia gigantea* (superphylum Lophotrochozoa) occur as ordered clusters, too. However, compared to *Lottia* and *Capitella*, the Hox gene cluster in the leech *Helobdella* (a clitellate annelid) is highly disrupted. A total of nineteen Hox genes have been identified; some Hox genes have been duplicated and others have been lost. The leech Hox genes occur in incomplete clusters or as isolated genes. Understanding the reorganization of Hox genes in the leech presents us with a good opportunity to examine the connection between gene order and expression.

P1.190 CHOUDHURY, S*; MANIKKAM, DK; BERG, O; MULLER, UK; California State University Fresno; *umuller@csufresno.edu*

Exploring asynchronous flight-muscle mechanics in insects through a bio-mimetic flapping machine

To explore the asynchronous flight-muscle activation in insects, we developed a bio-mimetic flapping machine. In beetles, flies, true bugs, and bees, the frequency of wing strokes is higher than the frequency of nerve impulses. The contractions of asynchronous muscles are sustained by oscillations under mechanical control, rather than nervous control. Thus, delayed stretch-activation allows the flight muscle to oscillate spontaneously when coupled to a resonant load. Our machine mimics the force vs. extension properties of a muscle through the use of a solenoidal linear actuator. The output of a Hall-effect position sensor controls the current to the solenoid. Sustained oscillations are observed when the feedback is delayed with respect to the instantaneous actuator position. We have tested the effects of damping, feedback delay, and restoring force on the flapping amplitude and frequency. The resonant frequency and optimal delays are not affected as damping is increased; however, oscillation cannot be achieved without raising the feedback gain. We have solved the corresponding delay differential equation for a damped, driven harmonic oscillator; this numerical map of oscillator amplitude as a function of damping and delay is in quantitative agreement with the behavior of the machine. For electro-mechanical robots, this machine is a flexible test bed for the exploration of distributed (vs. central) control of flapping motion; however, the model is not suitable for flight. Similar to insects, the absence of a separate 'function generator' – to define the flapping kinematics – is advantageous when autonomy, simplicity, and speed of the control system are crucial.

P2.56 CHOW, JS*; BERG, CL; HYMES, M; MCGEE, MD; WAINWRIGHT, PC; University of California, Davis; *jscchow@ucdavis.edu*

Convergent feeding kinematics in elongate cichlids

Feeding behaviors are often expected to diverge between phylogenetically distant and ecologically dissimilar species. We tested this assumption by examining the feeding behavior of *Crenicichla strigata* and *Rhamphochromis longiceps*, two distantly related cichlid species. *Crenichla strigata* is a benthic ambush predator from the Amazon River, while *Rhamphochromis longiceps* is a pelagic pursuit predator from Lake Malawi. The two species have independently evolved elongate heads with large jaws from morphologically and kinematically generalized species. We tested for the presence of convergent feeding kinematics by analyzing videos recorded using a Fastec Hispec 1 camera at 2000 frames per second to film three *C. strigata* and three *R. longiceps* capturing small cyprinid prey. Video sequences were digitized using a custom modification of the Dltdv3 package in MATLAB. We tracked eleven points on the head, body, prey item, and background through the duration of the strike. Then we generated six excursion variables and six time to peak movement variables for gape, hyoid depression, jaw protrusion, strike distance, lower jaw rotation, head elevation, and capture of the prey item. To analyze kinematics, we used mixed models with species and size as fixed effects, and individual as a random effect. We found no significant differences in the excursions and timings of *C. strigata* and *R. longiceps*, except for a marginally significant larger maximum gape in *R. longiceps*. This suggests that *Crenicichla strigata* and *Rhamphochromis longiceps* have evolved convergent feeding strikes despite clear differences in their evolutionary history, habitat, and predation strategies. Our results indicate that convergence in feeding behavior can occur between phylogenetically and ecologically divergent species.

30.1 CHRISTY, JOHN H; Smithsonian Tropical Research Institute; *christyj@si.edu*

Extreme synchrony, amplitude modulation and phase reversals in the semilunar reproductive cycle of the intertidal false limpet Siphonaria gigas on a rocky shore in Panama

Many intertidal organisms produce gametes or larvae once or twice each lunar month when tidal conditions most favor survival of these vulnerable early life stages. On shores with semidiurnal tides, the changing phase relationship between the lunar synodic (29.53 days) and anomalistic (27.55 days) cycles modulates the amplitude between successive spring and neap tides. Approximately every 7 months the amplitude difference changes from one half-lunar phase to the other (e.g., switches from new to full moon, or first to last quarter, and then reverses 7 months later). I continuously monitored the semilunar cycle of egg production by the false limpet *Siphonaria gigas* for 4.5 years and found that this simultaneous hermaphrodite tracks this complex tidal pattern. Individuals attached ribbons of eggs in jelly whorls to the rock over a two-day period twice each lunar month with most eggs deposited 1 day before the lowest neap tides. Eggs hatched to veliger larvae in 4 – 6 days. The intensity of reproduction varied inversely with the heights of the neap tides. Consequently eggs were covered by the tide for the least amount of time before they hatched. When the difference in heights between successive neap tides was large, the limpets produced eggs only on the neap set with lower high tides. Every 7 months when the neap tide height difference shifted between the first and last quarter moons the limpets too shifted their timing, but not immediately, leading to two or more out-of-phase egg deposition cycles. Extreme synchrony and precise timing of egg deposition to correspond with the lowest tides in the month may protect eggs best from predation by fish.

34.4 CHU, K.H.*; TSANG, L.M.; WU, T.H.; The Chinese University of Hong Kong; *kahouchu@cuhk.edu.hk*

High genetic divergence among Hong Kong stream faunal populations: Implications for biodiversity conservation of freshwater ecosystems

Freshwater organisms generally exhibit much more pronounced genetic structuring than their marine counterparts. While understanding the level and spatial distribution of genetic diversity is crucial for conservation management planning, such information have received little attention until recently in highly developed cities like Hong Kong and Singapore, where local extinction caused by habitat loss and degradation is severe. Here we compared the genetic divergence in mitochondrial genes of common freshwater fauna, represented by nine species of fishes and five species of invertebrates, collected from more than 20 streams in Hong Kong covering a land area <1,000 km^2. Surprisingly, except in three species of fishes, all species exhibit pronounced genetic architecture, with population in each stream frequently having its own unique haplotypes, even though some of the streams are separated only by a few kilometers. Moreover, genetic diversity within each stream is very low, usually with a single haplotype dominating the entire population. This reflects a low effective population size commonly observed in fragmented populations. The congruence in population subdivision observed across fauna suggests long term isolation among streams. Since conservation measures are often only considered long after urban development has begun, unexpected high genetic diversity of freshwater fauna over short distances has significant conservation implications as a substantial amount of biodiversity may have already been lost due to past development. Careful conservation planning of freshwater ecosystems is needed for future development in Hong Kong and elsewhere.

127.3 CHUCHOLL, C.; University of Ulm, Germany; *cchucholl@aol.com*

Marmorkrebs gaining ground in Europe: the role of the pet trade as invasion pathway

Biological invasions are one of the leading threats to global biodiversity and involve the transportation, introduction, establishment, and spread of alien organisms. Owing to its exclusive occurrence in the pet trade, the Marmorkrebs (*Procambarus fallax* f. *virginalis*) is an ideal model-organism to assess the mechanisms of introductions from aquaria, a novel invasion pathway of alien crayfish in Europe. Here, I summarize the results of two recent studies that elucidate 1) the determinants of crayfish introductions from aquaria and 2) the spatio-temporal dynamics of Marmorkrebs records in Europe. Multiple logistic regression analysis showed that species' availability and size were the principal predictors of the likelihood of being recorded as introduced from aquaria, with Marmorkrebs being among the species most commonly available. A greater availability/popularity is potentially related to a higher number of release events and, thus, higher propagule pressure. Consequently, fourteen of the sixteen European Marmorkrebs records are from Germany, where Marmorkrebs have been popular pets since the early 2000s. At least six records represent established populations, which is a strong increase beyond the one Marmorkrebs population known prior to 2010. Overall, the results indicate that the pet trade generates substantial propagule pressure, which drives the establishment success of Marmorkrebs in nature. A high propagule pressure increases the likelihood of release events at suitable habitats, i.e. summer-warm lentic habitats, where Marmorkrebs are able to establish populations.

P3.57 CHULAKOTE, S.S.Y*; SMITH, C.M; University of Hawaii, Manoa; *scottsyc@hawaii.edu*

Quantifying Herbivory Pressure and Preference: Are Native or Invasive Macroalgae Preferred?

Although assessments of Hawai'i's reef habitats have documented fish biomass and assemblage, few studies on herbivory pressure have been done. This experiment was done to quantify grazing pressure in four study sites (Waikiki Marine Life Conservation District (MLCD), Waikiki-Diamond Head Fisheries Management Area (FMA), and a nearshore and offshore site in the Paiko reef) and determine if there is a preference towards native or invasive macro algae using pairwise comparisons over multiple 24 hour experimental runs. Grazing pressure was moderately low for all macro-algal species across all sites while the only statistical differences in preference were seen in *Acanthophora spicifera* and *Gracilaria salicornia* over its native pairwise counterparts in the Waikiki-Diamond Head FMA. Previous studies that have indicated low fish biomass in conjunction with our observed low grazing pressure may suggest a lack in abundance of herbivores that are unable to prevent or reverse coral-algal phase shifts. Herbivore preference of two dominate invasive macro-algae seen in our study however may imply certain key herbivore species as viable biocontrol options for management.

P1.63 CHURCHES, N*; KOHN, A.B.; KOCOT, K.M.; SWALLA, B.J.; MOROZ , L.L.; Univ of Washington, Univ of Florida, Auburn Univ; *nthnchrchs@yahoo.com*
Collagens in the ctenophore Pleurobrachia bachei : Remarkable expansion and diversity of genes controlling the extracellular matrix in basal metazoans.
The evolution of multicellular animals required the development of epithelial tissues that function in controlling the transport of molecules from environment to organism. Collagen proteins are crucial to the formation of epithelial tissues, and are therefore critical in understanding the origins of multicellularity and Metazoan evolution. We characterized the collagen complement from the sequenced genome of the ctenophore *Pleurobrachia bachei*. 1) We discovered that *P.bachei* has 7 distinct type IV collagen genes, an expansion unseen in any organism sequenced to date. These genes show unique distribution across the genome: four were in an in-line pattern (*αA* and *αB*, *αD* and *αE*); two were found independent of other genes (*αF*, *αG*), while another two were aligned in a head-to-head fashion (*αB*,*αC*). This exceptional arrangement suggests both traditional and inverted gene duplication events in the ctenophore lineage. Ctenophore collagen intron/exon arrangements were also uniquely diverse, with a range of 14-40 exons, depending on the gene. 2) Phylogenetic analysis revealed two distinct collagen groups, the α1-like and α2-like sub-families that are common in bilaterians. Yet, gene to gene comparisons reveal a more diverse type IV collagen complement than even found in chordates including humans. 3) We found differential expression between the sub-family gene types, indicating unique physiological use of different collagens. Our findings imply that the common ancestor to all Metazoa might have contained a much more developed collagen complement than was previously appreciated. At the same time, there is extensive parallel evolution of ancestral collagens with remarkable functional specification and diversity of body plans in ctenophores.

62.6 CHURCHILL, C.K.C.*; ALEJANDRINO, A.; VALDÉS, A.; Ó FOIGHIL, D.; University of California, Santa Barbara, Iowa State University, California State Polytechnic University, Pomona, University of Michigan, Ann Arbor; *celia.churchill@gmail.com*
Parallel sexual rekeying supports non-geographic planktonic speciation
The relative roles of geographic and biological barriers as mechanisms of genetic isolation are highly debated in evolutionary biology, yet knowing how speciation occurs is essential to our understanding of biodiversity. In the open ocean, differentiating between the two is particularly difficult because of the high levels of gene flow found in pelagic communities. The marine neuston is a promising system for investigating planktonic speciation mechanisms; located at the surface of the planet's subtropical oceans, the neuston's isobathic nature renders it exceptionally tractable both for sampling and understanding localized ecological variation. Here, we use molecular phylogenetics to test the hypothesis that geography is the primary isolating mechanism in a group of predatory neustonic nudibranchs with simultaneous hermaphroditic reproduction (Glaucinae). Glaucinae comprises two valid species with different distributions: *Glaucus atlanticus* is circumtropical and *G. marginatus* is Indo-Pacific. Our results are the inverse of allopatric expectations: *G. atlanticus* is panmictic, whereas *G. marginatus* contains four species in two clades with overlapping distributions. Within the *G. marginatus* species complex, a parallel reproductive change has occurred in each cryptic species pair: the loss of a bursa copulatrix. We hypothesize that its presence or absence affects mating behavior by changing the mechanics of penial insertion. Our results show that details of genital morphology are better predictors of latent evolutionary relationships among glaucinid lineages than biogeography, and support biological isolation as the primary driver of speciation—a novel result in a planktonic system.

83.4 CIELOCHA, J. J.*; YONEVA, A.; JENSEN, K.; Univ. of Kansas, Bulgarian Academy of Sciences; *jjcielocha@ku.edu*
Insights into spermatozoon ultrastructure of lecanicephalidean tapeworms (Platyhelminthes: Cestoda)
Spermatozoon ultrastructural characters have shown to be informative in phylogenetic studies in many invertebrate groups. Comparative data exist on sperm ultrastructure of most cestode orders, though information for the elasmobranch cestode order Lecanicephalidea is limited. The only previous data on lecanicephalidean sperm ultrastructure came from a specimen of *Tetragonocephalum* (Justine, 2001). Mature spermatozoa of *Tetragonocephalum* were described as possessing a single axoneme, crested body, and parallel cortical microtubules. Based on these data, Levron et al. (2010) postulated a spiral nucleus. Specimens of *Tetragonocephalum* as well as three additional lecanicephalidean genera were collected from rays from the Solomon Islands and fixed for transmission electron microscopy (TEM). Posterior proglottids with well-developed external seminal vesicles were cut from the strobila of each individual and processed for TEM. Proglottids were embedded in Spurr's resin. Ultrathin sections were cut on an ultramicrotome, mounted on copper grids, double stained with uranyl acetate and lead citrate, and observed with TEM. A single axoneme, crested body, parallel cortical microtubules and spiral nucleus were observed in individuals from all four genera. While spermatozoa of *Cephalobothrium* and *Adelobothrium* possessed a single crested body and ten parallel cortical microtubules medial to the rested body, *Flapocephalus* appears to have two crested bodies, and *Tetragonocephalum* possesses 20 parallel cortical microtubules peripheral to the crested body. In general, these characteristics are consistent with the minimal data available for species of closely related cestode orders, however the degree of variation was unexpected. The phylogenetic utility of spermatozoon ultrastructural characters can only fully be tested with a broader sampling of species within other cestode orders.

P1.220 CIMINO, R. L.*; RICHMOND, J. P.; University of North Florida; *cimino.rachel@gmail.com*
Assessing seasonality of the free-ranging Florida Manatee (Trichechus manatus latirostris).
Growth hormone (GH), a component of the somatotropic axis, links energy regulation and nutritional status. Growth hormone increases lipolysis when nutritional status is low (energy deficit), and inhibits lipogenesis. In some species, GH concentrations are greater during short photoperiods (less than 12 hours of daylight) than in long photoperiods (greater than 12 hours of daylight), likely increasing adipose utilization to meet maintenance energy requirements during times of limited or reduced intake. The Florida manatee (*Trichechus manatus latirostris*) is a marine mammal with a unique adipose storage site. Manatee blubber structure is distinctive from other marine mammals and exhibits seasonal changes in quantity. The objective of this research was to investigate the seasonality of GH in the Florida manatee. We hypothesized that GH concentrations would be greater during short photoperiods corresponding with diminished blubber layer and low metabolic rate. Serum GH concentrations were quantified in adult manatee serum during short (females: n=10; males: n=8) and long (females: n=9; males: n=9) photoperiods by radioimmunoassay. Growth hormone concentrations in all animals were greater during the short photoperiod (p=0.02). Males tended to have greater GH concentrations than females (p=0.06), but exhibited a similar pattern between photoperiods (p=0.36). Increased GH in conjunction with reduced blubber thickness may indicate low nutritional status and an increased reliance on blubber energy reserves during short photoperiods similar to other mammal species.

108.6 CLAGHORN, GC*; FONSECA, IAT; FIELDER, J; BARBER, C; GARLAND JR, T; Univ. of California, Riverside; *gclag001@ucr.edu*

Manipulating central fatigue in mice bred for high voluntary wheel running using a serotonin agonist and antagonist

Central fatigue limits the performance of an organism to less than the level that might be predicted by classic models of physiological maxima, and numerous studies have shown that the concentration of serotonin (5-hydroxytryptamine; 5-HT) in the brain increases at the onset of fatigue. Central fatigue has been studied primarily in relation to forced exercise, and not voluntary exercise. We hypothesized that neurobiological differences related to central fatigue could explain evolutionary differences in both endurance capacity and levels of voluntary exercise. Mice from 4 lines that had been selectively bred for high voluntary wheel running (HR lines) for over 60 generations were previously shown to have higher endurance than those from 4 non-selected control (C) lines. We predicted that a 5-HT1A agonist (8-OH-DPAT) or antagonist (WAY 100 635) would alter endurance and the evolutionary advantage of HR lines during forced exercise. Male mice were endurance-tested three times using a forced treadmill protocol at 7-9 weeks of age under a randomized series of three pharmaceutical conditions, a vehicle injection, a low-dose of the designated drug (0.2 mg/kg body mass for 8-OH-DPAT and 35 µg/kg WAY 100 635) or a high dose (2 mg/kg body mass for 8-OH-DPAT and 350 µg/kg WAY 100 635). Time and distance to exhaustion were recorded. The same mice were then given wheel access for 14 days, until wheel running had reached an apparent plateau, and then subjected to a similar set of injections during the nightly peak of wheel running (1 injection/night) while wheel revolutions were recorded automatically. Supported by NSF Predoctoral Fellowship to GC and NSF grant IOS-1121273 to TG.

P1.20 CLAMP, J.C.*; SONG, W.; North Carolina Central Univ., Ocean Univ. of China; *jclamp@nccu.edu*

An International Research Coordination Network for Biodiversity of Ciliates

The International Research Coordination Network for Biodiversity of Ciliates (IRCN–BC) is a joint project between U.S. and Chinese researchers, funded by the National Science Foundation (Dimensions of Biodiversity; DEB 1136580) and the Natural Science Foundation of China, that promotes multidisciplinary, integrative research on biodiversity of ciliated protists and fosters international cooperation in studies of biodiversity. It welcomes participation by researchers investigating any facet of biodiversity of ciliates or other protists as well as prokaryotes or multicellular eukaryotes that interact with ciliates in some way. Our goal is to attract a broad input of expertise, outlooks, and technical skills into collaborative research projects. The IRCN–BC sponsors one major workshop or symposium each year and funds travel by researchers to accomplish research collaborations, to visit participating laboratories for specialized training, or to attend workshops and professional meetings. Major objectives of the IRCN-BC are the following: 1) defining the "Grand Challenges" of ciliate/protistan biodiversity and finding strategies for addressing them; 2) fostering new, international research collaborations; 3) generating new grant proposals for integrative biodiversity studies; 4) forming and using working groups to accomplish specific, broadly based, collaborative projects; 5) developing new data-sharing structures; 6) recommendation of new, enhanced standards for deposition of archival material. For more information please visit our website at http://biodiversityciliatessc.myspecies.info/.

P2.199 CLANCY, D.L.*; DAVIS, T.; RUIZ, G.; COHEN, C.S.; San Francisco State Univ, Alaska Department of Fish and Game, Smithsonian Environmental Research Center, Edgewater, MD; *darragh@sfsu.edu*

Examining Genetic Diversity of an Invasive Colonial Ascidian in Southeast Alaska

In 2010, an isolated population of the invasive colonial ascidian, *Didemnum vexillum*, was discovered during a Bioblitz survey in Whiting Harbor, Alaska. Believed to be native to Japan, *D. vexillum* has now been reported in Europe, New Zealand and North America. As *D. vexillum* is an aggressive invader, and many communities in Alaska depend on their relatively pristine natural environment for economic and cultural practices, this invasion has become a significant cause for concern. Examining the possible pathways of *D. vexillum* to Whiting Harbor will allow us to learn how *D. vexillum* spreads and possibly how future invasions can be prevented. In order to characterize this invasion, we sampled the Whiting Harbor population, and compared it to other studies of *D. vexillum* populations around the world. We genotyped 31 specimens from around Whiting Harbor at a 586-bp fragment of the mitochondrial cytochrome oxidase subunit I (COI). We found three haplotypes with a haplotype diversity of 0.5720±0.0453. When compared to previously reported haplotype diversities of other locations around the Pacific ocean, where *D. vexillum* originated, we find it is lower than Japan and the western coast of North America (first reported in 1993), but higher than the population in New Zealand (2001). It is expected that an older invasion would have higher diversity than a newer one because it has had more time for continued or diversely sourced inoculations. Possible explanations for why the newer Alaska invasion has a higher diversity than New Zealand are having a higher rate of repeated invasions, or having established earlier than first detected. To better understand the source population(s) of *D. vexillum* in Alaska, we are investigating further with comparisons using nuclear loci.

84.2 CLARK, X*; SIMPSON, SJ; CLISSOLD, FJ; University of Sydney, NSW, Australia; *ximonie.clark@sydney.edu.au*

Does Size Matter? The Interaction of Body Size, Temperature and Nutrition

Temperature is a major factor that influences an ectotherms growth and development. Importantly temperature impacts herbivorous ectotherms nutritional biology in multiple ways. Variation in temperature can lead to changes in an animals nutritional requirements as well as the efficiency that they can extract and convert nutrients to body mass. In addition, the ratio and amounts of nutrients an animal can obtain varies with both temperature and plant species. This interactive effect has led to *Locusta migratoria* (African Migratory Locust) both following and reversing the Temperature Size Rule, a form of phenotypic plasticity where ectotherms typically grow larger but more slowly as temperatures decrease. Recently we have shown that a smaller locust, *Chortoicetes terminifera*, does not show any effect of temperature on final body size. Smaller locusts are more efficient at extracting nutrients; hence the initial size of an herbivorous insect may have profound effects on the degree with which temperature impacts nutritional outcomes. We will discuss results of the morphological and behavioural implications surrounding the interaction of temperature and nutrition, such as the importance of host plant selection, thermoregulation and microclimate use, and the potential impacts future climate change may have on body size.

P3.8A CLARK, X*; CLISSOLD, FJ; CHARLESTON, MA; SIMPSON, SJ; University of Sydney, NSW, Australia; *ximonie.clark@sydney.edu.au*
Foraging in a nutritionally complex world: tests using agent-based models and locusts
Animals face challenges of matching the demand for obtaining multiple nutrients from the environment or suffering fitness costs. Two general herbivore foraging strategies are defined by the degree to which herbivores consume foods that deviate in composition from their optimal balance of nutrients. Nutrient generalists consume various foods that differ largely in nutrient content from their intake target, whereas specialists eat foods very similar to that required. The strategy herbivores adopt depends on dietary history; however, behavioural plasticity allows animals to optimise fitness in variable environments. This study aimed to investigate whether nutritional environments encountered alter the foraging strategy of the nutrient specialist, *Locusta migratoria*. Simulating the fitness outcomes for each foraging strategy using an agent-based model indicates, for the nutrient generalist strategy, that the best fitness is produced by increasing consumption of a highly imbalanced food when encountered at high frequencies. Furthermore, the nutrient specialist does not benefit by increasing consumption of highly imbalanced foods. A laboratory experiment using *L. migratoria*, was conducted to determine the conditions under which the locusts shifted from a specialist to a generalist. After being subjected to temporal variations of highly imbalanced foods, *L. migratoria* adopted a more generalist strategy. Through a combined experimental and modeling approach we have shown that *L. migratoria* can adjust foraging behaviour to better suit their specific environment and likely maximise fitness.

18.2 CLAVERIE, T*; WAINWRIGHT, P C; Univ. of California, Davis; *tclaverie@ucdavis.edu*
Fractal radiation: repeated patterns of diversification along an axis of body elongation in fishes
We explored patterns of body shape diversification in the mega-diverse spiny-rayed fishes. Geometric morphometric tools were used with landmark data collected from lateral-view photographs to characterize body shape for more than 2000 species of spiny-rayed fishes belonging to more than 40 families. Across the entire data set the first principal component of morphological variation reflects the extent of body elongation or shortening. When we conducted a separate PCA on each fish family we found the most common first PC reflects body elongation. Using available time calibrated species-level phylogenies for several individual families we worked up from the base to the tip of each tree, calculating PCAs at each node. At most nodes variation in body elongation characterized the first PC, even at very shallow phylogenetic scales. This fractal pattern, where elongation is the dominant axis of body shape evolution, whether the scale is across spiny-rayed fishes or within much smaller clades that are less than 10 million years old, indicates that fish body shape evolution has been characterized by repeated, similar changes in elongation. The repeated nature of the pattern raises the question of whether the morphology and developmental genetics underlying this axis of shape change is consistent, and highlights the importance of understanding the morphological and genetic underpinnings of this axis of body shape as well as its performance and ecological consequences.

P1.146 CLAVIJO-BAQUET, S*; PETIT, M; VéZINA, F; Pontificia Universidad Católica de Chile, Université du Québec à Rimouski; *sclavijo@bio.puc.cl*
TESTING CAUSAL RELATIONSHIPS BETWEEN METABOLIC RATES AND FITNESS IN BLACK CAPPED CHICKADEE (Poecile atricapillus): IMPLICATIONS FOR THE EVOLUTION OF ENDOTHERMY
The evolution of endothermy and the associated heat production mechanisms are still one of the most intriguing questions in comparative biology. In this sense, several models have been proposed to explain it, named the parental care model, thermoregulatory model and aerobic capacity model. The main difference between these models is that they point out a different trait as target of natural selection during the evolution of endothermy. However, few studies have evaluated the relationship between these physiological traits and fitness and most studies used a correlational approach and mammalian models to test hypotheses. Here, we evaluated two of the most important models (parental care and thermoregulatory models) testing causal relationships between physiological traits as body temperature (T_b), basal metabolic rate (BMR) or thermogenic capacity (M_{sum}) with fitness in black-capped chickadees (*Poecile atricapillus*). We first estimated the probability of survival based on two years of capture-recapture data and then performed structural equation modeling (SEM) including M_{sum}, BMR, T_b and body mass. This provided a set of causal-effect relationships representing each model proposed for the evolution of endothermy which we could then evaluate using a model selection approach.

P3.15 CLEMENTS, R*; RYCROFT, N; ATEMA, J; Boston University; *reenac@bu.edu*
Establishing Antennule Flick Rate as an Assay for Odor Detection in Lobsters
Olfactory cues are important sources of information for marine organisms. The major odor detection organ for lobsters are the antennules. Aesthetasc sensilla on these antennules process social odor information. In order to function properly, the lobster flicks its antennules. Thus flicking, the lobster equivalent of sniffing, can be used as a measurement of odor detection by the animal. To measure flick rate lobsters were placed in a flume and exposed to a small stream of food odor-flavored seawater directed at the antennules; we use unscented seawater as a control. All tests were video recorded for later analysis. Flicking frequency increased in response to increasing concentrations of food odor. However, we are interested here in the lobster's detection of social odors. Male lobsters fight to establish dominance and losing males are capable of remembering the urine odor of the winner for over a week. We are currently testing if antennule flick responses can be used as an assay to recognize social odors in a number of different relationships, including dominance.

33.2 CLEMMENSEN, SF*; HULSEY, CD; University of Tennessee; *sclemmen@utk.edu*

Effects of morphological phenotypic plasticity on cichlid transcriptome expression

Trophic divergence in cichlid fish is linked to shifts in pharyngeal jaw morphology. However, it is unknown how much of this dramatic trophic specialization is due to the ability of these species to respond dynamically to their preferred diet type. Hypertrophy is observed in the major muscles of the lower pharyngeal jaw muscular sling in response to a diet shift in lab-reared *Vieja maculicauda* cichlids. We used next-gen whole transcriptome sequencing to identify genes that are up- and downregulated in these muscles in response to diet shifts.

27.6 CLIFTON, G.T.*; HEDRICK, T.L.; BIEWENER, A.A.; Concord Field Station, Harvard U., Bedford, MA, U. of N. Carolina, Chapel Hill, CFS, Harvard U., Bedford, MA; *gclifton@fas.harvard.edu*

Running on water: The impressive rushing behaviour of Western and Clark's Grebes

As foot-propelled diving birds, Western and Clark's grebes (*Aechmophorus occidentalis* and *clarkii*) spend almost their entire life in the water. They rely heavily on their powerful legs and unique lobate feet to hunt for fish, sometimes diving over 40 meters. But, grebes are best known for their elaborate pair bonding displays. The most spectacular display, *rushing*, is performed by these two species, which involves the birds lunging out of the water and running across the surface. Weighing up to 2000g (an order of magnitude larger than the Basilisk lizard), rushing grebes are the largest animals to run on the water surface without the aid of wing flapping. We present the first quantifiable high-speed footage of rushing (filmed at 325 fps). Previous estimates from sound recordings suggest that the birds use 16-20 steps per second as they run, traversing 5-20 meters. We find rates up to 22 steps per second and observe that birds with step rates less than 13 steps per second are unable to sustain rushing, ending early with a dive. Kinematic analyses of Basilisk lizards have shown that they must always keep one foot submerged, whereas some grebes exhibit an aerial phase. The movements of the birds show that Western and Clark's grebes exploit their unique hindlimb morphology during this display. The asymmetrically lobed feet are fully splayed for maximal impulse during the water slap. The trajectory of the foot through the water makes use of the flattened tarsometatarsus. While the unusual grebe hindlimb has been suggested to be important for underwater swimming, it is likely that it has also enabled rushing. Future work will quantify the hydrodynamic forces during rushing and analyze specific contributions of hindlimb elements.

24.2 CLISSOLD, F.J.*; SIMPSON, S.J.; The Univ. of Sydney, Australia; *fiona.clissold@sydney.edu.au*

Plant quality is more than just nutrients: host plant choice is determined by temperature and nutrients.

Temperature and nutrition interact to affect the life histories of ectotherms. These interactions are generally believed to be mediated via metabolic rate, rather than by changes in the rates and ratios at which particular nutrients are digested, absorbed and utilized. We show that the rates and balance of protein and carbohydrate absorbed from particular host plants by a model herbivore, the locust, is temperature dependent. Furthermore, locusts were able to choose body temperatures and/or host plants so that protein and carbohydrate were differentially absorbed to redress experimentally imposed nutrient imbalances. Hence, 'diet quality' is temperature sensitive and insect herbivores can manipulate this relationship to their own ends. These findings suggest micro-climatic effects may be of more importance than previously appreciated for understanding the consequences changed environmental temperatures and microclimate on animal-plant interactions.

P3.140 CLISSOLD, F.J.*; BROWN, Z.; SIMPSON, S.J.; The Univ. of Sydney, Australia; *fiona.clissold@sydney.edu.au*

Diet-induced enlargement of the gastrointestinal tract increases nutrient absorption rates in locusts by allowing larger meals rather than better absorptive efficiency.

Increasing the size of the gastrointestinal tract (GIT) is a plastic response commonly seen when animals feed on poor quality diets. This increase may simply function to permit larger meal sizes, but it has also been suggested that plastic growth of the GIT may serve as a means of rebalancing nutritionally imbalanced ingesta by allowing selective absorption of limiting nutrients. We determined the dietary conditions that induced GIT plasticity in an insect herbivore, the locust. In an insect herbivore, the migratory locust, a synthetic diet with a high ratio of protein to carbohydrate was found to induce weight enhancement of the GIT. Increases to the mass of the foregut and midgut caeca resulted in a similar, 20-30% increase in absorption rates of both protein and carbohydrate when feeding from three biomechanically and chemically different grasses. Greater net absorption of macronutrients occurred because these locusts ate meals that were larger, but transited at the same time and with the same digestive efficiency as in locusts where the GIT was unenhanced. Thus, volumetric plasticity of the GIT did not improve nutritional homeostasis, but increased the rate of nutrient uptake.

P3.42 CLOSEK, CJ*; SUNAGAWA, S; DESALVO, MK; PICENO, YM; DESANTIS, TZ; BRODIE, EL; VOOLSTRA, CR; ANDERSEN, GL; MEDINA, M; University of California, Merced, European Molecular Biology Laboratory, Heidelberg, Germany, University of California, San Francisco, Lawrence Berkeley National Laboratory, King Abdullah University of Science and Technology; *closek@gmail.com*

How Bacteria and Genes Reflect the Health States of Corals

Human population growth and environmental change have been noted to contribute to coral mortality and more recently disease events. In the Caribbean Sea, Yellow Band Disease (YBD) is widespread and affects several coral species including *Montastraea* spp., which are dominant reef building species in this region. Although the disease results in tissue loss, it is unclear how it affects the associated bacterial community structure and the coral-host. In this study, a dual approach of high-density 16S rRNA gene microarrays and host cDNA microarrays were used to characterize YBD. Relative bacterial diversity and abundances were compared to profile diseased colonies. In addition, cDNA microarrays were used to profile the coral transcriptomic response to YBD. Using these high-throughput approaches we aimed to 1) survey the coral-associated microbial community, 2) aid the discovery of novel bacteria, 3) identify disease-causing pathogen candidates, and 4) evaluate which genes are regulated in disease events. The results of this work refine our understanding of *M. faveolata* under varying health conditions and reveal the bacterial diversity associated with YBD. This study highlights response variables and key symbiotic associations that are disrupted during a disease event.

S3-1.1 COATES, M. I.; Univ. of Chicago, Chicago; *mcoates@uchicago.edu*

Vertebrate diversity and phylogeny across the fish-to-tetrapod transition

The popular idea of the fish-to-tetrapod transition covers a series of changes to the gnathostome body plan: mid-line fins are lost; digited limbs replace paired fins; a sacrum links vertebrae to hips; gills are reduced; a distinct neck separates the head from shoulders. Such changes (and many more) occur within taxa traditionally designated as fish, deep within the tetrapod stem lineage. Moreover, if traditional, anatomical character-based definitions of taxa are used, then the broad shape of tetrapod evolution resembles an ice-cream cone: the classic spindle diagram. A few proto-tetrapods exhibiting a classic mosaic of fish- and tetrapod-like features emerge within the Devonian Period some 380 million years ago, and these earliest forms constitute a phylogenetic fuse preceding a dramatic evolutionary radiation within the Mississippian (around 340 million years ago) from which sprang the roots of modern amniotes and lissamphibians. However, if the tetrapods are defined on the basis of all taxa more closely related to living forms than to lungfishes (or coelacanths), then the picture of diversity flanking the fish-to-tetrapod transition changes. Diverse and abundant Devonian tetrapods are cut down by the end Devonian (360 million years ago) Hangenberg extinction, the causes and consequences of which are only now being investigated. Modern vertebrate diversity, dominated by tetrapods, teleosts and elasmobranchs, is contingent upon this event. The fish-to-tetrapod transition occurred within a very different and earlier faunal setting, and begs questions about survivorship versus extinction, recovery and replacement, and the extent to which the phylogenetic pattern apparent among early tetrapods is repeated within the other major vertebrate clades.

P1.33 COCKETT, P.M.*; BIRD, C.E.; Texas A&M University - Corpus Christi; *pcockett@islander.tamucc.edu*

Biogeographic patterns in the reproductive timing of broadcast-spawners

There is strong selective pressure for synchronization of reproductive timing in broadcast-spawners, which reproduce by releasing their gametes into the water column. When studied in detail, however, there is typically variation in reproductive timing within populations. Reproductive timing can influence population structure, speciation, and is a critical parameter in fisheries management. Here, we correlate the reproductive timing of the three endemic broadcast-spawning Hawaiian limpets (*Cellana exarata*, *C. sandwicensis*, and *C. talcosa*) at several locations with known patterns of genetic partitioning and the evolutionary history of these taxa. The abundance of Hawaiian limpets, a culturally important delicacy known as ‘opihi, has plummeted 10 fold over the last century due to over-fishing and there has been a recent movement to update the management strategies for this species. Here, we add to the previously published information on the spawning times of Hawaiian *Cellana* (two species at one site), and assess the efficacy of fishery closures designed to protect spawning. Resulting data suggest that different sites exhibit different patterns of spawning timing within and among species that do not perfectly correlate with mtDNA population genetic structure. However, the species with the most ancestral characters and lowest amount of population structure, *C. exarata*, exhibits the greatest degree of synchronicity in reproductive timing. The lack of synchronization among species on the scale of months suggests that a simple pattern of closed and open seasons will not be effective in protecting spawning for all species.

18.1 COLLAR, D.C.*; MEHTA, R.S.; HOLZMAN, R.; WAINWRIGHT, P.C.; Univ. of California, Santa Cruz, Tel Aviv Univ., Univ. of California, Davis; *dcollar@ucsc.edu*

The morphological and kinematic basis of suction feeding performance evolution

Organismal performance is a product of the size and shape of morphological structures and the way organisms use them (i.e., kinematics). Performance evolution, therefore, may result from change in morphology, kinematics, or both. Although performance has featured prominently in evolutionary studies, focus has generally been on performance as a link between morphology and ecology. Much less is known about the relative importance of the morphological and kinematic changes underlying performance evolution. In this study, we examine the basis of suction feeding performance evolution and fit evolutionary models to morphological, kinematic, and performance data for 17 centrarchid fish species and a robust, time-calibrated phylogenetic tree. We find that feeding performance has diverged toward separate adaptive optima in piscivores and insectivores, and this pattern is evident in morphology but not kinematics. Piscivorous centrarchids have enhanced success rates on evasive prey and evolved toward a morphological peak featuring large oral cavities, limited upper jaw protrusion, and shallow heads. Insectivores, on the other hand, have increased ability to feed on attached prey and have evolved small mouths, extensive upper jaw protrusion, and deep skulls. Despite their evolution toward separate optima for performance and morphology, piscivores and insectivores show no evidence of divergence in kinematics. These results suggest performance evolution has been a consequence of morphological but not kinematic changes. Even though both morphology and kinematics are important in determining performance, our results imply that different evolutionary processes have shaped these levels of design.

S11-1.6 COLLIN, R; STRI, Panama; *collinR@si.edu*
Genetic, Environmental and Social Control of Sex Change in Molluscs
Molluscs show a wide diversity of sexual strategies and mechanisms of sex determination. There are both gastropod and bivalve families that are each primarily dioecious, simultaneous hermaphrodites, or sequential hermaphrodites. The multiple evolutionary origins of sex change among molluscs would give power to comparative analyses of the factors associated with this strategy, but data on all but a few groups are too sparse to draw many solid conclusions. However, some generalizations can be drawn. Sex change is primarily protrandrous in gastropods and either protandrous or alternating in bivalves. Many simultaneous hermaphrodites exhibit protandrous simultaneous hermaphroditism. Protandry may be considered an extreme case of this strategy but often occurs in groups that are primarily dioecious and is not so common among clades of simultaneous hermaphrodites. Sex change is associated with a sedentary life-style or limited mobility in gastropods, and possibly with brooding in both gastropods and bivalves? Sex change has been shown experimentally to be environmentally mediated. The timing of or size at sex change responds to interactions with conspecifics as well as environmental factors like food availability and stress. Finally, some evidence indicates that there is a genetic component to an individual's propensity to change sex.

116.1 COLLINS, A.G.*; DOHRMANN, M.; National Systematics Lab, Smithsonian; *collinsa@si.edu*
Can greater relative complexity in skeletal structure explain why hexactinellid molecular-based phylogenies correspond better to traditional systematics, as compared to other sponge groups?
Continuous efforts over the past two decades let us improve the systematics of sponges through the simultaneous consideration of phylogenetic hypotheses and the distribution of morphological characters. For Demospongiae and Calcarea, molecular studies suggest that a fairly large number of higher-level taxa are not monophyletic. In contrast, for Hexactinellida (glass sponges) there is a relatively closer match between clades suggested by molecular analyses and traditionally defined taxa. One hypothesis to explain these contrasting situations is that hexactinellids exhibit a more complex set of characters used in traditional taxonomy, as compared to other sponges. Defining and measuring complexity is far from simple, but we attempt to quantify the relative complexity of those characters (body form, skeletal architecture, and spicule form) used in traditional taxonomy of sponges. We focus on structural complexity, as opposed to functional, emphasizing pattern over process, and attempt to measure the overall differentiation of these characters within clades. We quantify, albeit crudely, sponge skeletal complexity, defined as the length of the shortest complete description of an entity, by tabulating the number of terms used to describe it. Somewhat against expectations, we find that the lexicon used to describe demosponge skeletal structure is more than two times that of hexactinellids, suggesting the demosponges are both more diverse (structurally) and species rich than hexactinellids. If one normalizes by species richness, hexactinellid complexity greatly exceeds that of both demosponges and calacareans, which could explain why molecular phylogenies better reflect traditional glass sponge taxonomy.

101.6 COLMENARES, DJ*; DYHR, JP; MORGANSEN, KA; DANIEL, TL; Univ. of Washington; *djc26@uw.edu*
Agile airframes II: closing the loop on abdominal actuation
Flying organisms achieve flight stability by employing a multitude of control surfaces, most notably the wings. However, airframe deformations, such as abdominal motions in the hawk moth *Manduca sexta*, have recently been shown to play a significant role in stabilizing flight. We sought to determine the control potential of abdominal deflections using a closed-loop flight arena. Tethered moths controlled the velocity of a projected black bar with their abdominal angle. Image velocity varied according to the difference between the abdominal angle and the set point (relative to the average abdominal angle), scaled by a gain factor. Experimental trials were performed for a ten-fold range of gains at three different set points and consisted of 60s periods during which the moths attempted to stabilize the drifting bar. We measured performance as the percentage of trial time in which the animal stabilized image velocity below 5 °/s. The moths were capable of stabilizing the image for all experimental conditions, with the highest average performance (50%) occurring at the medium gain and the set point corresponding to the average abdominal angle. Poor performance (<50%) during low gain trials was characterized by steady state error, likely the result of the relatively low image velocities. For high gain trials, the decreased performance (<35%) was characterized by large abdominal oscillations. These results support an active and plastic role for the abdomen in flight control, but also tested the limits of the abdominal control circuit. Adaptation to the range of gains indicates that the controller is robust to changes in body dynamics, while changes in set point demonstrate the behavior is learned and not reflexive.

S1-2.2 COMBES, SA*; IWASAKI, JM; PANDIT, MM; SWITZER, CM; WEILAND, TJ; Harvard Univ, Univ Otago, NZ, Indiana Univ, Middlebury Coll; *scombes@oeb.harvard.edu*
The role of identity in predator-prey interactions: Are mechanics and strategy one-size-fits-all or tailored to each adversary?
The dynamics of predator-prey interactions vary enormously, depending on the substrate/medium in which they occur, and on the locomotory modes, motor and sensory capabilities, and behavioral strategies of predator and prey. Encounters are often described as either active chases, in which each participant is aware of and reacts to the other, or as ambush predation, in which predators pounce on unsuspecting prey. In reality, most interactions lie somewhere in the middle, and in many cases it is difficult to discern how (or even if) the participants respond to each others' actions. To further complicate matters, most predators pursue a range of different prey, and most organisms are preyed upon by a variety of predators. Because mechanistic studies of predation are scarce, we do not yet know whether predators employ a general kinematic and behavioral strategy when pursuing most prey, or whether they tailor their pursuit to each prey type; nor do we know how widely related prey species differ in their survival strategies and in their motor and sensory capabilities. To address these questions, we examined aerial interactions between dragonflies and dipteran prey, filming encounters with high-speed video to reconstruct 3-d trajectories and quantify biomechanics and strategy. We studied five species of libellulid dragonflies pursuing four species of dipteran prey, including fruit flies, mosquitoes, houseflies and deerflies. By analyzing large numbers of encounters between different predator-prey pairs, we were able to identify common mechanical features of dragonfly predation, infer which prey species can sense and actively respond to approaching predators, and pinpoint key factors that help determine the outcome of predator-prey interactions.

144.4 CONCANNON, M.R.*; ALBERTSON, R.C.; UMass Amherst; *mrconcan@cns.umass.edu*

Developmental and genetic basis of a morphological novelty in East African cichlids

The production of novel phenotypic variation provides new traits on which selection can act and is often associated with expanded ecological opportunity. For this reason the developmental and genetic origins of phenotypic novelty are key questions in evo-devo research. The massive adaptive radiation of East African (EA) cichlids is most commonly associated with convergence, but there are also several instances of novelty that have evolved in this group. Craniofacial variation is a major axis of divergence among EA cichlids, and a species at the far end of the phenotypic spectrum, *Labeotropheus fuelleborni* (LF), has an enhanced facial feature of unknown form and function. This novelty is a fleshy elongated snout ('flap') that rests on the upper jaw, and is absent from any other cichlid, including a phenotypically similar ecological competitor, *Tropheops red cheek* (TRC). We analyzed flap development in both species and found that it begins to diverge relatively late in development when fry are about 1.4 cm in standard length, at which point the flap continues to grow isometrically in LF and plateaus in TRC. We also generated an F2 hybrid mapping population from a cross between LF and TRC, and a high-resolution linkage map in order to perform quantitative trait loci (QTL) mapping for flap size. We identified three significant QTL, which is consistent with our estimated number of loci (Castle-Wright estimator = 4-5 factors). Further, our QTL model is consistent with both a dominant and additive mode of inheritance, with little evidence for epistasis. Given these data and the tractability of this system, we are poised to identify the specific genetic loci and developmental mode of action involved in the evolution of this trait as well as a foundation for its ecological and biological significance.

123.1 CONDON, C*; COOPER, B; YEAMAN, S; ANGILLETTA, M; Arizona State University, Indiana University, University of British Columbia ; *chcondon@asu.edu*

Evolution of thermal plasticity in changing environments.

Environmental fluctuations should favor genotypes that can perform across a broad range of conditions. When these fluctuations occur primarily among generations, developmental plasticity should evolve. Although genotypes from different populations frequently differ in their plasticity, no general support exists for the idea that more environmental variation leads to greater plasticity. We studied the evolution of developmental plasticity in populations of *Drosophila melanogaster* that had evolved for more than three years in one of four environments: two constant environments (16 and 25°C), a temporally variable environment (alternating between 16 and 25°C each generation), and a spatially variable environment (gene flow between sub-populations at 16 and 25°C). Flies that evolved in the temporally variable environment had greater plasticity of fecundity than those that evolved in constant or spatially variable environments. However, this greater plasticity of fecundity might have come at the cost of poor heat and cold tolerance; flies from the temporally variable lines had shorter survival during heat exposure and slower recovery from cold exposure than did flies from the other selection lines. These results suggest a tradeoff between plasticity and tolerance.

48.2 CONNOR, K.M.*; GRACEY, A.Y.; Univ. of California, Irvine, Univ. of Southern Califronia; *kwasiconnor@hotmail.com*

Molecular and biochemical observations of Mytilus californianus under constant submergence

The mussel *Mytilus californianus* reside predominantly in the intertidal zone, a fluctuating environment at the interface of the terrestrial and marine biomes. However, cryptic populations have been found occupying subtidal regions offshore, which raise questions about what physiological mechanisms allow *M. californianus* to thrive in both environments. As a sessile species *M. californianus* encounters hourly, daily and seasonal fluctuations in oxygen, temperature, salinity and nutrient availability as a consequence of tidal and climate processes; whereas, these same physical and biological factors are comparatively more stable in subtidal environments. In order to investigate the link between intertidal and subtidal physiology, we performed transcript and metabolite screens of mussels held under constant submergence and compared the results to our previously published screens of mussels in a simulated intertidal environment. Specifically, submerged mussels were observed to exhibit either an open or closed valve state corresponding to periods of active cardiac activity and bradycardia respectively, and gill tissue was sampled from individuals exhibiting both states. Enrichment analysis of significantly expressed genes revealed that genes up-regulated in mussels exhibiting bradycardia and active activity were enriched for genes expressed during the simulated low and high tide respectively. A metabolomics screen revealed elevated levels of succinate, malate and alanine in mussels exhibiting bradycardia which suggested the activation of anaerobic pathways that are known to be induced during aerial exposure. Additionally, we observed higher levels of carnitine-conjugate intermediates of the fatty acid derivatives and branched-chain amino acid (BCKA) catabolism.

P2.11 CONOVER, A.E.*; MUÑOZ, M.M.; BORONOW, K; COOKE, E; SHIELDS, I; LANDESTOY, M.A.; LOSOS, J.B.; GASTEL, J; Stuyvesant High School, Harvard University, Trinity University, Sociedad Ornitologica de la Hispaniola; *asaconover@gmail.com*

Does parasite load affect thermoregulation in a diverse clade of Caribbean anoles?

In light of rising environmental temperatures and predictions of further warming throughout the coming century, there is concern for the survival of many species worldwide. Ectotherms are especially vulnerable to the effects of climate warming as their performance (and fitness) is so tightly linked to temperature. Current models have attempted to predict the effect that a temperature increase could have on a thermoregulating ectotherm, but most lack population-level data on thermoregulatory ability or data on how geographic patterns in body condition (i.e., parasite load) affect behavioral strategies and body temperature. The cybotoid and distichoid clades of Hispaniolan trunk-ground anoles inhabit a wide range of habitats and thermal environments, ranging from sea level to over 2,500 meters. In this study we examine how thermoregulation varies across thermal environments and the effect parasite load has on basking behavior and activity rate in populations from each of these clades along two different elevational gradients—the Cordillera Central and the Baoruco Mountains. This study will help us understand the effects that multiple types of parasites have on anoles and help inform predictions on the anoles' capacity to deal with climate change.

P3.50 COOK, E.Y.*; OWERKOWICZ, T; California State Univ., San Bernardino; *cooke300@coyote.csusb.edu*

New experimental model to investigate effects of augmented intracardiac shunt

Central vascular shunting is present in all vertebrates during development and lost only in mammals and birds after birth/hatching. The persistence of cardiac shunting among extant reptiles has been queried numerous times, and its adaptive function cast in doubt. Recently, independent studies of experimental elimination of the pulmonary bypass shunt in crocodilians have yielded conflicting results. In contrast to previous approaches, we developed a new squamate model with an augmented intracardiac shunt. The derived cardiac morphology of varanid lizards maintains pressure separation between the pulmonary and systemic circuits and allows only for a small washout shunt from the cavum venosum into the left aorta (LAo). We hypothesised that surgical ligation of the LAo will promote admixture of deoxygenated and oxygenated bloodstreams and effectively augment the intracardiac shunt. We confirmed this by measurement of blood oxygen tension (pO_2) with in-dwelling micro-optodes positioned in the right aorta (RAo) and pulmonary artery (PA) in anaesthetized juvenile savannah monitors (*Varanus exanthematicus*). Following LAo ligation, we observed an increased pO_2 in the PA and a decreased pO_2 in the RAo, indicating a greater shunt magnitude. We suggest this animal model will facilitate the investigation of increased shunt fraction on overall oxygen transport, tissue growth and oxidative stress. Ultimately, it may help to elucidate whether central vascular shunts serve an adaptive function which might explain their prevalence in reptiles.

95.4 COOK, EG*; MUNOZ, MM; CONOVER, AE; SHIELDS, IH; BORONOW, KE; MURPHY, TG; JOHNSON, MA; Trinity University, San Antonio, Harvard University, Cambridge, Stuyvesant High School, New York, Harvard Univeristy, Cambridge; *ecook1@trinity.edu*

Is dewlap color an honest indicator of health in Anolis lizards? An analysis of population differences in body condition and parasite load.

Vibrantly colored ornaments often vary among members of the same species, and in some cases, such variability communicates information about the quality of an individual. However, which factors produce this variation is not well understood in many taxa. *Anolis* lizards possess dewlaps, brightly colored throat fans that are extended during behavioral interactions and vary in coloration both across the genus, and within the same species or even the same population. In this study, we investigated whether dewlap coloration serves as an indicator of two measures of male quality—body condition and parasite load—in populations of two Caribbean anoles, *Anolis cybotes* and *Anolis distichus*. We captured lizards of each species from 5-6 populations at 5-6 different elevational sites distributed throughout two mountain chains in the Dominican Republic. For each individual, we measured body length and mass, counted ectoparasitic mites, and quantified dewlap coloration using objective spectrometry. Measures of dewlap color were correlated with body condition and parasite load in each of the species when the analyses combined samples from all elevations; however, the relationships between color, body condition, and parasite load differed across the elevational sites. These results suggest that ecological factors at the different elevations, such as diet or temperature, may contribute more to dewlap color variation across populations than general animal health.

128.5 COON, CAC*; BRACE, AJ; MARTIN, LB; Univ. of South Florida, Tampa; *ccoon@mail.usf.edu*

Resistance and tolerance in invasive and native songbirds in Kenya: evidence of parasite spillback

Avian malaria is more prevalent in invasive house sparrows (*Passer domesticus*) compared to native passerines in recently invaded Kenya (<60 years). We sought to determine whether this finding was due to different immunological strategies between invasive house sparrows and native songbirds. Therefore, we experimentally infected house sparrows and native congeners, grey-headed sparrows (*Passer griseus*), with endemic coccidia, in Nakuru, near the edge of the ongoing range expansion of house sparrows in Kenya. We hypothesized that house sparrows would be more parasite tolerant (i.e. hosts mitigate negative fitness consequences associated with infection) and less parasite resistant (i.e. hosts actively prevent or clear parasites) as compared to native birds. While there was no statistical evidence of differences in tolerance between the two species, exposed house sparrows shed over 12 times as many infectious coccidia oocysts as native grey-headed sparrows. Such high levels of shedding likely have very important effects on parasite prevalence in invaded communities and may be indirectly helping house sparrows to compete with native songbirds and establish in new territories.

65.5 COOPER, L/N*; ROSS, A/E; FOLTZ, S/L; MOORE, I/T; DAVIS , J/E; Radford University, Virginia Tech; *lncooper@radford.edu*

Stop on Red: Neophobia and corticosterone in house sparrows (Passer domesticus)

When confronted with novel stimuli, animals must evaluate both the stimulus itself as well as their surrounding environment. Particular stimulus traits play an important role in determining both rapidity and depth of investigatory behavior. Color is a feature which may prove to be relevant to many passerine birds, given its natural association with food, sexual display and potential danger. In previous studies we have found that house sparrows (*Passer domesticus*) exhibit caution in approaching red colored items, in addition to a sex difference, with males displaying less hesitance than females. Here we will discuss this work as well as recent studies on the development of red avoidance and its relationship to fledging. I will also discuss the findings from recent studies of the effect of color exposure on circulating corticosterone levels, and the relationship between individual corticosterone response profile and an individual's exploratory behavior.

28.2 COOPER, LISA N*; SEARS, KAREN; SIMMONS, NANCY; NEOMED, Ohio, University of Illinois, Urbana-Champaign, American Museum of Natural History, New York; *l.noelle.cooper@gmail.com*
Regional alterations in bone thickness and density helped bats acquire active flight
The origin and diversification of bats are intimately linked with flight, therefore bats face a host of locomotor challenges not encountered by terrestrial mammals. For decades biologists have presented the need for elongated wing bones as one of the primary selective pressures shaping bat locomotor morphology and behavior. Only recently, biologists have reported that bat wing bones display decreased cross-sectional geometries and densities relative to terrestrial mammals. These architectural novelties likely increase bone compliance to accommodate the high bending strains that result from powered flight. This study investigates this fundamental issue of chiropteran bone function by testing hypotheses that relate evolutionary bone architecture with in vivo bone function. High resolution micro-CT scans of a taxonomically diverse sample of approximately thirty extant bats showed that, compared to terrestrial rodents, bats displayed thinner cortices forelimb and vertebral elements, and the mandible was only 80-85% as dense. Hindlimb elements showed a surprising range of thicknesses that were correlated mostly with locomotor patterns. Preliminary character state reconstructions, using mice as an outgroup, showed that the evolution of forelimb cortical bone thickness displayed little homoplasy, and the megabat *Cynopterus* displayed unusually thick cortices. Taken together, these data based on scans of the appendicular and axial skeletons of bats and mice showed that lightening of the chiropteran skeleton is localized to mostly the wing bones and is therefore associated with the acquisition of active flight, rather than a systemic lightening of the entire skeleton.

103.4 COOPER, B.S.*; HAMMAD, L.A.; MONTOOTH, K.L.; Indiana University; *brascoop@indiana.edu*
The evolution of cellular generalization and specialization in natural populations of Drosophila melanogaster
Changes in the environment can profoundly impact the fluidity of cell membranes. For small insects like *Drosophila melanogaster*, both changes in temperature and amounts of environmental ethanol perturb membrane fluidity. When environments vary greatly, alleles that enable cellular generalization should be favored by selection. Antagonistic pleiotropy and mutation accumulation, however, can create negative genetic correlations in fitness across environments leading to decreased performance of generalist relative to specialist genotypes. Our previous work has shown that an increased degree of cellular plasticity evolves in an experimentally variable environment, consistent with the selective advantage of an environmentally sensitive allele with associated costs in constant environments. This evolution of increased cellular plasticity enables specialization within generations in environments that vary among generations. Here, we extend this work to natural populations by evaluating the evolution of cellular generalization and specialization in populations of *D. melanogaster* from Vermont, Indiana, and North Carolina. We use two measures of the lipid composition of cell membranes as indices of physiological plasticity (a.k.a. acclimation) to evaluate the evolution of cellular generalization: (1) change in the ratio of phosphatidylethanolamine (PE) to phosphatidylcholine (PC) and (2) change in lipid saturation in cool (16ºC) relative to warm (26ºC) developmental conditions. We then evaluate the composition of cell membranes within each developmental environment to identify the evolution of cellular specialization in environments that differ in mean temperature. Our results shed light on the mechanisms underlying the evolution of generalization and specialization in environments that differ in mean and variance of temperature.

P2.21 COOPER-MULLIN, C.*; JIMENEZ, A.J.; VAN BROCKLYN, J.R.; WILLIAMS, J.B.; The Ohio State University; *coopermullinc@gmail.com*
A protocol for wild avian muscle cell culture.
Understanding physiological properties at a cellular level in wild bird species can help address basic questions on how cellular traits can be linked to whole-animal physiology. Traditionally, cellular metabolic studies have focused on fibroblasts, since they are easily cultured and manipulated, but these cells represent barely 1% of total-organism metabolic rate. Skeletal muscle makes up a large fraction, 25-30%, of body mass in an individual, and, therefore, contributes substantially to whole-animal metabolism. However, avian muscle cell cultures have only been developed in captive birds. Here we have modified previous protocols for domestic birds that now allow us to culture muscle cells from wild species. Our goal is to understand the link between cellular and whole animal metabolic rates.

P2.213 CORBIN, K.M.*; ALEMSEGED, Z.; Univ. of California, San Diego, California Academy of Sciences; *kcorbin@ucsd.edu*
Is Paranthropus monophyletic? Incorporating modular relationships in a cladistic analysis
The three species of “robust” australopithecine, east African *Paranthropus aethiopicus* and *P. boisei* and south African *P. robustus*, have extremely derived masticatory systems for heavy chewing. Various studies have characterized the group as monophyletic, polyphyletic, or paraphyletic. The derived masticatory complex is often cited as being more prone to homoplasy than other craniodental features used in analyses. Many analyses have excluded masticatory features as a conservative test of the position of these three species, but few have considered characters that are developmentally or evolutionarily integrated, and thus not valid independent characters for a cladistic analysis. In this study, characters were amassed from the literature and missing data were filled in with specimens from the California Academy of Sciences Anthropology and Mammalogy collections. Cladistic parsimony analyses were run with PAUP* 4.0 in several configurations: with all characters; with characters related to specific masticatory traits collapsed into single characters; with integrated characters collapsed; and with both masticatory and integrated characters collapsed. In all analyses, “robust” australopithecine monophyly was maintained with excellent bootstrap support and consistency indices. The relationship of the basal “gracile” australopithecine species to the robust australopithecines was not resolved. A monophyletic origin for *Paranthropus* suggests that sometime in its evolutionary history, *P. robustus* migrated from east to south Africa, where basal species *P. aethiopicus* and sister species *P. boisei* lived.

P3.194 CORCORAN, MA*; PACE, CM; FUQUA, RD; NISHIKAWA, KC; Northern Arizona University; *michele.corcoran@coconino.edu*
The effect of eccentric exercise on whole animal performance and muscle properties.
Animals performing vertical jumps are thought to utilize elastic structures to store energy and increase jump height. Additionally, eccentric (lengthening) muscle contractions may provide additional elastic recoil energy and have been suggested to play a role in jumping. Eccentric exercise may affect structures in muscle that contribute to elastic recoil, such as titin. Therefore, we asked whether eccentric exercise changes animal performance (in this case vertical jumping) and whether corresponding changes could occur in the muscle properties that are attributable to titin? Eccentric exercise training was performed on mice using a downhill treadmill. The mice were trained every day for a maximum of 30 minutes for 5 weeks, walking at a speed of 18 cm/sec at downhill angles starting at -16° and increasing to -28°. At the end of the training period, maximal jumps were elicited from the mice. The highest jump for each mouse was recorded using a high speed camera and jump height was measured. Jumping data were also collected from a control group of mice who had never been exercised. After jumping, mice from both groups were euthanized and active and passive stiffness was measured from the soleus muscle using a servomotor force lever. There was no difference in jump height between the exercised and non-exercised groups of mice. However, the soleus muscle from exercised mice exhibited greater passive stiffness, although maximum isometric force was similar between the two groups. These data suggest that, although there wasn't an overall performance difference, the eccentric training affected the muscle properties of the mice. In particular, because passive muscle stiffness increased after eccentric training, it appears that this training affected titin based muscle stiffness in the mice.

P1.111 CORDER, KR*; SCHAEFFER , PJ; Miami University; *keely.corder@gmail.com*
Regulation of adipose storage by temperature and light cycles following migration in the Gray Catbird, Dumetella carolinensis
Prior to their migration, birds make physiological and behavioral adjustments to accumulate fat stores to fuel their journey. The majority of these fat stores are utilized during their long-distance flights. However, birds often complete vernal migrations with residual fat, which may be advantageous as it could assist with the demands of harsh weather and aid breeding success. Beyond ensuring a successful migration, it is unclear whether excess fat stores are beneficial following autumnal migrations. Retaining any excess stores could be detrimental due to increased predation risk. In this study, Gray Catbirds (*Dumetella carolinensis*) were caught prior to autumnal migration with high amounts of adipose and then housed in incubators mimicking light and temperature cycles of either tropical wintering grounds or the capture site in SW Ohio. In doing this, we determine if climate cues are sufficient for fat loss without the energetic demand of the migratory event and begin to seek a mechanism for regulation of adiposity post-migration.

P2.80 CORDERO, GA; Iowa State University, Ames; *gcordero@iastate.edu*
Deep Phylogenetic Character Reversal Enhances Scapula Functionality in Shell-Closing Systems of Recent Turtle Lineages
Skeletal evolution in terrestrial vertebrates (tetrapods) generally proceeds via the modification of preexisting structures. However, in complex skeletal modules, the reappearance of characters present in an ancestor (phylogenetic character reversal) frequently occurs. To distinguish between these processes, I studied the development and evolution of shell-closing systems in recent (8-15 Ma) turtle lineages. Character states of the dorsal scapula (segmented or unsegmented) were mapped onto a phylogeny and development of the scapula was observed. The scapula was shown to arise as a single continuous unit that secondarily becomes segmented during late embryogenesis. Segmentation of the dorsal scapula is required for the formation of a specialized joint that mediates anterior-posterior movement of the pectoral girdle during activation of the shell-closing system. Parsimony ancestral state reconstructions, aided with descriptions from the fossil record, supported the hypothesis of a deep phylogenetic character reversal associated with the segmented dorsal scapula of turtles. The oldest known turtle fossil (220 Ma) did not feature this character state, though it was present in some ancient reptilian lineages (~270 Ma). My observations support theory on the capacity for animal genomes to encode for the patterning of convergent anatomical structures. Observed segmentation of the dorsal scapula during embryogenesis invokes a role for the highly conserved bone morphogenetic protein pathway coupled with homeobox gene expression. To test this hypothesis, I am currently investigating differential gene expression during development of the scapula across turtle phylogeny.

P3.35 CORNELL, A.E.; Simon Fraser University; *acornell@sfu.ca*
Vegetation Density as an Indicator of Wood Thrush Abundance
Wood Thrush (*Hylocichla mustelina*), a neotropical migrant of Eastern North America, have been declining throughout their range since the 1970s. Some suggest that causes may include fragmentation and degradation of breeding habitat, which leads to higher nest predation and brood parasitism rates. Density of vegetation may be an important habitat quality indicator, as Wood Thrush show marked preference for dense understory nest sites. Over the past 21 years the Missouri Ozark Forest Ecosystem Project (MOFEP) has observed a decline in Wood Thrush at control, uneven-aged, and even-aged forest management sites. The decrease could be a related to changes in vegetation density due to harvest of treatment sites; control sites may have decreased understory vegetation density as the forest matures and the canopy closes. This study investigated the abundance of Wood Thrush at varying vegetation densities at two experimental plots with uneven-aged treatment, two with even-aged treatment, and two control plots. The entire 2500 hectare site was surveyed for Wood Thrush using spot maps during eight weeks of the breeding season. A 6" by 8' density board was used to estimate the density of understory vegetation from the ground up. Vegetation density was found to be positively correlated with Wood Thrush abundance. This evidence suggests that Wood Thrush select territories with higher densities of vegetation for reproduction. If the cause of Wood Thrush decline is the decrease in breeding habitat quality, understanding habitat preferences like vegetation density will be key to their conservation.

P2.167 CORNWELL, F.J.*; BRAUER, C.L.; KRAJNIAK, K.G.; Southern Illinois Univ. Edwardsville; *fcornwe@siue.edu*

The Effects of APKQYVRFamide and other FMRFamide Related Peptides on the Isolated Crop-Gizzard of the Earthworm Lumbricus terrestris.

The digestive tract of the earthworm *Lumbricus terrestris* responds to a variety of neurotransmitters including FMRFamide and its related peptides (FaRPs). Recently we identified the first earthworm FaRP, APKQYVRFamide, from the genes of *Lumbricus rubellus*. The goal of this project was to examine the effects of this peptide and structurally similar peptides on the crop-gizzard of *L. terrestris*. The crop-gizzard of the worm was removed and placed into a bath filled with worm saline. All movements of the crop-gizzard were recorded with a Grass force transducer and were displayed on a computer using Iworx Labscribe 2. Increasing concentrations of peptide were added to the bath and adequate time was allowed for each to take effect. The resulting changes in contractions were used to create log-concentration response curves. APKQYVRFamide caused a concentration dependent decrease in contraction amplitude with a threshold of 10^{-6}M, while FMRFamide caused the same response with a threshold of 10^{-8} M. Since the earthworm peptide contains a tyrosine (Y) in place of the phenylalanine (F) in FMRFamide, we also challenged the tissue with YMRFamide, a FaRP found in leeches. YMRFamide caused a dose-dependent decrease in amplitude with a threshold of 10^{-6}M. These results suggest that APKQYVRFamide may play a role in controlling the motility of the earthworm crop-gizzard. They also indicate that receptor prefers F instead of Y in the fourth position from the C-terminus.

118.3 CORREA, S.*; ZOBEL-THROPP, P.; BINFORD, G.; SUTER, R.; GARB, J.E.; University of Massachusetts Lowell, Lewis and Clark College, Vassar College; *scorr006@ucr.edu*

Exploring the silk and the silk-like venom from the spitting spider Scytodes thoracica.

Scytodids have evolved a unique way to capture prey from a distance. Scytodids spit an adhesive glue from their fangs onto prey. The ejected material contains long, fibrous strands with structural similarities to abdominal spider silk. We characterized venom and silk gland proteins from a spitting spider species, *Scytodes thoracica*, to determine its composition and possible evolutionary connections between the silk-like venom and their abdominal silk proteins (spidroins). We identified two novel spidroins: *S. thoracica* fibroin 1 and 2 showing the characteristics of all known spidroins, including repetitive sequences and conserved C-terminal domains. Amino acid composition analyses indicate that *S. thoracica* fibroin 1 is the major component of the major ampullate silk from this species. *S. thoracica* dragline silk was found to have high toughness, but was not as tough as previously described. Phylogenetic analyses suggest that proteins comprising spider dragline silk evolved independently, and is attributed to multiple gene duplication events. Forty percent of *S. thoracica* venom gland cDNAs encoded a family of glycine rich peptides, whereas another 17% of venom cDNAs encoded putative venom toxins. No venom cDNAs were homologous to spidroins, but the high expression of glycine-rich peptides suggest they constitute a major component of the *Scytodes* venom spit. Results indicate that scytodids evolved a unique way of synthesizing a fibrous silk-like material from their venom glands using novel proteins, supporting the proposed novel silk gene hypothesis.

11.4 CORTES, P.A*; BACIGALUPE, L; CONTRERAS, C.I; VARAS, V; BLIER, P.U; OPAZO, J.C; Universidad Austral de Chile, Université du Québec à Rimouski; *pablocortesgarcia@gmail.com*

Discovering the genetic basis of torpor in a Chilean marsupial

Torpor is the physiologically controlled reduction of metabolic rate and body temperature experienced by small endotherms when facing periods of low temperature and/or food resources. This phenotype is characterized by an almost complete suppression of all expensive physiological processes with the aim of reducing energy expenditure. Nevertheless, some processes continue to operate at lower levels of activity, as they are critical for survival. The high demand of energy required during rewarming, to reach normothermy, represents an important constraint. Torpor and arousal from torpor involves a complex physiological reorganization at different organizational levels, underpinned by changes in genes expression. Accordingly in this study we investigated the reaction norm of (1) gene expression and (2) mitochondrial performance along different stages of torpor bout (deep torpor, arousal and normothermy) in the Chilean marsupial *Thylamys elegans*. More specifically we (1) performed a large-scale gene expression screening (RNA-seq) and (2) examined mitochondrial oxygen consumption and different enzymes of the electron transport system associated with torpor in liver. The gene expression profiles revealed a modest level of transcriptional changes along different stages of torpor bout. Functional analysis shows that genes involved in pathways associated to lipid metabolism are increased, whereas those involved in protein biosynthesis and detoxification are decreased during torpor and rewarming. For mitochondrial performance, high level of phenotypic flexibility was observed during the different stages of torpor. Taken together, these findings revealed important metabolic process those are critical during torpor in marsupials.

P2.222 CORTES GARCIA, M.E.*; CLOSEK, C.J.; MEDINA, M.; University of California, Merced; *mcortesgarcia@ucmerced.edu*

Symbiodinium changes under coral disease events in Montastraea faveolata

Caribbean coral reefs have experienced an increase in the number of diseases and disease outbreaks within the last 10 years. One disease, Yellow Band Disease (YBD), also known as Yellow Blotch Disease, is widespread throughout the Caribbean and affects several coral species including *Montastraea spp.*, which are dominant reef building species in this region. While it is known that corals live in symbiosis with dinoflagellate endosymbionts (*Symbiodinium spp.*), little is known of the interactions between *Symbiodinium* and diseased corals. *Montastraea faveolata* colonies found in the Caribbean Sea are associated with multiple clades of *Symbiodinium*. In this study we collected samples from both healthy and diseased colonies. We extracted DNA and amplified the *Symbiodinium* 18S ribosomal DNA gene. We analyzed phylotype polymorphism by restriction fragment length polymorphisms (RFLP) to compare *Symbiodinium* clade signatures across samples. We observed changes in *Symbiodinium* clade diversity when comparing healthy vs YBD inflicted *M. faveolata* colonies.

P2.141 COSENZA, K. S.*; CHANG, E. S.; MYKLES, D. L.; Colorado State Univ, UC Davis Bodega Marine Lab; *kcosenza@rams.colostate.edu*

Effects of ecdysteroids on myostatin and mTOR signaling expression in crustacean skeletal muscle

During premolt, increasing ecdysteroid levels cause claw muscle atrophy in *Gecarcinus lateralis*, allowing withdrawal of the claw at ecdysis. Myostatin (Gl-Mstn) is negatively correlated to ecdysteroids, while protein synthesis is up-regulated to allow myofibril remodeling during premolt. In thoracic muscle, which does not atrophy during premolt, ecdysteroid levels and Gl-Mstn mRNA are not correlated. In mammals, glucocorticoids inhibit mechanistic Target of Rapamycin (mTOR)-dependent protein synthesis. Our hypothesis is that ecdysteroids inhibit Gl-Mstn expression through the ecdysteroid receptor. Gl-Mstn, in turn, inhibits protein synthesis via Smad transcription factors. In *Homo sapiens*, Smad response elements occur in the promoters of three genes (Rheb, PRAS40, and TSC) in the mTOR signaling pathway. Using DNA walking, an ecdysone receptor (EcR) response element was located near the 5' end of the Gl-Mstn promoter region (932 bp), suggesting that Gl-Mstn expression is regulated by ecdysteroids. Gl-Mstn, Gl-EF2, Gl-mTOR, Gl-Rheb, Gl-Akt, and Gl-S6K mRNAs were quantified by qPCR. After two weeks of daily 20-hydroxyecdysone (20E) injections, Gl-Mstn mRNA levels were significantly decreased in claw muscle. By contrast, a single 20E injection had no effect on gene expression over 24 h. Limb bud autotomy, which suspends premolt by lowering hemolymph ecdysteroid, increased Gl-mRNA levels in claw muscle. Unexpectedly, expression of Gl-mTOR, Gl-Rheb, Gl-Akt, and Gl-S6K was increased by LBA. The data suggest that Gl-Mstn expression is regulated by ecdysteroids. However, there was no consistent linkage between expression of Gl-Mstn and expression of mTOR signaling components. Supported by NSF (IBN-0618203).

1.2 COSTA, D.P.*; SCHWARZ, L.K.; MARESH, J.; ROBINSON, P.W.; CROCKER, D.E.; Univ. of California, Santa Cruz, Sonoma State University; *costa@ucsc.edu*

A Bioenergetics Approach to Understanding the Population Consequences of Natural and Anthropogenic Disturbance

A major hurdle with marine mammal conservation and management is to know if and when measurable short term responses result in biologically meaningful changes in populations. We have been measuring the behavioral and energetic response of pinnipeds to environmental variations such as ENSO events, which cause reductions in prey availability, to assess their ability to accommodate to changing conditions. The ability of animals to respond to natural perturbations can be used to estimate their response to anthropogenic disturbance. Pinnipeds offer a unique system to study this question; there are extensive data on their reproductive and foraging energetics that can be coupled with their reproductive success. Long term demographic data exist that can be used to infer population consequences. Finally, they exhibit a diverse range of life history patterns from income breeders to capital breeders. First we consider whether there is a difference in the ability of capital and income breeders to accommodate to environmental perturbation. Second using northern elephant seals we integrate these bioenergetic measures to examine the coupling between short term reductions in foraging success to reproductive success and whether and when this results in a population level effect.

85.1 COUGHLIN, DJ*; WOYTANOWSKI, JR; Widener Univ.; *djcoughlin@widener.edu*

Thermal Acclimation in Rainbow Smelt, Osmerus mordax, Leads to Faster Myotomal Muscle Contractile Properties and improved swimming performance.

Rainbow smelt (*Osmerus mordax*) display an impressive ability to acclimate to very cold water temperatures. These fish express both anti-freeze proteins and glycerol in their plasma, liver, muscle and other tissues to avoid freezing at sub-zero temperatures. Maintenance of glycerol levels requires active feeding in very cold water. To understand how these fish can maintain activity at cold temperatures, we explored thermal acclimation by the myotome of smelt exposed to cold water. We hypothesized that cold-acclimated fish would show enhanced swimming ability due to shifts in muscle contractile properties. We also predicted that shifts in swimming performance would be associated with changes in the expression patterns of muscle proteins such as parvalbumin (PV) and myosin heavy chain (MyHC). Swimming studies show significantly faster swimming by smelt acclimated to 5ºC compared to fish acclimated to 20ºC. The cold-acclimated fish also had faster muscle contractile properties, such as a maximum shortening velocity (Vmax) almost double that of warm-acclimated fish. Cold-acclimation is associated with a modest increase in PV levels in the swimming muscle. More significantly, fluorescence microscopy using anti-MyHC antibodies indicates that MyHC expression in the myotomal muscle shifts in response to exposure to cold water. The complex set of physiological responses that comprise cold-acclimation in smelt includes modifications in muscle function to permit active locomotion in cold.

42.4 COVI, J.A.*; BADER, B.D.; CHANG, E.S.; MYKLES, D.L.; Univ. of North Carolina at Wilmington, Colorado State Univ., Bodega Marine Laboratory; *covij@uncw.edu*

Comparative assessment of Smad expression in two models of muscle atrophy for the blackback land crab, Gecarcinus lateralis

In decapod crustaceans, reversible atrophy of claw muscle is imperative for successful withdrawal of the claw at ecdysis. The execution of this regulated atrophy is under the control of molting hormones termed ecdysteroids. By contrast, thoracic musculature atrophies in response to unweighting, but not elevated ecdysteroids. Published data for *Gecarcinus lateralis* support a role for a myostatin-like factor in mediating both atrophy induced by unweighting and atrophy regulated by ecdysteroids, albeit by what appear to be different regulatory strategies. Myostatin is a member of the TGF-β superfamily well known for its role as a negative regulator of muscle mass in mammals. Transduction of the myostatin signal between its membrane-bound receptor and the nucleus is dependent on a family of transcription factors known as Smads. Phosphorylation of R-Smad by the myostatin receptor initiates Smad activation and translocation to the nucleus. Inhibitory Smads (I-Smad) limit the duration of the myostatin signal by antagonizing the action of R-Smads. Both I-Smad and R-Smad are expressed in decapod skeletal muscle. Expression of R-Smad mRNA in both unweighted and weighted thoracic muscle did not change appreciably during a molting cycle initiated by multiple limb autotomy. However, R-Smad expression increased significantly in claw muscle during premolt, and decreased over 3.5 fold during postmolt. Expression of R-Smad during a molt cycle initiated by eyestalk ablation presented a different response; R-Smad copy number decreased during premolt in claw and thoracic muscle. This suggests that R-Smad expression in skeletal muscle is regulated, in part, by a factor produced in the eyestalks. Supported by NSF (IBN-0618203)

P2.212 COX, CL*; STRINGER, JF; STREICHER, JW; MOSELEY, MA; CHIPPINDALE, PT; University of Virginia, The University of Texas-Arlington; *clcox@virginia.edu*
Cryptic genetic diversity and refugial dynamics in the flathead snake
Determining the role of geography in structuring phylogenetic relationships within species can be useful for inferring biogeography, detecting cryptic genetic diversity, and revising species boundaries within a clade. However, broad inferences about how geography influences genetic diversity and speciation can be limited by the taxonomic breadth of phylogeographic studies. For many groups of vertebrates (especially small and cryptic species) these phylogenetic relationships are not well understood. We assessed the genetic relationships among populations of the small and cryptic flathead snake (*Tantilla gracilis*) by sequencing the mitochondrial genes of *ND4* and *cytb* (total of ~1200 bp) for over 70 snakes from across their geographic range. Phylogenetic relationships were analyzed using maximum parsimony, maximum likelihood and Bayesian inference. We found substantial phylogenetic structure within the flathead snake, with geographically consistent western and eastern clades separated by approximately 2% sequence divergence. Additionally, we found multiple well-supported and geographically restricted clades in south Texas, central Texas and Louisiana. These results highlight cryptic genetic diversity within flathead snakes and suggest a pattern of historical glacial refugia and range expansion. Our findings of cryptic phylogenetic structure in flathead snakes in a geographically homogenous area highlight the importance of taxonomic diversity in phylogeographic research.

133.2 COX, R.M.*; DAUGHERTY, C.; PRICE, J.; MCGLOTHLIN, J.W.; CALSBEEK, R.; University of Virginia, Virginia Tech, Dartmouth College; *rmc3u@virginia.edu*
Proximate and ultimate mechanisms for intraspecific variation in male body size and sexual size dimorphism in the brown anole (Anolis sagrei))
Intraspecific variation can arise from genetic changes due to variation in selection and/or from phenotypic plasticity in response to local environmental conditions. These processes can differentially impact males and females, leading to intraspecific variation in sexual dimorphism. We combined studies of natural selection in the wild with common-garden studies in captivity to investigate the proximate and ultimate basis of intraspecific variation in male-biased sexual size dimorphism (SSD) in two island populations of the brown anole, *Anolis sagrei*. In the wild, SSD was significantly greater on Exuma than on Eleuthera. This difference arose primarily from intraspecific variation in the growth and body size of adult males, rather than females. However, patterns of viability selection on body size were highly congruent on both islands: females experienced stabilizing selection favoring intermediate size, whereas males experienced directional selection favoring larger size. Thus, sex-specific selection matched the overall pattern of male-biased SSD, but population differences in the magnitude of SSD were not associated with local differences in selection. Body condition was significantly lower on Eleuthera than on Exuma, suggesting that intraspecific variation in SSD reflects local variation in energy availability that disproportionately impact males on account of their greater absolute energy requirements. Nonetheless, our common-garden experiment indicated a strong genetic component to island differences in the growth and body size of adult males. We discuss these results in light of current research targeting the quantitative genetics of growth and sexual dimorphism.

P3.11 CRALL, JD*; COMBES, SA; Concord Field Station, Harvard University; *jcrall@oeb.harvard.edu*
Blown in the wind: Bumblebee temporal foraging patterns in naturally varying wind conditions
Variation in wind increases the cost of insect flight and is likely to be an important factor in the foraging costs of pollinating insects. Few studies to date, however, have investigated how insect foraging patterns respond to wind. We marked more than 80 workers from a bumblebee colony (*Bombus impatiens*) with unique radio frequency identification (RFID) tags and placed the colony outdoors at the Harvard Forest (Petersham, MA). For two weeks we recorded when individual bees entered and exited the hive, while simultaneously measuring wind speeds from a three dimensional sonic anemometer operating at 5 Hz. Interestingly, temporal foraging patterns of bumblebee workers are individually distinct and remarkably constant over several days, despite strong variation in both direction and intensity of wind flow and turbulence. These results imply that bumblebees continue to forage in variable wind conditions, and are thus good candidates for future studies of adaptations to flight in turbulent wind conditions.

39.5 CRALL, JD*; KOVAC, M; CORNWALL, M; WOOD, RJ; PIERCE , NE; COMBES, SA; Concord Field Station, Harvard University, Imperial College London, Museum of Comparative Zoology, Harvard University, Wyss Institute, Harvard University, Museum of Comparative Zoology, Harvard University; *jcrall@oeb.harvard.edu*
Shaping up: Aerodynamics and evolution of butterfly wing planform
Wing shape is likely to be an important factor in aerodynamic force production and efficiency in insects. Despite a wealth of studies on wing shape in both birds and bats, however, relatively few studies have investigated the importance of wing shape for insects. For 270 species of butterflies (Rhopalocera), we extracted wing outlines from images of male specimens. For each of these wing outlines, we calculated wing centroid and aspect ratio values, as well as estimating body mass and wing loading from specimen images. Wing centroid and aspect ratio vary systematically with body size, with a smaller wing centroid and higher aspect ratio associated with larger body size in butterflies. Lower wing centroids are also strongly associated with higher wing loading. Comparative analysis shows these relationships are independent of the phylogenetic history of the species studied. Finally, steady-state computational fluid dynamics analysis of the same wing shapes across a range of Reynolds numbers confirms that wing shape has a strong influence on aerodynamic efficiency of wings. This study indicates that wing shape (a) has phenotypic consequences for insect flight performance and (b) shows strong variation across insects, and is thus an excellent candidate for future comparative studies on insect flight performance.

127.8 CRANDALL, K.A.; George Washington University; *kcrandall@gwu.edu*

Assembling the Tree of Life with a special focus on the Freshwater Crayfish

The US National Science Foundation has sponsored a Tree of Life program for the past 10 years, yet there appears to be no completely assembled tree. Recently, NSF funded a group of collaborators to assemble the Tree of Life. I will outline our team and our approach to assembling the tree of life. Furthermore, I will invite all of you to add branches and leaves to the tree to help flush it out to the best of our abilities. I will then take a look at this tree with respect to the decapod crustaceans and in particular the freshwater crayfishes – outlining the details of their phylogenetic relationships. The decapod relationships are the culmination of the last 6 years of effort of the Decapod Tree of Life group. We used a combination of Sanger and next-gen sequencing approaches to sample decapods from 90% of the 185 extant families resulting in the most comprehensive sampling to date. I demonstrate the implications for our phylogeny on taxonomic relationships, morphological evolution of key features, and timing of major diversification events. I will pay particular attention to the lobsters and then the freshwater crayfishes.

P1.198 CRANDELL, KE; University of Montana, Missoula; *kristen.crandell@umontana.edu*

The function of avian distal wing bones during flight

Avian wing bones have specialized via fusion and reduction to form a four-bar automatic linkage system and reduce distal limb mass. Given this reduction, the complexities of wing motion during upstroke are surprising. We undertook the present study to better understand skeletal mechanisms of the linkage system and wrist. Wrist bones have been highly reduced to two main bones: the radiale and the ulnare. These two bones have specific morphologies that correlate with wing stroke style during slow flight. Early studies of morphology suggest that the wing tip reversal upstroke style occurs due to a passive interaction between the wrist bones. To produce the pronation of the manus during upstroke, the ventral ridge of the carpometacarpus is thought to slide along the ventral ramus of the ulnare. During downstroke, this same morphology is thought to transfer distal force on the wing from the carpometacarpus to the ulna. These key morphological features of the wrist are relied heavily upon as diagnostic clues toward aerial or terrestrial lifestyle of fossils. As these predictions are based off of morphology alone, here we explored the interaction of the distal wing bones in the pigeon during slow level flight, using bi-planar fluoroscopy and marker-based XROMM to reconstruct 3-D motion. Our data suggest that the manus operates independently of both the radiale and ulnare during upstroke. Further, we find preliminary evidence that supports a "flat plate" hypothesis: each bone element appears to follow as predicted by an automatic linkage system during downstroke and provide a unified, flat 4-bar system. NSF IOS-0923606 and IOS-0919799.

P1.89 CRANE, R.L.*; MERZ, R.A.; Swarthmore College; *rcrane140@gmail.com*

Are they stuck in the mud: Sediment properties and the burrowing abilities of two species of lugworm in False Bay, Washington

If burrowing organisms use crack propagation to move through the sediment, then the material properties of the sediment affecting crack growth should relate to animal distribution and their success in burrowing. Material properties of the sediment are also likely to be related to grain size distribution. To test these ideas we examined two morphologically similar species of lugworm that inhabit different areas of False Bay, WA. We developed a penetration test to quantify the stiffness of undisturbed sediment in the field at sites inhabited by either *Abarenicola pacifica* or *Abarenicola claparedi*. We collected sediment cores at these sites and analyzed their grain size distributions. *A. pacifica* lived exclusively in stiffer, poorly-sorted sediments with a high proportion of silts and clays, while *A. claparedi* were found only in less stiff, well-sorted sediments dominated by fine sands (0.125-0.250 mm). Additionally, we observed and timed individuals of both species burrowing in the field in both types of undisturbed sediment. *A. claparedi* struggled in the stiff sediment. They were slower to initiate successful burrows and when they did so burrowed at shallower angles. In contrast, in both sediment types, *A. pacifica* initiated burrows more quickly and typically constructed nearly vertical burrow shafts. Although larval settlement initially dictates the distribution of these species, both are reported to periodically relocate as juveniles or adults. Our experiments show that if this is true, *A. claparedi* would be unsuccessful in moving into or through stiffer muddy sediments. *A. pacifica* would not seem to be limited by initiating a burrow in softer sediments associated with *A. claparedi*, but its exclusion from these areas suggests that it is limited by some other factor.

4.4 CRAVEN, B.A.*; RICHTER, J.P.; RUMPLE, C.R.; QUIGLEY, A.P.; RANSLOW, A.N.; NEUBERGER, T.; KRANE, M.H.; YEE, K.K.; WYSOCKI, C.J.; VAN VALKENBURGH, B.; Penn State University, Monell Chemical Senses Center, University of California, Los Angeles; *craven@psu.edu*

Reconstructing Respiration and Olfaction in the Mammalian Nasal Cavity

The mammalian nasal cavity is a multi-purpose organ that houses a convoluted airway labyrinth responsible for respiratory air conditioning, filtering of environmental contaminants, and chemical sensing. Because of the complexity of the nasal cavity, the anatomy and function of these upper airways remain poorly understood in most mammals. However, recent advances in medical imaging, experimental and computational methods, and histological techniques are now permitting examination of interspecies differences in nasal anatomy and the resulting functional implications regarding respiration and olfaction. This presentation will highlight the research being carried out by our multidisciplinary team to better understand the form and function of the nose in different mammalian species that include terrestrial and semi-aquatic carnivorans (coyote, bobcat, sea otter), ungulates (white-tailed deer), and rodents (gray squirrel). Specifically, modern high-resolution medical imaging modalities are being combined with histological data to generate three-dimensional virtual reconstructions of the mammalian nose, which are used in computational fluid dynamics (CFD) simulations of nasal airflow, respiratory heat and moisture exchange, and odorant mass transport. State-of-the-art flow measurement experiments in transparent physical models are being used to validate the computational simulations. An overview of our approach, techniques, and results to date will be presented. Supported by NSF grants IOS-1120375 (to BAC and MHK), IOS-1118852 (to CJW), NSF IOB-0517748 (to BVV), and NSF IOS-1119768 (to BVV).

P1.203 CRAWFORD, C.H.*; KING, B.D.; CLARK, A.J.; College of Charleston; *crawford.callie@gmail.com*

Material Properties of Taut and Slack Skins in Elongate Fishes

The mechanical response of fish skin to tensile stresses produced by axial bending during swimming could vary with tautness. High skin tautness in lamprey, cartilaginous fishes, and bony fishes results from myoseptal tendinous connections between the skin and axial muscles. Hagfishes possess loose-fitting skin due to the absence of these myoseptal connections yet employ the anguilliform mode of swimming also used by elongate taxa with tighter skin. We compared the tensile mechanics of loose skin from Pacific hagfish, *Eptatretus stoutii*, with tight skin from sea lamprey, *Petromyzon marinus*, and penpoint gunnel, *Apodichthys flavidus*. Skin samples were dissected from dorsolateral surfaces at 25% and 75% TL, and then subjected to quasi-static uniaxial tensile tests to failure. We measured strength (peak stress) and stiffness (Young's modulus) from *E. stoutii* skin and *A. flavidus* skin loaded in both longitudinal and circumferential directions, and stiffness from *P. marinus* skin loaded longitudinally. Mean stiffness and strength in all species examined occur within the range observed in other fishes. Neither strength nor stiffness differed significantly with respect to location on the body in any species. Hagfish and gunnel skins are anisotropic, with *E. stoutii* skin being more resistant to longitudinally directed stresses, and *A. flavidus* skin being more resistant to circumferentially directed stresses. The anisotropy in *A. flavidus* skin is characteristic to published records on elasmobranch and teleost skins. The atypical pattern of anisotropy in hagfish skin may be attributed to its reduced tautness and the extreme knotting and torsional movements readily employed during feeding bouts on oversized prey.

S6-2.3 CRESPI, Erica J.*; WARNE, Robin W.; LEDON-RETTIG, Cristina C.; Washington State University, Southern Illinois University, North Carolina State University; *erica.crespi@wsu.edu*

Integrating stress physiology with quantitative evolutionary models to predict population responses to environmental change: An amphibian perspective

The allostatic load and reactive scope conceptual models provide a rubric for integrating neuroendocrine stress axis activity with intrinsic and extrinsic factors within a life history; however the challenge ahead is to design studies that test specific ecological and evolutionary hypotheses with physiological data. Therefore, we need to take concepts generated by either allostatic load or reactive scope models one step further to determine how relationships between glucocorticoids and fitness (survival or reproduction) impact evolutionary and population dynamics with the use of demographic, epidemiological and quantitative genetic models. These models can also be used in a predictive way to assess which life history traits we should be focusing on when relating the impact of GCs on life history traits to project population-level effects (e.g., use of parameter elasticities within demographic models). Here, we describe three studies of amphibians that have used quantitative models that explicitly examine the influence of glucocorticoids (in response to environmental stress) in 1) the process of evolutionary adaptation, 2) projecting disease dynamics, and 3) predicting population dynamics. In all three contexts, these models provided a framework in which individual-level stress responses can be scaled up to population-level assessments of stress in order to address broader biological questions. Future collaborations among environmental endocrinologists and evolutionary and population biologists will facilitate the integration of stress physiology into the fields of population biology, evolutionary ecology, and conservation biology.

S5-1.1 CREWS, D; University of Texas at Austin; *crews@mail.utexas.edu*

Targets for hormone-mediated sex ratio adjustment in vertebrates

When considering sex ratios, we have to first define the nature of the question. Are we speaking of the gonads, secondary and accessory sex structures, physiology, brain, behavior, or all of the above elements. If these elements are not concordant, the exceptions can prove illustrative of underlying processes at both the proximate and ultimate levels. At each of these levels 'sex' is the binary outcome resulting from the modulation of conserved networks of genes, proteins, cells, organs and, in the case of the brain, discrete nuclei. These networks operate at multiple, and sequential levels that usually are linear during the lifespan, but in some instances reversals are possible. For example, the gonads arise from a single anlagen and, in most instances ovaries or testes result, although ovotestes are the norm in some species and gonadal reversal a property of other species. Other sexually dimorphic structures differentiate from multiple anlaga by reciprocal and sex-specific atrophy/hypertrophy typically in an exaggerated manner, although the capacity to develop structures characteristic of the opposite gonadal sex remains inherent and intact. A perspective that integrates these different properties will be presented.

56.5 CRINO, O.L.*; DRISCOLL, S.C.; PRATHER , C.T.; BREUNER, C.W.; University of Montana; *ondicrino@gmail.com*

Does developmental stress modulate reproductive tactics in the zebra finch?

The long-term effects of developmental stress on phenotype and performance are well-known. In comparison, the effects of developmental stress on fitness remain largely unexplored. Developmental stress in known to decrease the quality of sexually selected traits (e.g. bird song) and, therefore, is assumed to decrease reproductive success. However, animals exposed to developmental stress may compensate for poor quality sexually selected traits by pursuing alternative reproductive tactics such as increased parental investment. Here, we explored the fitness consequences of developmental stress in male zebra finches (*Taeniopygia guttata*). Specifically, we investigated whether adult males exposed to stress during development sire fewer nestlings through extra-pair copulations, but invest more in parental behavior and, thus, rear nestlings in greater condition. These data will allow us to empirically evaluate how developmental stress affects reproductive success and draw inferences about the role of developmental stress in shaping alternative reproductive tactics.

58.4 CRISWELL, KE*; FINARELLI, JA; FRIEDMAN, M; GARWOOD, R; COATES, MI; University of Chicago, University College Dublin, Oxford University, University of Manchester and Diamond Light Source; *kcriswell@uchicago.edu*
Deltoptychius: investigating the roots of the chimaeroid cranial condition
Chondrichthyes includes elasmobranchs and holocephalans, but little is known about the early memberships of these groups. In the early 1980s the fossil collector S. P. Wood discovered exceptional specimens of *Deltoptychius*, a Lower Carboniferous holocephalan, while excavating the fossil fish site at Bearsden, Scotland (Serpukhovian: ~326-318 Ma). *Deltoptychius* traditionally was diagnosed by features including a head shield and presence of mandibular spines. CT scanning of the Bearsden specimens revealed numerous characters that were not previously known, including details of the braincase concealed by the dermatocranium. Additional comparisons with recent chimaeras and early chondrichthyans such as *Chondrenchelys*, iniopterygians, and *Pucapampella*, allowed us to investigate character transformations that occurred during the evolutionary history of this group. *Deltoptychius* shares with modern holocephalans the anterior location of the jaw articulation, similar size and position of the otic capsules, the presence of tooth plates, and the presence of a dorsum sellae. However, more primitive characteristics also are present. For the first time we see cranial characters approaching the general gnathostome condition within an otherwise undeniably holocephalan taxon.

83.6 CROCE, H.M.*; TURNER, R.L.; Florida Institute of Technology; *hcroce@my.fit.edu*
The Gomphoid Synarthrosis: a New Joint in Echinoderms
Certain ossicles in crinoid, echinoid, asteroid, and ophiuroid echinoderms have long been thought to fuse. The development of these ossicle systems has not been well studied, often due to obstruction by other ossicles. Here, the development of vertebral ossicles in the ophiuroid *Ophiophragmus filograneus* was examined. Arm tips, cleaned of soft tissue, were studied using scanning electron microscopy. Vertebral ossicles originate under the ocular in halves. The two ambulacral ossicles grow towards each other; the stereom branches and eventually interdigitates like a three-dimensional jigsaw puzzle. As vertebrae grow, ambulacral ossicles interlock tightly, creating a suture line, which has been taken before as evidence of fusion. In mature vertebrae, the suture line was not always visible at articular surfaces, indicating fusion. This study suggests that interdigitation of ambulacral ossicles forms an immobile joint, a gomphoid synarthrosis, joining vertebral ossicles in ophiuroids. We examined the gomphoid synarthrosis in vertebrae for the percentage by weight of magnesium making up the stereom. A higher magnesium content imparts greater strength to the ossicle; thus, this area is an excellent candidate for strengthening with magnesium. The gomphoid synarthrosis in *O.filograneus* vertebrae is not, however, strengthened in this way. Other ossicle systems in echinoderms reported to fuse include compound plates and auricles of Aristotle's lantern in echinoids, genital plates of irregular echinoids, the circumoral ring of brisingid asteroids, and infrabasal calyx plates and juncture of the stem and calyx in crinoids. These ossicle systems will also be examined for the presence of a gomphoid synarthrosis or fusion.

P1.114 CROCKER-BUTA, S.P*; SECOR, S.M.; University of Alabama, Tuscaloosa; *spcrockerbuta@crimson.ua.edu*
Determinates and repeatability of specific dynamic action for the corn snake Pantherophis guttatus
Mandatory to meal ingestion, digestion, and absorption is an increase in energy expenditure that accumulates as the specific dynamic action (SDA) of the meal. To explore determinants of the magnitude and duration of the SDA response, we examined the effects of meal size, body temperature, and body size on the postfeeding metabolic responses and SDA of the corn snake *Pantherophis guttatus*. We also tested the repeatability of the SDA responses among a group of corn snakes that repeatedly consumed rodent meals equaling 25% of snake body mass. For meals ranging from 5% to 45% of snake body mass, postprandial peak VO_2, duration of significant metabolic response, and SDA increased with meal size. A 9-fold increase in meal size generated an 11-fold increase in SDA, due to a 2.6-fold increase in peak VO_2 and a 4-fold increase in duration. Experiments conducted at 20, 25, 30, and 35 C with 25% meal sizes demonstrated a temperature dependent increase in standard metabolic rate (SMR) and peak VO_2 with body temperature. However there was no significant variation in SDA or the SDA coefficient among temperature treatments. Over a 46-fold range in body mass, SMR, peak VO_2, and SDA scaled with mass exponents of 0.77, 0.93, and 1.00. For a set of 10 individuals consuming 25% size meals in multiple trials, none of the measured (e.g., SMR and peak VO_2) or calculated (e.g., scope, SDA, and SDA coefficient) variables differed among or between trials.

55.2 CROCKETT, E.L.; Ohio University; *crockett@ohiou.edu*
Risky Fats and Antioxidant Arsenals in Cold- and Warm-Bodied Fishes
Fishes living at cold body temperatures are rich in biological membranes that are fortified with polyunsaturated fatty acids (PUFA). PUFA are particularly susceptible to lipid peroxidation, a process initiated by reactive oxygen species (ROS) and propagated by oxidized lipids. Lipid peroxidation can damage the structure and integrity of biological membranes, and compromise the function of membrane-associated proteins. Although fishes at warmer temperatures do not contain as much lipid, or PUFA, they are confronted by higher rates of ROS production and lipid peroxidation. In our work with intracellular membranes from both temperate and Antarctic fishes, it is becoming apparent that phospholipid composition alone does not predict the inherent susceptibility of biological membranes to lipid peroxidation. Total antioxidant capacities, levels of low molecular weight antioxidants, and potential oxidants contribute to the protection against, or promotion of, oxidative injury. Activities of enzymatic antioxidants, including the family of glutathione peroxidases, are not altered with temperature acclimation. Levels of products of lipid peroxidation (e.g., phospholipid hydroperoxides) are a function of lipid quantity, more so than compositional quality. Taken together, our studies indicate that despite higher lipid contents, the risks of lipid peroxidation at low temperature are not greater than those faced by animals at warm temperatures. Fishes at cold and warm temperatures appear to require different arsenals to provide sufficient protection against lipid peroxidation. Supported by NSF IOS 0842624, ANT 0741301 and ANT 1043576.

61.1 CROFTS, S; Univ. of Washington, Seattle; *croftss@uw.edu*

The effects of tooth structure and loading on the distribution and magnitude of strain in durophagous teeth

A broad range of taxa, both extant and extinct, have teeth that are specialized to break hard prey items, including several elasmobranch lineages, bony fishes, mammals and reptiles. These teeth have two competing functional demands – to break the prey item and to avoid breakage themselves. While these teeth all serve the same general function, shapes ranges from broad flat plates, to more rounded teeth with stress concentrators, and even cupped shapes. Furthermore there are presumably different constraints on teeth, dependent on the frequency that they are used and replaced, and the specific hard prey. To better understand the functional constraints on tooth morphology, I digitally constructed four series of models that graded from one morphological extreme to another, covering the range of tooth morphologies seen in nature. These models varied in the degree of convexity and concavity of the occlusal surface, and the morphology of a stress concentrating cusp. Using finite element analysis (FEA), I applied different loading regimes to the models, to mimic different potential prey items. I measured maximum principal strain to determine which model teeth would be most likely to fracture, and where that fracture would be most likely to occur. Both the magnitude of strains and the distribution through the models changed with the morphology and with different loading regimes. This suggests different optimal shapes, where strain is lowest in the tooth, possibly dependent on prey type. Laser scans of the slightly domed teeth of the extinct placodont *Placodus sp.*, were also analyzed and compared to the predicted optimal tooth shapes.

45.2 CROSSIN, GT*; PHILLIPS, RA; LATTIN, CR; ROMERO, LM; WILLIAMS, TD; Dalhousie University, British Antarctic Survey, Tufts University, Tufts University, Simon Fraser University; *gtc@dal.ca*

Corticosterone mediated costs of reproduction facilitate a tradeoff between current and future reproduction.

Life-history theory predicts costs of reproduction. One possible mediator of those costs involves the secretion of glucocorticoid hormones, which can be indexed by analyzing concentrations in feathers grown during breeding activity in birds. In the broadest sense, glucocorticoids mediate physiological responses to unpredictable environmental stressors, function as metabolic regulators during predictable events like reproduction, but can also have negative effects (e.g. moult, brood desertion). Here we show that corticosterone ("Cort") in feathers grown during the reproductive season reflects breeding effort in two Antarctic seabird species (giant petrels, *Macronectes spp.*). In females of both species, but not males, feather Cort (fCort) was nearly 1.5 fold higher in successful breeders versus failed breeders (those that lost their chick), suggesting a cost of successful reproduction; high fCort levels in females reflect the elevated plasma Cort levels required to support high metabolic demands of successful chick-rearing. Increased fCort and successful breeding also led to delayed moult prior to winter migrations. By monitoring individuals in the following year, we then link fCort levels and pre-migration moult score to subsequent breeding effort. A cost of reproduction, as indexed by high fCort and a delayed initiation of moult, were predictive of deferred breeding in the following year. Cort levels and the timing of moult thus provide a potential mechanism for the tradeoff between current and future reproduction.

105.2 CROSTON, R.*; HAUBER, M.E.; CUNY Graduate Center, CUNY Hunter College, CUNY Graduate Center; *RCroston@gc.cuny.edu*

Spectral tuning and foreign egg rejection in American robins (Turdus migratorius)

By laying their eggs in the nests of other birds, avian brood parasites impose the cost of rearing their young upon the hosts. Recognition and rejection of foreign eggs are the primary and most effective host defenses against costly brood parasitism. Yet, hosts of parasitic brown-headed cowbirds (*Molothrus ater*) challenge co-evolutionary theory because most hosts accept parasitic eggs despite their drastically different appearance from the hosts' own. American robins (*Turdus migratorius*) are one of few cowbird hosts to reject foreign eggs. Previous research yielded equivocal evidence whether egg rejection by robins evolved specifically in response to cowbird parasitism, or is based on recognition of own eggs and not specific to cowbird eggs. Our research employed avian visual perceptual modeling and behavioral experimentation to investigate mechanisms driving parasitic egg rejection in robins. We modeled effects of overall chromatic difference as JNDs (just noticeable differences) on rejection rates in response model eggs with artificial colors spanning the entire avian spectral sensitivity range. We then modeled effects of differences in quantum photoreceptor catches between natural and model eggs to determine which photoreceptor inputs best predict the rejection responses. The model best predicting rejection rates contained values from all photoreceptor types in the avian visual system, but JND values were not significant. Experimental eggs mimicking cowbird egg ground color were rejected in all experimental trials, but these differed little in JND value from both real and model robin mimetic eggs, which were typically accepted. We propose a nested rejection criterion where foreign egg rejection is driven primarily by differences across most regions of the avian visual spectrum, but beige eggs (as laid by parasitic cowbirds) are also always rejected.

12.4 CUFF, A.R.*; RAYFIELD, E.; University of Bristol, UK; *Andrew.Cuff@bristol.ac.uk*

Finite element validation of an avian skull using ex vivo measurements

Finite element models (FEMs) have potential to describe the detailed biomechanics of musculoskeletal systems. Validation studies assist in deducing how models reflect reality, yet in avians this is particularly difficult due to thin bone, the presence of a keratinous rhamphotheca and the kinetic nature of skulls. In order to validate a FEM of a large avian skull, a computed tomography (CT) scanned ostrich (*Struthio camelus*) skull was dissected and an artificial tendon (carbon fiber loops embedded in resin) attached at the M. psuedotemporalis superficialis muscle site. Using a specialised rig, the artificial tendon had loads applied that were within limits ascertained from PCSA during dissection. The strains on the skull were measured *ex vivo* using strain gauges applied to 14 sites. Using the CT scans, the cortical bone, cancellous bone, sutures and rhamphotheca were segmented using Avizo 6.3. The surface generated was transferred into Hypermesh 10 to produce a series of models with increasingly fine mesh size (convergence testing). Using the converged mesh size, the model was loaded with identical boundary conditions to the *ex vivo* skull. Material properties from both the literature and nano-indentation studies on another ostrich skull were used. Results show that there are broad similarities between *ex vivo* measurements and models run with homogenous properties from either the literature or nano-indentation. The presence of sutures affects strains differently across the entire skull, whilst a rhamphotheca lowers strains. Principal strain alignments are also closely matched. By validating the method on avian skulls it allows more accurate parameterisation for future studies.

14.2 CUI, R.*; SCHUMER, M.; KRUESI, K.; ANDOLFATTO, P.; ROSENTHAL, G.; Texas A&M University, Princeton University, Universidad Nacional Autónoma de México; *melop@tamu.edu*

Revealing extensive reticulate evolution in Xiphophorus fishes using high-throughput phylogenomics

Recent research has demonstrated that hybridization, a process once thought rare in animals, is remarkably common. Though hybridization presents challenges in reconstructing phylogenies, it may play an important role in adaptation (and potentially speciation) in many species. In the present study we use next-generation sequencing techniques to examine phylogenetic relationships, historical gene flow and its implications in biogeographic patterns and trait evolution in a genus of freshwater fish (*Xiphophorus*). We found extensive ancient gene flow between and within clades. Two species were found to contain almost even-admixture of genomes from different ancestries, making them good candidates for hybrid speciation. Other species contained smaller proportions from the minor ancestry. Cyto-nuclear conflict of topology was found to be an unreliable indicator of hybridization. Sexually selected traits can be better optimized on a reticulate phylogeny and the sword ornament may have spread through hybridization. The new phylogeny also shed light on palaeobiogeography of the genus. We identified multiple secondary invasions by platyfishes towards the north across the trans-mexican volcanic belt, followed by hybridization with earlier settlers. Our study highlights the potential role of hybridization in these fishes. QTL mapping of ecologically or sexually important traits will allow us to investigate in more detail the role of introgression in adaptation and speciation.

76.1 CULLEN, J.A.*; MAIE, T.; SCHOENFUSS, H.L.; BLOB, R.W.; Clemson Univ., St. Cloud State Univ.; *jcullen@clemson.edu*

Can exaptation facilitate terrestrial invasion? Oral kinematics of climbing and feeding in a waterfall-climbing gobiid fish

Species of the gobiid fish genus *Sicyopterus* use a novel inching behavior to climb waterfalls, in which an oral sucker is cyclically protracted and attached to the climbing surface. This genus also has a distinctive feeding behavior in which the premaxilla is cyclically protracted to scrape diatoms from the substrate. With such generally similar motions, it is possible that one of these distinctive patterns was coopted from the other, representing an example of evolutionary exaptation. To evaluate this possibility, we used high-speed video to film climbing and feeding in *S. stimpsoni* from Hawai'i, and measured oral kinematics for two comparisons: (1) Feeding kinematics of *S. stimpsoni* vs two suction feeding gobies (*Awaous guamensis* and *Lentipes concolor*), to assess what novel jaw movements are required for algal grazing; (2) Oral kinematics in feeding vs climbing for *S. stimpsoni*, to quantify their similarity and evaluate the potential for either to represent an exaptation from the other. Premaxillary movements were most different between scraping and suction feeding taxa. Between climbing and feeding, *S. stimpsoni* showed significant differences in the maximum values of several kinematic variables, but overall profiles of motion through the cycle matched very closely for most variables, even with differences in maximum values. Current data cannot resolve whether oral kinematics for climbing was coopted from feeding, or feeding kinematics coopted from climbing, but similarities between feeding and climbing in *S. stimpsoni* are consistent with evidence of exaptation, with modifications, between these behaviors. NSF-IOS 0817911, 0817794.

P2.15 CULPEPPER, K.M.*; PODRABSKY, J.E.; Portland State University; *kristin8@pdx.edu*

Expression levels of cell cycle regulator Akt (PKB) reveals contradictory results during diapause and anoxia-induced dormancy in embryos of the annual killifish Austrofundulus limnaeus.

Understanding the molecular underpinnings of anoxia tolerance may aid in the prevention and treatment of stroke and ischemia in humans. Embryos of the annual killifish, *Austrofundulus limnaeus*, enter a state of metabolic and developmental arrest termed diapause II (DII) in order to survive the dry season of their natural habitats, ephemeral ponds in South America. Additionally, previous reports show that throughout development *A. limnaeus* embryos have 2-fold magnitude higher anoxia tolerance than any other vertebrate studied, making them an excellent model to study the effects of oxygen deprivation. Due to this astonishing feat, we examined the role of Akt (Protein Kinase B), a serine/threonine-specific kinase involved with G_1- to S-phase transitions, across development of *A. limnaeus* embryos and in response to anoxia. Immunoblot results revealed that phosphorylated Akt (pAkt) levels steadily increased following fertilization, peaked at DII, and decreased during subsequent development, except for a stage-specific spike in concentration at 12 days post-DII (dpd). These data suggest that cell cycle arrest associated with entrance into DII is not regulated by low levels of pAKT. Next, we assayed pAkt levels in 12 dpd embryos subjected to 1h and 48h of anoxia, followed by 1h, 6h, and 24h of recovery. Levels of pAkt were significantly reduced following 48h exposure to anoxia and protein expression returned to control levels by 6h of normoxia. This suggests that pAkt may play a role in arresting cell cycle progression in embryos exposed to prolonged anoxia. Overall, our results indicate a contradictory role for pAkt in cell cycle regulation associated with diapause and anoxia-induced dormancy.

134.1 CUNNINGHAM, CB*; NELSON, AC; RUFF, JS; POTTS, WK; University of Utah; *cbc83@uga.edu*

MUP expression is linked with sociality not competitive ability in male house mice

Although success in physical conflict is a major determinant of mammalian fitness, little is known about the relationship between chemical communication and an individual's competitive ability. Mice excrete large amounts of protein in their urine, most of which are Major Urinary Proteins (MUPs). MUPs are polymorphic and are involved in signaling individual identity, and their expression responds to changes in the social environment. However, it is not known how MUP expression relates to competitive ability. Here, we assessed the relationship between MUP expression, experience in a socially competitive environment, and competitive ability. Mixed sex groups were introduced into semi-natural enclosures and remained for multiple days to assess male competitive ability; urine samples were taken before and after each of two rounds of competition. MUP expression was strongly influenced by accumulating social experience; i.e., MUP expression increased after each social period. This supports the idea that MUPs function in social communication. Surprisingly, competitive ability lacked a strong association with MUP expression. However, a sire's competitive ability was negatively associated with his sons' MUP expression. This suggests that competitive ability might have a trans-generational influence on MUP expression. In conclusion, our results challenge the claim that MUP levels are not biologically meaningful.

P2.6 CUPP, JR, P/V; Eastern Kentucky University;
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Posthatching Brooding Behavior in Green Salamanders, Aneides aeneus

In SE Kentucky, female *Aneides aeneus* rear their young in crevices of sandstone rock cliffs. Following an egg brooding period of about 73 days, females remain with the hatchlings for 3-5 weeks. Eggs deposited in July hatch in late September. At first, new hatchlings are aggregated on the remaining egg suspension material. Females remain near and in front of hatchlings. After the first week or two, the hatchlings continue to remain close but show some movement. One or two of them may move into small recesses within the crevice. Into week three, hatchlings may begin to move about the crevice and to other adjacent crevices. During 3-5 weeks after hatching, the young may venture out to other areas. The number of young often dwindles somewhat. In some instances, females left the young and did not return. While only females have been reported to brood hatchlings, in this study, a male was observed in front of a group of hatchlings for three successive weeks. In another instance, one hatchling was found on the tail of a male in a crevice adjacent to a brooding crevice containing a female. Posthatching brooding behavior may play an important role in the survival of hatchling green salamanders.

P1.141 CURRIE, A/E*; PODOLSKY, R/D; University of Maryland, College Park; *acurrie@umces.edu*

Effects of temperature on ouabain-insensitive ATPase activity in tube feet of northern and southern populations of the sea urchin Arbacia punctulata

Changes in ocean temperature are expected to have widespread effects on biological processes. Identifying temperature-sensitive processes that are critical to function is important for understanding both patterns of geographic variation and future responses to climate change. Population comparisons offer a way to examine past responses to temperature and other abiotic factors along a latitudinal gradient. We focused on enzymatic activity in tube feet of the sea urchin *Arbacia punctulata*, in particular the effects of temperature on the activity of Na+K+-ATPase. This enzyme can be responsible for a substantial (25 to 40%) portion of the total energy budget and tube feet are one of the most metabolically active tissues in the sea urchin body. We compared northern (Woods Hole, MA) and southern (Charleston, SC) populations that were collected and held at temperatures differing by about 10ºC. Assays on tissue homogenates were run with and without ouabain, a glycoside known to specifically inhibit Na+K+-ATPase activity, to measure the contribution of this enzyme to total ATPase activity. Across a range of concentrations (0.1 to 16 mM) ouabain showed little to no effect on ATPase activity. Total activity for both northern and southern animals increased linearly as a function of assay temperature. Contrary to our predictions, at any given temperature ATPase activity standardized per unit protein was higher in the southern population, although when standardized per unit tube foot surface values were more similar. These data suggest that populations at colder temperatures may be less equipped to maintain adequate levels of ATPase activity in metabolically active tissue and may be most sensitive to anticipated temperature increases.

P2.219 CURTIS, NE*; MIDDLEBROOKS, ML; SCHWARTZ, JA; PIERCE, SK; Rollins College, Univ. of South Florida;
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PAM analysis of 3 sacoglossan species reveals differences in photosynthetic function and chloroplast longevity

The sea slug *Elysia clarki* sequesters photosynthetically functional chloroplasts from at least a dozen algal species and maintains these plastids for up to 4 months. *Elysia patina* and *Placida kingstoni* also feed on some of the same species, but cannot maintain plastids longer than 2 weeks. We starved *E. clarki*, *E. patina*, and *P. kingstoni* until they lost their green coloration, and then *E. clarki* were fed on either *Bryopsis plumosa* or *Penicillus lamourouxi*, while *E. patina* were fed *P. capitatus* and *P. kingstoni* were fed *B. plumosa*. Photosynthetic activity was measured using PAM analysis and the slugs were immediately re-starved. PAM measurements continued with starvation until photosynthesis ceased. Initially, *P. lamourouxi* and *B. plumosa* fed *E. clarki* had photosynthetic rates that were statistically equivalent. However, as length of starvation increased, photosynthetic rates decreased. After 12 weeks, *B. plumosa* fed *E. clarki* were not photosynthesizing, while *P. lamourouxi* fed *E. clarki* still had some PAM activity. Also, *P. capitatus* fed *E. clarki* (published previously) had lower PAM values than either *B. plumosa* fed or *P. lamourouxi* fed *E. clarki* at 0 weeks starvation, but higher values at 4 and 12 weeks starvation. Freshly fed *E. patina* had photosynthetic activity initially, which declined over the next 12 days of starvation. Freshly fed *P. kingstoni* specimens also had immediate photosynthetic activity, but it rapidly dropped to 0 over the next 4 hours of starvation. Thus, longevity and photosynthetic activity of sequestered chloroplasts in *E. clarki* depends on the algal source. However, among slug species, specific adaptations account for the tremendous variation in the length and functionality of these kleptoplastic associations.

137.3 D'AGUILLO, M.C.*; HAROLD, A.S.; College of Charleston ; *mcdagu@email.wm.edu*

Detection and characterization of an ontogenetic diet shift in the Naked Goby, Gobiosoma bosc

Ontogenetic shifts in diet allow organisms to maximize energy conservation, presumably by reducing the time spent foraging or increasing net energy intake. As many diet studies are descriptive and report only frequency or counts of prey items, the ability to precisely quantify and describe a diet shift can be challenging. The goals of this study were to report the diet composition of the Naked Goby, *Gobiosoma bosc*, and examine if there is a threshold body size at which the diet shifts from dominance of meiofauna to dominance of macrofauna. *Gobiosoma bosc* specimens were collected from oyster reefs in the Charleston Harbor estuary by examination of removable oyster shell and seine. To investigate diet composition, the digestive tract was removed from *G. bosc* individuals and prey types were identified to the lowest taxonomic level possible, measured, and enumerated. Stomach content analysis reveals *G. bosc* primarily consumes harpacticoid copepods from the meiofauna, and polychaetes and amphipods from the macrofauna. The consumption of macrofauna begins at a small predator size (11 mm standard length), and while the number of macrofaunal organisms ingested does not increase with predator size, the volume of macrofauna does. Both the number and volume of meiofaunal organisms consumed decreases with predator standard length, suggesting strong reduction of meiofauna in the diet around a predator size of 25 mm. The use of different prey response variables to characterize a diet shift, with insights into the potential roles of morphology and behavior driving this particular diet shift, will be discussed.

22.2 D'ALBA, L*; JONES, D; BADAWY, H; SHAWKEY, MD; University of Akron, Griffith University; *ldalba@wooster.edu*

Mechanisms of egg defense in Megapodes: avoiding infection in a compost heap

Interactions, over evolutionary time, between bacteria and vertebrate animals remain poorly understood. Infection is an important source of mortality for avian embryos but parental behaviors and eggs themselves can provide a network of antimicrobial defenses. Australian brush-turkeys (Alectura lathami) are unique among birds in that they produce heat for developing embryos not by sitting on eggs but by burying them in carefully tended mounds of soil and microbially decomposing vegetation. Despite the extremely high microbial abundance in these mounds, brush-turkey eggs are rarely infected, suggesting that they possess strong defensive mechanisms. To identify these mechanisms we first quantified antimicrobial albumen proteins and characterized eggshell structure, finding that albumen was not unusually antimicrobial, but that eggshells present a cuticle composed of nanometer-sized calcite spheres. Experimental tests revealed that these modified eggshells were significantly more hydrophobic and better at preventing penetration into the egg contents than control eggs. Our results show that the mutualistic cultivation of bacteria by megapodes has necessitated the evolution of novel defense mechanisms against parasitism.

P1.142 D'ELIA, G.; FEIJOO, M.; LESSA, E.P.; NAYA, D.E.*; PARDIñAS, U.F.J.; TETA, P.; TOMASCO, I.H.; VALDEZ, L.; Universidad Austral de Chile, Chile, Universidad de la Republica, Uruguay, Centro Nacional Patagonico, Argentina; *dnaya@fcien.edu.uy*

Comparing digestive and renal traits among populations of the rodents Abrotrhix olivacea and A. longipilis

The present study was aimed at evaluating variation in several attributes related to digestive and renal physiology in four populations of *Abrotrhix olivacea* and four populations of *A. longipilis*, at from two different latitdues (40ºS and 47ºS) and inhabiting two contrasting biomes (Austral forest and Patagonian steepe) at each latitude. We found that: (1) Except for the southern population of *A. longipilis*, individuals from the steepe are smaller than individuals from the forest and have lighter small and large intestines; (2) The weight of the stomach and the cecum did not change with latitude or habitat; (3) Kidneys wet mass and the U/P ratio did not show a clear pattern of variation with regard to latitude nor to habitat. However, when data are reanalized as function of the annual rainfall recorded at each locality, it is observed: (1) A positive correlation between (residuals of) small intestine wet mass and rainfall; (2) A negative correlation between (residual of) kidneys wet mass and rainfall only for *A. olivacea*; (3) A negative correlation between U/P and rainfall. Hence, obtained results indicate that digestive and renal traits are correlated, at the population level, with the accumulated rainfall; that is, with the environmental variable that is probably driving the major differences among the two biomes evaluated. Founded by: FONDECYT 1110737 (Chile), CISC C043-348 (Uruguay), PICT 2008-0547 (Argentina).

P1.151 DABE, E.C.*; KOHN, A.B.; BOBKOVA, Y.; KOCOT, K.; CITARELLA, M.; BOSTWICK, C.J.; WINTERS, G.C.; SWALLA, B.J.; MOROZ, L.L.; University of Florida,Whitney Lab for Marine Biosciences, Marineland, FL, University of Washington, Seattle,WA; *edabe2@ufl.edu*

Epigenomic Signatures in Basal Metazoans: DNA Methyltransferase in Pleurobrachia bachei

DNA methylation is an epigenetic modification crucial to cell differentiation and development. In the majority of bilaterians 5-methylcytosine DNA methylation occurs at CpG sites and islands controlling gene transcription. Contrary to *Drosophila* and *C. elegans* that have lost this machinery, possibly due to their compact genome sizes and short life cycle, here we show that the phylum *Ctenophora* has conserved methylation machinery. Using the data from the recently sequenced genome of *Pleurobrachia bachei* we cloned DNA 5-cytosine methyltransferase (DNMT) and characterized its expression in major developmental stages and adult ctenophores.Distinctive mRNA expression in the digestive system, (stomach, pharynx and mouth), tentacles and unique patterns in between ciliated comb rows in adult Pleurobrachia collectively suggest that DNMT mRNA expression levels are both cell-specific and noticeable in areas of high proliferation. Next using colorimetric ELISA assay for methylated DNA we directly showed that DNA methylation does occur in the Pleurobrachia genome, although it was significantly lower than in the molluscan (*Aplysia*) and mammalian (*Ratus*) nervous tissues. Combined, our data suggest that the small genome of the ctenophore *Pleurobrachia bachei* has functional DNA methylation machinery, possibly involved in epigenetic control of somatic cell divisions and regulation of mRNA expression at zones of proliferation.

P2.41 DABRUZZI, TF*; RIBERO, L; POLGAR, G; BENNETT, WA; University of West Florida, University of Malaya; *tfd2@students.uwf.edu*

The Life Less Aquatic: Water loss resistance in mudskippers and its role in emergent behavior

Mudskippers are amphibious fishes common to tropical western Pacific mangrove habitats. In areas with two or more syntopic species, emersion patterns and presumably desiccation risks can vary greatly. We hypothesized that mudskippers would exhibit significant resistance to water loss, and that resistance values would differ relative to each species' emergent behavior and habitat conditions. Total and cutaneous resistance to evaporative water loss were determined for barred, *Periophthalmus argentilineatus* and common, *Periophthalmus kalolo* mudskippers from mangroves on Hoga Island, southeast Sulawesi, Indonesia as well as for golden spotted, *Periophthalmus chrysospilos*, and dusky gilled, *Periophthalmus variabilis*, mudskippers from mangroves in Kula Lumpur, Malaysia. All four species tested showed significant cutaneous resistance values when compared to their agar replicates; however, no significant differences were found between total or cutaneous resistance values between species. Water loss resistance values were somewhat low, but no doubt play an important role in extending emergence times. Higher resistance values may not be compatible with cutaneous respiration or necessary for fishes that must frequently return to pools to eliminate nitrogenous wastes.

140.2 DAILEY, R.E.*; RICHMOND, J.P.; University of North Florida, Jacksonville; *rachael.dailey@unf.edu*

Impact of nutritional status on ghrelin and growth hormone in phocid seal pups

Marine mammals have unique metabolic demands related to adipose accretion, yet previous studies show metabolic hormones involved in nutrient partitioning follow similar patterns to terrestrial mammals. Growth hormone (GH) and other components of the somatotropic axis promote growth, regulate nutrient partitioning, and are responsive to nutrient intake. In terrestrial mammals, GH increases with undernutrition, decreases with refeeding, and inhibits adipose accretion. Ghrelin responds similarly to GH with changes in nutrient intake, but has the opposite effect on adipose. Given this promotion of adiposity and the importance of adipose to marine mammals, we hypothesized that ghrelin may have a differential response to increased nutrient intake in marine mammals. This longitudinal study quantified ghrelin and GH from a fasted state through refeeding in harbor seal (n=10) and northern elephant seal (n=9) pups bi-weekly for 8 weeks. Body condition increased during refeeding ($p < 0.005$), reflecting lean tissue growth and adipose accretion. Surprisingly, ghrelin concentrations increased upon refeeding in both species ($p < 0.05$). However, in northern elephant seals ghrelin increased at week 2 ($p < 0.001$) while in harbor seals ghrelin increased at week 4 ($p < 0.05$). As expected, GH concentrations decreased throughout refeeding for both species ($p < 0.01$). While reduced GH concentrations favor adipose accretion, the atypical response of ghrelin may be a mechanism for promoting rapid compensatory deposition of lipids after fasting. Because significant adipose accretion is vital for survival in pinnipeds, this response to refeeding could be an adaptation to preferentially allocate nutrients to adipose when faced with nutritional challenges.

P3.151 DALLMANN, C.J.*; MONGEAU, J.-M.; JAYARAM, K.; MAHAVADI, A.; FULL, R.J.; Univ. of Bielefeld, Univ. of California, Berkeley; *jmmongeau@berkeley.edu*

Dynamic response of antenna flagellum in the American cockroach

The integration of information from sensory structures on a moving body during dynamic, high-bandwidth tasks is a challenge for locomoting animals and engineers seeking to design highly-mobile robots capable of autonomously navigating in natural environments. In locomotion-mediated tactile sensing both body and sensor dynamics must be quantified. We took the first step to elucidate the dynamic response of the sensor by studying the antennae of *Periplaneta americana*, a cockroach that escapes predators by integrating information from this sensory appendage in tasks such as wall following and collision avoidance while rapidly running up to 80 cm/s . High-speed videos of free vibration responses to initial deflections from five intact antenna flagella revealed a mean damped natural frequency of 18 ± 3.0 Hz and damping ratio of 0.52 ± 0.092. As the antenna was under-damped, 93.3% of the perturbation was rejected within the first cycle (69 ms), which corresponds to within one stride period during high-speed running. A linear, second-order model captured about 95% of the variance in the dynamic response. An impulse-like perturbation near the antennal tip revealed dynamics characteristic of a near perfect inelastic collision with antennal bending showing peak curvature close to the site of impact. Results suggest that antennae of *P. americana* are less damped than those of slowly walking stick insects, but more damped than vertebrate vibrissae. Further elucidating antennal mechanical tuning will lead to hypotheses integrating distributed mechanosensory inputs from a dynamic sensory appendage operating on a rapidly moving body and generate predictions about neural tuning and encoding.

38.4 DALTON, B. E. *; CRONIN, T. W.; CARLETON, K. L.; University of Maryland, Baltimore County; *briand7@gmail.com*

Coexpression of Spectrally Distinct Opsins: A Novel Mechanism of Photoreceptor Tuning?

Detection of predators is a critical task that many animals accomplish visually. Because predators often appear as dark objects, their detection can be facilitated by making the background appear as bright as possible. According to the matching pigment hypothesis, this is accomplished by a receptor that is tuned to the background light spectrum. In nature, the color of the background differs with angle of view. Therefore, maximizing predator detection across the visual field requires multiple receptors tuned to heterogeneous backgrounds. Although cone cells sensitive to different wavelengths have been found in varying ratios across the retinas of diverse animals, the ecological function of this variation is largely unknown. Here, we tested whether opsins are expressed in retinal regions where they increase light absorbance of the corresponding backgrounds. Using in situ hybridization we found that cichlid fish coexpress spectrally distinct opsin genes in specific regions the retina. In these regions, coexpression increases light absorbance of the respective viewing backgrounds. Thus, opsin coexpression seems to tune the photoreceptors to their light environment. We confirmed the presence of cone cells containing opsin mixtures by microspectrophotometry. Interestingly, the frequency of coexpression varies among individuals, from just a small number of widely distributed double cones in some fish, to regionally abundant coexpression in others. Visual modeling is being used to evaluate the effect of coexpression on detection distance of dark objects such as predators. Ongoing work also includes light habitat manipulation to examine phenotypic plasticity and in situ experiments to determine the opsin expression patterns of wild-caught individuals.

P3.29 DANIELS, K/D*; SCHROER, M/L; PROPPER, C/R; Northern Arizona University, Flagstaff; *kdd42@nau.edu*

Morphological and Behavioral Differences between a Fish Population from a Wastewater Effluent Pond Compared to a Reference Lake

Globally, reclaimed wastewater effluent (WWE) is an important resource for irrigation, recreation, creation of wetlands, and direct recharge of aquifers. However, in the last decade many studies have found that exposure to WWE affects several aspects of endocrine function in aquatic vertebrates, including their behavior. To evaluate the effects of WWE on a local fish population, we compared several morphological traits in fathead minnow (*Pimephales promelas*)) populations from a WWE pond to a nearby reference lake receiving no WWE. Fish from the WWE pond were significantly larger, had greater testes and ovarian weights (though not gonadosomatic indices), and were less active than fish from the reference pond. There were significant differences in the age structure of the two populations that may explain the morphological differences, with animals from the reference lake having significantly more juvenile fish. Reference lake fish had high tapeworm burden (100% of juveniles and 0% adults) that may contribute to the lack of adult fish in this population. WWE pond fish had brain cysts suggestive of a trematode infection. The finding of age structure and parasitic infection between these two bodies of water suggests that understanding the impact of exposure to WWE on populations of organisms needs to take into account more than the chemicals potentially released in the water system.

100.1 DANOS, N*; AZIZI, E; Univ. of California, Irvine; *ndanos@uci.edu*

Muscle-collagen interactions at the fiber bundle level.

The passive force-length properties of muscle fibers are thought to be important determinants of a muscle's operating length and force production. The extra-cellular collagen surrounding muscle fibers (endomysium) and fascicles (perimysium) have long been considered the structures responsible for passive elasticity in muscle. However, few studies to date have developed a direct link between the mechanical properties of these intramuscular connective tissues and the passive elasticity of muscle fibers. In addition, it remains unclear how connective tissue structures within muscle impact contractile performance. We explore the role of collagen in the extracellular matrix of muscle fibers and bundles by first comparing collagen density and passive stiffness in the anconeus muscle of three species of anurans with divergent loading regimes: the bullfrog *Rana catesbiana*, the cane toad *Bufo marinus* and the African clawed frog *Xenopus laevis*. We then examine the *in vitro* passive and active properties of muscle fiber bundles before and after a collagenase treatment that partially digests extracellular collagen. We find that the fiber bundles begin to develop tension at longer lengths after collagenase treatment. Active tetanic contractions after collagenase treatment reach lower maximum forces and develop force more slowly compared with pre-collagenase contractions. The results indicate that endomysium and perimysium collagen contributes both to passive stiffness and to the profile of active force production in muscle.

P2.45 DARAKANANDA, K.*; CONNOLLY, E.; HITCHCOCK, A.; JEONG, J.; QUIST, A.; ROBBINS, A.; ELLERBY, D.; Wellesley College; *dellerby@wellesley.edu*

Preferred escape trajectories are not associated with performance benefits in the bluegill sunfish.

Fish show a high degree of variability in escape behavior, particularly in regard to their chosen direction of escape relative to a threat. By analyzing multiple escape responses from individual bluegill sunfish we have reconstructed, in detail, the circular frequency distribution of their escape angles. In most individuals, escape angles cluster around two or three preferred directions. This variation has largely been viewed as a behavioral strategy that limits the extent to which predators can predict escape behavior. It may also be driven by underlying proximate factors relating to musculoskeletal mechanical properties or to the hydrodynamics of thrust production during the fish fast-start. This being the case, there may be performance benefits associated with the preferred trajectories. To test this we compared performance, as indicated by peak velocity, peak acceleration, and distance moved, between escapes performed at or near the preferred escape angles and those performed at infrequently chosen angles. There were no detectable differences in performance in relation to escape angle. This is suggestive of the observed escape angle distribution being largely associated with behavioral factors, rather than being dictated by proximate factors relating to escape performance.

71.2 DAS, S.*; NAJAR, F.Z.; LAI, H.C.; WILEY, G.; GAFFNEY, P.M.; ROE, B.A.; DURICA, D.S.; Univ. of Okahoma, OMRF; *sunetra.das-1@ou.edu*

NGS analyses of genes expressed during limb regeneration in the crab, Uca pugilator

Limb regeneration in fiddler crabs involves formation of a proliferating blastema, its differentiation into a segmented 'mini limb' (basal phase) and hypertrophic growth of the 'mini limb' via protein synthesis and water uptake (proecdysial phase). These phases are tightly coordinated with the molt cycle, i.e. accompanied by distinct fluctuations in circulating ecdysteroid titers, providing a useful model system to study changes in global gene expression. Among crustaceans, genomic and RNA-seq datasets are limited. We gave generated pilot transcriptome profiles to examine steady state changes in global gene expression during the limb regeneration process, including blastema, early and late proecdysial limb buds, using 454 and Illumina sequencing technology (NGS). Following sequencing, the reads were assembled de-novo by using the Newbler Assembler for 454 and the Trinity and SOAP Assemblers for Illumina sequence data. We have generated 103,700 and 704,395 sequences (all libraries combined) from the 454 and Illumina platforms, respectively. The average contig lengths from proecdysial libraries built by the three assemblers were: 511 bp (Newbler), 186 bp (Trinity) and 629 bp (SOAP). Analyses of the sequence data are available online at http://www.genome.ou.edu/crab.html, where the databases are both BLAST and keyword searchable. The database contains putative isoforms not detected through cDNA library cloning or anchored PCR. We have also obtained metabolic profiles from early blastemal, and early and late proecdysial limb buds using the KEGG database. Further analysis of metabolic profiles, in association with experimental manipulation of ecdysteroid responsiveness, should provide information on gene pathways subject to ecdysteroid control.

P3.152 DASKALANTONAKIS, D.*; CASSIDY, R.; BRUMLOW, C.; ROWE, M.; ROWE, A.; The Univ. of Texas, Austin, Sam Houston State Univ., Sam Houston State Univ.; *ahrowe@utexas.edu*

RNA-Seq analysis of sensory neurons from grasshopper mice: exploring the genetic basis for differential sensitivity to bark scorpion pain-inducing toxins in a scorpion predator

Pain is adaptive - warning of tissue damage. Because noxious stimuli produce short-term (escape) and long-term (avoidance) responses, many animals use painful venom to deter predators. The Texas striped bark scorpion [(TSB) (*Centruroides vittatus*)] produces the sensation of burning pain by injecting toxins that activate sensory neurons. Mearns' grasshopper mice [(MG) (*Onychomys arenicola*)] attack, kill, and consume TSB scorpions. We measured the sensitivity of MG mice to TSB scorpion pain-inducing toxins by recording the duration of paw licking in mice whose hind paw had been injected with TSB venom; house mice (Mus) were used as a control. Mean paw licking scores for MG mice were significantly less than house mice, suggesting the former have evolved insensitivity to TSB's pain-inducing toxins. Additionally, individual MG mice exhibited differential sensitivity to this scorpion's painful toxins. While some mice were insensitive, others were highly so. These same MG mice, however, did not respond differentially to injections of another painful stimulus, formalin. These data suggest that individual variation in MG mice's sensitivity to TSB pain-inducing toxins is specific to this scorpion's toxins, and does not represent individual variability in each mouse's threshold to pain. To determine the genetic basis for differential sensitivity to TSB pain-inducing toxins, we are sequencing mRNA (Illumina HiSeq) from the sensory neurons of low and high sensitivity MG mice. Analyses are focused on genes expressed in the pain pathway. Our goal is to identify differences between sensitivity phenotypes in the structure and expression of these genes.

44.4 DAVIDOWITZ, G.*; RAGUSO, R.A.; GOYRET, J.; VON ARX, M.; CONTRERAS, H.L.; Univ. of Arizona, Cornell Univ., Univ. of La Verne; *goggy@email.arizona.edu*

Relative humidity - nectar concentration interactions in hawkmoth foraging

In the wild, the tobacco hornworm hawkmoth (*Manduca sexta*) uses both high and low concentration nectars and can imbibe over half its body weight in nectar. In the desert Southwest (US), water imbibed from nectar is likely to play an important role in preventing desiccation. When relative humidity is high, however, the benefits of nectar-derived water may be reduced or completely eliminated. This study examines the interaction between RH and nectar consumption in the hawkmoth *Manduca sexta*. We show that the percent of moths drinking, the proportion of time spent foraging and the average volume of nectar imbibed throughout a moth's lifetime, all decreased with increasing RH. Specifically, the average volume of water imbibed decreased significantly as RH increased. However, per foraging bout, moths imbibed more nectar as RH increased. The volume of water consumed per bout did not change with RH. Despite the clear effects of RH on nectar foraging behavior, the total amount of energy consumed did not change with RH. We suggest that RH influences foraging decisions in the hawkmoth *Manduca sexta* as a mechanism of osmoregulation and not one of energy acquisition.

140.3 DAVIES, S*; DEVICHE, P; Arizona State University; *scott.davies@asu.edu*

The effect of food availability on the seasonal reproductive development of birds

Birds use food availability to synchronize seasonal reproductive activity with local environmental conditions, but the mechanism(s) by which this cue affects the hypothalamus-pituitary-gonadal (HPG) axis remain(s) poorly understood. We examined the effect of food availability on the HPG axis of adult male Abert's Towhees, *Melozone aberti*. We exposed captive birds to long days to stimulate reproductive development and assigned them to one of three groups: ad lib food, restricted food availability, in which they received 70% of ad lib consumption for four weeks, or two weeks of food restriction followed by two weeks of ad lib food. Two weeks of food restriction decreased body mass, furcular fat, and pectoral muscle. Food availability had no effect on the number, area, or optical density of gonadotropin-releasing hormone (GnRH-I) cell bodies, or the optical density of GnRH-I fibers in the median eminence (ME). Treatment also had no effect on the number or optical density of gonadotropin-inhibitory hormone (GnIH) cell bodies, or the optical density of ME GnIH fibers. However, the area of GnIH cell bodies was largest in ad lib birds and smallest in food restricted birds. Although paired testis masses and seminiferous tubule diameters were similar across groups, plasma testosterone (T) levels were higher in ad lib birds than in food restricted or reinstated ad lib birds, and there was no difference between food restricted and reinstated ad lib birds. The width of the cloacal protuberance (CP; an androgen-sensitive secondary sexual characteristic) was a function of food availability, with food restriction decreasing CP width and reinstating ad lib food increasing CP width. Thus, food availability affected the HPG axis, but this influence was specific to some components of the axis. Specifically, food restriction may affect the HPG axis by increasing GnIH secretion and decreasing T secretion.

54.4 DAVIES, S/W*; TREML, E; KENKEL, C/D; MATZ, M/V; University of Texas at Austin, The University of Queensland; *daviessw@gmail.com*

Understanding Connectivity of Acropora Corals Across Remote Islands Using Genetics and Biophysical Modeling

Many Indo-Pacific *Acropora* corals have species ranges that exceed thousands of kilometers. These ranges seem to contradict the growing consensus that dispersal distances of many marine species are less than previously assumed. Understanding larval dispersal is imperative to predicting population level responses to climate change. Few studies have looked into the connectivity among isolated reefs across large geographical scales. Knowledge of source-sink dynamics between remote reefs is important as they occur as discrete stepping-stones across large expanses, and extinctions of individual populations may have far-reaching demographic effects. Here we employ a spatially explicit biophysical model to predict larval dispersal between Micronesian islands. These predictions were then evaluated against genetic data and coalescent models of gene flow in two *Acropora* species. We analyzed twelve SSR loci across nearly 2000 individuals to determine connectivity patterns and the distribution of genetic diversity in *Acropora hyacinthus* and *A. digitifera* in Micronesia at different spatial scales, with samples from 22 reef sites across 9 island groups. Due to westerly equatorial Pacific Ocean currents, we hypothesized that genotypic diversity would decrease from west to east across Palau, the Caroline Islands and into the Marshall Islands, and that migration would predominantly be west to east. We observed strong genetic structure across Micronesia for both species with highly significant FST and isolation by distance signatures. However, dispersal routes modeled by the coalescent approach and the biophysical model are more complex than the simple isolation by distance model, which might help explain the extensive ranges of *Acropora*.

P3.68 DAVIES, R.E.*; BRANDER, S.M.; HE, G.; CONNON, R.E.; DENISON, M.S.; University of California, Davis, University of North Carolina, Wilmington; *beeka_hd1@hotmail.com*

Comparison of two endocrine disruptor in vitro screening assays and the potential for conflicting measurements

The U.S. Environment Protection Agency has recommended that endocrine disruptor screening be conducted on a variety of chemicals under the Endocrine Disruptor Screening Program, including the pyrethroid insecticide bifenthrin. Another contaminant of emerging concern is ibuprofen, a non-steroidal anti-inflammatory drug. Bifenthrin has been shown to have both estrogenic and anti-estrogenic properties *in vitro* and *in vivo*, and ibuprofen is known to mediate levels of prostaglandins, lipid mediators involved in aspects of reproduction. High throughput screening using cell lines to evaluate the potential for estrogenic or androgenic activity is now an established method of prioritizing contaminants for further assessment, but results can differ depending upon the cell lines used. Conflicting findings may be observed depending on the sensitivity and specificity of the system to endocrine responses and interpretation may depend on the complexity, context and design of the screening systems. The majority of previous *in vitro* assays have used concentrations of bifenthrin and ibuprofen much higher than usually detected in the environment. We will present comparative results from tests conducted on environmentally relevant concentrations in two cell systems, the CALUX and YES/YAS, and consider their potential for assessing endocrine disruption in aquatic ecosystems, and discuss differences in the quantitation of endocrine disrupting potential between the assay types.

P3.93 DAVIS, JS*; SIDOTE, J; MONTUELLE, SJ; WOOD, R; WILLIAMS, SH; Ohio University; *jd330008@ohio.edu*

3D Kinematics and Muscle Activity Pattern During Mastication in Ferrets (Mustela putorius furo)

Jaw movements and adductor muscle activity were simultaneously recorded during mastication in adult ferrets (*Mustela putorius furo*) using biplanar fluoroscopy and electromyography. Reconstruction of masticatory movements using XROMM facilitated the observation of movements of the mandibular symphysis and condyles. An average ferret chewing cycle lasts approximately 300 ms, of which roughly 60% is opening and 40% is closing. Initial puncture crushing cycles are characterized by a distinct slow-opening phase (approximately 60% of total jaw opening) in which the jaw is steadied by the balancing side posterior temporalis while the tongue is used to position the food. During opening, the dentaries rotate around their long axes causing the eversion of the alveolar margins and separation of the mandibular symphysis. Maximum separation of the symphysis occurs during fast-opening. During closing, the alveolar margins invert, and occlusion at the carnassial teeth drives the working-side dentary to invert further, supporting the hypothesis that tooth occlusion drives masticatory movements during the power stroke. As the pellet is further reduced, both closing and fast opening become relatively shorter components of the chewing cycle. Despite a relatively constrained TMJ due to a tight glenoid fossa, mediolateral translation of the condyle occurs. However, there is very little anteroposteror translation, consistent with the restrictions imposed by the well-developed pre- and postglenoid processes.

S3-1.4 DAVIS, Marcus C; Kennesaw State University; *mdavi144@kennesaw.edu*

The deep homology of the tetrapod limb: Combining fossil and genetic datasets.

The evolution of tetrapod limbs from fish fins was a significant functional shift. But how significant was this shift in terms of morphology and gene regulation? The fossil record provides insight into the morphological changes. However, to understand the underlying mechanisms we must peer into the gene regulatory networks of living vertebrates. Until recently, data from gene expression and functional studies in tetrapods and teleosts supported the notion that the distal region of the tetrapod limb, the autopod (wrist, ankle, and digits), was an evolutionary novelty. In contrast, the fossil data suggests that the autopod was already present in fish fins prior to the origin of tetrapods, and was subsequently modified for new adaptive roles in terrestrial locomotion, feeding, and support. Data from phylogenetically more basal extant taxa has helped to reconcile these datasets. Hox genes encode transcription factors that provide positional identity along animal axes, including the axes of the fins/limbs. Our analysis of Hox expression in a basal actinopterygian, the North American paddlefish, *Polyodon spathula* reveals patterns of expression long considered to be developmental hallmarks of the autopod and shown in tetrapods to be controlled by a 'digit enhancer' regulatory region. But we also observe differences: For example, in *Polyodon*, early and late phases of HoxD expression overlap proximodistally, whereas in tetrapods these phases are spatially segregated. These data demonstrate that aspects of Hox expression once considered unique to autopod sare, in fact, ancestral to tetrapod limbs. However, our data also show that tetrapod limbs exhibit a unique regulatory context – different in key ways from the fins of fish. Together, these results suggest that novelty in the tetrapod limb has arisen by changes in regulation of an ancient and conserved pattern of gene expression.

36.5 DAVIS, M. J.*; SWANSON, B. O.; Gonzaga University; *mdavis6@zagmail.gonzaga.edu*

Wave Energetics in Fiddler Crabs: Variability in Signaling Investment

Fiddler crabs are a group of small, intertidal crustaceans that exhibit a high degree of sexual dimorphism. Male fiddler crabs are characterized by strong body asymmetry, as the large major claw can constitute more than half of the organism's body mass. Males within this genus both wave the major claw to attract a mate during courtship, and also fight with the major claw for control of mating burrows. Both of these functions are essential for male mating success. Fiddler crab species are highly variable in claw morphology and in the kinematics of waving. Here, we quantify energetic investment in waving across 14 species of fiddler crabs. Using field observations and video analysis of courtship, we calculated waving rates (waves/second), waving time budgets (percent time spent waving), and the energetic cost of a wave (Joules/wave). Additionally, morphological and mechanical measurements were made for each of these species. Wave energetics are highly variable across species. Work (J) per wave varies by two orders of magnitude. Wave rates ranged from 0.29 to 1.1 waves/second. All species studied waved frequently during courtship periods, with 28% to 77% of time spent waving. Combining these data sets, we estimate each species' energetic commitment to waving. We then use these data to test hypotheses about the relationship between waving investment and morphology (e.g. body size, claw force), and reproductive behavior.

P2.87 DAVIS, T*; KITTS, J; CHAVEZ, A; POND, B; BACHMAN, N; INGALLS, J; TEMKIN, M; HORN, R; MILLER, B; SCHREIBER, A; St. Lawrence University; *aschreiber@stlawu.edu*

Pharmacological suppression of matrixmetalloprotease (MMP) activity with doxycycline inhibits intestinal remodeling and enteric neuronal development during Xenopus laevis metamorphosis

Metamorphosis of the herbivorous X. laevis tadpole into a carnivorous frog is accompanied by an abrupt remodeling of the gut: the intestine shortens in length by 75%, the connective tissue and smooth muscle layers thicken, enteric neuronal cell bodies form clusters and have increased axon cable diameter, and the lumen becomes highly involuted. Virtually all aspects of amphibian metamorphosis are mediated by thyroid hormone (TH), and the mRNAs of several matrixmetalloprotease (MMPs) are known to be upregulated directly (i.e. stromelysin-3) or indirectly (e.g. gelatinase A and MT1-MMP) in the mesenchyme of the small intestine by TH. Although the kinetics of intestinal MMP mRNA expression have been studied extensively in the amphibian model and shown to correlate with gut remodeling, the influence of actual MMP enzymatic activity on intestinal remodeling has not been well-described. Here we show that treatment of pre-metamorphic tadpoles (Nieuwkoop and Faber stage 50 and 54) with a broad-spectrum inhibitor of MMP activity (doxycycline) inhibits virtually all aspects of intestinal remodeling, including shortening, thickening of the mesenchyme and smooth muscle layers, enteric neuronal clustering and changes in axonal cable diameter, and development of involutions on the lumen compared with controls following treatment with TH (3 nM triiodothyronine) for 4 days. Concurrent treatment with doxycycline and TH did not, however, inhibit upregulation of mRNA for stromelysin-3 (a TH direct-response MMP). These findings directly support the hypothesis that an upregulation of TH-responsive MMP activity during metamorphosis mediates diverse changes that accompany intestinal remodeling.

P3.59 DAVIS-BERG, E. C.; Columbia College Chicago; *edavisberg@colum.edu*
Changes in Molluscan fauna due to succession " 1940s to present
Long-term successional changes were assessed for the native molluscan fauna in a re-established forest ecosystem. In 1948, the Fitch Natural History Reservation located in Douglas County, Kansas northeast of Lawrence. Prior to the foundation of the Reserve one year earlier, the non-forested areas were heavily cultivated or grazed. In the late 1940s and 1950s, numerous surveys of molluscan fauna were performed. It has since been allowed to undergo natural succession, returning to a primarily forested ecosystem. This area was extensively surveyed for molluscan fauna in the late 1940s through the 1950s. These surveys have provided a species list by location along with information on the local ecology at the time. To assess changes in the molluscan fauna due to succession and time, I have sampled three sites; two terrestrial and one aquatic at the University of Kansas Fitch Natural History Reservation, over the years 2004 - 2007. All sites were identified with GPS coordinates and were of different habitats to better sample the diversity of mollusks found in the areas. These results allow us to see how the molluscan fauna has changed and stayed the same on this Reservation over the last 50 - 60 years. We are able to document changes in the species composition from the original surveys including the presence of species which are new to Reservation.

S2-1.3 DAY, Troy; Queen's University; *tday@mast.queensu.ca*
Evolutionary consequences of nongenetic inheritance
There has been widespread interest in recent years in inheritance mechanisms that exist alongside genetic inheritance, and the role that these might play in evolution. I will present some work that develops a unified theoretical framework for modeling evolution under the combined effects of genetic and nongenetic inheritance. Despite the considerable diversity of proximate mechanisms of nongenetic inheritance, I will show how they can all be integrated within a relatively simple theory. The approach will be illustrated with some examples that show how nongenetic inheritance can leads to novel predictions and patterns of evolution that would otherwise be unexpected.

P1.140 DAYAN, DI*; OLESKIAK, MF; University of Miami, Miami FL; *ddayan@rsmas.miami.edu*
Phenotypic Plasticity and Adaptation in Fundulus Glycolytic Muscle Physiology
Throughout their natural history, organisms become adapted to specific thermal environments, resulting in discrete ranges of temperatures at which physiological processes are optimized. For many organisms, however, body temperature fluctuates in a thermally variable environment. In response, organisms often reversibly alter their phenotype in a process termed phenotypic plasticity. Due to their diverse environmental distributions, known phylogeny and highly plastic traits, members of the fish genus *Fundulus* are excellent models to investigate the relationship between phenotypic plasticity and adaptation. We analyze glycolytic muscle gene expression profiles of two *Fundulus* species acclimated to a range of environmentally relevant temperatures using cDNA microarrays and find evidence of both evolution by natural selection and a robust acclimation response. Furthermore, gene-by-environment interactions make many evolved differences between populations apparent only under some environmental conditions. This observation is largely due to among population differences in phenotypic plasticity. The majority of genes that demonstrate a significant effect of acclimation or adaptation, however, are not shared. Neither process is dominant and plasticity and evolution appear to primarily operate orthogonally. Finally, these putatively adaptive differences may have functional consequences that are consistent with what is know about the thermal biology and ecology of this species providing many hypotheses for future physiological research.

132.6 DAYGER, CA*; CEASE, AJ; LUTTERSCHMIDT, DI; Portland State Univ, OR, Univ of Sydney, Australia; *cdayger@pdx.edu*
Body condition modulates responses to capture stress and exogenous corticosterone in female red-sided garter snakes.
Many studies have examined the role of corticosterone (CORT) in male reproduction, but relatively little is known about how CORT affects female mating behavior. We treated female red-sided garter snakes (*Thamnophis sirtalis parietalis*) with capture stress during the spring mating season in Manitoba, Canada. Blood samples were collected before (0h), during (2h) and after (4h) capture stress treatment. Stress-treated and control females were then placed individually in an arena containing 20 males and latency to copulate was recorded. Body condition was determined as the residual from a regression of body mass on snout-vent-length. Capture stress significantly increased plasma CORT ($p=0.025$). However, only females with negative body condition exhibited increased CORT after 2 hours of capture stress ($p=0.043$). Importantly, baseline CORT did not differ between females with negative or positive body conditions, suggesting that differences in hormonal stress responses were related to differences in hypothalamus-pituitary-adrenal axis sensitivity. Similar to previous results in male red-sided garter snakes, capture stress did not influence mating behavior ($p=0.090$). These results suggest that females may also be behaviorally resistant to capture stress during the mating season. However, in a second experiment, exogenous CORT (15 or 60 µg) significantly increased latency to copulate ($p=0.010$). Interestingly, only females with negative body condition responded to the lower CORT dose, suggesting that glucocorticoid receptor sensitivity and/or density varies with body condition. Collectively, our results indicate that female body condition modulates hormonal and behavioral responses to elevated CORT during their short mating season.

P2.207 DE GUZMAN, H.J.*; GAMBI, M.C.; CALOSI, P.; GIANGRANDE, A.; SCHULZE, A.; Texas A&M University at Galveston, Galveston, TX, Stazione Zoologica Anton Dohrn, Napoli (Italy), Marine Biology and Ecology Research Centre, University of Plymouth, UK, Università del Salento, Lecce (Italy); *heidijane07@neo.tamu.edu*

Genetic diversity of the sabellid polychaete Amphiglena mediterranea Leydig from shallow carbon dioxide vents and non-acidified control areas in the Mediterranean Sea

Marine carbon dioxide vents are common in the Mediterranean Sea, especially around Italy and Greece. They cause a natural gradient of pH and water acidic conditions and can be considered a useful "natural laboratory" for studying adaptation and effects of ocean acidification on wild populations and communities. In a well studied CO_2 vent system on the island of Ischia (Italy), the Castello Aragonese, the sabellid polychaete *Amphiglena mediterranea* is one of the most common invertebrate species thriving in the most acidified conditions. The aim of this study is to determine whether populations of *A. mediterranea* exposed to low pH conditions, from such cold CO_2 vents, are genetically distinct from populations at non-acidified control sites to test for possible local adaptation. Specimens were collected from two near locations at the CO_2 vents of Castello Aragonese with slightly different mean pH conditions, as well as from four non-acidified control locations at different distances to the vents. Genetic diversity among the *A. mediterranea* populations was examined with two mitochondrial markers, cytochrome c oxidase subunit I and cytochrome b. Our results are consistent with the hypothesis that the genetic structure within *A. mediterranea* is more a function of geographic distance and limited dispersal capabilities than of habitat characteristics, such as pH. Being a brooder, recruitment in *A. mediterranea* is expected to be mostly local, resulting in a high degree of genetic distinctness of individual populations. However, occasional gene flow seems to occur at least among populations in the same general area.

71.3 DE JONG, D*; CAVACO, N; SEAVER, E; University of Hawaii, Honolulu; *ddejong@hawaii.edu*

Dynamic Hox gene expression during Capitella teleta juvenile development and posterior regeneration

Hox genes encode transcription factors that play essential roles in anterior-posterior patterning during the development of most metazoans. While most research has concentrated on their involvement in body plan specification during development, their role in regeneration following removal of body segments has only recently begun to be investigated. *Capitella teleta*, a polychaete annelid, displays spatial and temporal co-linearity of Hox genes in both larval and juvenile stages. *Capitella* is also able to regenerate posterior segments following amputation and continually generates segments from a posterior growth zone throughout its life. We are investigating the role Hox genes play in these processes. We examined expression of 11 of the 12 known *Capitella* Hox genes in 14 day juveniles and compared them with previously described expression patterns in 3 day juveniles. At both stages, Hox genes are expressed in the ventral nerve cord ganglia in discrete yet overlapping domains along the anterior-posterior axis. However, a subset of patterns differ between 3d and 14d juveniles. Following amputation of 14d juveniles, certain Hox genes show dynamic expression patterns while the expression of others is unchanged. Expression of Hox genes in regenerating tissue is preceded by onset of cell proliferation and expression of various putative stem cell markers, such as *vasa*, *nanos* and *piwi*. This indicates that following initial proliferation and cell specification of precursors, at least some Hox genes are likely involved in patterning the regenerating ventral nerve cord. These and further investigations will not only reveal the importance of the Hox code in *Capitella* regeneration, but will also shed light on the evolution of patterning during regeneration.

S7-1.4 DE LA IGLESIA, Horacio O.; SMARR, B.*; University of Washington; *horaciod@uw.edu*

Finding A Temporal Niche

Ecologists and physiologists are familiar with Hutchinson's notion of ecological niche, the multidimensional space delineated by the range of resources in which a species survives and reproduces. Yet, few of us are used to include "time" among the critical orthogonal axes that define this multidimensional space. Recent studies have shown that the time allocation to specific physiological and behavioral functions is likely critical for survival. The pattern of activity of individuals in the wild can change dramatically and studies in our laboratory have shown that these "temporal niche switches" may be based in radically different physiological mechanisms. I will discuss the notion of temporal niche, the importance of temporal niche switching and present data on the underlying mechanisms determining the temporal niche of a species.

49.5 DE LEEUW, JR; LIVINGSTON, KR; PORTER, ME; PORTER, JH*; Indiana University, Vassar College; *jolong@vassar.edu*

When Swarm Intelligence Isn't: Common Goals Alone Explain Emergence of Group Coordination in Asocial Embodied Robots

Swarm theory postulates that local, sensory-based interactions between members of a group drive the formation of synchronized group behavior. We demonstrate that sensory information about other group members is not necessary for simple-minded autonomous fish-like robots to school. Our surface-swimming robots lack the ability to sense one another, yet they school when all individuals share the single goal to detect and swim up a gradient of light in a circular pool. As individual goal-directedness increases group coordination also increases, an effect that is robust in groups of different sizes. Our results demonstrate that even without direct knowledge of agents with the same goals, individual agents can reap the benefits of schooling; asocial school may have created the necessary conditions for the evolution of social swarms.

P3.213 DE LOS SANTOS, R; MCCUE, M.D.*; St. Mary's University; *mmccue1@stmarytx.edu*

Atmospheric oxygen availability affects insect thermotolerance at upper lethal temperatures, but oxygen delivery is not limiting under normoxia

Most natural environments experience fluctuating temperatures that acutely affect an organism's physiology and ultimately a species' biogeographic distribution. A popular paradigm in ectotherm thermobiology posits that O_2 delivery to tissues becomes limiting as body temperature increases and eventually causes death at upper lethal temperatures. Because of the limited direct, experimental evidence supporting this paradigm, we explored the effect of ambient oxygen availability on the thermotolerance of several thousand insects representing six species (*Acheta domesticus, Hippodamia convergens, Gromphadorhina portentosa, Pogonomyrmex occidentalis, Tenebrio molitor*, and *Zophobus morio*), four taxonomic orders (Blattodea, Coleoptera, Hymenoptera, and Orthoptera), and multiple life stages (e.g., adults vs. larvae or nymphs). Survival curves of insects exposed to temperatures predetermined to cause death within one hour under normoxic conditions (21% O_2) were compared with survival curves measured under artificial oxygen conditions (0, 10, 35, and 95% O_2). Kaplan-Meier Log Rank analyses followed by Holm-Sidak pairwise comparisons revealed that: 1) anoxia sharply diminished survival times in all groups studied, 2) thermotolerance under moderate hyperoxia (35% O_2) was no different from moderate hypoxia (10% O_2); 3) insects exposed to either moderate or extreme hyperoxia (95% O_2) showed no improved performance and occasionally reduced thermotolerance, and 4) thermotolerance differed with body mass and developmental stage among conspecifics, but that larger individuals are no more likely to be limited by oxygen delivery than much smaller conspecifics. We conclude that some factor(s) separate from oxygen delivery (e.g. denaturing protein or genetic material, membrane degradation, hypercapnia, etc.) is responsible for death of insects at upper lethal temperatures.

P2.23 DEBRISH, A*; MAGANA, C; BRUMMITT, S; ADAMS, N; California Polytechnic State University, San Luis Obispo, CA; *nadams@calpoly.edu*

Exposure of adult purple sea urchins, Strongylocentrotus purpuratus, to solar ultraviolet radiation (sUVR) affects embryo resistance

Ultraviolet radiation (UVR) causes physiological stress in marine organisms including sea urchins. Some sea urchin species appear to provide some maternal investment to protect offspring from environmental effects of UVR. We examined how solar UVR exposure of the adults affects maternal investment in eggs and embryos of the purple sea urchins, *Strongylocentrotus purpuratus*. We exposed adults to or protected them from solar UVR for 6 months using Plexiglas filters. We sampled gonads every two months to compare the gonadal index (wet wt. of gonad/wet wt. of adult) between the UV treatments, sex and time. In addition, we compared spawned egg volume between treatments and the amount of UV-induced developmental delays in embryos of eggs spawned from the adults exposed to or protected from UVR. Split plot ANOVAs revealed that there was no significant difference in the gonadal index or volume of eggs spawned between females of the two treatments. The embryos however, experienced a significant difference in UV-resistance between maternal UV treatments. Specifically, embryos from the UV-exposed mothers experienced lower amounts of UV-induced delays in cell division than embryos from mothers protected from UVR ($P<0.05$, $n=4$). Therefore, although exposure to UVR does not affect the volume of sea urchin gonads or eggs it appears to alter the maternal investment, conferring greater protection to eggs from UV-induced damage. We are currently comparing proteomic profiles among batches of these eggs and embryos to identify whether specific proteins differ and contribute to differential resistance to UVR.

P2.145 DELALIO, L*; DION, S; BOOTES, A; TRACKA, K; KUNDU, A; MAGUIRE, M; SMITH, WA; Northeastern University; *w.smith@neu.edu*

Direct effects of hypoxia and nitric oxide on the secretion of ecdysone by insect prothoracic glands

Insect molting and metamorphosis are stimulated by ecdysone secreted by the prothoracic glands. A recent study suggests that tissue oxygenation may play a role in the timing of a molt during a given insect stage; hypoxic *Manduca sexta* larvae molt at a lower weight than normoxic larvae. Further, in *Drosophila*, the signaling gas nitric oxide (NO) appears to be required for prothoracic gland function. Knockdown of nitric oxide synthase in the prothoracic glands prolongs feeding and blocks metamorphosis. We set out to directly examine the effects of hypoxia and NO on ecdysone secretion, using glands from feeding fifth (last) larval stage *M. sexta*. Treatment of prothoracic glands with the NO mimetic DETA-NONOate (0.1 mM or 10 mM) did not directly stimulate ecdysone secretion. We also quantified, with the use of real-time PCR, the effects of NO on the expression of nuclear factors associated with ecdysone secretion including *Manduca* hormone receptor 3 (MHR3), which was decreased by NO. Hypoxia had an inhibitory effect on ecdysone secretion. Incubation of prothoracic glands for 12 hours in 2% oxygen led to a significant reduction in ecdysone secretion as compared to normoxic (20% oxygen) controls. Cellular viability was confirmed by trypan blue exclusion. Our results suggest that while oxygen and NO can modify the timing of a larval molt, and hence body size, these effects in *M. sexta* are not mediated by direct effects on ecdysone secretion. Rather, changes such as accelerated release of upstream stimulatory hormones, the responsiveness of the prothoracic glands to stimulation, or enhanced target tissue responsiveness to ecdysone may be responsible for observed effects on molting.

41.3 DELEPINE, M.B.*; BARANNYK, O.L.; SHADWICK, R.E.; Univ. of British Columbia, Vancouver, Univ. of Victoria, BC; *delepine@zoology.ubc.ca*

Performance of Thunniform Propulsion: A High Bio-fidelity Experimental Study

Tunas, lamnid sharks and whales are some of the fastest sustained swimming animals. These animals are part of the thunniform propulsion (TP) group, characterized by streamlined bodies with narrow necking of the caudal peduncle and high aspect ratio lunate tail that generates lift-based thrust. For these unique reasons, TP has received considerable attention from biologists and engineers. TP is assumed to have the highest propulsive performance (PP) of all swimming modes, meaning high propulsive efficiency at fast swimming speeds. However there is no direct empirical evidence to support this common idea, due to the difficulty of obtaining force measurements for these animals. Consequently, indirect approaches are used, such as theoretical and experimental studies. But these experiments oversimplify the animal (motion, shape or material property) and/or the flow condition. Our goal was to assess the PP of the Atlantic bluefin tuna, *Thunnus thynnus*, which is our case study for TP, by an experimental approach of the current highest bio-fidelity. A computed tomography scanner and a polyjet™ 3D printer were used to make two tail models: one with materials of similar properties than the *in vivo* measurements and a rigid one. Each model was actuated in a water tunnel by a computer controlled, motorized system to follow motion paths typical for a tuna. Propulsive efficiencies and thrust coefficients were calculated from the forces and torque measurement for each motion regime. Vortex shedding was visualized by means of digital particle image velocimetry. In conclusion, the PP of other animals and propellers were compared with our results, and major parameters responsible for this enhanced performance were identified.

107.6 DEMES, KW*; PRUITT, JN; HARLEY, CDG; CARRINGTON, E; University of British Columbia, University of Pittsburgh, University of Washington, Friday Harbor Labs; *demes@zoology.ubc.ca*

Survival of the weakest: Decreased frond mechanical strength increases survival in a wave-swept kept via self-pruning

Organisms' ability to withstand the physical forces of their environment is a key determinant of their success. Mechanical performance of organisms is often dictated by the properties of the tissues which compose them. In mechanically stressful habitats, intraspecific variation in tissue properties may result in differential fitness and enable natural selection to act on material performance. We tested the hypothesis that tissue mechanical properties influence survivorship (a fitness component) of the perennial kelp, *Egregia menziesii*, in a mechanically stressful, wave-swept intertidal habitat. We measured intraspecific variation in frond strength and flexibility in 38 E. menziesii and tracked their survivorship in the field over the winter storm season to determine if variation in mechanical properties led to differential survivorship. Significant inter-individual variation was found in most mechanical properties, including strength and flexibility. Individuals with increased flexibility and decreased strength were more likely to survive the duration of our study, although this effect was more pronounced in individuals with smaller holdfasts. Increased frond strength was also associated with a reduction in self-thinning, potentially explaining the observed increase in whole plant mortality with increasing frond strength. Results from this study demonstrate that variation in tissue mechanical properties among conspecifics can influence survivorship and this has important evolutionary implications.

80.1 DENNY, MW*; MARTONE, PT; Stanford University, University of British Columbia; *mwdenny@stanford.edu*

Indefatigable: Erect Coralline Alga Is Immune To Fatigue

Intertidal organisms are subjected to intense hydrodynamic forces as waves break on shore. These repeated insults can cause an organism's structural materials to fatigue and fail even though no single force would be sufficient to break the plant or animal. Indeed, Mach et al. (2011) found that mortality in the intertidal red alga *Mazzaella flaccida* was caused by fatigue rather than by the one-time imposition of extreme force. When pulled to 50% of one-time breaking stress, *Mazzaella* breaks after a few thousand cycles. One might suppose that erect coralline algae--composed of rigid calcified segments separated by genicula: small, flexible joints--would be even more susceptible to fatigue: strain is concentrated in the genicula. We tested this supposition by repeatedly loading fronds of *Calliarthron cheilosporioides*, a coralline alga common on wave washed shores in California. Loaded to 50% of its one-time breaking stress *Calliarthron* commonly survives more than a million cycles, with a record of 52 million. The maximum lifetime of *Calliarthron* is six years, during which it experiences only a small fraction of this number of stressful events. Thus, *Calliarthron* is immune to fatigue failure. We hypothesize that *Calliarthron*'s fatigue resistance is due to the microscale structure of its genicula. Each geniculum is a single layer of cells that are attached at their ends to the calcified segments but have minimal adherence to each other. This lack of adhesion allows each cell to act as a "crack stopper," inhibiting the growth of fatigue cracks. Reference: Mach, KJ, Tepler SK, Staaf AV, Bohnhoff JC, and Denny MW. (2011) *J. Exp. Biol.* 214: 1571-1585.

17.7 DEORA, T.*; SINGH, A.K.; SANE, S.P.; National Centre for Biological Sciences, TIFR, Bangalore; *tanvid@ncbs.res.in*

A general mechanical model of the Dipteran thorax

The evolutionary miniaturization of body size in diverse insects meant that their wing beat frequencies had to substantially increase to meet the aerodynamic requirements of flight. In many cases, wing beat frequencies far exceed 100 Hz to rates that challenge the ability of the nervous system to directly control every wing stroke. However, because subtle alterations of wing strokes can result in significant aerial maneuvers, these insects still need to ensure that their wing motion is accurate. How do insects handle the dual challenge of being both fast and accurate? The evolution of indirect and asynchronous flight muscles partially addresses the challenge of enhancing wing beat frequency, but it is relatively unknown how insects coordinate their wing motion with respect to other flight related sensory organs. Using the black soldier fly, *Hermetia illucens*, we show that the answer lies in the physical architecture of the thorax, which includes a system of multiple, distributed mechanical linkages that connect the wings and halteres. These allow the wings to oscillate in phase with each other, but the halteres oscillate anti-phase to the wings. Moreover, this coordination between the wings and halteres is essential for flight and its disruption causes flight defects. Based on the principles investigated during the course of the study, we propose a general mechanical model of the Dipteran thorax that explains how insects manage to maintain the mutual phase relationships between their wings and halteres.

144.1 DEPEW, M. J.*; COMPAGNUCCI, C.; FISH, J.; DEBIAIS, M.; COOLON, M.; BERTOCCHINI, F.; CASANE, D.; MAZAN, S.; UCSF, KCL, CNRS, Universidad de Cantabria, Universite ´ Paris Diderot, Station biologique de Roscoff ; *michael.j.depew@gmail.com*

Pattern and Polarity in the Development and Evolution of the Gnathostome Jaw: Both Conservation and Heterotopy in the Branchial Arches of the Shark, Scyliorhinus canicula

The acquisition of jaws constitutes a landmark event in vertebrate evolution. Jaw development involves an intricate spatiotemporal series of reciprocal inductive and responsive interactions between the cephalic epithelia and mesenchyme. The coordinated regulation of these interactions is critical for both the ontogenetic registration of the jaws and the evolutionary elaboration of jaw morphology. A 'Hinge and Caps' model has been proposed that addresses the mechanisms of jaw development by placing the articulation, and subsequently the polarity, of the upper and lower jaws in the context of neural crest competence to respond to positionally located epithelial signals. This model has been built on evidence gathered mostly in amniotes and augmented by a much smaller data set on the zebrafish and Xenopus, as well as by work focused on the jawless lamprey. Chondrichthyans are the most basal extant gnathostomes, and comprise the crucial clade uniting aminiotes and aganthans; yet despite their critical phylogenetic position, evidence of the molecular and cellular underpinnings of jaw development in chondrichthyans is still lacking. Recent advances in genome and molecular developmental biology of the lesser spotted dogfish shark, Scyliorhinus canicula, make it ideal for the molecular study of chondrichthyan jaw development. Here, we have further examined the empirical foundation for the 'Hinge and Caps' model by investigating evidence of heterotopic (relative changes in position) and heterochronic (relative changes in timing) shifts in gene expression, relative to animotes such as mice, in the jaw primordia of S. canicula.

S1-1.3 DERBY, Charles; Georgia State University; *cderby@gsu.edu*

The role of chemicals in interactions between inking molluscs and their predators

Inking is a striking behavior of marine molluscs such as sea hares, octopus, squid, and cuttlefish. Inking can function as an antipredatory defense by acting as a visual smoke screen or visual decoy, especially in fast-moving cephalopods. But molluscs also use ink as a chemical defense. Ink of the slow-moving sea hares acts on the chemosensory systems of would-be predators such as crustaceans (spiny lobsters, blue crabs), fish (sharks, sea catfish, wrasses), and sea anemones through an impressive array of mechanisms. These include sensory inactivation (using chemicals in ink to disrupt the reception of appetitive chemicals naturally released by the would-be prey), deterrence (using aversive or unpalatable chemicals in the ink to deter the attack), and phagomimicry (using appetitive chemicals in ink to attract the predator to the ink and away from the releaser). Ink also functions as a chemical defense through alarm cues: sea hares show escape behavior when they detect ink from conspecifics. The chemical deterrents and alarm cues are diverse in molecular structure, numerous, and include both diet-derived and *de novo* synthesized molecules. Some alarm chemicals are multifunctional molecules, having been co-opted from other functions including as sun screens and antimicrobials. Fast-moving molluscs, such as squid, may also use ink as a chemical defense, since their ink contains chemicals that are unpalatable to predatory fish. Thus, using ink in both the chemical and visual realms may be a common defensive mechanism for inking animals. These modes of chemical defense contribute together with other defenses to protect inking animals from predators. Supported by NSF IOS-1036742

18.4 DES ROCHES, S.*; TORRESDAL, J.; MORGAN, T.; BRINKMEYER, M.; HARMON, L.J.; ROSENBLUM, E.B.; University of Idaho, University of California, Berkeley; *simone.desroches@gmail.com*

BEYOND BLACK AND WHITE: COMPARATIVE ECOMORPHOLOGY IN THREE RAPIDLY EVOLVING LIZARD SPECIES AT WHITE SANDS

Determining which traits enable organisms to colonize and persist in new environments is crucial to understanding adaptation and ecological speciation. Selection can simultaneously act on morphology and behaviour to influence performance. We investigated ecomorphological change during adaptation and incipient ecological speciation for three lizard species in New Mexico that have white and dark forms on White Sands and the surrounding Chihuahuan Desert, respectively. For each species, we compared morphology, startle response behaviour (to a simulated predator), and sprint speed performance (on white sand or dark soil substrate) between colour forms. In all species, the two colour forms exhibited differences in morphology (e.g. body size, limb length) and startle response (on matched and mismatched substrates). Sprint speed also differed between forms on alternate substrates. Although not related to morphological differences between forms, speed was influenced by startle response on alternate substrates in two species: individuals that sprinted immediately when stimulated achieved a faster maximum. Our results demonstrate a relationship between performance and behaviour in White Sands lizards and their dark soil counterparts suggesting that differences in behavioural response across populations may be important during ecological speciation. More generally, our results demonstrate the importance of examining the effect of both morphology and behaviour on performance.

69.3 DETRICH, H.W.*; YAN, Y.L.; TITUS, T.; ALLARD, C.; ALBERTSON, R.C.; POSTLETHWAIT, J.H.; Northeastern Univ., Boston, Univ. of Oregon, Eugene, Univ. of Massachusetts, Amherst; *iceman@neu.edu*

Evolutionary developmental biology of notothenioid fishes: through the genomic looking glass

Comparative genomics provides a global perspective of the evolutionary changes in developmental programs that control phenotypic diversity among related organisms, and many of these naturally adaptive phenotypes mimic deleterious human diseases. Some Antarctic fish provide an evolutionary mutant model for osteopenic diseases of elderly humans. Ancestral notothenioid fish were benthic and lacked a swim bladder, an organ of buoyancy. As the Southern Ocean cooled to -1.9°C, notothenioids filled pelagic niches left vacant by local extinction of other species by evolving strategies to reduce body density, including decreases in bone mineral density in several clades. To identify genes causing the adaptive demineralization of bone in Antarctic fish, which may be orthologous to genes responsible for low bone mineral density in aging humans, we are comparing the molecular genetics of skeletal development in embryos of the robustly ossified, benthic Bullhead notothen, *Notothenia coriiceps*, and of the osteopenic, benthopelagic Blackfin icefish, *Chaenocephalus aceratus*. First, we have generated reference transcriptomes for the two species by sequencing total cDNA from multiple bones and soft tissues by RNAseq. Second, we have cultured embryos of the two species and sampled them at intervals to obtain stage-specific total mRNA. Cross-comparison of the reference-normalized developmental cDNA samples will enable us to identify the molecular-genetic basis of the evolution of osteopenia by the icefish, and our results may provide clues to age-related osteopenia in humans. Support: NSF grant ANT-0944517 (HWD); NIH grant R01AG031922 (JHP, HWD, RCA).

109.3 DEVRIES, MS*; WINTERS, CP; HOLBROOK, AL; JAWOR, JM; University of Southern Mississippi; *margaret.devries@eagles.usm.edu*

It's Complicated: Testosterone Production, Aggression, and Parental Care in Male Northern Cardinals

Interrelationships of testosterone (T), male aggression, and paternal care have received much investigative attention. Many studies have focused on examining such relationships with avian species characterized by relatively brief periods of territoriality and breeding. Few have investigated links between circulating T and reproductive behavior with birds that are year-round territorial residents and have lengthy breeding seasons, such as the Northern Cardinal *Cardinalis cardinalis*. Here, we report findings from a 4-year project with the male cardinal examining aspects of T production and potential interconnections with circulating T, aggression, and paternal care. Our work suggests that male cardinals have the physiological capacity to significantly increase T levels during non-reproductive periods in response to standardized gonadotropin-releasing hormone (GnRH) injections. Male cardinals maintained the ability to significantly elevate T following GnRH injections across the pre-breeding and breeding seasons; yet, circulating T levels were not significantly higher following simulated aggressive encounters and no relationship existed between T concentrations and the degree of paternal care provided by individuals. This lack of relationship between relative circulating levels of T and behavioral performance suggests a complex association between T and reproductive behavior among males of this species. Whether this complicated relationship of circulating T and male behavior is unique to the cardinal or characteristic of other temperate resident species exhibiting a similar behavioral ecology is unknown and deserves greater attention.

133.5 DIAL, KP*; MARTIN, TE; Univ. of Montana, Missoula; *kdial@mso.umt.edu*

Predation correlates of locomotor ontogeny among altricial bird species in Arizona and Borneo: Relative development at fledging

Locomotor ontogeny among species is incredibly diverse and could be under strong selection from environmental pressures like predation risk. Laboratory studies on precocial species have demonstrated that dramatic differences exist in the rate of development between the forelimbs and hindlimbs, with correspondingly different capacities of locomotor performance. Does such variation in locomotor ontogeny change with level of predation in the natural environment? In this study, we explore variation in locomotor ontogeny among altricial songbirds that show a wide range in fledging time (8-18 days) and in their risk of nest predation associated with different nest types (e.g., ground, off-ground, and cavity). We find that in two very different environments, north temperate (northern Arizona) and tropical (Borneo, Malaysia), species with relatively high predation risk develop their locomotor appendages fast but fledge early when locomotor appendages are relatively small. In contrast, species that have relatively low risk of predation develop slower but prolong their stay in the nest and fledge with much more fully developed wings and legs. Such differences lead to variation in wing loading and performance and provide novel insight into the developmental tradeoffs that influence the evolution of avian diversity.

P2.40 DIAL, T.R.*; SUMMERS, A.P.; BRAINERD, E.L.; Brown University, University of Washington; *terry_dial@brown.edu*

Tradeoffs in anguilliform locomotion over complex substrates in Stichaeid fishes

Elongate body forms have repeatedly evolved throughout ectothermic vertebrates. Anguilliform locomotion works by propagating undulatory waves down the length of an elongate body offering proficient aquatic locomotion but also permitting various degrees of terrestrial locomotor competence. Terrestrial movement involves body waves creating contact points to push against the substrate in order to propel the animal forward or downward (i.e., to bury). Tradeoffs may exist among alternate body forms that utilize aquatic, intertidal, over-ground terrestrial, and digging locomotion. This study compared locomotor performance between three species of Pricklebacks (Teleosei: Stichaeidae), a group of elongate fishes that span subtidal-intertidal habitats. We measured whole body velocity, amplitude, frequency, wavelength and Froude efficiency (ratio of forward speed to wave speed) in *Xiphister atropurpureus* (intertidal), *Lumpenus sagitta* (subtidal) and *Anoplarchus purpurescens* (intertidal and subtidal), over five substrates (water, plexi glass, sand, pebbles and rocks). Substrates elicited differential performance: all three species were significantly slower when moving over land, but not all suffer a reduction in efficiency. *X. atropurpureus* was found to move as efficiently on land as in water (Fr=0.7, $P<0.05$). *L. sagitta* was only efficient in water, (Fr=0.75) whereas *A. purpurescens* was efficient in water and over rocks (Fr=0.5), but not on the other substrates. This study suggests there is a species-specific gradient of performance as animals transition from water to land consistent with their preferred habitat. Within the Stichaeidae, *A. purpurescens* illustrates the predicted tradeoff of possessing an intermediate body form, and corresponding locomotor performance, between *X. atropurpureus* (proficient on land) and *L. sagitta* (proficient in water).

S6-1.6 DIAMOND, SE*; PELINI, SL; ELLISON, AM; GOTELLI, NJ; SANDERS, NJ; DUNN, RR; North Carolina State Univ., Bowling Green State Univ., Harvard Forest, Univ. of Vermont, Univ. of Tennessee; *sarah_diamond@ncsu.edu*

Using physiology to predict ectotherm responses to environmental change

Global changes in land-use and climate ensure that species are increasingly likely to encounter novel environments. This places a renewed urgency on understanding biological responses to environmental novelty. However, because these changes are occurring at a global scale with potential impacts on millions of species, we cannot develop predictions for how each species might respond. Rather, we need a predictive framework that reduces the dimensionality of this task by identifying key characteristics of those taxa and regions that are most at risk. We focus on the predictive ability of physiological tolerance of extreme temperatures in ectotherms. Here, we build upon our previous work showing that ants inhabiting lower latitudes tend to be at the greatest risk under climate change owing to environmental temperatures being close to their thermal limits. Among our two large-scale experimental warming arrays, positioned at the northern and southern boundaries of temperate hardwood forests in eastern North America, ant thermal tolerance was strongly predictive of ant responses at the low latitude site where temperatures routinely exceed ant thermal limits, but not the high latitude site where temperatures remain below ant thermal limits. While thermal tolerance explained a substantial portion of the variance in ant responses to warming, we found that carpenter ants (*Camponotus* sp.) were consistently some of the strongest outliers, occupying conditions well below their thermal limits. We further dissect the mechanisms underlying carpenter ant responses to warming, focusing on additional physiological traits including immune defenses and species interactions between ant hosts and their symbionts.

S8-2.1 DIAZ, M.C.*; THACKER, R.W.T; REDMOND, N.; COLLINS, A.G; Museo Marino, NE, Venezuela, U. Alabama at Birmingham, USA, NMNH, Smithsonian Institution, USA, NMNH, Smithsonian Institution, USA; *taxochica@gmail.com*

"Don't judge a book by its cover: Discovering two new Verongida genera (Class Demospongiae, Porifera)"

Integrating morphological and molecular data is crucial when morphological characters are absent, or poorly represented, requiring genetic evidence to discern species identity and relationships. Among hundreds of specimens collected by the PorTol project were two morphospecies lacking any evidence of skeletal elements, one from Panama, the other from Moorea. Histological and molecular (18S) evidence were gathered to identify them. Histological sections of the Panama material corroborated the absence of any skeleton, and showed the existence of large, sac-shaped choanocyte chambers. The 18S analysis revealed that this species is allied with members of Ianthellidae (Verongida), which includes three genera with a total of 19 species, none present in the Caribbean. This species has a sister group relationship to a clade containing the skeleton-bearing Ianthellidae (*Ianthella* and *Anomoianthella*), while the third askeletal genus *Hexadella* is placed as a separate clade. This phylogenetic information supports the erection of a fourth genus for this family. Histological sections of the Moorea material revealed representatives of three genera among the samples initially considered to represent a single species. One showed the presence of amorphous, pith-dominated fibers (*Pseudoceratina* cf. *purpurea*) and another showed the existence of rare single fibers with pith and bark (*Suberea* sp.). A third species represents another askeletal genus of Verongida, placed within a clade of Aplysinellidae and Pseudoceratiniidae by 18S analyses. These findings demonstrate the importance of complementing the histology of askeletal sponges with genetic information that can clarify the real affinities and/or identities of the taxa.

75.2 DIAZ, S; SHIRKEY, NJ; THALER, CD; CARDULLO, RA; HAMMOND, KA*; Univ. of California, Riverside; *khammond@ucr.edu*

Phenotypic Changes in Lung Function After Acclimation to High Altitude in Deer Mice

Small mammals living at high altitude face low O_2 partial pressures, cold ambient temperatures necessitating an increase in energy expenditure. Deer mice (Peromyscus maniculatus) inhabit a broad altitudinal range (0 to 4000 m) in the US and are used as a model species to demonstrate genetic adaptations in hemoglobin O_2 affinity. It appears from recent research, however that the hemoglobin/genetic adaptations are insufficient to explain the highly successful active life history of deer mice. Previously, we have reported that deer mice also display phenotypic changes in organ size (heart, lung, gut, and blood volume) that vary along the altitudinal gradient, are linked to the improved aerobic performance necessary for high levels of activity. We have also reported moderate changes in pulmonary surfactant composition that may lead to changes in surface tension to support aerobic activity in the low O_2 availability at high altitude. Here we report results showing that although mice living at high altitude produce the same total amount of surfactant lipid as those living at low altitude, 85% of high altitude individuals (n=13) include lipids that were not detected in low altitude mice (n=11). Conversely, 65% of low altitude individuals have lipid species that were not detected in high altitude individuals. Also while there is a nearly double amount of surfactant protein B (responsible for spreading lipids) in mice at high altitude there is enough variability in the levels of this protein so that this difference is not statistically significant. From these results, we predict that subtle changes in surfactant composition are important at high altitude but they must be accompanied by changes in lung architecture (and lung mass).

P3.207 DIAZ-ALMEYDA, E*; MEDINA, M; IGLESIAS-PRIETO, R; University of California Merced, Unidad Academica Puerto Morelos, UNAM; *ediaz-almeyda@ucmerced.edu*

Exploring physiological effects of temperature sensor activation in Symbiodinium

Symbiodinium is a genus of dinoflagellates that lives in symbiosis with a variety of marine invertebrates, and other eukaryote groups including corals. Rising temperatures due to climate change cause the breakdown of this symbiosis, in a phenomenon designated as coral bleaching. This phenomenon threatens coral reefs on a global scale. It has been proposed that the dinoflagellates are the most temperature sensitive component of the symbiosis and therefore responsible for the fragility of reefs. TRP channels have been identified as temperature sensors in a variety of organisms, but it's role has not been explored in the context of climate change in symbiotic dinoflagellates. These channels can be activated by increases in temperature or by exposing the cells to capsaicin. In order to test if a temperature increases have similar effect as the chemical activation of the TRP channel, here we characterize the physiological responses of *Symbiodinium* cultures exposed to 100uM of capsaicin. Changes in growth rate relative to the control (no capsaicin) were observed. Non-significant changes were observed in the quantum yield of charge separation (Fv/Fm). A decrease in the oxygen production was measured with the presence of capsaicin. Ultra-structural changes were observed under fluorescent microscopy. Collectively, our results suggest that capsaicin has a different physiological effect than those observed in thermally stressed algal cultures.

65.1 DICKENS, M.J.*; BENTLEY, G.E.; Univ. of California, Berkeley; *m.dickens@berkeley.edu*

Endocannabinoid regulation of glucocorticoids — its for the birds

Endocrine regulation of corticosterone (CORT) release during the stress response is well described in wild birds. Neural mechanisms impinging upon this endocrine system and regulating it seasonally are less well defined. Typically, the CORT response is down-regulated during molt in seasonally-breeding birds, yet underlying mechanisms of this phenomenon are unclear. The endocannabinoid (eCB) system, a lipid-signaling pathway, may act as a central influence upon baseline and stress-induced CORT release in a seasonal manner. Here, we demonstrate a role for the eCB system in regulating the changing CORT response between breeding and molting conditions. First, using two groups of male European starlings, we targeted action at the eCB neural receptor (CB1) by injecting a CB1 specific antagonist, AM251, and measured subsequent CORT concentrations. CORT significantly increased with injection of the antagonist regardless of observed seasonal changes in CORT concentrations. These data suggest that blockade of the eCB signal *releases* the CORT response. Notably, the antagonist resulted in greater CORT increases in breeding males. Thus, the eCB system likely acts to inhibit the CORT response, an effect which may be stronger in breeding versus molting birds. Using in situ hybridization, we confirmed the presence of CB1 receptor expression in the paraventricular nucleus (PVN) of the hypothalamus, hippocampus (HP) and nucleus taeniae amygdala (TnA), sites known for their role in eCB-mediated CORT regulation in mammals. qPCR data suggest that the highest degree of CB1 expression in these nuclei occurs in the TnA followed by the HP and then PVN. Overall, these findings indicate a previously unidentified role for the endocannabinoid system in the regulation of the avian stress response.

P3.181 DICKENS, M.J.*; BALTHAZART, J.; CORNIL, C.A.; Univ. of California, Berkeley, Univ. of Liege; *m.dickens@berkeley.edu*

Correlation between local brain estradiol concentrations and aromatase activity after acute stress or sexual interaction

Testosterone aromatization in the brain is known to play a key role in male sexual behavior of Japanese quail. Local brain aromatase activity (AA) can be rapidly regulated in vivo (<5 min) but how these changes correlate to changes in estradiol concentration (E2) in the tissue remains unclear. Here we examine rapid changes of E2 and AA in microdissected nuclei of male and female quail after 5 min of sexual interaction (demonstrated to decrease AA in the preoptic area-hypothalamus, HPOA), 15 min of restraint stress (demonstrated to increase AA in the HPOA) or in control conditions. Individual brains were microdissected to isolate HPOA and medio-basal hypothalamus (MBH), and estradiol was extracted and assayed using an UltraSensitive radioimmunoassay in part of each sample while AA was assayed in the rest. In females, E2 and AA were stable across experimental groups and there was a significant, positive correlation between E2 and AA in both HPOA and MBH suggesting that females rely on local AA rather than ovarian production to maintain nuclei-specific E2. In the male HPOA, sexual interactions tended to decrease AA (as predicted) with a corresponding decrease in E2 and there was a positive, significant correlation between AA and E2. Surprisingly, however, stress increased AA (as predicted) but E2 significantly decreased to nearly half of control concentrations. This suggests that acute stress may initiate a previously unidentified phenomenon to regulate local E2. While these data suggest a new context-dependent regulation of AA and E2 following stress, they also further confirm rapid changes in local E2 that may then mediate rapid behavioral effects.

101.4 DICKERSON, BH*; HOWELL, DB; DANIEL, TL; University of Washington; *bdicker@uw.edu*

Moths respond to inertial yaw rotations with lateral abdominal movements.

Multimodal sensory information processing is a key component of insect flight control. While visual information is crucial, mechanoreception serves an equally important role because of its relatively fast processing time. For example, in both tethered and freely flying hawkmoths, there is a powerful abdominal reflex to a mechanical pitch stimulus, an axis of rotation in which the animal is unstable. However, in other rotational axes, there is no clear evidence supporting abdominal reflexive responses to inertial rotational stimuli in the yaw axis. To determine whether there are responses to pure yaw rotation, we tethered hawkmoths, *Manduca sexta* (n = 6) to a rotating servomotor. Moths were subject repeated trials of 2.5 Hz sinusoidal rotations with an amplitude of 40 degrees under both light and dark conditions. In all trials, moths exhibited flight behavior. We found that there is a significant abdominal response to yaw stimuli with a gain of 0.19 ± 0.1. Thus both yaw and pitch stimuli induce significant abdominal reflexes. Those responses could be detected by mechanosensory structures in the antennae or elsewhere, such as in the wings.

84.4 DICKSON, M.M.*; ZIMMERMANN, S.A.; LIWANAG, H.E.M.; ESPINOZA, R.E.; California State University, Northridge, California State University, Northridge; Adelphi University; *matthew.dickson.417@my.csun.edu*

Evolution on Your Porch: Physiological Adaptation by Mediterranean House Geckos to their Introduced Niches

Adaptation is essential for organisms to persist in changing environments. Physiological adaptations should be especially important to ectotherms, which are closely coupled to their abiotic environments. Introduced species may be more likely to evolutionarily adapt to local climates because of small founder populations and strong selective pressures in their new environments. To test these ideas, we compared the thermal tolerances (critical thermal minimum, CT_{min} and panting threshold, T_{pant}) and temperature-dependent rates of evaporative water loss (EWL) of Mediterranean House Geckos (*Hemidactylus turcicus*) from different climates. These familiar "porch light" geckos have been widely introduced throughout North America over the past century. Introduced geckos were collected from regions representing three climates: desert (hot/dry), Mediterranean (warm/dry), and semitropical (hot/humid). We hypothesized that geckos from these three climates would exhibit differences in temperature tolerances and EWL consistent with local adaptation. Geckos experiencing lower daytime temperatures had lower CT_{min} compared to geckos from hotter climates, consistent with local adaptation. However, we found no significant differences in T_{pant} among geckos from differing climates. Geckos from arid climates had lower rates of EWL at high temperatures compared to geckos from humid regions, also indicating adaptive evolution. Future studies will include temperature-dependent metabolism and sprint performance. Ultimately these data will be used to develop mechanistic climatic niche models to predict the future range expansion of this species in North America.

S11-1.2 DIGGLE, P.K.; Univeristy of Colorado, Boulder; *pamela.diggle@colorado.edu*

Metamers, modules, phenotypic plasticity, and the evolution of diverse sexual systems in plants

Plant development is metameric: apical meristems produce a sequence of repeated units over space and time. These metamers, in turn, may be modular with the potential for independent adjustment of component traits. As a result, plastic developmental responses can occur at multiple levels of the phenotype. For example, flowers within inflorescences are metamers, and within individual flowers the development of the androecium (male reproductive structures) and gynoecium (female reproductive strictures) may (or may not) be relatively independent and modular. Changes in allocation to male vs. female reproduction potentially can occur via modification of intra-floral development and via the number and timing of metamer production. Both types of response, however, occur with in the context of "whole plant" properties such as architecture. I will discuss the relationship between phenotypically plastic responses at multiple levels of organization to the evolution of the diverse sexual systems observed among plants.

P2.34 DILLY, GF*; HOFMANN, G; Univ. of California, Santa Barbara; *geoff.dilly@lifesci.ucsb.edu*

The Transcriptome of Antarctic Sea Urchin (Sterechinus neumayeri) Larvae

A commonly found Antarctic echinoid, *Sterechinus neumayeri* has been used as a model species in ecology, physiology, larval and reproductive biology. Reflecting a focus on global change research, current larval studies have focused on the effects of thermal stress and elevated CO_2 on the physiology and development of *S. neumayeri* larvae. To complement morphological and physiological investigations on experimentally treated larvae, transcriptomic and proteomic analyses will be necessary to understand the underlying biomolecular responses to these multiple stresses. However, because there is no completed genome for this species, it is necessary to first build a transcriptome reference library for further experimental research. To this end, we collaborated with the Center for Genomics and Bioinformatics at Indiana University to pyrosequence an inclusive transcriptome of larval *S. neumayeri* maintained under a variety of conditions and multiple life stages. Thirteen larval samples were used to create the cDNA library, representing treatments on day 11 (early gastrula), 19 (early pluteus), and 30 (pluteus) of development. Each developmental stage included larvae maintained at three CO_2 levels averaging 421, 652, and 1071 ppm. To identify potential thermal stress response gene candidates in our cDNA library, four additional heat shocked samples with temperatures ranging from 0 °C to 20 °C were included. A normalized cDNA pool was sequenced using 454 technology resulting in 1.34M reads with an average length of 600 base pairs for a total library 689M bp. Analysis of the annotated results are presented here. This library will be fundamentally important to progressing genomic, proteomic, and comparative research on this model species.

131.4 DING, Y*; SHARPE, S.S.; GOLDMAN, D.I.; Georgia Tech; *dingyang@gatech.edu*

Emergence of a Neuromechanical Phase Lag in a Resistive Force Dominated Medium

Undulatory locomotion is a common gait used by organisms in fluids, on land, andeven within sand. This mode of locomotion relies on propagation of a traveling wave of body bending, producing thrust which propels the animal in the opposite direction. Many previous studies have shown that the wave of muscle activation progresses faster than the wave of curvature. This leads to an increasing phase lag between activation and curvature at more posterior segments, known as the neuromechanical phase lag. A number of multi-parameter neuromechanical models have been proposed to account for the phase lag, but are difficult to analyze to reveal basic principles. Here we demonstrate that in addition to kinematic similarities, undulatory sand-swimming of the sandfish lizard also neuromechancially resembles swimming in fluids. Using the simplest model of undulatory sand-swimming consisting of prescribed kinematics and granular resistive forces, we show that with no fitting parameters, the biological measurements quantitatively match model predicted phase lag between the local body curvature and torque exerted by granular resistive forces. Analyzing the model reveals the dominant mechanism responsible for the phase lag: different integration length over a traveling force pattern for different positions along the body. Our results demonstrate that movement in the non-inertial resistive force dominated granular mediumis a simple system for studying neuromechanics, allowing detailed comparisons between experiment and theory. Such comparison can give insight into principles that generate the neuromechanical phase lags in other environments.

34.3 DOLCEMASCOLO, P*; DILEO, K; Montclair State University, NJ Division of Fish and Wildlife; *dolcemascop1@gmail.com*

The Genetics of Colonization: Evidence for a Recent Range Expansion in Hyla cinerea

Green tree frogs, *Hyla cinerea*, are ubiquitous across their geographic range, from Delaware south along the Atlantic Coastal Plain to Florida, westward along the Gulf Coastal Plain to eastern Texas, and north into the Mississippi River Valley to southern Illinois. In June 2011, a large population of *H. cinerea* was discovered in southwestern New Jersey along the Delaware River. This was the first recorded occurrence of *H. cinerea* in NJ and represents a possible range expansion past their northern-most limit in Delaware. Subsequent reports of this species have been confirmed along the Delaware Bayshore. Northeastward range expansions by this species have been documented in Illinois and recently metamorphosed *H. cinerea* have been found 0.5 km from the nearest breeding habitat, demonstrating dispersal capacity. To determine whether the NJ population was established via colonization by Delaware tree frogs, genetic analyses were undertaken. Toe clips were collected from both populations and partial sequences of the mitochondrial ND1 gene were used to generate a statistical parsimony network. Four haplotypes were distinguished, with all NJ haplotypes being identical to the most prevalent Delaware haplotype and the Delaware haplotypes differing by at most one base pair. A sequence from a Louisiana green tree frog obtained from GenBank could not be joined in the network with 95% confidence. These results indicate a recent movement of Delaware frogs into NJ. Museum specimens collected throughout the species' range are being analyzed in order to place the new NJ population in the context of species-wide diversity. Although movement may have been human-mediated, rising temperatures are possibly favoring the persistence and establishment of these frogs in new areas.

80.3 DOLINAJEC, T.H.*; KOEHL, M.A.R.; Univ. of California, Berkeley; *dolinajec@berkeley.edu*

Hydrodynamic forces and moments on microscopic aquatic animals

Many aquatic animals are microscopic and interact with the water around them at a range of velocities in which both viscous and inertial forces are important. In spite of their biological importance, hydrodynamic forces on bodies in this size and velocity range are poorly understood. We studied how the morphology and orientation of a variety of ecologically-important microscopic marine animals (copepod, veliger larva, barnacle nauplius and cyprid larvae) affect the forces they experience while swimming in the water column, and while on surfaces (e.g. predator tentacles, benthic substrata). Our focus was on a range of velocities that these animals would encounter while swimming or while on surfaces in wave-swept habitats. We measured hydrodynamic forces on dynamically-scaled physical models because they offer a better signal-to-noise ratio and enable manipulations of orientation and posture that are not possible for real microscopic organisms. We measured drag, lift, and side forces as well as moments about three axes for each model in different orientations relative to the flow and substratum. These forces and moments can reoriented swimming animals , or push, lift, peel, or shear animals off surfaces. We found that body shape, orientation, and proximity to a surface had significant effects on the magnitudes of the forces and moments on the animals. Drag was the dominant force and lift was negligible in all cases. In contrast, orientation determined whether shearing or peeling moments were greatest on attached animals. These results indicate that the forces and moments that can tumble or dislodge organisms in this little-studied size range depend on body shape, and can vary drastically with changes in posture and orientation.

S1-2.1 DOMENICI, P; CNR- National Research Council, Oristano, Italy; *paolo.domenici@cnr.it*

Escape responses in fishes

The escape response is a common anti-predator behaviour observed in most animal species. Fish escape responses have long been considered all-or-none, stereotypic responses. However, recent work has shown that the kinematics and timing of fish escape responses are quite diverse, both within and across species. The kinematics, spatial and temporal characteristics of fish escape responses may be affected by a number of factors. Among these, stimulus characteristics (direction, intensity, distance), schooling, and environmental factors (i.e. hypoxia, temperature) can play an important role in modulating escape responses. Here, I argue that the variability found in kinematics and timing of escape responses in fish and other animals does not necessarily form a continuum, but rather reveals multimodal patterns of distributions in many case studies. Escape latencies are not always minimized, possibly as a result of a graded system through which sub-maximal responses may be used when the threat is not maximal, or in extreme environmental conditions. Similarly, specific patterns of escape directions were found. While maximizing unpredictability would correspond to random directions of escape, work on various species shows that escape trajectories are not random, although they can be multimodal as found in many species. Theoretical work suggests that optimal trajectories for escape should span 90-180 degrees from the predator's attack, depending on the ratio between the speeds of predators and prey. Experimental results are in line with this prediction. Temporal, directional and kinematic patterns of escape response will be discussed in terms of their potential physiological and functional bases and their evolutionary significance.

93.4 DOMINONI, DM*; PARTECKE, J; Max Planck Institute for Ornithology, Germany; *ddominoni@orn.mpg.de*

Long-term effects of chronic artificial night light exposure on life-history traits of songbirds

We live in the urban millennium, the age of globalization and urban sprawl. Rapid expansion of cities is accompanied by extreme habitat change, and one of the most peculiar characteristics of urbanization is the presence of artificial light at night. However, little is known about the effects of light pollution on wild animals. We hypothesized that light at night may alter daylength perception and therefore modify seasonal timing. We experimentally tested our hypothesis using captive European blackbirds (*Turdus merula*) as model species. City and forest blackbirds were exposed to either dark nights or low light intensities at night (0.3 lux), and seasonal variation of testicular cycles, plasma testosterone and molt was determined for two consecutive years. In 2011, birds under light at night developed their testes up to one month earlier than control birds kept under dark nights. The same effect was detected in the timing of testosterone secretion and molt. Moreover, regardless of the light treatment city birds developed their testes earlier than forest conspecifics. In 2012, birds under light at night kept their reproductive system shut down for the entire spring and did not molt, whereas control birds showed the same timing of reproduction and molt of 2011, with city birds being earlier than forest birds. In conclusion, here we show that i) light at night can advance timing of reproduction and molt and ii) chronic and long-term exposition to light at night can suppress fitness-relevant life-history stages such as reproduction and molt. Our results emphasize the impact of human-induced lighting on the ecology of hundreds of millions of animals living in cities and call urgently for an understanding of the fitness consequences of light pollution.

110.1 DOMYAN, ET; KRONENBERG, Z; VICKREY, AI; YANDELL, M; SHAPIRO, MD*; Univ. of Utah; *shapiro@biology.utah.edu*

Genomic and developmental basis of diversity in the domestic pigeon

Domestic pigeons are spectacularly diverse and exhibit variation in more traits than any other bird species. Despite intense historical interest in pigeon genetics, little is known about the molecular basis of their vast diversity. We used genome-wide scans of allele frequency differentiation and a probabilistic gene-finder to identify regions of the pigeon genome associated with derived traits. Strikingly, one such scan revealed a shared haplotype in all pigeons with derived head crest phenotypes, suggesting that a causative mutation occurred just once and spread to multiple breeds by ancient and recent introgression. A single shared variant is perfectly associated with the crest phenotype across 79 diverse breeds of domestic pigeon, and is therefore a convincing candidate for the crest (cr) locus of classical pigeon genetics. This locus appears to act as a developmental switch for the trait, but the tremendous variation in crest phenotypes suggests that other loci must contribute as well.

7.1 DOO, SS*; FAN, TY; FUJITA, K; MAYFIELD, AB; CHEN, HK; NGUYEN, HD; BYRNE, M; National Museum of Marine Biology and Aquarium, University of the Ryukyus, University of Sydney; *stevedoo@gmail.com*

Developing molecular techniques to assess resilience in large benthic foraminiferan communities

Large benthic Foraminifera (LBFs) compose a significant portion of calcareous sediments in coral reef ecosystems, buffering against diel changes in seawater chemistry and contributing to maintenance of coral sand cays. The vast majority of recent studies on biological responses of large benthic Foraminifera (LBF) to changing climates have indicated deleterious effects on these crucial organisms. In this study, we present new techniques developed to monitor effects of changing climates to the foraminferal holobiont. Western blotting technique was used to determine protein expression of RuBiSCO, a highly conserved rate-limiting photosystem II enzyme, in *Baculogypsina sphaerulata* collected from intertidal algal flats of the coral island Xiao Liu Chiu, Taiwan. Data indicated reduced protein expression (~50% decrease) of RuBiSCO in response to an acute heat stress (5hr) at +8°C. In a separate project, the potential for recovery in two common LBFs, *Calcarina gaudichaudii* (diatom-bearing) and *Amphisorus hemprichii* (dinoflagellate-bearing) was assessed by subjecting specimens to 24 h heat stress (amb, +4°C, +8°C), then returning foraminiferans to ambient conditions for an additional 24h. Maximum dark adapted yield (Fv/Fm) measurements of *C. gaudichaudii* indicate increased Fv/Fm values in mild heating (+4°C) treatments, while no significant effects were observed after return to ambient temperatures. The response of *A. hemprechii* indicated no significant effects of heat stress up to +8°C to Fv/Fm values after 24h heating, but deleterious effects were observed in our +8°C treatment after 24h of return to ambient temperatures.

23.3 DORES, R.M.*; LIANG, L.; Univ. of Denver, Denver; *rdores@du.edu*

Humans are also mammals; using the human melanocortin-2 receptor as a model for analyzing the evolution of MC2Rs.

Studies on the human melanocortin-2 receptor indicate that: a) this MC2R can only be activated by ACTH, but not by any of the MSH-sized melanocortins; b) human MC2R requires interaction with the accessory protein MRAP1 for functional activation; 3) spontaneous mutations in the human gene can result in either loss of function mutations or trafficking impaired mutants. This information can be used as a reference point for evaluating the evolution of MC2R orthologs in non-anmiote tetrapods, teleosts, and cartilaginous fishes. From these comparisons it is possible to re-construct the functional evolution of the melanocortin-2 receptor, a critical component in the HPA/HPI of teleosts and tetrapods.

P1.154 DORFMAN, R.E.*; LI, D.; BENNER, I.; LEFEBVRE, S.; CARPENTER, E.J.; KOMADA, T.; STILLMAN, J.; San Francisco State University; *Racheld@mail.sfsu.edu*
Transcriptomic analysis of the effects of Ocean Acidification and Increased Temperature in the coccolithophore Emiliania huxleyi
Calcifying marine phytoplankton (i.e. coccolithophores) play an important role in the global carbon cycle. Global change related shifts in temperature, nutrient composition, and pH via ocean acidification alter the biology of coccolithophores. The world's most abundant coccolithophore, *Emiliania huxleyi*, exhibits contrasting physiological responses to increased CO_2, but little is known about the molecular mechanisms involved in the response to increasing CO_2 or temperature. *E. huxleyi* (Strain CCMP371) was grown in continuous chemostat cultures for over 200 generations at "present" (380 ppm, 20°C) and "future" (800 ppm, 24°C) ocean conditions. Two replicates of each chemostat treatment were run, and n=6 samples were taken from each chemostat (n=24 samples total) after 200 generations. Total RNA was purified from each sample and used for the construction of RNA-seq cDNA libraries, which were sequenced on the Illumina HiSeq2000 platform in order to gain insight into the transcriptome response. For each library we obtained an average of about 50,000,000 sequence reads. When mapped against the *E. huxleyi* genome and trimmed for quality, these reads corresponded to at least 22,000 genes that were expressed. Over 700 genes were differentially expressed between the two treatments, with the majority of these genes upregulated in present ocean conditions relative to future conditions. Our analysis of the specific cellular pathways that are affected by ocean acidification will provide insight as to how coccolithophores might respond to future environmental change, as well as provide opportunities to target the specific physiological mechanisms involved in the response of these cells to future ocean conditions.

97.3 DORGAN, K.M.*; LAW, C.J.; ROUSE, G.W.; Scripps Institution of Oceanography; *kdorgan@ucsd.edu*
Meandering through marine muds: kinematics of burrowing and swimming by the polychaete Armandia brevis
Mechanical interactions between organisms and their environments are integral to locomotion, but mechanical responses of soils and sediments to forces applied by burrowing organisms are poorly understood. Recent work has shown that muddy sediments are elastic solids through which animals extend burrows by fracture. However, *Armandia brevis*, a mud-burrowing opheliid polychaete annelid, lacks an expansible anterior consistent with fracturing mud, and instead uses undulatory movements to burrow. Here we show that *A. brevis* neither fractures nor fluidizes sediments, but instead uses a third mechanism, plastically rearranging sediment grains to create a burrow. In addition, the curvature of the undulating body fits meander geometry used to describe rivers, and changes in curvature over time driven by muscle contraction are similar for swimming and burrowing worms, indicating that the same gait is used in both media. Large calculated friction forces for undulatory burrowers suggest that sediment mechanics affect undulatory and peristaltic burrowers differently; undulatory burrowing may be more effective for small worms that live in sediments not compacted or cohesive enough to extend burrows by fracture.

P1.2 DOUGHERTY, L/F*; CALDWELL, R/L; University of California, Berkeley; *lindseydougherty@berkeley.edu*
Mechanisms, ultrastructure and behavioral function of flashing in Ctenoides ales: "electric scallops"
At 20m, the ocean is an environment in which light is variable as long wavelengths are absorbed rapidly with depth, yet many organisms use visual displays that require ambient light for reflection. The mechanisms that produce and perceive light underwater are remarkable examples of biological engineering and unique sensory systems specialized for dynamic habitats. *Ctenoides ales* are bivalves that live at depths up to 20m inside small crevices. Despite their light-limited habitat, they evolved an iridescent mantle edge that flashes bright blue light, leading to their common name "electric scallops". They are the only species of bivalve known to have a light display. The flashing was investigated using electron microscopy, spectrometry, molecular phylogenetics and high speed video. Spectrometry indicated the light is within the blue range of 445-483nm with a peak reflection of 22.8%. High-speed video revealed that the mantle edge furls and then unfurls the reflective tissue to produce the flashing. Transmission electron microscopy (TEM) indicated the presence of electron-dense reflective vesicles roughly 0.2µm in diameter on the ventral half of the mantle tip, while TEM of the related *C. scaber*, which does not produce a light display, lacked any similar cells. There are no published sequences for *C. ales*, so molecular phylogenetics were done for comparative studies. These placed *C. ales* nearest two *Acesta* species, one *Lima* species and *C. annulata* using a 16S primer. Additional sequencing is being done using 28S and CO1 primers. The behavioral purpose of the light display remains unknown. We are testing the hypotheses that the light display acts in phototaxic prey luring or as a deimatic anti-predation display.

46.1 DOWD, W.W.*; FELTON, C.; HEYMANN, H.M.; KOST, L.E.; SOMERO, G.N.; Loyola Marymount University, Hopkins Marine Station of Stanford University; *wdowd@lmu.edu*
Small-scale spatial and temporal variation in metabolic and antioxidant enzyme capacities within a population of rocky intertidal mussels (Mytilus californianus)
Denizens of wave-exposed, rocky intertidal shores inhabit a spatially complex and dynamic environment, characterized by rhythmic and/or stochastic exposures to both environmental (e.g., emersion, desiccation, temperature extremes) and biological challenges (e.g., predation, competition, food availability). Much effort has been devoted to studying patterns of physiological and/or genetic variation within and between such species, along latitudinal, vertical, seasonal or other relatively large scales. More recently, attention has been focused on small-scale, intra-population variation in physiology and the factors that might regulate it. For example, other work has documented temporal variation in gene expression in the intertidal mussel *Mytilus californianus* over the course of tidal cycles. In the present study, we approached this issue of intra-population variation from a functional perspective. We quantified temporal changes (over a 5-d period) in biochemical capacities for ATP generation (citrate synthase and malate dehydrogenase) and antioxidant defense (catalase and superoxide dismutase) in mussels from four different micro-sites separated in space by short distances. The patterns of temporal variation varied among micro-sites, but overall metabolic and antioxidant capacities were strongly correlated. We then examined candidate environmental factors that might contribute to spatial and temporal variation in physiology, including variation in emersion time, thermal history, or food abundance. Our results implicate a complex suite of interacting factors that influence the biochemical state of intertidal mussels.

141.5 DOWNS, C.J.*; BRICKNER-BRAUN, I.; VATNICK, I.; PINSHOW, B.; Ben-Gurion Univ., of the Negev, Midreshet Ben-Gurion, Israel, Widener Univ., Chester, PA, Ben-Gurion Univ. of the Negev, Midreshet Ben-Gurion, Israel; *downsc@gmail.com*

Jirds living in a hypercapnic environment incur energetic costs, but don't appear to care.

Animals use burrows to avoid predation, find protection from adverse environmental conditions, raise young, and hoard food. But, burrow dwellers are isolated from atmospheric sources and sinks for exchange of respiratory gases and if CO_2 accumulates in burrows of animals with high metabolic demands, the question is: are these animals physiologically and behaviorally adapted to high inspired FCO_2? We investigated how exposure to high FCO_2 (0.07) affected total evaporative water loss (TEWL), metabolic rate (MR), respiratory rate (*f*), and activity patterns of the Sundevall's jird (*Meriones crassus*), a semi-fossorial desert rodent. Assuming that breathing CO_2-rich air is stressful, we hypothesized that the above variables all increase under hypercapnic conditions. We found that jirds breathing high FCO_2 had higher resting and daily MR and higher *f* than jirds breathing CO_2-free air; the jirds were also more active and slept less. However, average TEWL did not differ between treatments. We concluded that living in a hypercapnic environment is energetically costly, but does not increase TEWL, and therefore hypothesized that Sundevall's jirds should prefer environments with atmospheric FCO_2 to hypercapnic surroundings. To test this hypothesis, we did a choice experiment, but found no difference in the time jirds spent in fresh or CO_2-rich air. Thus, despite the energetic cost of inhabiting a hypercapnic environment, jirds did not leave it. This suggests that the costs to fitness of leaving a burrow with high FCO_2 (e.g., risk of predation, thermoregulating in the desert) may be greater than the physiological costs of staying in the hypercapnic environment.

P1.34 DOWNS, L.K.*; BARRILE, G.M.; BOWER, C.D.; HRANITZ, J.M.; KLINGER, J.M.; MOORE, J.T.; Bloomsburg University, Bloomsburg; *lkd30583@huskies.bloomu.edu*

Island Dwarfism Affects Female Fecundity in Fowler's Toad: Quantity Versus Quality?

Previous research comparing island and mainland populations of Anaxyrus (formerly Bufo) fowleri documented high population densities and island dwarfism in the population on Assateague Island, Virginia. The small insular body size compared to mainland size does not appear to be caused by a simple factor, such as low genetic diversity. Instead, age structure, competition, and harsh conditions on the island remain hypothetical causes that need to be integrated with organismal life history responses. One of the life history responses analyzed in this study is reproductive output, as corresponding intraspecific variation may be related to insular body size differences. In 2011, we conducted a pilot study of female fecundity in the population of A. Fowleri on Assateague Island compared to those on the adjacent mainland by measuring clutch size (number of eggs) and egg diameter. We found that island and mainland populations differed, with the mainland females depositing larger clutches. We hypothesized this was due to their larger SVL. We found no difference in egg diameter. In 2012, we increased our sample size, collecting from the same locations as the previous year and adding an additional mainland site. Our results indicated that, although there was still a significant difference between island and mainland populations, there were also annual differences in clutch sizes of eggs collected at the same mainland site from 2011 to 2012. There was no significant difference in egg diameter in 2012. These findings may result from annual climate variation and resource variability. If so, such variation may affect their activity levels thereby limiting storage reserves for egg production. These results also indicate that dwarfism affects reproductive output through clutch size but not egg size, highlighting a quantity not quality based trade off.

P2.107 DOWNS, C.J.*; ST. JULIANA, J.R.; WIELEBNOWSKI, N.; KRASNOV, B.R.; KHOKHLOVA, I.S.; Ben-Gurion Univ. of the Negev, Israel, Ben-Gurion Univ. of the Negev, Israel; Indiana State Univ., Terre Haute, Indiana; Ivy Tech Community College Wabash Valley, Terre Haute, Indiana , Chicago Zoological Society, Brookfield Zoo, Illinois; *downsc@gmail.com*

Are ectoparasites always harmful to their hosts?

Parasites by definition harm their hosts, whereas hosts defend themselves against parasites. While the negative effects of endo- and micro-parasites have been repeatedly demonstrated, studies on ectoparasites often failed to reveal this. Parasites are distributed unevenly among different host species. The host species that supports majority of parasite individuals is considered as the principal host for that parasite, while other hosts are considered as auxiliary hosts. Using fleas parasitic on small mammals as a model host-parasite association, we measured the effects of 4 different fleas on fecal glucocorticoid metabolite concentrations (FGMC) of 8 different hosts. The level of FGMC among rodent species infested by the same flea increased with the phylogenetic distance of a given rodent from the principal host of a given flea species. We also compared metabolic rates of parasitized and non-parasitized hosts in 8 different flea-rodents pairs. We found that metabolic rate of the auxiliary host increased with flea infestation while no such changes were found in the principal host. This indicates that the principal host have greater tolerance for parasite than an auxiliary host. In addition, host-induced flea mortality increased with the phylogenetic distance of a given rodent from the principal host of this flea species. These results suggest that the degree of parasite-induced harm is determined by history of association of a given host and a given parasite during which a parasite may fine-tune its strategy of host exploitation not to evoke anti-parasitic defense of its host.

55.1 DRIEDZIC, W. R. ; Memorial University, NL, Canada; *wdriedzic@mun.ca*

Glycerol Production and Cellular Uptake Mechanisms in Rainbow Smelt

Rainbow smelt is a small (≈10cm) fish that feeds under the sea ice during winter. Freeze resistance is achieved in part by the accumulation of high levels of glycerol (200 – 400 mM). Glycerol is produced primarily in the liver and builds up in all tissues via delivery through the circulatory system. Initial glycerol production is fuelled by liver glycogen but thereafter animals must continue to feed to survive as glycerol is continuously lost across the gills and skin at a rate of ≈10% per day. Dietary protein serves as a major source of glycerol. Regardless of the source of glycerol, the final metabolic steps involve the conversion of DHAP to G3P to glycerol. The glycerol cycle is controlled at the level of G3DPH, PEPCK, PDH, and enzymes of amino acid trafficking. Cellular uptake mechanisms remain to be addressed. Tissue glycerol equilibrates with glycerol in the plasma. At least in heart, glycerol appears to enter cells by passive diffusion down the concentration gradient with a linear relationship between extracellular glycerol and rate of uptake. Red blood cells (RBCs) present a different dynamic. In RBCs glycerol uptake shows two linear relationships with a transition point around 50 mM extracellular glycerol. The slope of the second phase is much steeper and is eliminated by phloretin, a blocker of facilitated transport. I propose RBCs have a low affinity aquaglyceroporin (AQGP) that facilitates glycerol entry at relatively high levels of extracellular glycerol. I further speculate that the presence of such an AQGP relates to the unique loading/unloading demand placed upon RBCs and no other tissues. Theoretically, RBCs show loose glycerol upon transiting the gill. Upon passage through the liver circulation the RBCs should reload at high extracellular glycerol levels.

P2.150 DRIVER, P*; GEORGE, S; Georgia Southern University, Statesboro, Georgia; *georges@georgiasouthern.edu*

Grazing by (Pisaster ochraceus larvae and dispersion of algae at and below haloclines

Thin phytoplankton layers are characterized by dense concentration of cells a few centimeters to several meters thick at haloclines. They extend horizontally for kilometers and can persist for days. These dense concentrations of phytoplankton have the potential to influence the behavior, feeding success, and predation by higher trophic levels. This study looked at changes in the vertical distribution and persistence of two algae *Isochrysis galbana* and *Rhodomonas* sp. at concentrations of 12,000-66,000 cells/ml, at and below a halocline in the presence and absence of a predator *Pisaster ochraceus* larvae. Three treatments with two replicates per treatment were set up, columns with, a) algae at the halocline + larvae, b) algae at the halocline – larvae, c) no algae + larvae in halocline. In each case, approximately 100 larvae were gravity fed to the bottom of each column. Patch width for *Rhodomonas* sp. remained near one cm for six hours while patch width for *I. galbana* increased to two cm in six hrs. For both algal species, cell concentration at the halocline declined significantly in the presence of *Pisaster* larvae. A greater decrease in cell concentration was observed for *I. galbana* when the food was at the bottom of the column rather than at the halocline. This was observed in the presence and absence of larvae. This indicates that for *I. galbana*, the decline in algal cell concentration at the bottom of the column might be due to cell movement towards the halocline. Interestingly, larvae remained around the halocline in the presence or absence of food for 6 hours. Living in stratified layers where thin phytoplankton layers might exist can be advantageous for *P. ochraceus* larvae by providing them with resources to feed, grow, and metamorphose but might also expose them to predation by higher trophic levels.

30.6 DRURY, J.P.*; ANDERSON, C.N.; GRETHER, G.F.; Univ. of California, Los Angeles, Oberlin College; *druryj@ucla.edu*

Reproductive interference and interspecific territoriality in rubyspot damselflies (Hetaerina spp.)

Male rubyspot damselflies (*Hetaerina* spp.) defend territories they use solely for accessing females. In rivers throughout the southern U.S. and Mexico with two or more *Hetaerina* spp., there is much variation in whether species pairs engage in interspecific territoriality. Previous research shows that agonistic character displacement has likely acted on some species pairs such that male competitor recognition diverges in sympatric populations. New field data and simulations that quantify the cost of sharing a territory with heterospecifics demonstrate that interspecific territoriality occurs in those species pairs that exhibit heterospecific reproductive interference (i.e. when males clasp heterospecific females). This observation suggests that between-species aggressive interactions are the adaptive outcome of selection on males competing for access to conspecific females.

52.3 DU, X.*; CRAWFORD, D.L.; OLEKSIAK , M.F.; Univ. of Miami, Miami, FL; *xdu2011@gmail.com*

Effects of PAHs on Respiration and Gene Expression in Primary Hepatocytes isolated from Natural Populations of Fundulus heteroclitus

We are investigating the effect of polycyclic aromatic hydrocarbons (PAHs) on metabolic function and gene expression using primary hepatocytes from two populations of the salt marsh teleost *Fundulus heteroclitus*: one population inhabiting a Superfund site highly contaminated with PAHs and a nearby reference population. Individuals from the population inhabiting the Superfund site are resistant to the PAHs in their environment, but the mechanism of this resistance is not yet well understood. Because PAHs are known to affect metabolism, mitochondrial respiration will be measured in primary hepatocytes using high resolution respirometry. The activities of specific complexes in the electron transport chain will be quantified by exposing hepatocytes to the corresponding substrates and blockers and then correlated with changes in gene expression. Differences between the polluted and reference populations will provide insights into PAH resistance and help us to better understand the evolution and adaptation of natural populations in response to anthropogenic pollution.

4.3 DUDEK, DM*; GAO, L; LU, H; MUELLER, R; Virginia Tech, Shandong Univ, Virginia Tech & Shandong Univ; *dmdudek@vt.edu*

Mechanics of bat vocal folds

Many bat species emit ultrasonic pulses as part of their active biosonar sensing. These pulses are produced, as in other mammals, through vibrating membranes called vocal folds. However, the performance of bats stands out through a singular combination of four features, namely high output amplitudes, miniaturization, efficiency, and reliability, that vastly outperforms any other solutions found in nature or in man-made technology. Output sound pressure levels as high as three times the human pain threshold have been reported, produced by a vibrating area measuring less than a mm^2. Researchers have failed to detect an increase in the energy consumption ascribable to the emission of ultrasonic signals. Hence, bats must be efficient in converting metabolic into ultrasonic energy to an extent that vastly exceeds current technical capabilities, where the production of strong ultrasonic signals requires input powers on the order of 100W. Finally, bats repetitively produce sonar signals for extended periods of time. Nevertheless, their biosonar pulses remain free from the signs of hoarseness that are readily detectable in the voices of other mammals and humans. This indicates the presence of special mechanisms to ensure reliability and repeatability of the signals in bats. To begin to understand this impressive performance, we measured the mechanical properties of vocal folds from the great roundleaf bat, *Hipposideros armiger*. Compared to similarly sized rats, who emit ultrasound via whistle rather than vocal fold, bat vocal folds are stiffer and show less and slower relaxation processes. Because of all these unique features and the wide performance gap between bat biosonar and ultrasound production by man-made devices, bat biosonar could be a paragon to inspire the design of miniature ultrasonic emitters, enabling miniature active sensing for autonomous systems.

139.1 DUDLEY, R*; KASPARI, M; YANOVIAK, SP; Univ. of California, Berkeley, Univ. of Oklahoma, Univ. of Louisville; *wings@berkeley.edu*

Lust for Salt in the Western Amazon

Although the use of mineral licks by diverse Amazonian birds and mammals is well known, the ultimate motivation for such behavior remains unclear. Because aerosol deposition of salts declines with distance from oceanic sources, lick visitation in the western Amazon can best be explained by demand for salt given the low concentration of this micronutrient in the plant tissues consumed by these taxa. Empirically, we have shown that sodium limitation influences ant foraging behavior, and impinges via effects on microbial and invertebrate decomposers on ecosystem rates of carbon cycling. The biogeographical context of sodium availability has been largely overlooked but has substantial pantropical implications for herbivore and decomposer performance in inland rainforests.

P2.179 DULLEN, K.R.*; ORCZEWSKA, J.I.; ORTEGO, M.; O'BRIEN, K.M.; Univ of Alaska Fairbanks; *krdullen2@alaska.edu*

Creatine kinase isoforms differ between hearts of red- and white-blooded Antarctic fishes

Creatine kinase (CK) produces creatine phosphate, shutting energy between mitochondria and myofibrils in muscle, and may also shuttle phospholipids from the outer to inner mitochondrial membrane. There are three isoforms of CK. Sarcomeric and ubiquitous (sMtCK and uMtCK) are in mitochondria; muscle (mmCK) is in the cytosol. Antarctic icefishes, lacking the oxygen-binding protein hemoglobin have significantly higher densities of mitochondria in heart ventricles compared to closely related red-blooded notothenioids. Mitochondria from icefishes are also larger with less densely packed cristae compared to red-blooded fishes. We hypothesized that CK distribution and isoform expression might differ between hearts of red- and white-blooded fishes due to differences in mitochondrial morphology and diffusion distances. CK transcript levels, isoform distribution and maximal activities were measured in hearts of red- and white-blooded notothenioids. Maximal activity of CK per g tissue was equivalent among most red- and white-blooded fishes but distribution of isoforms differed. The mitochondrial isoforms were not detected in icefishes by western blotting, nor were transcript levels of sMtCK using quantitative PCR. All three isoforms were detected in red-blooded fishes, and mRNA and protein mmCK were detected in icefishes. Consistent with this, the activity of CK was significantly higher in mitochondria of red-blooded fishes and nearly undetectable in icefish, and significantly higher in the cytosol of icefishes compared to most red-blooded fishes. The lack of mitochondrial CK in hearts of icefish may restrict the transfer of phospholipids to the inner membrane and contribute to their unusual morphology.

132.3 DUNCAN , C.A.*; RILEY, L.G.; Fresno State Univ.; *cduncan@csufresno.edu*

Direct Effects of Cortisol on Appetite Regulation in the Brain of Tilapia, Oreochromis mossambicus

Food intake in vertebrates is under the regulation of appetite stimulating (e.g. neuropeptide Y, ghrelin) and appetite inhibiting (e.g. corticotropin-releasing hormone) signals in the brain. The efficacy of these brain signals are influenced by environmental and social factors as well as the hormonal milieu within the animal. Previous work has established that stress and cortisol consistently decrease food intake in fish. However, the link between cortisol and appetite is not well understood in any species of fish. The response to acute stressors is likely adaptive, but when exposed to chronic stress, the adaptive value might be lost. A recent report from our laboratory has shown that a single injection of cortisol decreased food intake in tilapia, which appears to be mediated by a reduction in the ghrelin signaling pathway via NPY in the telencephalon region of the brain. The present study was designed to test the direct effects of cortisol on regions of the brain known to regulate appetite. The telencephalon and hypothalamus were individually dissected from tilapia and cultured separately in cortisol-containing media for 24 h. Following treatment, mRNA levels of genes involved in appetite regulation were quantified from each brain region. In the telencephalon, cortisol decreased NPY mRNA levels while increasing the ghrelin signaling pathway. In the hypothalamus, cortisol decreased CRH and NPY mRNA levels. This study is novel because it is the first to report the direct effects of cortisol in fish. Furthermore, these data suggest that the direct actions of cortisol on appetite might be mediated by a decrease in NPY and hypothalamic CRH as well as an increase in the ghrelin signaling pathway in the telencephalon. Supported by USDA to LGR.

36.6 DUNKIN, R.C.*; WILLIAMS, T.M.; KOOPMAN, H.N.; U.C. Santa Cruz, U.N.C. Wilmington; *dunkin@biology.ucsc.edu*

Adaptations of Elephant Skin for Non-Evaporative and Evaporative Heat Loss

Despite lacking sweat glands, elephants have among the highest rates of cutaneous water loss (CWL) of a variety of arid dwelling herbivores. Though the unique morphology of elephant skin has been recognized, neither its thermal nor water barrier properties have been investigated. We measured thermal conductivity (W m^{-1}ºC^{-1}) and conductance (W m^{-2}ºC^{-1}) as well as cutaneous water loss (CWL, mg cm^{-2} hr^{-1}) and resistance (s cm^{-1}) of integument from Asian (n = 4) and African (n = 2) elephants and correlated these values with morphological and compositional analysis of the skin. Manatee (n=5) and pig (n=5) integument were also included for comparison. We found significant inter and intra-species variation in morphology and composition of the integument which corresponded to differences in both the thermal and water barrier properties. The thermal conductivity of Asian (0.19 ± 0.01 W m^{-1}ºC^{-1}) and African elephant (0.23 ± 0.13 W m^{-1}ºC^{-1}) integument approached the upper limit of previously measured values as a result of high water and low lipid content. CWL was significantly greater ($p<0.0001$, $F = 54.21$) and resistance significantly lower ($p<0.0001$, $F = 35.11$) in both the elephant and manatee integument relative to that of the pig at all measured temperatures. All four species demonstrated a significant increase in resistance at the highest temperature treatment (39.7ºC) but this was most pronounced in elephants and manatees and may correlate with the transition temperature of stratum corneum lipids. Our results indicate that elephant integument conducts heat up to 11 times better than mammals with arctic or sub-arctic pelage and loses water at rates that are comparable to some amphibians, allowing elephants to maximize both non-evaporative and evaporative heat loss.

S4-2.1 DUNN, CW; Brown University; *casey_dunn@brown.edu*
The Comparative Biology of Gene Expression
Phylogenetic analyses of gene expression have great potential for addressing a wide range of questions. They will, for example, provide new tools for understanding the relationships between genes and phenotypes by identifying genes that have evolutionary shifts in expression that are correlated with evolutionary changes in morphological and developmental characters of interest. There are a variety of challenges that must be addressed for such studies to realize their potential. There are the technical challenges of measuring gene expression that confront any investigator working with non-model organisms, including the isolation of high quality RNA and assessing biological variation in field-collected samples. The other major set of challenges is to develop comparative methods suitable for phylogenetic analysis of large multidimensional datasets. In most comparative studies, the number n of samples (independent contrasts) has been greater than the number p of variables (characters). The behavior of comparative methods for these classic "n greater than p" problems are now well understood under a wide variety of conditions. In gene expression studies, and studies based on other high-throughput tools, the number n of samples is dwarfed by the number p of variables. These new "n less than p" comparative analyses raise a variety of challenges. In particular, the covariance matrices are non-invertible. This precludes some standard analysis methods, and raises the risk that observed covariances are an artifact of the limited number of samples rather than actual relationships. A variety of developments in other fields where non-invertible covariance matrices are obtained are directly relevant to these challenges in comparative analyses.

132.4 DURANT, SE*; HOPKINS, WA; HEPP, GR; ROMERO, LM; Tufts Univ, Virginia Tech, Auburn Univ; *sarah.durant@tufts.edu*
Energetic constraints and parental care: is corticosterone an important mediator of incubation behavior in a precocial bird?
Suppression of the adrenocortical response (e.g., corticosterone release) to an acute stressor is a physiological adjustment thought to decrease the likelihood of avian parents abandoning their nests. However, some periods of parental care, like incubation, are energetically costly, thus corticosterone could increase during these stages to allow incubating parents to utilize energy reserves. Wood ducks (*Aix sponsa*) have ~30 day incubation periods and only the female incubates the eggs. We hypothesized that corticosterone would be important in regulating energy availability during incubation in this species. Because resources invested in reproduction increase with clutch size, we also hypothesized that clutch size would influence plasma corticosterone during incubation. We measured baseline and stress-induced corticosterone in incubating females during early and late stages of incubation. At both stages of incubation all hens had low baseline corticosterone levels. However, we found that stress-induced corticosterone was 105% greater late in incubation than early in incubation. We also detected a significant negative correlation between female body mass and stress-induced corticosterone late in incubation, but not during the early stages of incubation. Furthermore, we found a significant positive relationship between stress-induced corticosterone and clutch size. These lines of evidence support the hypothesis that incubation in wood ducks is energetically costly and corticosterone is important in catabolizing energy stores needed to support the energetic demands of incubating hens. Our findings suggest that corticosterone's role in supporting parental care behaviors are dynamic and are influenced by several factors and that there is a greater physiological cost associated with incubating larger clutches.

133.1 DURST, PAP*; ROTH, VL; Duke University; *paul.durst@duke.edu*
Examining factors influencing body size change for insular rodents
When organisms colonize an island, they often undergo dramatic shifts in size. This phenomenon has been observed in birds, reptiles, amphibians and even plants, but it is especially evident among mammals, where insular shifts towards larger body sizes in small species and smaller body sizes in large species have come to be known as the "island rule". Despite early assertions that mammals followed this rule with law-like regularity, it is now clear that the island rule is an oversimplification of a complex process where exceptions abound. Multiple processes have been hypothesized to influence these size shifts, but no single variable has proven to be capable of explaining a significant portion of the size variance observed on islands. The order Rodentia has presented particular challenges to the island rule because among rodents on islands exist cases of both size increase and decrease with little apparent relation to original body size. To address this issue, we previously assembled a data set of insular rodent populations and made use of classification tree methods to identify which hypothesized processes were most useful in predicting the direction of size change for insular rodents. We found the most important factor predicting direction of change to be mainland body mass and while other variables had some predictive power, their roles in determining direction of size change were more context-dependent. Here, we expand our data set and confirm some previous findings, we use more traditional linear methods to focus on how these predictor variables influence the degree of size change, and we explore to what extent different degrees of size change reflect a significant difference between island and mainland rodent populations.

77.3 DUTEL, H*; HERREL, A; CLÉMENT, G; HERBIN, M; Muséum national d'Histoire naturelle; *dutel@mnhn.fr*
Bite performance of the extant coelacanth Latimeria chalumnae
The coelacanth *Latimeria* is the only extant genus of a group of lobe-finned vertebrates (sarcopterygian) originating in the Devonian times. Since its discovery in 1938, this genus has been of considerable interest due to its striking similarity with fossil coelacanths and the presence of anatomical features that are only known in fossil sarcopterygian fishes. Notably, it is the only extend genus showing a skull divided into an anterior (i.e. ethmosphenoid) and a posterior (i.e. otoccipital) part, which articulate by means of an intracranial joint. This complex articulation is thought to allow an elevation of the snout by 10° to 20°, which would enhance mouth opening distance and velocity allowing a powerful suction. Although the cranial anatomy of *Latimeria* is well known, the function of its kinetic joint during feeding remains poorly understood. Indeed, the lack of information on some key anatomical structures as well as on the actual movements of the cranial elements during feeding has led to the proposition of a number of hypotheses on the role of the intracranial joint and other structural elements of the head during jaw movement. Based on morphological data acquired from the recent dissection of a coelacanth specimen from the MNHN collections, we re-describe the jaw closer muscles, and estimate bite forces using a static equilibrium model. Implications in the skull kinesis and feeding behaviour of *Latimeria* will be discussed, and future directions of this study will be presented.

101.5 DYHR, JP*; COWAN, NJ; MORGANSEN, KA; DANIEL, TL; Univ. of Washington, Johns Hopkins Univ.; *jdyhr@uw.edu*

Agile airframes I: maneuverability from abdominal actuation

Flying animals face trade-offs between maintaining stability versus the ability to accomplish quick maneuvers. Unlike terrestrial or aquatic locomotion, flight requires the active and continuous generation of lift forces and control along multiple degrees of freedom. For insects, maintenance of flight stability is particularly difficult about the pitch axis, which is further destabilized by oscillations generated by the periodic forcing of the wing beats. This instability requires sensory feedback to actively coordinate motor responses to pitch stimuli in order to stabilize flight. Here we investigate the extent to which pitch instability can be controlled, not by the wings, but through the deformation of the animals' "airframe" via abdominal flexion. To accomplish this, we developed analytic methods for determining how control of abdominal angle in the hawkmoth *Manduca sexta* contributes to stability. By combining measured sensory gains and delays with a model of a pitching flexing animal we found that moths operate on the very edge of stability, within 1% of the dynamic range. Thus, small changes in control surfaces can move the animal to unstable (and maneuverable) dynamics. In this way, the animal may take advantage of multiple motor outputs, such that small changes in single outputs can quickly shift the animal to an agile regime, while the other outputs are available to quickly stabilize the animal.

41.6 EBERLE, AL*; REINHALL, PG; MOUNTCASTLE, AM; DANIEL, TL; Univ. of Washington, Seattle, Harvard Univ., Boston; *eberle10@uw.edu*

Fluid-solid coupled model of flapping flexing insect wings reveals multiple maxima for flight forces

Many insect wings deform significantly during flight. This deformation is due to musculoskeletal forcing of the wing base, which results in passive emergent bending, along with aerodynamic loading of the surrounding fluid. Since deformation can change the amount of lift and thrust that the wing develops, the mechanical structure of the wing can influence flight performance. We explored two key issues associated with the design of compliant wings: over a range of driving frequencies, how does wing stiffness influence (1) the lift and thrust generated and (2) the relative importance of fluid loading. Since the parameter space is expansive, experimental methods and robotic realizations are not feasible. Thus, we developed a computational model that uses vortex methods and a spring-mass-damper model to couple the fluid loading to the structural dynamics. Actuation frequencies and flexural stiffnesses for the model were based on a range of values that encompass those measured for a number of insect taxa (4-80 Hz; 10^{-7}-10^{-5} N m^2). Over the entire range of parameters, we show that fluid loading never contributes more than 10% to the average flight forces. We also show a non-monotonic relationship for lift and thrust, which exhibits more than five local maxima over the same range of parameters. This non-monotonic relationship follows from several interacting periodic phenomena: elastic vibrations, oscillatory boundary conditions, and vortex shedding. As a result, for insect wings of any given stiffness or driving frequency, there exist multiple local maxima for lift and thrust.

S2-2.2 ECKER, Joseph; The Salk Institute for Biological Studies; *ecker@salk.edu*

Personal and Population Level Epigenome Dynamics

Natural epigenetic variation provides a source for the generation of phenotypic diversity, but to understand its contribution to phenotypic diversity, its interaction with genetic variation requires further investigation. We have carried out population-wide analyses of genomes, transcriptomes, and methylomes of wild strains of Arabidopsis. Association analyses of the epialleles with genetic variants identified thousands methylQTL, providing the first population estimate of genetically dependent methylation variation. Analysis of invariably methylated transposons and genes across this population indicates that hundreds of silenced loci are epigenetically reactivated during male gametogenesis, which facilitates their silencing in future generations.

P1.227 EDMONDS, K.E.; Indiana University Southeast; *kedmonds@ius.edu*

Effects of Photoperiod, Melatonin, and Gonadal Steroids on Gastrointestinal Development in the Male Marsh Rice Rat (Oryzomys palustris)

Environmental factors can regulate the development of various physiological systems in many species. Photoperiod and melatonin are known to inhibit significantly the reproductive system in seasonal breeders, but effects on the GI tract have not been as extensively studied. The present study examined whether photoperiod, melatonin, and gonadal steroids affect reproductive and gastrointestinal (GI) development in juvenile male rice rats. Rice rats were subjected to long (14L:10D) or short (12L:12D) photoperiods, the presence of control or melatonin implants (20 mm total), or the presence of empty or testosterone implants (10 mm total) in separate experiments from 21-56 days of age. The following masses were examined: body, testes, seminal vesicles (SV), Harderian glands (HG), and wet (W) and dry (D) masses of the stomach (St), small intestine (SI), cecum (Ce), and colon (Co). In addition, small intestine and colon lengths were measured. Short photoperiods reduced body, testes, SV, HG, WSt, WCo, and DCo masses and the lengths of the SI and Co. Melatonin implants reduced body, testes, SV, HG, WSt, WCe, WCo, DSt, DCe, and DCo masses and the lengths of the SI and Co. Testosterone implants had no effect on any end point measured except for a significant increase in SV mass. These data show that photoperiod and melatonin affect growth, reproduction, and GI development in males, but that testosterone supplementation is without effect on any GI end points. The effects of castration on GI development are currently being examined. It is hypothesized that changes in gut capacity may be a necessary mechanism for coping with likely seasonal changes in metabolic requirements. (Supported by funds from IU Southeast.)

13.4 EDMUNDS, PJ*; FAN, TY; California State University, Northridge, National Museum of Marine Biology and Aquarium, Taiwan, Republic of China; *peter.edmunds@csun.edu*

Evidence that high pCO2 affects coral recruits through perturbed protein metabolism

The recruitment of larvae to benthic surfaces is critical for scleractinian corals, for the outcome determines where adults will live for decades and the extent to which populations grow. In the coming century, rising pCO2 poses new challenges to coral recruits, and while there is evidence of negative effects, little is known of the proximal mechanisms involved. We have developed techniques to grow coral recruits under ecologically relevant conditions and test their response to environmental conditions in the first few days of benthic existence. Initial experiments using this technique reveal that recruitment in Seriatopora caliendrum involves a 70% increase in metabolic rate within 3 d of settling, and that 86 Pa pCO2 depresses metabolic rate 12% within 5 d of benthic existence. The reduction in respiration at high pCO2 suggests that metabolic depression may be used as a short-term response to hypercapnea. We indirectly explored the role of protein synthesis in mediating these changes by measuring the respiration of S. caliendrum recruits with and without the protein inhibitor emetine following 1-4 d at 45 (ambient) versus 77 Pa pCO2 at 25.3°C. Two days after settlement, respiration was affected by the interaction of emetine and pCO2, with respiration reduced 63% at 45 Pa pCO2, but 26% at 77 Pa pCO2; this interaction disappeared in 5-day old corals, in which respiration was reduced 28% by emetine. These results suggest that high pCO2 affects protein metabolism in coral recruits, potentially by impairing protein synthesis but incurring new costs through other pathways. Further investigations of the effects of high pCO2 on protein metabolism in corals may be productive.

59.1 EDSINGER-GONZALES, E.*; BREDESON, J.V.; LEUNG, A.V.; ZIMMERMAN, C.R.; DIAZ, D.E.; TREW, D.F.; BRUSCO, D.G.; WHITBURN, E.; MARTINEZ, G.; INGLE, H.; RUBADO-MEJIA, J.V.; MUGGLESTONE, L.E.; LAZEN J., SCOTT M.A., COLSTON T.J., TREW T., WERNER P., GIORGI G., ROWNING B.A., ROKHSAR D.S. ; UC Berkeley, Merritt College; *eegonzales@berkeley.edu*

Ciliogenesis, neurogenesis, and the intersection of aneural and neural larval swimming behaviors in the genome-enabled marine snail Lottia gigantea.

Larval swimming often begins prior to gastrulation in marine invertebrates. Thus, larval swimming may span both aneural and neural behavioral controls in taxa having a nervous system. To test this idea, we characterized larval swimming, ciliogenesis, and neurogenesis in *Lottia gigantea*. Swimming behavior was characterized by observation and video analysis. Cilia functioned by six hours post-fertilization, and swimming movements become increasingly complex. Ciliogenesis was characterized by electron microscopy, immunohistochemistry, and *in situ* hybridization. Although prototroch cilia functioned early, a stereotypic shifting of cells and the formation of ciliary plates still needed to occur, and may influence swimming behavior and ability. Surprisingly, cilia-related transcription factors were expressed within distinct domains of the prototroch. Also surprising, structural proteins functioning in ciliary motility were expressed in both motile and non-motile ciliated cells. Neurogenesis was characterized by neurotransmitter immunohistochemistry. Diverse spatiotemporal patterns of expression were observed, with the earliest onset occurring between fifteen and eighteen hours, long after establishment of complex swimming behaviors. Our results suggest that the prototroch is under both aneural and neural control in *Lottia*, with later neural control potentially modulating an aneural system. Understanding aneural versus neural control in marine invertebrate larvae may provide new insights into the early evolution of animal behavior and nervous systems, and new perspectives on neuronal function in human health and disease.

113.1 EDWARDS, TM; Louisiana Tech University; *tedwards@latech.edu*

Estrogens and Plants

Our lab has shown that estrogenicity in soybeans varies among plant organs, and changes across the season as plants mature, and respond to seasonal environmental change. Estrogenicity of plant tissues comes from “phytoestrogens” - lignans, coumestans, and especially flavonoids. These plant molecules serve myriad physiological and ecological roles in plants, including UV protection, auxin transport regulation, attraction of pollinators and symbionts, and modulation of herbivore endocrine function. The effects on herbivores are due to cross-reactivity of phytoestrogens with animal estrogen receptors. We have also shown that exogenous estradiol (an animal estrogen), genistein (a phytoestrogen), and bisphenol A (an estrogenic component of plastics) alter development, growth, and reproduction in green beans. Our data show that plants are sensitive to environmental estrogens as are animals. These observations suggest a larger ecological and evolutionary role for estrogens as cross-taxa signaling agents, a hypothesis that is supported by recent findings of flavonoids in basal groups – red, green, and brown algae, and mixtures of cyanobacteria and diatoms.

95.2 EDWARDS, JE*; LAILVAUX, SP; University of New Orleans, Louisiana; *edjessicaedwards@gmail.com*

Staged Interactions between female pairs and male pairs of Anolis carolinensis and Anolis sagrei Lizards

The introduced lizard *Anolis sagrei* is known to commonly replace *Anolis carolinensis* as the most abundant anole of urban areas and other open environments. Although studies of interspecific interactions typically focus on males, interactions between females also might play an important role in shaping habitat use within multi-species communities. To measure interspecific aggressive behaviour in each sex, we caught 90 *A. carolinensis* and *A. sagrei* males and females of various sizes and randomly matched female-female and male-male pairs in staged interspecific interactions in lab. We examined whether species identity, bite force, dewlap size and body size affected the outcome of interspecific interactions, and tested the prediction that bite force and size would be the most important determinants of interaction outcomes in both sexes. Preliminary analyses suggest that interactions between female conspecifics may potentially play a larger role than interactions between males.

106.5 EERNISSE, D.J.*; BROOKER, L.R.; Cal State Fullerton, Univ. Sunshine Coast, Qld.; *deernisse@fullerton.edu*
Phylogeny and biogeography of the shell-eyed chitons
Over their half a billion-year history, chitons have had numerous aesthete sensory organs in their shells, with shadow detection as one of their proposed functions. Much more recently, a clade of chitons have diversified that have not only aesthetes but also much larger ocelli, and these are image forming and each has an aragonitic lens, retina, and other hallmarks of animal visual systems. Shell-eyed chitons are not known as fossils older than the Miocene yet since then have become some of the most common reef-dwelling chitons in tropical and southern hemisphere localities worldwide. Despite their ecological importance and their status as the animals with the most recently evolved eyes, their phylogenetic relationships have not been well resolved. They have been classified as either Toniciinae or Acanthopleurinae within Chitonidae based on whether the girdle is nude or is covered with calcareous armor (spines or scales), respectively. We tested this subdivision with DNA sequence comparisons. Our results strongly corroborate the shell-eyed clade but not its internal subdivision into conventional groupings. Instead, our results support separate New World and Old World radiations, with loss of girdle elements corresponding to polyphyletic lineages nested within the shell-eyed clade. There is also intriguing evidence of regional patterns of speciation or phylogeographic divergence. For example, *Acanthopleura gemmata* from northeastern Australia have closer affinities with western Pacific populations from New Caledonia than they do with *A. "gemmata"* from Western Australia, and the latter have closer affinities with Indian Ocean populations as far west as Africa. In between, populations north of Australia are different again with likely unrecognized species diversity. Improved phylogenetic and biogeographic resolution will allow us to relate variation in ocelli to the pattern of evolutionary diversification.

P3.2 EGDORF, T.C.*; KIRSCHMAN, L; CRESPI, E; BRUNNER, J; WARNE, R; Southern Illinois University Carbondale; *tcegdorf7@yahoo.com*
The Effects of Size Hierarchies on Infection and Transmission of Ranavirus in Amphibians
The mechanisms that contribute to high variation in pathogenic infection dynamics among individuals in structured populations are poorly understood. Individual variation in exposure, susceptibility and recovery to infection are fundamental drivers of pathogen and disease dynamics in host populations. Yet, the physiological and behavioral determinants that underlie such individual variation in structured animal population have not been well examined. Here we use ranavirus, an emerging and directly transmitted disease of ectothermic vertebrates, to test the effects of size dependent physiology and behavior on disease susceptibility and transmission in wood frog larvae. Wood frog tadpoles naturally form large size hierarchies in which growth, development, stress physiology and immune function vary consistently with size. Presumably, these size dependent traits are also likely reflected in differences in behaviors as well. In this study, we hypothesized that larger individuals within a hierarchy would display more aggressive behaviors with higher contact rates that would increase the transmission rates of ranavirus within a population than their smaller counterparts. Counter to this process, however, we also hypothesized that smaller tadpoles would be more susceptible infection because of consistently higher concentrations of glucocorticoid hormones; an immunosuppressive hormone under chronic elevated levels. Through these efforts this study can provide insight into how population structuring and individual traits contribute to epidemic outbreaks of disease.

123.3 EGGE, AR*; NOH, S; ELLER, OC; HAHN, DA; MORGAN, TJ; Kansas State University, University of Florida; *aegge@ksu.edu*
Physiological and Genomic Variation in Rapid Cold Hardening and Developmental Acclimation in Drosophila melanogaster
Adaptation and plastic responses to daily and seasonal fluctuations can lie in both long- and short-term adaptive responses controlled by functional regions of the genome. The rapid cold hardening response (RCH) and the developmental acclimation response (DACC) are two types of acclimation that have been widely explored. RCH manifests itself as an increase in survivorship or fitness of an organism following a pre-treatment of minutes to hours at a cooler temperature before exposure to a cold shock temperature, while DACC pre-treatment spans egg-to-adult development. Full physiological and genetic analyses of the variation in RCH and DACC have yet to be explored. *Drosophila melanogaster* is a cosmopolitan species often used as a model organism for tracking genetic responses to environmental stresses and adaptation. Our research focuses on the comparison of short (RCH) and long term (DACC) cold acclimation in the *Drosophila* Genetic Reference Panel (DGRP) to determine the genetic and physiological sources of variation among lines of natural *Drosophila melanogaster*. Each line was reared at both 18° C and 25° C, and tested for survivorship at a one-hour cold shock and a two-hour RCH pretreatment followed by a one-hour cold shock to determine the RCH and DACC responses. There was significant genetic variation among the lines for both short- and long-term acclimation responses. The phenotypic responses did not share any significant SNPs across the DGRP genomes, although RCH at 25° and DACC were phenotypically correlated among the DGRP lines. Functional mutation analysis has confirmed the functional role of several associated candidate genes in short or long-term cold acclimation responses.

69.5 EGGINTON, S; University of Birmingham, UK; *s.egginton@bham.ac.uk*
Control of branchial artery tone in Antarctic fish
We examined potential vasomotor control mechanisms in Antarctic fishes, compared with teleosts of different phylogenetic relatedness from both cold and temperate environments. In general, vascular constrictor activity showed a modest α and β adrenergic tonus, but with greater potency for cholinergic and serotonergic vasoconstriction, in Antarctic notothenioids and both related and phylogenetic sister group species from warmer waters around New Zealand. This unusual pattern of control appears to be primarily a consequence of evolutionary lineage rather than low environmental temperature, but may be modified according to functional demand e.g. a pelagic species showed a dominance of vasodilatation over vasoconstriction. Prostanoid vasodilators were effective in reducing vascular tone, but a variety of potential nitrodilators all failed to elicit a response (though they were active in trout vessels). Polar and temperate northern hemisphere species, phylogenetically distant from each other and the nototheniids, showed both similarities and differences making simple inferences about phenotype vs. genotype difficult. In light of a reduced importance for the classical adrenergic and nitroergic vascular control, maintenance of adequate cardiovascular control at extremely low temperatures likely involves compensation by a variety of other vasoactive substances. In addition, each species possessed a unique pattern of vascular innervation that partially differentiated between nototheniids and non-nototheniids, while functional consequences for oxygen delivery to locomotory muscle also involve changes in microvascular structure. We conclude there is little evidence for cold adaptation of branchial artery contractility, and mechanisms of vascular control likely reflect phylogeny rather than thermal history.

108.5 EICHINGER, J.M.*; SATTERLIE, R.A.; Univ. of North Carolina Wilmington; *jme1463@uncw.edu*
Neuromuscular Facilitation in the Motor Networks of Cubomedusae
The first modern physiological analysis of cnidarian nerve nets was performed by Pantin, in which he provided the first detailed investigation of the "staircase" effect. He later coined the term "facilitation" to describe the process in which a train of sufficient stimuli affects the response to subsequent stimuli in the direction of augmentation. In the case of jellyfish, a succession of stimuli elicits a graded increase in the force of muscle contraction. This process is frequency dependent in that decreasing interpulse interval produces stronger contractions. Jellyfish swim via rhythmic contractions of the bell musculature and rely on frequency dependent neuromuscular facilitation (FDNF) as a mechanism to produce strong, periodic contractions and efficient swimming. Cubomedusae further rely on FDNF for the existence of a biphasic modulatory potential within the swim system where jellyfish swim at approximately 80% of maximum. These data were taken from the subumbrella of *C. marsupialis*, but recently it has been shown in this and another species (*T. cystophora*) that the subumbrellar network is sparsely innervated and relatively disorganized as is stereotypical of a nerve net. The velarium and frenulum exhibit significantly higher network densities, and neurons of the latter align with radial muscle fibers. Similar networks in the retractor muscles of some anemones exhibit rapid conduction velocities and faster times to maximal facilitation. Here we investigated the facilitation properties of the subumbrella, velarium and frenulum in two box jellyfish species (*C. quadrumanus* and *T. haplonema*) seasonally local to North Carolina. Differences in facilitation properties were found between muscle sheets as well as different size classes of the same species. These results may offer clues to the functioning of different muscle sheets in executing complex swimming behaviors.

148.2 EITING, T.P.*; PEROT, J.B.; DUMONT, E.R.; UMass Amherst; *tpeiting@bio.umass.edu*
Nasal airway morphology and olfactory airflow in phyllostomid bats
The shape of the mammalian nasal passages plays a key role in the principal functions of the nose: respiration, olfaction, and in some bat species, echolocation. However, we still have only a rudimentary understanding of how differences in the shape of the nasal passages relate to differences in functional abilities between species. Our approach to tackling this problem has been to examine patterns of airflow among closely related species of phyllostomid bats. These species differ substantially in the relative length of the rostrum, with corresponding differences in internal airway morphology. In this study we hypothesize that these morphological differences impact the patterns of airflow to and within the olfactory region of the nose. We predict that air arrives to the olfactory region more quickly in short-faced species because of the shorter distance air travels to reach this region. We also predict that the extensive development of the olfactory recess in some species allows odorant-laden air to remain entrained for longer periods of time, potentially improving olfactory performance in these species. We used CFD to study airflow and histological preparations to examine the distribution of olfactory epithelia in three phyllostomid species. As in rodents and dogs, we found that the majority of airflow is directed ventrally through the airway, never contacting the olfactory region. Short-faced species have more extensively developed olfactory recesses, which experienced slower airflow. These short-faced species are also dedicated frugivores, so more extensive olfactory recesses may relate to these species' reliance on olfaction in foraging. This association between the morphology of the olfactory recess and airflow is consistent with previous suggestions that the olfactory recess plays a key role in olfactory function.

P1.160 ELDER, H.*; TODGHAM, A.; TOMANEK, L.; California Polytechnic State University, San Luis Obispo, California State University, San Francisco; *hollandelder@gmail.com*
Changes in global protein abundance patterns in the intertidal owl limpet Lottia gigantea in response to acute heat stress
The owl limpet *Lottia gigantea* inhabits one of the most variable thermal marine environments known, the rocky intertidal zone, and occurs from northern California to southern Baja California. Its limited mobility in the intertidal zone and its close-to-completion genome sequence provide ideal parameters for the study of its thermal biology using a proteomics approach. To characterize the response of limpets to increased temperature, specimens were randomly divided into three groups that would experience emersion at 13°C, 25°C, and 30°C for two hours. After treatment, the limpets were quickly returned to ambient ocean conditions at approximately 13°C. Limpets from each treatment group were sampled at 0, 6, and 18 h of recovery at 13°C for proteomic analysis. Foot tissue was immediately frozen and subsequently prepared for analysis with 2D gel electrophoresis. Using matrix-assisted laser desorption ionization tandem time-of-flight (MALDI TOF/TOF) mass spectrometry and the existing *Lottia* genomic database we were able to identify a number of proteins changing with acute heat stress under conditions of emersion. In a preliminary test ($p<0.02$) between the 6 hour recovery 13°C control and the 30°C heat shock groups, it was found that there were 21 significant proteins changing between the two groups. The changing proteins constituted 12% of protein abundance in these groups. Identification of these proteins and those in the other groups will give an understanding of changes in protein abundance in response to heat stress in this emerging model organism.

8.2 ELDER, L*; SEIBEL, B; Univ. of Rhode Island; *leab83@my.uri.edu*
The effect of thermal stress and hypoxia on the hyperiid amphipod Phronima
Hyperiid amphipods in the Eastern Tropical Pacific migrate across a temperature gradient of 10 degrees or more and spend daytime at oxygen levels less than 5µM. To determine if these current conditions are physiologically demanding, oxygen consumption, lactate accumulation and HSP 70 expression were measured in the hyperiid amphipod *Phronima*. Thermal stress experiments were conducted at 23ºC, the approximate maximum surface temperature in the region, with recovery at 10-20ºC or further thermal stress up to 29ºC. Separate respiration experiments were performed under conditions equivalent to day and nighttime exposure, 10°C hypoxia (1% O_2), and 20°C normoxia (21% O_2). Oxygen consumption decreased from 2.82 µM O_2/g*h in normoxia to 1.82 µM O_2/g*h in hypoxia. The Q10 (a measure of temperature dependence of metabolism) is approximately 2 between 10 and 20°C. L-lactate, an index of anaerobic ATP production, was significantly higher, in hypoxic (8.92 ± 1.33 mmol/L Lactate), compared to normoxic, (3.47 ± .47 mmol/L lactate) specimens. In hypoxic conditions lactate accumulation increased at higher temperatures, and was elevated after 24hrs at 23ºC even in oxygen saturated conditions. These data indicate that amphipods are near maximum thermal levels and approaching critical oxygen levels during their current migration. Climate change is predicted to cause an increase in oceanic temperatures and decease in oceanic oxygen levels. Ecological implications of these changes will be discussed.

132.5 ELDERBROCK, EK*; SMALL, TW; SCHOECH, SJ; University of Memphis; *kldrbrck@memphis.edu*

Effects of supplemental food and corticosterone treatment on begging and feeding behavior in Florida Scrub-Jays (Aphelocoma coerulescens)

Begging is believed to communicate an honest signal of a nestling's nutritional needs. When a nestling requires more food, it will beg to elicit feeding from its parents. The rate and duration of this behavior and the parental response may be influenced by a number of factors. In this study we investigated the roles of two such factors: 1) food availability through supplemental feeding and 2) an individual's corticosterone (CORT) levels, a hormone known to influence begging and parental behavior. We studied the role of food availability by indirectly supplementing all nestling Florida Scrub-Jays (*Aphelocoma coerulescens*) within a brood by providing ad libitum supplemental food (meal worms) to their parents during the nesting period. The role of CORT was examined by feeding one nestling per assigned CORT treated nest a CORT-injected wax worm twice-daily for 4 days (Days 8-11 post-hatch) and a second nestling in the same nest a vehicle-injected wax worm. We quantified nestling and adult behaviors using high definition videos recorded with a camera set atop a pole (3-6 meters tall) on Days 5, 8, 11, and 13 post-hatch. We found that the rate and duration of begging of all nestlings in the CORT treated nests was greater than that of nestlings in food supplemented and control nests. In addition, the adults with CORT treated nestlings in their nest visited a greater number of times per hour and fed nestlings more frequently than did controls. Individual nestling behavior and data on nestling baseline and stress-induced CORT levels (collected on Day 11) will also be discussed.

83.3 ELIASON, C.M.*; MAIA, R.; SHAWKEY, M.D.; University of Akron; *cme16@zips.uakron.edu*

Optics and evolution of iridescence in the wings of ducks

The colors of birds are diverse but limited relative to what they can perceive. This mismatch may be partially caused by the properties of their color-producing mechanisms. Aside from pigments, several classes of highly ordered nanostructures (e.g., thin films, multilayers, photonic crystals) can produce a range of colors. However, the variability of any single nanostructural class has rarely been explored. Dabbling ducks are a speciose clade with substantial interspecific variation in the iridescent coloration of their wing patches (specula). We used electron microscopy, spectrophotometry, refractive index-matching experiments, optical modeling and phylogenetic comparative methods to investigate the mechanism and evolution of these colors. We show that color is produced by a complex nanostructure consisting of a thin film of keratin and hexagonally arranged melanin rods (melanosomes) within feather barbules. Although the range of potential variation of this nanostructure is theoretically broad, only relatively close-packed, energetically stable variants producing more saturated colors were observed, suggesting that ducks are either physically constrained to these configurations or are under selection for the colors that they produce. Thus, we further tested how functionally independent components of this nanostructure evolve within this limited region of morphospace and found that melanosome diameter and spacing evolve at different rates, but species explore available morphospace uniformly. Taken together, these results reveal a previously undescribed color-producing nanostructure and suggest that both physical variability and constraints within single nanostructural classes may help explain the broader patterns of color across Aves.

P1.188 ELLIS, H.I.*; BOWMAN, R.; University of San Diego, Archbold Biological Station; *ellis@sandiego.edu*

Energy Budgets for Florida Scrub-jays: a Changing Landscape Matters

Field metabolic rates (FMR) were measured on Florida scrub-jays (*Aphelecoma coerulescens*) in two habitats using doubly labeled water. One group of jays lived in wildland habitat; the other in a suburban area where the habitat was badly degraded. During the breeding season FMR of suburban birds exceeded that of wildland birds by up to 100% (in males; less in females, but they may be fed at the nest by helpers). This very high cost may help explain why suburban jay populations are sinks. Wildland FMRs are about 3 x BMR during breeding; for suburban males, it is 6 x BMR. Jays from both habitats have an FMR only 1.5-2.0 x BMR in winter and fall, so it is the breeding season that separates them energetically. A low water economy index (mL/kJ) and low water fluxes in both habitats indicate that these jays are well adapted to their xeric habitat. (All doubly labeled water samples were analyzed in the lab of Ken Nagy at UCLA; this work was facilitated by Glen Woolfenden, now deceased.)

P1.35 ELLIS, E*; SIMON, C; MARSHALL, D; HILL, K; OWEN, C; KAMP, P; Univ. of California, Santa Barbara, Univ. of Connecticut, Storrs, Univ. of Waikato; *eellis@umail.ucsb.edu*

Differential Pleistocene diversification and phylogeographic patterns on New Zealand's North Island

Comparative biogeographers have long questioned the extent to which co-distributed species respond similarly to environmental change. The best evidence for such responses would be identical patterns of cladogenesis in multiple co-distributed taxa. Complete evolutionary independence--where each species responds differently to environmental stimuli--would be of no predictive value for unstudied species. Phylogeographic patterns were examined for six North Island, New Zealand forest and shrub cicada taxa in the genus *Kikihia* based on mitochondrial DNA data. New Zealand is an excellent place to conduct phylogeographic research due to its well-studied and rapidly changing landsape. During the Pleistocene, NZ experienced glaciers, low temperatures, and dramatic vegetational shifts. Such habitat-modification events would displace animals. Many forest species were hypothesized to have existed only in small refugia during glacial maxima. Five species of cicada show various degrees of concordance with intraspecific mitochondrial clade biogeographic boundaries found in previously studied taxa. A previously unidentified zone of interest was found in the East Cape region. Four species of *Kikihia* analyzed appear to have been most affected by previous glacial cycles, rather than the most recent glacial cycle, as was hypothesized, and must have persisted in isolated glacial refugia (contributing to diversification). We compared our results to phylogeographic patterns present in other invertebrate taxa in an attempt to determine common boundaries and the geological events most likely to be important in genetic differentiation.

52.5 ELSBERRY, L.A.*; BURNAFORD, J.L.; California State University, Fullerton; *lelsberry@fullerton.edu*
Regional comparisons of the effects of summer and winter low tide conditions on photosynthetic recovery in a high intertidal alga
Because the timing of low tides varies among locations along the US west coast, populations of a species can experience different abiotic conditions in different regions. We studied populations of the high intertidal alga *Endocladia muricata* in Washington and southern California to determine how individuals responded to regional ambient low tide conditions. We collected individuals from the high and low edges of the alga's tidal distribution in winter and summer and determined their ability to recover from one hour and four hour exposures to low tide conditions. Low tide treatments were fully factorial with two hydration levels and three temperatures (winter=10°C, 20°C, 30°C; summer=20°C, 30°C, 40°C). We compared post-emersion photosynthetic rates to pre-emersion rates to evaluate recovery. Completeness and rate of recovery differed between individuals collected at different tidal heights and was affected by low tide temperature, desiccation state, and the length of the low tide exposure. Individuals from the high edge of *Endocladia*'s tidal distribution recovered from low tide conditions more completely than low edge individuals. In both regions and seasons, recovery was slowed following four hour low tide exposure compared to one hour low tide exposure. Individuals in high temperature treatments frequently showed reduced recovery relative to individuals in low temperature treatments, although the interaction between hydration status and temperature varied among seasons and regions. Understanding geographic variation in the factors that affect individual photosynthetic recovery following low tide exposure may help us make predictions about the persistence of populations in the face of climate change.

17.8 ELZINGA, M. J.*; DICKINSON, M. H.; California Institute of Technology; University of Washington, University of Washington; *elzingam@caltech.edu*
Stroke features involved in the stabilization of longitudinal forward flight in flies
The ability to regulate forward speed is an essential capability for flying animals. Here, we use a dynamically scaled robot to gain insight into how flapping insects adjust stroke features to regulate and stabilize level forward flight. The results suggest that few changes to hovering kinematics are actually required to meet lift and thrust requirements, and the primary driver of equilibrium velocity is the aerodynamic pitch moment. This finding is consistent with prior hypotheses and observations regarding the relationship between body pitch and flight speed in fruit flies. We considered three different deformations of hovering wing kinematics, which were inspired by previous experimental studies and that result in the generation of a pitch moment: a shift in the mean stroke position, upstroke to downstroke differences in wing rotation angle, and upstroke to downstroke differences in stroke deviation. The results suggest that a shift in the mean stroke position is a likely candidate for trimming the pitch moment at all speeds, whereas shifts in the wing rotation angle are required only at high speeds. The results also show that the dynamics may be stabilized with the addition of a pitch damper, but the magnitude of required damping increases with flight speed. We posit that differences in stroke deviation between the upstroke and downstroke play a critical role in this stabilization. Fast mechanosensory feedback of the pitch rate enables active damping which becomes inherently gain scheduled with flight speed when pitch torque is generated by differences in deviation. This provides an elegant solution for flight stabilization across a wide range of flight speeds.

143.4 EME, J.; Univ. of North Texas; *dane.crossley@unt.edu*
Ontogeny of Cardiovascular Physiology In Embryonic Reptiles: Capacity for and susceptible periods of Environmentally-induced Phenotypic Plasticity.
In response to chronic developmental stress, embryonic reptiles exhibit phenotypic plasticity resulting in multiple morphological and physiological modifications. Utilizing the developmental stressor, chronic hypoxic, we have investigated the plasticity of cardiovascular regulatory maturation in two species, the American alligator and the common snapping turtle. These species exhibit both common and unique responses to developmental challenges. Both species exhibit phenotypic plasticity in relative heart mass and intrinsic heart rate, with a common increase in heart mass and depression in heart rate in response to hypoxic stress. However, they differ in their capacity to modify the timing of cardio-regulatory ability and the strength of each regulatory mechanism during development. These include the activation of vagal tone on the heart and a cardiovascular chemoreflex. To investigate the developmental periods during which the cardiovascular system is amenable to environmentally induced phenotypic change, we focused on the American alligator. Relocation of hypoxic (10% O_2) incubated embryos to normoxia (H to N) at 70% of incubation returned heart mass to control values measured at 90% of development. The opposite manipulation (N to H) did not result in an increase in relative heart mass compared with hypoxic-incubated (control) animals measured at 90%. Physiological phenotype was also altered by this manipulation resulting in an intrinsic heart rate that was reduced by the N to H shift compared to the H to N change. Collectively these data indicate that the degree cardiovascular developmental phenotypic plasticity is species dependent and may require exposure during finite windows of development to produce a given response. NSF CAREER IBN IOS-0845741 to DAC

P3.210 EMERSON, S.E.*; MORRIS, T.A.; BERNER, N.J.; Sewanee: University of the South; *nberner@sewanee.edu*
Effect of diet lipids on measures of seasonal acclimation in the Eastern red spotted newt (Notophthalmus viridescens viridescens)
Eastern red spotted newts are active in the winter. Our previous work shows that they acclimate enzyme activity, metabolic rate, behavioral thermoregulation, and membrane phospholipid fatty acid (FA) composition in skeletal muscle seasonally. We have also shown that membrane FA composition affects cytochrome c oxidase (CCO) activity; a more polyunsaturated membrane leads to higher CCO activity, as CCO is a membrane-bound enzyme. We tested the hypothesis that the change in membrane FA composition also drives the acclimatory changes in metabolic rate and behavioral thermoregulation. Newts were maintained in the laboratory at 25°C, 12:12 L:D, and three groups of newts were fed three different diets featuring three different types of lipids: saturated FAs (SFA); monounsaturated FAs (MUFA); and ω-3 polyunsaturated FAs (PUFA). After feeding the newts these diets for ten weeks, we determined their preferred cloacal temperature in a thermal gradient, and their standard metabolic rates (SMR, measured as oxygen consumption after one week of food deprivation) at 25 and 8°C. The preferred cloacal temperature of newts fed the high SFA diet was significantly higher ($p = 0.008$) than that of newts fed the high PUFA diet, and the newts fed a high MUFA diet had an intermediate preferred cloacal temperature. In addition, at 25°C newts fed the high PUFA diet had the highest SMR, significantly higher than the newts fed the SFA diet ($p = 0.012$). Newts fed the high MUFA diet had an intermediate SMR. At 8°C SMR did not vary with diet. Thus, the high PUFA diet led to other changes that are also indicative of winter acclimation (lower preferred cloacal temperature and higher SMR) suggesting that membrane composition plays an important role in winter acclimation in this species.

82.2 ENG, CM*; PANCHERI, FQ; LIEBERMAN, DE; BIEWENER, AA; DORFMANN, A; Harvard University, Tufts University; *cmeng@fas.harvard.edu*

Pulling in two directions: biaxial material properties of fascia lata

We tested the biaxial material properties of goat fascia lata (FL), a highly organized collagenous tissue that is in intimate connection with the thigh muscles. Previous studies show that lower limb fascia plays a key role in limb stability and force transmission across segments, and recent work measuring muscle and fascia strain *in vivo* provides evidence that the FL may store and recover limb kinetic energy in locomoting goats. Further investigation is critical in determining how fascia stiffness and hysteresis influence its potential to serve a variety of functions during locomotion. Because FL has a sheet-like structure and attaches to muscles and bones at multiple sites, it must be strained biaxially, and its functional potential cannot be assessed using uniaxial tests. Furthermore, *in situ* experiments suggest that biaxial strains modulate longitudinal stiffness in aponeuroses, fascia-like structures found at muscle-tendon junctions. We used planar biaxial testing with strain control to investigate the hypothesis that, like aponeuroses, fascia stiffness can be modulated by different biaxial strain conditions. Because the two layers of collagen fibers in the FL are oriented approximately perpendicular to each other, we performed biaxial tests on longitudinal and transversely oriented samples in each goat. Samples were cycled to multiple strain levels while the non-cycling direction was held constant at 0% and 3% strain. Results show that FL stiffness and hysteresis are higher in the longitudinal vs. transverse direction and stiffness does not increase with perpendicular strain in either direction. Differences in material response in the longitudinal vs. transverse direction and in aponeuroses vs. fascia are likely related to collagen fiber content and orientation.

51.6 EPEL, D.; Stanford University; *depel@stanford.edu*

Epigenetics as a stress response and its differing roles in the embryo and in the adult

I explore the view that that the adult and the embryo handle environmental change in radically different ways. The adult handles change through *reversible and temporary* changes referred to as the *adaptive* stress response. The response can ensue from environmental changes in temperature, xenobiotic, oxygen, nutrients and osmolality etc., The embryo might utilize similar reversible stress responses during the development period, but the most important response to environmental change are embryo-unique *adaptive* epigenetic mechanisms. The outcome is an *irreversible change in phenotype* resulting from the deployment of alternative developmental pathways in response to specific environmental signals. The signals that the embryo responds to could come from sensing nutrients, predators, photoperiod, maternal behavior, chemicals and probably a plethora of unappreciated environmental signals. Irreversible epigenetic changes also occur in the adult but these appear to be *maladaptive*. I end with a discussion of how this reframing of adult vs embryo stress responses provides a new view of epigenetics and its changing role during the life history of the organism.

142.5 ERICKSON, GM*; KRICK, BA; NORELL, MA; SAWYER, WG; Florida State Univ., Tallahassee, Univ. of Florida, Gainesville, American Museum of Natural History, New York; *gerickson@bio.fsu.edu*

Complex Dental Structure and Wear Biomechanics in Hadrosaurid Dinosaurs

Mammalian grinding dentitions are composed of four major tissues that differentially wear, creating coarse surfaces for pulverizing tough plants and liberating nutrients. Although such dentition evolved repeatedly in mammals (e.g. horses, bison, elephants), a similar innovation occurred much earlier (~85 ma) within the duck-billed dinosaur group Hadrosauridae, fueling their 35 million year occupation of Laurasian mega-herbivorous niches. How this complexity was achieved is unknown, as reptilian teeth are generally two-tissue structures presumably lacking biomechanical attributes for grinding. Here we show that hadrosaurids broke from the primitive reptilian archetype and evolved a six-tissue dental composition that is among the most sophisticated known. Three-dimensional wear models incorporating fossilized wear properties reveal how these tissues interacted for grinding and ecological specialization.

S11-1.7 ERISMAN, Brad; Scripps Institution of Oceanography, UC San Diego; *berisman@ucsd.edu*

Evolution of hermaphroditism in fishes

Sexual patterns in fishes are incredibly diverse compared to other vertebrates, as hermaphroditism is taxonomically widespread and takes on many forms including simultaneous, protogynous, and protandrous hermaphroditism, bi-directional sex change and androdioecy. The proximate mechanisms that influence the timing, incidence, and forms of hermaphroditism in fishes are supported by numerous theoretical and empirical studies on their mating systems and sexual patterns, but few have examined aspects of sex allocation theory within a phylogenetic context. However, comparative phylogenetic reconstructions of the evolutionary history of several families of teleost fishes have begun to emerge and are providing clues regarding the mechanisms that have shaped the evolution of sex allocation in animals. For example, evolutionary transformations from protogyny to gonochorism in groupers (Epinephelidae) are associated with equivalent transformations in mating group structure from paired to group spawning, and sperm competition is considerably higher in gonochoric species than in protogynous species. These results provide explicit phylogenetic support for predictions of the size advantage model (SAM), demonstrating that selection for protogynous sex change decreases as mating group size and sperm competition intensity increase. Comparative analyses of sex change in wrasses (Labridae) provide further support of the SAM and suggest that male size advantage drives the evolution of protogynous sex change. Finally, phylogenetic reconstructions of sexual patterns in seabasses (Serranidae) indicate that sexual patterns in fishes can evolve in several directions within single lineages and do not require functional intermediates.

66.5 ERNST, D.A.*; BROTHERS, J.R.; LOHMANN, K.J.; University of North Carolina at Chapel Hill;
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Nomadic Ghosts: Patterns of Burrow Occupancy in the Ghost Crab Ocypode quadrata

The ghost crab, *Ocypode quadrata*, is a semi-terrestrial crab indigenous to sandy, western Atlantic beaches. During summer months, crabs dig burrows into the beach and take refuge underground during daylight hours, emerging at night to forage over considerable areas. Relatively little is known, however, about burrow use and occupancy. As a first step toward determining whether crabs return to the same burrow each morning or instead find or excavate new ones, crabs on a beach in eastern Florida were captured after sunset using traps that fit over the burrow entrance. Each crab was marked and then released either outside the burrow entrance or within the burrow. The following day, traps were set at the same burrows. Among the 30 burrows where crabs had been released outside, 63.3% were occupied the next day; of the occupants, 94.7% were new arrivals rather than crabs that had occupied the same burrows the night before. Among the 30 burrows where crabs were released inside, 76.7% were occupied the next day; in this case, however, about half of the occupants (47.8%) were previous residents, whereas the other half (52.2%) were new arrivals. These data imply that many crabs take up residence in burrows that they did not excavate themselves. To further investigate whether ghost crabs opportunistically occupy empty burrows, artificial burrows (n=30) were constructed at a number of locations along the beach. Trapping results revealed that 33.3% of these new burrows were occupied within 24 hours. Taken together, the results suggest that many ghost crabs fail to return to the same burrow after a night of foraging and that crabs often occupy unfamiliar burrows opportunistically. Hypotheses regarding the observed burrow occupancy patterns will be discussed.

29.3 ESSOCK-BURNS, T.*; TARRELL, A.; MATHAI, P.; GOHAD, N.V.; MOUNT, A.S.; MAKI, J.S.; RITTSCHOF, D.; Duke University, Marquette University, Clemson University;
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Interactions between biofilm bacteria and barnacles Balanus amphitrite

Biofilms are associated with macrofouling organisms. We are interested in the interactions between bacterial communities and barnacles. Here, we report results bacteria-barnacle associations of larval stages, colonization of primary attachment of glue by bacteria, what happens to bacterial communities under juvenile barnacles as they grow, and experimental studies of bacterial communities associated with adult barnacles attached to dialysis membranes. Finally, direct contact tests using glue and bacteria isolated from surfaces. Barnacle nauplii and cyprids collected from the plankton no evidence of bacteria using epifluorescent microscopy and bacterial staining techniques. The same technique showed bacteria on the surface barnacle cyprid primary attachment glue. Bacteria are found under the base of 6-day old juvenile barnacles. By 14 days there are no bacteria present under the barnacles. Late juvenile barnacles were reattached to sheets of cellulose dialysis membrane and grown for 1-2 months. Denaturing Gradient Gel electrophoresis data show different bacterial composition of biofilms under barnacles than exposed biofilms on the membranes. Based on these results, we explored the interaction between bacteria isolated from surfaces and fresh barnacle glue in direct contact tests. Two major findings from the direct contact test are: 1) growth was stimulated by glue in bacteria grown in low and high nutrients and 2) bacterial growth in high nutrient conditions was unexpected and suggests hormesis. Our results suggest, the symbiosis between barnacles and bacterial communities is complex and may involve active management by barnacles.

47.2 EVANS, T.G.*; HOFMANN, G.E.; California State University East Bay, University of California Santa Barbara;
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Ocean acidification in the Northeast Pacific: a genomics perspective

Ocean acidification (OA), the decline in seawater pH caused by the absorption of atmospheric CO_2, has emerged as a global-scale consequence of anthropogenic activity. However, coastal zones of the Northeast Pacific Ocean already experience declines in pH as a result of oceanic upwelling, which exposes contemporary marine populations to seawater conditions not expected to occur in other parts of the ocean until 2100. To explore the impacts of OA in the Northeast Pacific, we capitalized on the availability of genomic resources for a keystone calcifier in the region, the purple sea urchin (*Strongylocentrotus purpuratus*) and monitored gene expression in larvae raised in laboratory mesocosms that simulate future ocean scenarios. We addressed three important questions surrounding the biological effects of OA in the Northeast Pacific: 1.) What are the molecular mechanisms that allow species to sustain function in a low pH ocean? 2.) Do responses to OA differ across species ranges? 3.) How will future ocean warming combine with OA to influence organismal function? Genome-wide transcriptomics provided considerable insight into all three questions. Firstly, modifying the transport and bioavailability of calcium, the primary cation used in the biomineralized structures of *S. purpuratus*, appears central to maintaining calcification in a low pH ocean. Secondly, *S. purpuratus* responded differently to OA across its biogeographic range and some populations may already be living near acclimatization thresholds. Finally, simultaneous exposure to warm and acidic seawater may negatively impact the cell cycle with potential ramifications for growth and development in future oceans.

32.5 FABRE, A-C*; SLATER, G; CORNETTE, R; PEIGNé, S; GOSWAMI, A; POUYDEBAT, E; CNRS and MNHN, France ; University College London, UK , Smithonian Institution, Washington, DC, MNHN, Paris, France, CNRS and MNHN, Paris, France, University College London, UK;
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Getting a grip on grasping in carnivorans: a three-dimensional analysis of forelimb shape

The ability to manipulate and grasp is often considered a hallmark of the humans associated with their bipedal locomotion and tool use. Yet, many other mammals use their forelimbs to manipulate food or objects. Carnivorans, and especially procyonids such as raccoons, are well known for their manipulation ability. Given that manipulation of objects often involves complex rotations of the lower forelimb we predict that species capable of manipulation show strong differences in the shape of the radius and ulna. Here we examine for a data set comprising eight species of procyonids, one ailurid and eight mustelids whether species with good manipulative skills differ from others in the shape of the forelimb elements. To do so we used a surface sliding semi-landmark approach capable of characterizing the articulations between bones in their full 3D complexity. The results analysed in a phylogenetic context show that carnivorans with high manipulative skills differ markedly from others in the shape of the forelimb bones. Both the proximal and distal articulation areas of ulna (axis 1) and radius (axes 1 and 2) discriminated between species with and without manipulative skills. The humerus also showed significant differences between manipulators and non-manipulators, but only on the second shape axis. Thus, our results confirm our prediction and illustrate that the functional signal of manipulation ability is stronger for the lower forelimb bones, which are most strongly implicated in the movement. Moreover, our results demonstrate the importance of using surface methods to capture non-discrete aspects of morphology related to complex movements.

50.4 FAIRCLOTH, B.C.*; GOWATY, P.A.; DRUMMOND, H.; WINKER, K.; GLENN, T.C.; University of California, Los Angeles, University of California, Los Angeles; Smithsonian Tropical Research Institute, Panama, Universidad Nacional Autónoma de México, University of Alaska Museum, University of Georgia; *brant@faircloth-lab.org*

Ultraconserved elements are abundant, universal markers for population genetic and behavioral studies

Ultraconserved elements (UCEs) are numerous, orthologous loci shared among large groups of taxa (e.g., amniotes, teleosts, etc.), and we have demonstrated that UCEs are universal markers useful for addressing phylogenetic hypotheses across these groups. However, the utility of UCEs at shallow levels of divergence is poorly understood. *In silico* work with human genome data and ongoing analyses of avian and reptilian genome sequence data strongly suggest that UCE loci are sufficiently variable to test hypotheses at the species, population, and individual levels. To test the assumption that UCE loci are useful at the population- and individual-level, we used target enrichment techniques and massively parallel sequencing to collect data from 5,000 UCE loci across all members of known-families representing three species of birds (*Sula nebouxii*, *Sialia sialis*, *Sialia mexicana*). After sequencing, we enriched an average of 4,160 (95 CI = 93) UCE loci from each individual having an average length of 622 bp (95 CI = 29) and totaling an average of 2.6 Mbp (95 CI = 17.2 Kbp) per individual. We will discuss the utility of these UCE data in behavioral (parentage/relatedness) and population genetic (diversity/structure) contexts, in addition to discussing these data in relation to ongoing projects using UCEs at the species level. We will also address the utility of UCEs as universal genetic markers allowing apples-to-apples comparisons at the species, population, and individual level across large taxonomic groups (e.g. tetrapods).

P2.71 FALTINE-GONZALEZ, D.Z.*; BABONIS, L.S.; MARTINDALE, M.Q.; Kewalo Marine Lab, Univ of Hawaii; *dylanfg@hawaii.edu*

Do opsins regulate cnidocyte firing in Nematostella vectensis?

Opsins are light-sensitive proteins used by organisms to perceive changes in light intensity. These proteins have been identified in the eyes of both vertebrates and invertebrates, and even in the photoreceptive tissues of some eyeless organisms. Recently, opsins have even been identified in eyeless cnidarians such as the hydrozoan *Hydra magnipapillata*, where they are thought to regulate the firing of cnidocytes. Cnidocytes, the stinging cells found only in cnidarians (jellyfish, sea anemones, etc), function in prey capture, movement, and defense of the organism. If opsins are regulating firing in *Hydra* then it is possible that they also regulate firing in other cnidarians such as *Nematostella vectensis*, the starlet sea anemone. *N. vectensis* is a model organism with 19 known opsin-like proteins, none of which has a currently known function. To test whether any of these opsin proteins regulate cnidocyte firing we isolated and cloned all the opsin sequences from the *N. vectensis* genome and performed *in situ* hybridizations to examine their expression patterns. Our preliminary results show that opsins are expressed in the ectoderm of various areas of *N. vectensis* with unique subsets of opsins being expressed specifically in the tentacle tips, mesenteries, and pharynx, in cells adjacent to cnidocytes. To determine if these opsins found adjacent to cnidocytes are regulating cnidocyte firing, we will continue these studies by performing double *in situ* hybridization to test if other elements of bilaterian phototrandsuction pathways (specifically CNG and arrestin genes) are coexpressed in opsin-expressing cells. Finally, we will then confirm that opsins are regulating cnidocyte firing by performing behavioral experiments.

S9-2.2 FANGUE, Nann A; HASENBEIN, Matthias; KOMOROSKE, Lisa; CONNON, Richard E*; Univ. of California Davis; *nafangue@ucdavis.edu*

Physiological and behavioral responses to multiple environmental stressors in San Francisco Bay-Delta fishes: linking mechanism to management

An important goal of aquatic conservation biology is to understand how environmental factors, both natural and anthropogenic, influence physiological performance, and further whether or not these physiological effects contribute to changes in the distribution, abundance, survival, and overall health of conservation-relevant species. In the San Francisco Bay-Delta (SFBD), many native fishes are in rapid decline and multiple stressors such as entrainment (i.e. fish drawn through intakes) at water pumping stations, loss of critical habitat, competition with and predation from non-native species, as well as contaminants and poor water quality have been attributed to this decline. This presentation will draw from our recent studies on ESA-listed fish species: delta smelt (*Hypomesus transpacificus*), green sturgeon (*Acipenser medirostris*), and chinook salmon (*Oncorhynchus tshawytscha*). The delta smelt is an endemic SFBD species with an annual life cycle and distinct life stages each with unique tolerances to salinity, turbidity, temperature and these factors in combination. Both green sturgeon and Chinook salmon are anadromous species that migrate through the SFBD and spawn in the associated watersheds. Adults and young-of-the-year encounter small- and large-scale agricultural and/or municipal water diversions during migration and entrainment risk is an understudied but significant source of mortality. We will highlight how physiological and behavioral studies that consider multiple and potentially interacting stressors are not only mechanistically revealing, but are necessary to define the habitat requirements of endangered species to aid resource managers in making informed decisions in support of fish conservation.

75.1 FARINA, SC*; FERRY, LA; Cornell University, Arizona State University; *scf59@cornell.edu*

Functional morphology of ventilation in four species of sculpins (Scorpaeniformes)

Fish move water over the gill tissue using pumps in both the buccal and opercular chambers. The pump in the opercular chamber consists of the opercular bones, or the gill cover, and a branchiostegal membrane supported by branchiostegal rays, which are long, slender bones articulating with the hyoid arch. Pelagic fishes tend to have relatively larger opercular bones and benthic fishes tend to have relatively larger branchiostegal membranes. This variation implies that there are important ecological and functional consequences of different opercular pump morphologies. Among four closely related scorpaeniform fishes (*Myoxocephalus polyacanthocephalus*, *Hemilepidotus hemilepidotus*, *Leptocottus armatus*, and *Dasycottus setiger*), we observed a continuum ranging from a large operculum (e.g., *M. polyacanthus*) to a large branchiostegal membrane (e.g., *D. setiger*). We obtained bi-planar video and simultaneous pressure transducer recordings in the buccal and opercular chambers, as well as maximum volumes of the chambers and the surface areas of the opercular bones and the branchiostegal membrane. Our goal was to determine which was most predictive of functional variation: differences in relative surface areas of operculum and branchiostegal membrane or differences in relative volumes of the buccal and opercular chambers. We found that the relative surface area of the operculum and branchiostegal membrane explained more of the variation in ventilation mechanics than did the relative volumes of the buccal and opercular chambers. These data suggest that ventilation biomechanics depend more on the morphology of the pumps driving the ventilatory current rather than the volume to which the chambers can expand.

75.4 FARMER, CG*; SCHACHNER, ER; SARRAZIN, JC; University of Utah; *cg.frmr@gmail.com*

Structure & Function in Sauropsid Lungs

The lung is among the most diverse organs in the vertebrate body but the functional underpinnings and evolutionary history of this diversity are poorly understood. Because gas exchange in the lungs is the first step in the oxygen cascade, this organ plays a key role in the ability of organisms to sustain vigorous exercise and is therefore inextricably linked with ecomorphological diversification. We have been using integrative approaches to study structure-function relationships in a range of vertebrates with the aim of understanding the evolutionary history of this organ. We are currently focusing on the potential role innovations in lung structure played during one of the greatest and most controversial radiations in vertebrate history, that of the Archosauria (e.g., pterosaurs, dinosaurs, crocodilians).

108.1 FARRAR, N*; RIESGO, A; LEYS, S; University of Alberta, Centro de Estudios Avanzados de Blanes-CSIC, Harvard University; *nfarrar@ualberta.ca*

Post-synaptic Density (PSD) and Axon Guidance Genes in the Transcriptomes of 8 Sponges

Sponges are morphologically simple metazoans that lack nerves or any form of synapse, yet the genome of the sponge *Amphimedon* possesses nearly all the genes required for synaptic communication. It is possible that *Amphimedon* is unusual among sponges in either lacking clearly identifiable synapses or in possessing PSD genes that are used for other functions. Here we report on findings from the transcriptomes of 8 sponges which represent all 4 sponge classes: Hexactinellida (*Aphrocallistes vastus*), Calcarea (*Sycon cactus*), Homoscleromorpha (*Corticium candelabrum*), and Demospongiae (*Spongilla lacustris*, *Petrosia ficiformis*, *Pseudospongos suberitoides*, *Ircinia fasciculate*). We used HMMer and BLAST search tools to find gene homologs in each of the transcriptomes and confirmed gene identity by phylogenetic analysis. As in *Amphimedon*, all 8 sponge transcriptomes possess many of the PSD genes. Among the sponges, *Aphrocallistes* shows the greatest number of PSD gene absences. Furthermore, while *Amphimedon* lacks ionotropic glutamate receptors (iGluRs), *Corticium*, *Sycon* and *Ircinia* have genes which Blast to iGluRs and contain motifs present in these channels. We also searched the transcriptomes for classical axon guidance molecules. Molecules identified in some sponge transcriptomes include netrin, deleted in colorectal cancer (DCC), unc5, neogenin, slit, robo, semaphorin, neuropilin and the cell adhesion molecule, DSCAM. The widespread presence of synaptic and neurodevelopmental molecules in sponges strongly implies these molecules functioned in other pathways or systems before being coopted into the neural tissues and systems of other metazoans, or that sponges lost neuronal tissues.

P3.178 FASANELLO, V,J.*; FISCHER, C.P.; FLETCHER, K.L.; MAKRIS, M.E.; SEECOF, O.M.; VASSALLO, B.G.; HAUSSMANN, M.F.; Bucknell Univ.; *mfh008@bucknell.edu*

Stress management: How do repeated stressors affect antioxidant capacity and oxidative damage?

Oxidative respiration results in the production of reactive oxygen species (ROS), which can damage proteins, membranes, and DNA. Organisms have evolved mechanisms such as antioxidant defense to reduce ROS propagation and the oxidative damage that results. Nevertheless, oxidative damage still occurs, and the accumulation of this damage is a critical component of the aging process. Previous work has shown that antioxidant levels can increase or decrease over an acute stress response. Repeated stressors at a young age may prepare antioxidant defenses for subsequent stress responses by increasing antioxidant levels through hormesis. In contrast, repeated stressors at a young age could exhaust antioxidant stores to result in greater oxidative damage. We tested these predictions in one month old Japanese quail (*Coturnix japonica*) over a twenty-three day period by exposing them to differing numbers of the same acute stress protocol: high stress (H; a total of eight stressors), low stress (L; two stressors, the initial and final), and naïve (N; only the final stressor). Plasma levels of oxidative damage and total antioxidant capacity were measured from the final acute stress response. We found that over this stress response, antioxidant levels significantly decreased in the H birds, increased in the N birds, and was intermediate in the L birds. This experiment shows that repeated stressors can exhaust antioxidant stores, suggesting that animals living in natural populations experiencing high levels of environmental stress may have higher loads of oxidative stress and increased cellular aging.

127.7 FAULKES, Z.; The University of Texas-Pan American; *zfaulkes@utpa.edu*

Fifty states of grey market: Assessing the pet trade for parthenogenetic marbled crayfish, Marmorkrebs, in North America

The parthenogenetic marbled crayfish, Marmorkrebs (*Procambarus fallax* f. *virginalis*), was discovered by European pet owners in the mid-1990s. The feature that makes Marmorkrebs scientifically interesting to researchers as potential model organisms– asexual reproduction – greatly increases the risk of Marmorkrebs establishing populations if they are released into the wild, and makes them attractive to pet owners. Many species have been introduced into non-native ecosystems because pets were released, accidentally or otherwise, and it would be useful to know how widely distributed Marmorkrebs are in the North American pet trade. Non-native crayfish have caused substantial ecological and economic damage, and several states and provinces have passed laws prohibiting the import or ownership of crayfish. Much of the pet trade is a grey market, however, and documenting the sale of animals, particularly invertebrates, is challenging. An online survey and monitoring of Internet websites shows that Marmorkrebs have been available in North America since at least 2003 (the year Marmorkrebs first appeared in a scientific publication). Marmorkrebs are kept as pets in at least 38 American states and five Canadian provinces, and this is probably an underestimate of their distribution. It seems likely that almost every state and province in North America either has, or soon will have, someone keeping Marmorkrebs as pets. Of eight states and provinces with laws that would prohibit owning Marmorkrebs, six had Marmorkrebs owners, who were apparently breaking local laws by keeping these crayfish. There are no confirmed cases of Marmorkrebs populations in natural North American habitats, but the pet trade creates a significant risk that this crayfish will be introduced.

P2.20 FAY, SA*; SWINEY, K; FOY, R; STILLMAN, JH; University of California, Berkeley, National Marine Fisheries Service, Kodiak, AK; *scott.a.fay@gmail.com*

De novo assembly of the Paralithodes camtschaticus (Red King Crab) transcriptome to inform its response to ocean acidification

The Red King Crab, *Paralithodes camtschaticus*, is an economically important fishery species in Alaska. Experimental results have shown decreased survival and changes in calcification rates in *P. camtschaticus* exposed to lower pH. The direct effects of climate warming and ocean acidification are highly variable among species, and the underlying molecular mechanisms that allow for acclimation and adaptation to these changes are likewise variable and poorly understood. RNA-seq, using Illumina sequencing of mRNA, allows the direct study of transcriptome-wide gene expression and holds promise to rapidly reveal the molecular underpinnings of biological processes in non-model species. To study differential gene expression a reference database of transcripts is necessary for mapping sequence reads. For species such as *P. camtschaticus* without existing genomic information, a reference transcriptome can to be built from the sequence reads themselves through *de novo* assembly. We sequenced the P. camtschaticus transcriptome in larvae that had been exposed to different pH conditions, and used the resulting sequence reads to compare two popular *de novo* transcriptome assemblers, Trinity and OASES. Trinity ran more than an order of magnitude faster than OASES, and yielded more transcripts with longer average transcript length, suggesting that Trinity is performs better as a *de novo* assembler. We anticipate that an annotated transcriptome coupled with differential gene expression studies from ongoing temperature and pH experiments will help us identify fine-scale molecular responses of *P. camtschaticus* to future ocean conditions.

3.2 FEILICH, K. L.*; LAUDER, G. V.; Harvard University, Cambridge, MA; *kfeilich@fas.harvard.edu*

Why do fish have different shapes? A test using simple physical models

Variation in fish tail and body morphology is one of the most frequently studied features in analyses of fish ecomorphology. There are myriad suggestions for why and how different caudal morphologies may be adaptive in light of fishes' ecology, but none empirically demonstrate a mechanistic basis for performance enhancement. We sought to determine the physical consequences of two traits with purported adaptive significance: peduncle depth and the presence of a tail fork, on undulatory swimming performance. These two traits are often believed to be associated with tradeoffs in swimming economy and acceleration in both inter- and intraspecific comparisons. We attached simple flexible plastic models of different tail shapes as well as the caudal fins of dead fishes to a robotic motor controller and measured force, flow, and 3D kinematics to demonstrate how variation in shape and stiffness may actually translate into differences in the energetic costs, force production, and swimming speed. Future studies using models and live fishes in a controlled way will better inform ecomorphological comparisons, bridging the gap in the experimental literature between body shape and swimming performance.

143.6 FELBINGER, K*; OWERKOWICZ, T; EME, J; SCHRINER, S/E; HICKS, J/W; California State University, San Bernardino, University of North Texas, Denton, University of California, Irvine; *kfelbing@hotmail.com*

Pulmonary bypass shunt reduces oxidative damage in the American alligator

Various hypotheses have been proposed to explain the evolutionary persistence of cardiac shunting among the vertebrates. We hypothesised that the right-to-left (R-L) shunt acts to reduce oxidative stress in tissues, and offers protection during periods of atmospheric hyperoxia. In order to test this hypothesis, we eliminated R-L shunting ability by surgical ligation of the left aorta (LAo) in juveniles of the American alligator (*Alligator mississippiensis*), effectively converting their circulatory system from in-parallel to in-series. Experimental animals (no R-L shunt; n=8) and sham-operated controls (shunt intact; n=8) were exposed for 25 days to normoxia (21%O_2) and hyperoxia (35%O_2) at 30°C. Plasma samples collected after each exposure were assayed for lipid peroxidation and antioxidant activity. We found significantly higher (+13%) malondialdehyde concentrations in response to hyperoxia in experimental animals, and no differences in catalase concentration between treatment groups. This suggests alligators without shunting ability suffered increased oxidative damage, but were unable to mount sufficient antioxidant defences to protect against reactive oxygen species. We suggest the pulmonary bypass shunt, by admixture of deoxygenated and oxygenated blood, reduces blood oxygen tension and limits oxidative damage to systemic tissues. Palaeoatmospheric oxygen fluctuations would have had limited effect on contemporary vertebrate taxa with in-parallel circulation. Evolution of in-series circulation in ancestors of mammals and bird must have necessitated upregulation of antioxidant expression. Funded by NSF grants IOB 0445680 and IOS 922756 to JWH.

P1.88 FELICE, R.F.; Ohio University; *ryanfelice@gmail.com*

Form and Function in the Avian Caudal Skeleton: A Phylogenetic Comparative Investigation

The tail apparatus in birds serves an important role in aerial locomotion, assisting the wings by contributing to lift, stability, and maneuverability, as well as reducing whole-body drag. Previous research has indicated that tail feather morphology in many birds corresponds to flight behavior (i.e., long distance migrants have tails that reduce drag, increasing efficiency). This study examined how caudal skeletal morphology correlates with flight mode (e.g., flap, soar) in the diverse "waterbird" clade (e.g., Ciconiiformes, Pelecaniformes, Procellariiformes, Sphenisciformes). Caudal skeletal morphology was quantified in two ways. The dimensions (e.g., length, width and height of the centrum, neural spine, transverse process, and ventral process) of the free caudal vertebrae were characterized using linear metrics. Pygostyle shape was quantified using Elliptical Fourier Analysis (EFA). EFA is a geometric morphometric method used for analyzing shape variation in complex structures that have few clearly delineated homologous landmarks, like the pygostyle. Preliminary analyses indicate that waterbird taxa differ in free caudal vertebra morphology primarily in the relative size of the transverse process and ventral process. Pygostyle shape varies among taxa in anteroposterior elongation, pointedness, and dorsoventral orientation. However, there is not a significant difference in caudal skeletal morphology among flight mode groups. Phylogenetic relatedness has a significant effect on caudal skeletal morphology as tested using Multivariate Phylogenetic Eigenvector Regression. These results suggest that evolutionary history, rather than flight mode, explains caudal skeletal variation in waterbirds. Thus, whereas caudal integument varies among flight mode groups, the underlying skeletal system does not, suggesting that the integument may be more labile in the face of selective pressures than is the skeleton.

87.1 FELLER, KD*; PORTER, ML; CRONIN, TW; UMBC, University of South Dakota; *kfeller1@umbc.edu*

Molecular and Morphological Description of Stomatopod Larvae

The stomatopod larval phase is adapted for survival in the pelagic environment. Larvae have thus evolved an overall morphology that is separate from the adult, making them difficult to identify since they lack the adult characters used to classify species. The traditional methods of larval species identification have been to either hatch larvae from a known mother or rear larvae through adulthood. The limits of these techniques have resulted in a small and patchy description of larval morphology and species diversity in the stomatopod literature. With the advances and accessibility of molecular techniques, DNA barcoding of the cytochrome oxidase I (CO1) mitochondrial gene has emerged as an adequate solution to the problems associated with larval species identification. We designed degenerative primers based on known stomatopod sequences to amplify an 864 base pair fragment of the CO1 gene. Larval sequences were then aligned with 138 adult reference sequences to construct a maximum-likelihood tree. Larval sequences that were reciprocally monophyletic or had a genetic distance of less than 3% from a reference sequence were regarded as a species. Using these methods, we have positively identified 14 species of stomatopod larvae from collections on the reef platform of Lizard Island Research Station (LIRS, Queensland, Australia). This represents approximately half of the adult species that have been sampled for DNA barcoding at LIRS. We have also sampled 8 species of stomatopod larvae with unknown species identities, suggesting a greater diversity of stomatopod species at LIRS than previously sampled. Based on these data, we have begun morphological descriptions of the last stage larval forms of commonly captured species at this site, including *Alima pacifica* and *Alima orientalis*. Continuing research will use barcode data to investigate genetic diversity within and among species.

P1.207 FEO, TJ*; PRUM, RO; Yale University; *teresa.feo@yale.edu*

Uncovering the morphological and developmental basis of vane asymmetry in flight feathers

Asymmetric flight feathers represent a novel innovation during the evolution of feathers as well as flight in birds. Asymmetric flight feathers are characterized by asymmetry in the width of the vanes that make up either side of the feather; the leading vane with respect the airflow is typically less than half the width of the trailing vane. The leading and trailing vanes are each comprised of a series of branches termed barbs, and it is therefore differences in barb morphology that produce the overall vane asymmetry. Over the past century researches have observed a variety of morphological differences between leading and trailing barbs, such as differences in barb angle or length, that could each contribute to vane asymmetry. However, there has been no comprehensive description of how each of these morphological differences contribute to the overall vane asymmetry within an individual feather, or how these differences are produced during the development of a feather. We describe the major features of barb morphology that contribute to vane asymmetry and describe when these features arise during the development of adult outer tail feathers from two parrot species. This study provides a detailed account of the specific developmental and morphological modifications that must have occurred during the evolution of asymmetric feathers.

P3.174 FERGUSON, S.M.*; LYNN, S.E.; University of Memphis, College of Wooster; *s.ferguson@memphis.edu*

Exogenous corticosterone reduces circulating testosterone but not courtship behavior in male zebra finches (Taeniopygia guttata)

Among vertebrates, environmental stressors can simultaneously activate the hypothalamo-pituitary-adrenal (HPA) axis, inhibit hypothalamo-pituitary-gonadal (HPG) axis activity, and alter reproductive behavior. For example, previous studies in zebra finches have shown that short-term fasting is a physiologically relevant stressor that increased total and free circulating CORT, decreased circulating T, and dampened courtship behavior. However, whether a direct relationship among CORT, T, and courtship behavior exists in this species is unclear. We specifically examined the effects of elevated CORT on both circulating T and courtship behavior in male zebra finches that had established pair bonds with females. We implanted males with CORT-filled silastic implants or empty implants (controls). Twenty-four hr post-treatment, when CORT levels in males reached a peak typical of fasting CORT levels in this species, females were removed from their mate's cage for 4 hrs. We then returned females to the male's cage, recorded courtship behavior for 15 min, and collected blood samples for hormone analysis. Males with elevated CORT due to implants (high CORT males) had lower circulating T concentrations than males with baseline CORT (low CORT males). However, courtship behaviors exhibited towards mates did not differ between high and low CORT males. Our results demonstrate that although elevated CORT resulted in dampened levels of circulating T, changes in CORT and T concentrations alone were not sufficient to influence behavior.

127.6 FERIA, TP; The University of Texas-Pan American; *tpferia@utpa.edu*

Predicting the range expansion of a partenogenic crayfish invader

Marmorkrebs, a parthenogenetic marbled crayfish, has high potential to become an invasive species since single individuals can establish a population and compete native species in places where it has been introduced. To assess the potential ecological threat arising from Marmorkrebs introductions, we developed species distribution models using the distribution of Procambarus fallax (the sexual form of Marmorkrebs) and exotic populations of Marmorkrebs in Madagascar, Europe, Japan and North. America. Geographic information (longitude/latitude) was correlated with nineteen climatic variables (precipitation/temperature) using a maximum entropy approach. Presence data was divided in 70% to elaborate and 30% to evaluate the models using the Area Under the Curve (AUC) in a ROC plot. All models had AUC values > 0.9, which indicate a high performance of the models. Madagascar, Europe, Japan and North America have suitable habitat for Marmorkrebs. The climatic variable with the greatest predictive power was precipitation in the warmest quarter, which may reflect a susceptibility to drought that has been documented for P. fallax. Recently data showed that Marmokrebs has established populations on all the studied countries, except in North America, where major concern are for the conservation of endemic species. Of special attention is the presence of Marmokrebs in Japan, since Marmorkrebs live in rice paddies which could represent a reduction of rice yields in this country. Programs of surveillance of introductions and eradication of Marmokrebs are encouraged, particularly in those areas where species have been established.

P2.190 FERNANDEZ, WL*; NATHAN, BP; MENZE, MA; Eastern Illinois University; *mmenze@eiu.edu*

Decline in Mitochondrial Respiration in Post-Ovariectomy Mice is Ameliorated by Beta-Estradiol

The female sex hormone estrogen has potent neuroprotective properties. Some of these effects may be due to direct modulation of mitochondrial functions. We hypothesized that beta-estradiol treatment will improve mitochondrial bioenergetics in ovariectomized mice. Mice (C57BL/6J, female, 4-10 months-old) were ovariectomized via bilateral incision and control animals underwent sham surgery (Sham). Ovariectomized mice were divided into two groups: One group received a subcutaneous injection of 17-beta-estradiol (E2) dissolved in corn oil (30 ng/g) 24 h prior to synaptosome isolation (estradiol group). The second group received corn oil alone (OviX). Synaptosomes were isolated from the forebrain by Percoll gradient centrifugation. Oxygen consumption of permeabilized synaptosomes was measured using Clark-type polarographic electrodes at 37 ° C. State 4 respiration rates were determined in presence of 5 mM pyruvate, 2 mM malate, 10 mM glutamate, 10 mM succinate, and 2 mM ADP. Our results revealed that state 4 rates dropped significantly in OviX mice (5.55 ± 0.32 pmol $O^2 \bullet s^{-1} \bullet \mu g^{-1}$ protein; n = 14, ±SE) compared to Sham (7.00 ± 0.28 pmol $O^2 \bullet s^{-1} \bullet \mu g^{-1}$ protein; n = 8, ±SE, $p < 0.05$). Respiration rates after estrogen treatment (6.96 ± 0.53 pmol $O^2 \bullet s^{-1} \bullet \mu g^{-1}$ protein) were significantly increased compared to OviX (n = 6, ±SE; $p < 0.05$) and indistinguishable from Sham ($p > 0.05$). However, no differences in state 4 rates were observed among groups in absence of succinate. Our data suggest that estrogen directly impacts mitochondrial activity. Additional studies are being carried out to determine whether succinate dehydrogenase levels are altered by E2 administration.

P2.205 FERREE, E.D.; Claremont Colleges, CA; *eferree@kecksci.claremont.edu*

Geographic variation in morphology of dark-eyed juncos and implications for population divergence

When geographic variation in morphology develops among closely related populations, it can help drive genetic divergence, and eventually speciation, when those morphological traits are the basis for social interactions that influence reproduction. The North American dark-eyed junco is an interesting case in speciation, because even though there are numerous subspecies with distinct breeding ranges and plumage coloration, based on genetic data and the presence of hybrid populations they are considered to belong to one species. Research within several junco populations has shown first, that wing length and the proportion of the tail feathers that are white ("tail white") influence an individual's dominance status and mating success, and second, that these traits can undergo rapid evolution when social and environmental conditions change. Using measurements taken from museum specimens, I determined how the magnitude, correlation between and sexual dimorphism of wing length and tail white varied geographically across 13 dark-eyed junco subspecies. I found significant variation in both traits, as well as in how they co-varied and the degree of sexual dimorphism. I discuss the results in relation to what they may indicate about the maintenance or further divergence of the junco subspecies.

P1.83 FERRER, E; Univ. of California, Berkeley; *eferrer@berkeley.edu*

Geometric morphometric analysis of varanid skulls reveals comparable disparity among regions despite varying species diversity

Extant Varanus are widespread in the Old World, but the geographic origin of the group is in question. The oldest known Varanus comes from the Late Eocene-Early Oligocene of Africa, with older varanoids in Asia, but present species diversity is highest in Indo-Asia and Indo-Australia. Recent molecular evidence shows some support for an Asian origin of monitor lizards. Although they are fairly conservative in morphology, varanids encompass a wide range of habitats and ecologies everywhere they are found. The main question of this study was whether low species diversity in African varanids translates to low morphological disparity as well. I conducted an exploratory analysis using geometric morphometrics to quantify the variation in the skulls of 25 species from African, Indo-Asian, and Indo-Australian regions. I photographed and landmarked 122 images of the skulls in several orientations using tpsDig to allow future comparison to fossil material. With the programs MorphoJ and R, I conducted a Procrustes superimposition and then ran principal component (PCA), canonical variate (CVA), and partial disparity analyses of species and regional groups. Based on the PCA and CVA analyses, African varanids encompass a large range of variation. They are generally situated in the middle of varanid morphospace, but they are also distinct when compared to monitors from other regions. There is considerable shape variation within varanids, although species such as V. komodoensis and V. exanthematicus expand the range of shape space greatly. Varanids from each of the main regions form closely related clades, but the species-poor African group still fills a substantial subset of the morphospace, indicating no lack of disparity relative to the overall shape space.

P2.108 FINKLER, M.S.; Indiana Univ. Kokomo; *mfinkler@iuk.edu*

Possible consequences of delayed nest emergence for hatchling snapping turtles (Chelydra serpentina): the timing of entry into aquatic environments influences body size, metabolic rate, and hematology.

Snapping turtle *(Chelydra serpentina)* hatchlings typically emerge from their nests soon after hatching and overwinter in aquatic habitats. Overwintering in nests is extremely rare, even in areas where freezing risks are low. I examined how the timing of entry into the aquatic environment influences body size, metabolic rate, and hematology. Body size and aerial O_2 consumption were measured weekly over a 28 day period in animals transferred from moistened sand into water (at equivalent temperatures) at 7, 14, or 21 days posthatching, and in animals held in moistened sand for the entire 28 day period. Animals maintained in sand experienced little change in live mass or carapace over the course of the experiment, whereas animals transferred to water gained mass (~5-7% within 24 h of transfer to water and ~9-12% at Day 28 compared to Day 7) and increased carapace length (~2-4% at Day 28 compared to Day 7). Aerial O_2 consumption rates decreased markedly within 24 hours of placement into water and remained low in aquatic animals compared to animals held in sand and measured at the same weekly intervals. Hematocrit and plasma osmolalities of animals held within water for at least one week were lower than those of Day 7 animals, whereas both measurements were higher in animals held in sand at Day 28 than at Day 7. The results suggest that hatchling snapping turtles that remain in terrestrial environments for prolonged periods experience changes in physiological condition (e.g., dehydration, stored energy substrate depletion, etc.) that could reduce survivorship during the first year of life.

S4-1.5 FISCHER, Antje H.L.*; COSENTINO, Carlo; SMITH, Joel; MBL, Università degli Studi Magna Graecia Catanzaro; *afischer@mbl.edu*

The first steps toward a Nematostella gene interaction network

Cnidarians, the sister group to Bilaterians, are particularly interesting for understanding the evolution of fundamental developmental programs, such as axis specification, gastrulation and germ layer specification. Many genes known to be involved in embryonic patterning in Bilaterians are also found in Cnidarians. However, little is known about how these genes are regulated, i.e., the gene regulatory network (GRN). The sea anemone *Nematostella vectensis* has emerged as a particularly suitable cnidarian model system for GRN studies. We present our first steps towards resolving the GRN for early development in *Nematostella*. Using an Illumina HiSeq to perform quantitative RNA-seq, we established a high-density gene expression time course, from fertilization to gastrulation. We compare absolute transcript levels for each gene with all others to determine the statistical dependencies between all gene pairs, a measure of genetic interaction. Additional information about putative regulatory gene interactions is provided by targeted perturbations of signaling pathways. The resulting interaction network (“interactome”) will offer first insights into which genes are the most interconnected. These core regulators will provide the starting point for more detailed network analyses. The obtained GRN will be compared to other organisms to gain a deeper understanding about the evolution of developmental programs across metazoans. As a starting point for the comparison we are performing quantitative RNA-seq experiments on high-density developmental time courses in the snail *Crepidula fornicata* and the ctenophore *Mnemiopsis leidyi*.

3.6 FISH, F E*; NEAL, D; FONTANELLA, J E; DINENNO, N; GABLER, M K; West Chester Univ., Pennsylvania, LaVision, Michigan; *ffish@wcupa.edu*

Flow patterns associated with swimming motions of benthic and pelagic batoids as visualized with DPIV

Batoid fishes display undulatory and oscillatory swimming kinematics of the enlarged pectoral fins that are associated with either benthic or pelagic habits, respectively. Each swimming mode is related to distinct flow patterns that are linked to the propulsive efficiency of the fin motion. Digital particle image velocimetry (DPIV) was used for quantitative flow visualization. Batoids were tested in a long still water tank, where the ray could dictate its own swimming speed, or in a flow tank at 0.25 m/s. The wake structures were visualized for the undulatory Atlantic stingray (*Dasyatis sabina*) and freshwater ray (*Potamotrygon motoro*) and the oscillatory cownose ray (*Rhinoptera bonasus*). The wake of the rays was characterized by vortices shed from the trailing edge of the pectoral fin with a posteriorly oriented momentum jet flow. For undulating rays swimming along the bottom of the tank, the momentum jet was horizontally directed, whereas when swimming in the water column, the jet was directed at a downward angle to the horizontal. The cownose ray produced a wake with a thrust-type vortex street of two staggered rows of alternating vortices that were generated from the distal end of the pectoral fin. The cambered profile of the rigid central body induced water movement in the wake with a downward directed component. The fluid motion and vorticity in the wake of swimming batoids show distinct differences in pattern that are associated with thrust production for each swimming mode, buoyancy control and with proximity to the bottom.

144.3 FISH, JL*; DEPEW, MJ; MARCUCIO, RS; Univ. of California, San Francisco; *jennifer.fish@ucsf.edu*

Developmental influences on variation and asymmetry of the jaw.

Evo-devo as a discipline seeks to understand how variation is generated in a way that can influence evolution. Variation is a salient feature of both normal and abnormal development, but the mechanisms responsible for its generation are largely unknown. We investigate developmental mechanisms generating variation in the lower jaw, or mandible, utilizing two strains of mutant mice that exhibit variable reduction in jaw size and asymmetry, *Fgf8* and *Satb2*. *Fgf8* is a secreted signaling factor that is expressed in multiple domains of the epithelia surrounding the developing jaw. *Satb2* is a transcription factor that is expressed in the mesenchyme of the developing jaw. Reduction in gene dosage of either *Fgf8* or *Satb2* causes micrognathia. Although both mutants exhibit asymmetry in the severity of the defects, *Fgf8* mutants exhibit directional asymmetry, with the left side of the jaw more severely affected. In contrast, asymmetry in *Satb2* heterozygotes is random. Further, significant reduction in jaw length is observed in mice heterozygous for *Satb2* (~50% *Satb2*), whereas mice heterozygous for $Fgf8^{\mathrm{Delta}}$ (~50% *Fgf8*) alleles are phenotypically normal. Micrognathia occurs in *Fgf8* mutants only when *Fgf8* is less than 40% ($Fgf8^{\mathrm{Neo/Neo}}$ mutants). Notably, $Satb2^{+/-}$ (heterozygous) mice have greater variation in mandibular length relative to both WT and mutant genotypes. These data indicate a non-linear relationship between genotype and phenotype, which likely derives from random perturbations in other intrinsic factors. We discuss how differences in the regulation of *Fgf8* and *Satb2* may contribute to differences in their susceptibility to random developmental perturbations, and thus differences in variation in RNA and protein levels and, ultimately, jaw size.

P3.80 FISHELSON, L; BALDWIN, C; HASTINGS, P*; Tel Aviv University, Smithsonian Institution, Scripps Institution of Oceanography; *phastings@ucsd.edu*

Gonad morphology and reproductive modes in fishes of the Tribe Starksiini (Teleostei, Blenniiformes)

The Starksiini is one of only two lineages of reef-dwelling blennies thought to exhibit internal fertilization. We studied the gonad morphology of 17 of the 30 species using standard histological methods. The testes are of the lobular type and have a small testicular gland. Isodiametric sperm (aquasperm) with a globular head or anisodiametric sperm (introsperm) with an elongate head, or both, were observed in various species. Ovaries are bilobed and exhibit either synchronous or asynchronous egg production. We found evidence of both internal and external fertilization and three modes of reproduction within the group. External fertilization and ovuliparity is suggested for the *Starksia atlantica* and *S. lepicoelia* species complexes by the presence in males of a short genital papilla that is free from the first anal-fin spine and by the absence of sperm within ovaries. Internal fertilization and zygoparity is indicated for most species by the presence of a long intromittent papilla in males that is adhered to the first anal-fin spine, "nests" of sperm within ovaries, absence of embryos within the ovarian lamellae and usually thick egg envelopes bearing dense covers of adhesive filaments. Internal fertilization and embryoparity is indicated for *Starksia fulva* and *Xenomedea rhodopyga* by an adhered intromittent papilla, anisodiametric sperm, delicate egg envelopes without adhesive filaments and developing embryos within ovarian follicles. Starksiins differ from internally fertilizing clinid blennies in retaining the testicular gland typical of labrisomids and in lacking sperm packaging typical of clinids and other internally fertilizing teleosts.

126.2 FITES , JS*; PARKER COLLIER, SM; OSWALD-RICHTER, KA; RAMSEY, JR; GAMMILL, WM; ROLLINS-SMITH, LA; Vanderbilt University, James Madison University; *jeffrey.s.fites@vanderbilt.edu*
Batrachochytrium dendrobatidis, an emergent pathogen linked to amphibian declines, produces factors that inhibit adaptive immunity in amphibians and mammals.
Batrachochytrium dendrobatidis (*Bd*) is a pathogenic chytrid fungus that infects the keratinized epithelium of amphibian skin to cause the lethal disease chytridiomycosis, which is linked to global amphibian declines. While adaptive immune defenses appear to be involved in resistance, a robust response is often lacking; and the mechanisms by which *Bd* avoids immune surveillance are not well understood. One hypothesis to explain the ineffective immune responses is that this fungus produces virulence factors that inhibit lymphocyte functions. To address this hypothesis, we studied the effects of *Bd* cells or supernatants on *in vitro* proliferation of *Xenopus laevis* splenic lymphocytes induced by PHA or other activators. Proliferation was inhibited by *Bd* cells or cell-free factors released by *Bd*. A closely related non-pathogenic chytrid, *Homolaphlyctis polyrhiza*, was poorly able to inhibit lymphocyte functions suggesting that *Bd* has unique virulence factors. These factors induced splenocyte apoptosis, activating both caspase 8 and caspase 9 pathways. *Bd* factors also inhibited activation and induced apoptosis in murine and human lymphocytes. Ongoing studies of the molecular nature of the fungal virulence factors suggest that they are soluble, non-protein components of the *Bd* cell wall. These results suggest that *Bd* has evolved a mechanism to impair adaptive immunity in host amphibians in order to colonize the skin. The inhibitory factors appear to target a pathway shared between amphibians and mammals.
Research Support: *NSF grants 0843207 and 1121758 to LR-S*

29.2 FITZPATRICK, B. M.; Univ. of Tennessee; *benfitz@utk.edu*
Symbiont transmission and maintenance of interspecific disequilibrium in structured populations
Microbial symbioses might be as ubiquitous and influential as genes in the evolution and development of some plant and animal phenotypes, and in some cases (e.g., mitochondria) the line is blurred between symbiont and host. Here I explore the proposition that host-symbiont relationships lie on a continuum from the intimacy of genes and organelles to the indifference of casually co-occurring species. A key question is whether symbiont transmission is similar enough to Mendelian gene transmission to generate and maintain associations between genomes that can evolve in the same way as conventional genotypes. I show that intergenomic associations can be described by the same basic models used for conventional linkage disequilibrium with one critical difference: recombination between genes ranges from 0.0 to 0.5, whereas recombination between host and symbiont ranges from 0.0 to 1.0. Thus, covariance between host and symbiont genomes depends on population history, geographic structure, selection, and vertical transmission rate, just as disequilibrium between genes within a genome. Host-symbiont coevolution can be affected by intergenomic epistasis and nonrandom mating just as coevolution between genes within a conventional genome. I illustrate the theoretical continuum between multilocus genetics and host-symbiont dynamics with a simple hybrid zone model where interspecific disequilibrium is maintained by population structure, and a reformulation of a gene-culture coevolution model with humans as hosts and cattle as symbionts.

3.1 FLAMMANG, B.E.*; LAUDER, G.V.; Harvard University; *bflammang@post.harvard.edu*
Backwards swimming by bluegill sunfish requires multifin coordination
Teleost fish, like the bluegill sunfish, have multiple flexible fins that are used as modifiable control surfaces. This helps to make fish highly maneuverable, permitting behaviors like reversing direction of motion and swimming backwards without having to rotate body position. To answer the question of how fish swim backwards we used high–speed videography and electromyography to determine the kinematics and muscle activity necessary to produce reverse direction propulsion in four bluegill sunfish. Comparison of backwards swimming to forwards swimming determined that the two swimming modes are not reciprocal actions. To swim forwards at low speeds, sunfish primarily used their pectoral fins only without appearing to use any other fins. Conversely, backwards swimming is a multifin effort, utilizing the pectoral, dorsal, anal, and caudal fins. The pectorals alternate direction synchronously, broadly flared on the outstroke and feathered on the instroke. The dorsal fin and dorsal portion of the caudal fin act out of phase as do the anal fin and ventral portion of the caudal fin. Electromyography of all muscles in the pectoral, dorsal, anal, and caudal fins demonstrated bilateral activation when the fin changed direction, suggesting that the fin is stiffened at this point. Because teleost fish are statically unstable, locomotion at slow speeds requires precise fin control to adequately balance the torques that are produced about the center of mass. Therefore, we expect that bluegill sunfish require a coordinated multifin motion pattern in order to swim backwards in a controlled manner.

125.2 FLIES, AS*; HOLEKAMP, KE; GRANT, CK; MANSFIELD, LS; Michigan State University, Custom Monoclonals International; *fliesand@msu.edu*
Immune defenses of captive and wild spotted hyenas (Crocuta crocuta): a comparative analysis
Evolutionary processes have shaped the vertebrate immune system over time, but proximate mechanisms control activation, duration, and intensity of an immune response. Ecological and demographic factors such as sex and pathogen pressure can influence immune function. Conventional immunology relies primarily on laboratory-reared animals, which introduces the possibility of altered developmental trajectories of the immune system as compared to animals in their natural habitat. Here we assessed differences in immune function between wild spotted hyenas that inhabit a pathogen-rich environment and captive hyenas that inhabit a more hygienic environment. We used the immune defense component model framework to characterize immune defenses along two continuums: constitutive to induced and non-specific to specific. Our results show that wild hyenas have significantly greater concentrations of total IgG, total IgM, natural anti-KLH IgG, and a trend for increased natural anti-KLH IgM. We observed no difference in bacterial killing ability between the wild and captive populations. This has important implications for serological monitoring of disease in wildlife. Furthermore, there is little evidence of disease-induced mortality in the wild hyena population, indicating that immune defenses are robust in this population. This leaves open the possibility that pathogen exposure is important for proper development and maintenance of the immune system, as suggested by the hygiene hypothesis.

11.7 FODOR, A*; KOHN, A.B.; SWALLA, B.J.; MOROZ, L.L.; Univ of Florida, Univ of Washington; *zebinini@gmail.com*
Quest for Muscle Specific Genes in Pleurobrachia bachei : Had mesoderm independently evolved in Ctenophores?
The nature and development of a mesoderm in basal metazoans has been questioned for over a hundred years, with arguments based on Porifera as the most basally branched lineage and Cnidarians possessing a diploblastic body plan with myoepithelial cell. However recent phylogenetic analysis suggests that Ctenophora may be the earliest lineage of animals, yet processing true neurons and muscles and remarkably complex behaviors. To address the molecular bases of the origins of muscular organization, we searched for the presence of mesoderm and muscle specific genes in the genome of *Pleurobrachia bachei*. Although some well-known bilaterian myogenic transcription factors were absent in the ctenophore genome, we found and cloned several muscle markers such as tropomyosin and calponin as well as β-catenin and 2 T-Box transcription factors. Interestingly, *in situ* hybridization of these genes showed expression not only in the muscular regions of *P. bachei*, but in the epidermal tissues as well, indicating there is an unknown function for these genes in non-muscular cells. At the same time some well-defined muscles were either not labeled or the expression of relative muscular markers was relatively low. The expression patterns for selected genes were also quite variable in *P. bachei* embryos. Our data suggest that ctenophores might represent a unique example of parallel evolution of mesoderm and muscular organization where many features in this lineage had evolved independently from cnidarians and bilaterian animals.

57.5 FOLTZ, S. L.*; DAVIS, J. E.; ROSS, A. E.; ROCK, R. P.; MOORE, I. T.; Virginia Tech, Radford University; *sarahf8@vt.edu*
Food supplementation of urban and rural sparrows: effects on corticosterone, weight, and territorial aggression
Urban areas are novel habitats that present animals with new challenges and opportunities. Our previous studies on song sparrows *(Melospiza melodia)* in southwestern Virginia found various physiological and behavioral differences between urban and rural populations. Specifically, urban populations often have higher baseline and post-stressor corticosterone levels, lower weight, and heightened territorial aggression relative to rural populations. Because both weight and corticosterone are related to energy balance, we hypothesized that variation in food availability between habitats may drive these observed differences. To test this hypothesis, we provided supplemental food to half of the observed territories in both urban and rural habitats. Territorial aggression was assessed by a simulated territorial intrusion in which we played previously recorded male song and observed the focal birds' behaviors. Birds were then caught, bled, and weighed. Surprisingly, we found no effect of habitat type or food supplementation on weight or corticosterone levels. However, rural control birds were significantly less aggressive that rural fed birds and all urban birds, indicating an effect of feeding and relationship with urbanization. Our results indicate that birds were not food-limited in this study season. However, because control birds' weight and corticosterone levels did not differ between habitats, we cannot conclude whether transient food limitation may have driven habitat-related differences observed in past years. The increased aggression of rural fed birds suggests that additional food may impact perceived territory quality or interactions with neighbors in habitat-specific ways.

P2.10 FONNER, C.W.*; WOODLEY, S.K.; Duquesne University, Pittsburgh; *fonnerc@duq.edu*
The Effects of Elevated Temperature on Locomotory Activity, Plasma Corticosterone, and White Blood Cells in the Semi-Terrestrial Salamander Desmognathus ochrophaeus
Animals are continually challenged by abiotic and biotic factors in their natural environments. One factor of growing concern is global climate change. North temperate habitats of many species of plethodontid salamanders are predicted to experience warming trends. Previous research has shown that acute exposure to elevated temperatures caused metabolic depression in *Desmognathus* salamanders. However, the behavioral correlates of acute metabolic depression are less clear. We measured the effects of short-term and long-term temperature changes on locomotory activity, a behavior associated with predator avoidance, foraging, and mate searching. The preferred temperature of *Desmognathus* salamanders is approximately 17°C and salamanders are active in the wild at 17°C and 24°C. *D. ochrophaeus* salamanders were housed at either 17°C or 24°C for two months, and then locomotory activity was measured at either 17°C or 24°C using a repeated measures cross-over design. We also examined changes in baseline plasma CORT and white blood cell differentials after acclimation to either 17°C or 24°C. Locomotory activity was similar regardless of acclimation temperature or testing temperature. Also, plasma CORT was the same regardless of acclimation temperature, whereas the relative proportions of white blood cells were different depending on acclimation temperature. To conclude, moderate changes in temperature do not appear to have adverse effects on locomotory activity or plasma CORT, although relative proportions of white blood cells were temperature sensitive.

9.2 FOO, SA*; BYRNE, M; Univ. of Sydney, Australia; *shawna@anatomy.usyd.edu.au*
Effects of ocean warming and ocean acidification on the sea urchin Heliocidaris tuberculata
The concurrent effects of ocean warming and ocean acidification will have deleterious effects on many marine invertebrates however certain species may show potential for adaptation. Adaptation to stressful climatic conditions depends on heritable genetic variance for stress tolerance present in populations. We studied the interactive effects of warming (+4°C) and acidification (-0.3-0.5 pH units) on development of the sea urchin Heliocidaris tuberculata, near future (2100) ocean conditions projected for the southeast Australian global change hot spot. There were significant effects of pH and temperature on early development with significant interaction between stressors. Decreased pH and increased temperature had negative effects on larval development with smaller larvae in near future levels of these stressors. However there was no significant interaction between warming and acidification on larval development. Multiple dam-sire crosses were used to quantify the effects of climate change on development to assess adaptive capacity.

138.4 FOSTER, K.L.*; HIGHAM, T.E.; Univ. of California, Riverside; *kfost001@ucr.edu*

Neuromuscular control of arboreal locomotion: how green anoles (Anolis carolinensis) deal with changes in incline and perch diameter

Arboreal habitats comprise a diverse array of inclines, substrate diameters, and obstacles that pose considerable functional challenges for locomotion. Arboreal lizards often alter limb kinematics as they execute the complex maneuvers necessary in this habitat. However, there is virtually no information regarding how limb muscles control and propel arboreal lizards. We assessed activity patterns of the biceps dorsalis, puboischiotibialis, ambiens pars dorsalis, caudofemorsalis, and peroneus brevis and longus using synchronized electromyography (EMG) and three dimensional high speed video of 9 adult male green anoles (*Anolis carolinensis*) running on flat (9cm wide) and small, round (1.3cm diameter) perches inclined at 0º, 45º, and 90º. The majority of muscles exhibited two bursts per stride, the first of which occurred during stance and had a greater amplitude and longer duration than the second. The activity patterns of all muscles were consistent with the propulsive functions hypothesized based on anatomy, although several appeared to have secondary antagonistic functions during the swing phase. Although EMG amplitude generally correlated positively with angular excursion of the corresponding joint, activity levels in the biceps, caudofemoralis, and peroneus were disproportionately greater at 90º, especially on the narrow perch, suggesting steep, small diameter perches may be suboptimal from a physiological perspective. However, the reverse was true on the small diameter inclined at 45º for the ambiens, which exhibited decreased recruitment despite greater knee extension than the other treatments. We show that these muscles respond differently to the challenges of perch diameter and incline and suggest that their relative contribution to propulsion may shift.

98.4 FOTI, DM*; GERMAN, DP; Univ. of California, Irvine; *dfoti@uci.edu*

Herbivorous prickleback fishes (family Stichaediae) express multiple amylase isoforms

Many herbivorous vertebrates are reliant upon soluble components of their food (e.g., starch) to meet their energetic needs. Thus, herbivorous vertebrates have elevated activities of the starch-degrading enzyme amylase in their digestive tracts. In this project, we sequenced the different amylase isoforms being expressed in prickleback fishes with different diets to better understand the underpinnings of dietary amylase activity variation. Amylase encoding sequences expressed in the pyloric caeca of pricklebacks were PCR amplified with degenerate oligonucleotides, cloned and sequenced. The nucleotide sequence at the 5'- and 3'-ends were confirmed by Rapid Amplification of cDNA Ends (RACE). The herbivorous fish *Cebidichthys violaceus* expresses at least two amylase isoforms (and likely three or more) that have 14 missense mutations. Two species of *Xiphister* (the herbivorous *X. mucosus* and omnivorous *X. atropurpureus*) express two isoforms with approximately 8 mutations among them, whereas the carnivorous *Anoplarchus purpurescens* appears to express a single isoform. The mutations in the *C. violaceus* transcripts suggest that the resultant proteins may differ in their catalytic activity. This study highlights how the elevated amylase activity in *X. mucosus* and *C. violaceous*, in light of the independent evolution of herbivory in these two species, may be explained by different genetic mechanisms underlying their digestive capabilities.

P1.49 FOUST, C.M.*; SCHREY, A.W.; RICHARDS, C.L.; Univ. of South Florida, Armstrong Atlantic State Univ.; *christyfoust@mail.usf.edu*

Genetic and Epigenetic Population Structure in Spartina alterniflora

Phenotypic plasticity of ecologically relevant traits is important to an organism's response to environmental variation within populations; however, the underlying mechanisms of plasticity are largely unknown. Ecological epigenetics, the study of changes in gene expression not due to changes in DNA sequence, may explain one of the mechanisms underlying phenotypic plasticity. Variation in DNA methylation can cause phenotypic variation among individuals, allow for an individual's response to changing environments, and can be stably transmitted across generations. The current study examines genetic and epigenetic variation and population structure in *Spartina alterniflora* along environmental gradients among multiple sites on Sapelo Island, Georgia in May 2011. We collected leaf samples along 10m transects (n=20 for each microhabitat) in low, middle, and high marsh areas, respectively, within each site. Each microhabitat corresponds to plants with different phenotypes for height (tall, intermediate, short, respectively). We screened AFLP and methylation sensitive AFLP (MS-AFLP) markers for genetic and epigenetic variation, respectively. If *S. alterniflora* responds to the different microhabitats via phenotypic plasticity, we expect to detect no genetic differentiation among microhabitats. If variation in DNA methylation corresponds to phenotypic variation but cannot be explained by genetic variation, our results would suggest that epigenetic regulation of certain genomic elements may be important in dealing with variable environmental conditions. Future studies addressing DNA methylation and gene expression will help to determine if epigenetics contributes to phenotypic plasticity and habitat differentiation of different phenotypes.

140.1 FOWLER, M.A.*; DEBIER, C; CHAMPAGNE, C.D.; CROCKER, D.E.; COSTA, D.P.; University of California Santa Cruz, Université catholique de Louvain, Sonoma State University; *mfowler@ucsc.edu*

Insulin as a differential regulator of lipid mobilization in fasting northern elephant seals

Animals that experience fasting concomitant with metabolically demanding activities are presented with conflicting demands of energy savings and energy expenditure. We aimed to understand 1) understand how fasting, molting northern elephant seals and fasting, lactating northern elephant seals differentially regulate the mobilization of lipid reserves and 2) how milk lipid content is regulated in lactating elephant seals. We sampled 36 lactating females in early lactation, 39 females in late lactation and eight early molt females and six late molt females. Mass, adiposity, circulating non-esterified fatty acids (NEFA), triacylglycerol (TAG), cortisol, insulin and growth hormone levels and milk lipid content were measured. Milk lipid increased from 31% lipid to 51% lipid over ~ 17 days of fasting and lactation. In lactating females increasing cortisol and decreasing insulin were significantly ($p<0.05$) related to NEFA levels, but in molting seals, only increasing cortisol was significantly ($p<0.05$) related to circulating NEFA. Milk lipid content varied significantly ($p<0.05$) with mass, adiposity, NEFA and TAG. Growth hormone was not related to metabolites or milk lipid. Decreasing insulin appears to be the differential regulator of lipolysis in lactating seals versus molting seals, facilitating the additional liberation of stored lipids required for milk synthesis. Milk lipid is strongly impacted by the supply of substrate to the mammary gland, indicating that the regulation of lipid mobilization from adipose reserves may be responsible for changes in milk lipid content.

P1.161 FOWLER, A*; ZUZOW, M; TOMANEK, L; California Polytechnic State University, San Luis Obispo; *aufowler@calpoly.edu*
The Proteomic Response of Tidally-entrained California Ribbed Mussel Mytilus californianus to Hypoxia Stress
Rocky intertidal organisms experience extreme shifts in abiotic factors, such as hypoxia stress, due to tidal fluxes. During low tides, the California ribbed mussel (Mytilus californianus) normally closes its shell to avoid desiccation instead of gaping to augment gas exchange, and thus faces hypoxia stress and anaerobic metabolism. The energetic expense is met to some degree through a simultaneous down-regulation of metabolism. To characterize how entrainment to a tidal rhythm alone affects protein synthesis in M. californianus, mussels were acclimated to tidal conditions with a photoperiod (12 h:12 h) to mimic natural circadian rhythms. There were three treatment groups: a normoxic control, one treated with 100% nitrogen gas for 12 h followed by sampling at 24 and 72 h in which the mussels recovered under normoxic conditions, and a second 100% nitrogen treated group, which was exposed for 72 h to simulate long-term hypoxic conditions. During the long-term hypoxia treatment, gill tissue was extracted at 6, 12, 24, and 72 h. After dissection, the tissue was homogenized, proteins were precipitated, rehydrated and subsequently separated according to charge, using isoelectric focusing, and size, using 2D-gel electrophoresis. Gel images were analyzed with Delta2D to match spots across gels and quantify proteins, and then digested with trypsin to be identified with MALDI-TOF/TOF mass spectrometry. Tidally-entrained mussels responded to hypoxia by producing molecular chaperones and oxidative stress proteins during low tide. Research studying the physiological responses by intertidal invertebrates to the hypoxic response during low tide has the potential to elucidate the effects of interacting environmental stressors on tolerance limits.

34.5 FOX, A M*; SCHREY, A W; MCCOY, E D; MUSHINSKY, H R; University of South Florida, Armstrong Atlantic State University; *amfox@mail.usf.edu*
Are roads a barrier to gene flow in a sand burrowing lizard, the Florida Sand Skink, Plestiodon reynoldsi?
The scrub of peninsular Florida is a highly imperiled ecosystem and home to numerous federally listed species. Effective conservation of these species will benefit from understanding how anthropogenic habitat modification alters the genetic characteristics of populations. Roads are a common anthropogenic habitat modification, and understanding their effect on local populations is important for management. Our goal is to determine if Florida State Road 40 (SR40), which bisects the Florida scrub habitat of the Ocala National Forest in northern peninsular Florida, is a barrier to gene flow in the threatened Florida Sand Skink, *Plestiodon reynoldsi*. The fossorial Sand Skink requires fine, well-drained sand for locomotion; thus, roads may have a direct impact on individual movement. Construction of SR40 began between 80 and 100 years ago, for which approximately 20-25 generations of the Florida Sand Skink have occurred prior to sample collection. We collected individuals (n = 44) from sites north and south of SR40 and screened them for allelic variation at 8 microsatellite DNA loci and mitochondrial DNA variation at the cytochrome-b gene. Because we know the approximate time SR40 altered the habitat of the Florid Sand Skink, we may be able to calibrate the time required for genetic characteristics of the local populations to change. We will also compare our findings to those from recent studies of the Florida Sand Skink in the southern extent of its range.

P1.67 FOZOUNI, P.*; RICHTER, D.J.; KING, N. ; Univ. of California, Berkeley; *pfozouni@berkeley.edu*
Illuminating the Biology of the Common Unicellular Ancestor of Animals and Choanoflagellates
All animals share a common unicellular ancestor that gave rise to the present diversity of animal forms. To better understand animal origins, we study choanoflagellates, the closest living relatives of animals. We hypothesize that genes shared exclusively between choanoflagellates and animals are likely to have played key roles in animal evolution, and we use sequencing as a tool to discover these genes. Only two of the twenty-one choanoflagellate species currently in culture have sequenced genomes: *Monosiga brevicollis* and *Salpingoeca rosetta*. These two genomes contain a diversity of gene families that were previously thought to have been animal-specific. However, *M. brevicollis* and *S. rosetta* are closely related within the phylogenetic tree of choanoflagellates, and thus shared gene loss in their common ancestor could lead to an underestimate of the true complexity of the ancestor of choanoflagellates and animals. To address this, we sequenced the transcriptomes of the remaining nineteen choanoflagellate species in culture. Using these data, we have reconstructed a substantially more complete estimate of the genomic complexity of the common unicellular ancestor of choanoflagellates and animals, including a marked increase in the number of genes we identify as exclusively shared between animals and choanoflagellates. Among these are a number of key gene families involved in diverse aspects of animal development and signaling, which we hypothesize were likely to have played roles in animal evolution. We will present several notable examples and discuss their implications for animal evolution.

P1.144 FRANCO , L. M*; CONTRERAS, C. I; CORTES, P. A; NESPOLO, R. F; UACH, Valdivia; *lidamarcelafranco@gmail.com*
Aerobic power, huddling and the efficiency of torpor in the South American marsupial, Dromiciops gliroides.
We provide a quantitative description of thermoregulatory capacities and energy-saving strategies in Dromiciops gliroides, a Microbiotherid marsupial inhabiting temperate rain forests. Unlike many mammals from temperate regions, preliminary studies have suggested that this species has low capacity for control and regulation of body temperature, but there is still an incomplete picture of its bioenergetics. In order to more fully understand the physiological capacities of this “living fossil”, we measured its scope of aerobic power and the interaction between huddling and torpor. Specifically, we evaluated: (1) the relation between basal (BMR) and maximum metabolic rate (MMR), and (2) the role of huddling on the characteristics of torpor at different temperatures. We found that BMR was 112% and MMR was 59% of the expected value for marsupials. As a result, factorial aerobic scope was 5.2, unusually low for mammals. Comparisons of energy expenditure and body temperature (using attached data-loggers), between grouped and isolated individuals showed that at 20°C, both average resting metabolic rate and body temperature were higher in groups, essentially because animals remained non-torpid. At 10°C, however, all individuals became torpid and no differences were observed between grouped and isolated individuals. In summary our study suggests that the main response of D. gliroides to low ambient temperature is reduced body temperature and torpor, irrespective of huddling. Low aerobic power and low time-consistency of most thermoregulatory traits of D. gliroides support the idea of poor thermoregulatory abilities in this species.

P2.113 FRANCOEUR, A.A.*; DORGAN, K.M.; University of California, San Diego, Scripps Institution of Oceanography; *afrancoe@ucsd.edu*

Mud versus sand: Morphological and behavioral comparison of two species of burrowing orbiniid polychaetes

Both morphological and mechanical constraints affect how organisms interact with their environments and consequently their distributions and functional roles. For burrowing animals, the mechanical responses of muddy sediments, elastic materials through which worms burrow by fracture, differ substantially from those of sands, non-cohesive granular materials. We focused on two closely related burrowing orbiniid polychaetes with divergent morphological features to address how morphological and environmental differences affect burrowing behaviors. *Naineris dendritica* lives in sand, has larger parapodia, and a shovel-shaped head, while *Leitoscoloplos pugettensis* lives in muddy sediments, has smaller parapodia, and a narrow pointed head. To relate morphological differences to the environments they inhabit, burrowing kinematics were analyzed in transparent analogs for mud and sand: gelatin and cryolite, respectively. Both species slipped backward following each cycle of forward movement but this slip was greater for *L. pugettensis* compared to *N. dendritica*. The head of *N. dendritica* widens following forward movement, and friction around this increased surface area may reduce slipping. Both species twist during peristalsis, further increasing the body thickness, but this is more pronounced and regular in *L. pugettensis*. Twisting increases the dorso-ventral forces applied to burrow walls, thus facilitating crack propagation in mud, while large parapodia and head widening reduce backward slipping, which in sand could result in collapse of the burrow. These divergent burrowing behaviors along with small morphological differences are consistent with the mechanical constraints on burrowing in the environments that these two species inhabit.

P1.132 FRASER, A*; SEGEV, T; GRAW, WA; SUCHOCKI, L; HALL, MI; Midwestern University; *fraser62@gmail.com*

Comparative morphology of owl and hawk extraocular muscles

Every vertebrate has six extraocular muscles that attach to the optic globe for the purposes of eye movement. Birds have two additional muscles attached to superior and inferior nictitating membranes, transparent membranes that can be drawn over the eye for protection. Owls and hawks are both relatively large-bodied, predatory groups of birds. Both groups use visual cues to hunt and as such exhibit large relative and absolute eye sizes. Hawks appear to have extraocular muscle function similar to other vertebrates in that they utilize eye movements to observe visual space. However, owls do not utilize extraocular motion and instead have evolved elaborate neck movements to observe visual space. While owls do not appear to move their eyes at all, they do retain reduced extraocular muscles in the same configuration as all other vertebrates. To date owl extraocular muscles have not been described. In this study, we describe owl extraocular muscles by comparing them to hawks. We dissected and observed extraocular muscles of eight birds of varying body size, including two barn owls (Tyto alba), two Great Horned Owls (Bubo virginians), two Red-tailed Hawks (Buteo jamaicensis), and two Harris Hawks (Parabuteo unicinctus). The extraocular muscles were removed and weighed to obtain relative sizes, and then prepared for histology and individual muscle fibers were counted. We discovered that hawks consistently have larger extraocular muscles than do owls, even when accounting for eye size and body size differences. However, the two additional muscles attached to the nictitating membranes were also reduced in the Barn Owl, but not in the Great Horned Owl.

S10-2.2 FRIEDRICH, M.; Wayne State University; *friedrichwsu@gmail.com*

Deep transcriptome insights into cave beetle eyes

The small carrion beetle genus *Ptomaphagus* diversified into more than 50 species, which range from ancestral surface dwellers to facultative and obligatory cave inhabitants in the Southeast of the United States. One of the best-studied representatives is the troglobite *Ptomaphagus hirtus*, which is endemic to the cave system of Mammoth Cave National Park. *P. hirtus* adults are characterized by complete reduction of the hind wings and near complete reduction of the compound eye to a small lens patch. In his survey of North American cave animals, Packard (1888) was unable to detect photoreceptors or optic neuropils in sections of the adult head of *P. hirtus*, which led him to conclude that *P. hirtus* lacks visual senses. This assessment, however, is in conflict with the induction of lens cell specification in the developing insect compound eye. The recent deep sequencing of the transcriptome of the adult *P. hirtus* head recovered orthologs of a large number of sensory, structural and regulatory vision-related genes. I will discuss how these data inform us about the organization of the visual system in *P. hirtus* and other microphthalmic cave arthropods.

P2.2 FRIESEN, C.R*; UHRIG, E.J.; MASON, R.T.; Oregon State University; *friesenc@science.oregonstate.edu*

The effect of mating with vasectomized males on subsequent mating behavior in female red-sided garter snakes.

Female sexual promiscuity is prevalent in nature. One consequence of female sexual promiscuity is that male-male competition often continues post-copulation within the female's reproductive tract. There are two central questions in the study of postcopulatory sexual selection. 1) What factors determine male fertilization success? 2) Why do females mate with multiple males? Explanations of female promiscuity propose that indirect benefits (genetic; good genes, and bet hedging etc.), and/or direct benefits (e.g., extra paternal care, obscuring paternity in social groups etc.) to females outweigh the costs of female promiscuity (e.g., increased predation risk, and exposure to STDs etc.). One hypothesized direct benefit is fertilization insurance; that is females remate to ensure they have sperm to fertilize their eggs. We tested whether female remating frequency was affected by mating with a sperm-depleted male. Our results indicate that when female red-sided garter snakes (Thamnophis sirtalis parietalis) mate with a vasectomized male, they are more likely to remate in semi-natural arenas. These males still produced a copulatory plug, but did not deliver sperm during mating. There are two non-mutually exclusive hypotheses that may account for our results. 1) Females can sense sperm stores within the reproductive tract and use this information to evaluate the quality of a recent mate and remate if they were sperm depleted. 2) The seminal fluid contains a substance(s) that affects female receptivity to subsequent matings. These hypotheses are intriguing as the first suggests a form of cryptic female choice in which females remate after mating with a suboptimal male and the second suggests sexual conflict in which males manipulate females to ensure their own reproductive success.

14.1 FRIESEN, C.R.*; MASON, R.T.; UHRIG, E.J.; BRENNAN, P.L.; Oregon State University, Oregon State Univeristy, Univ. of Massachusetts at Amherst; *friesenc@science.oregonstate.edu*

Sexual conflict during mating in red-sided garter snakes as evidenced by genital manipulation

Sexual conflict occurs when the evolutionary interests of females and males are divergent. Sex-differences in optimal copulation duration can be a source of conflict. Males may evolve mechanisms to prevent females from remating to ensure their reproductive success, while females may otherwise benefit from mating again with a different male. Increased copulation duration may be advantageous for males as it delays female remating. Males of many species actively guard females to prevent them from remating, and in some cases males produce copulatory plugs to prevent remating. This conflict may be especially onerous to a female if precopulatory choice is limited at the time of her first mating. Male red-sided garter snakes (Thamnophis sirtalis parietalis) produce a gelatinous copulatory plug during mating that occludes the opening of the female reproductive tract for approximately two days. The size of the plug is influenced by the copulation duration. We experimentally tested the contribution of male and female control over copulation duration. We ablated the largest basal spine on the male's hemipene and found a reduction in copulation duration and an increase in the variation of plug mass. Further we anesthetized the female's cloaca and found copulation duration increased in this treatment group as well. This suggests that males benefit from increased copulation duration while females actively try to reduce copulation duration. Therefore, sexual conflict is manifest in divergent copulation duration optima for males and females.

P3.74 FROEHLICH, JM*; FOWLER, ZG; REMILY, EA; ROMERO AROCHA, SR; GALT, NJ; BIGA, PR; UNIVERSITY OF ALABAMA AT BIRMINGHAM, NORTH DAKOTA STATE UNIVERSITY; *jmfroehlich@uab.edu*

THE INDETERMINATE GROWTH CONUNDRUM: How do fishes continue to grow throughout their lives?

It is well established that terrestrial vertebrates, namely mammals and birds, reach a growth plateau during ontogeny, resulting in highly restrictive growth potentials as adults. For decades, however, most teleost fishes have been recognized as indeterminate growers, possessing the ability to increase overall somatic size well into adulthood. The nonasymptotic growth potential of these animals begs the question: *how do fishes continue to grow throughout their lives?* Using skeletal muscle as a model, we present data supporting our hypothesis that teleosts rely on adult stem cells, termed myogenic precursor cells (MPCs) in this tissue, of increased proliferative and regenerative capacity to maintain "endless" growth. Consistent with this hypothesis, skeletal muscle of smaller, determinate-like fishes (~0.3-0.5 g) contains three- to seven-fold more MPCs than larger, indeterminate fishes (>1.5 g). Further, MPCs isolated from large danionins (*Devario aequipinnatus* and *Danio dangila*) and salmonids (*Oncorhynchus mykiss*) appear to proliferate to generate several-fold more progeny and express genes associated with self-renewal of the MPC niche, namely paired-box (Pax) and processivity factors (PCNA), than those of the determinate-like zebrafish (*Danio rerio*). Taken together, it appears that a small population of less committed, Pax-expressing MPCs affords most teleosts indeterminate growth in skeletal muscle, although it remains to be determined if this mechanism is conserved among agnathans, chondrichthyans, chondrosteans and other neopterygiians.

P1.39 FULBRIGHT, M.F.*; GIENGER, C.M.; Austin Peay State University, Center of Excellence for Field Biology; *mfulbright@my.apsu.edu*

Habitat Selection and Body Temperatures of Free-ranging Cottonmouths, Agkistrodon piscivorus.

The ecology of snakes is linked to their thermal needs. Within an area, there may be a variety of thermal regimes, which afford reptiles the ability to thermoregulate based on the thermal resources available. The movements and thermal needs have been shown to be different among snake species based on sex and reproductive condition (e.g. gravid vs. non-gravid females). We implanted radio-transmitters and temperature loggers in nine adult male free-ranging western cottonmouths, Agkistrodon piscivorus in Cheatham County, Tennessee. This population is near the northern range limit for the species. At each new capture and relocation, we recorded life history data (e.g. sex, age, snout-vent length, tail length, and mass) and we measured 24 habitat variables at the point of capture. All snakes were PIT-tagged for identification of recaptures. A random point was measured for each snake captured. Throughout the study area, we placed 11 operative thermal models to record temperatures available to snakes. Because the snakes have to cross a heavily traveled walking path to get to their hibernacula, we were concerned with what environmental temperatures were associated with their movements across the trail, in order to potentially reduce human interactions. We found that snakes showed habitat selection that differed from randomly selected comparison sites, there was a large overlap in the home ranges of each snake, and site selection varied among individuals and across an ontogenetic range of body sizes. Juveniles were captured along the edges of the wetland, while larger individuals were more likely to be found towards the center of the slough.

P1.92 FULL, T. *; ROBINSON, H.E.; HOLZMAN, R.; SHAVIT, U.; KOEHL, M.A.R.; Univ. of California, Berkeley, Tel Aviv Univ., Technion; *toryrfull@gmail.com*

Sea Anemone tentacles flutter and flap in water flow in the field

Many benthic marine animals use flexible tentacles to capture planktonic prey from the water flowing past them. Water velocities past tentacles determine the supply of prey and the hydrodynamic forces that can deform tentacles and wash captured prey off tentacles. We used the "Glasrose" sea anemone, *Aiptasia diaphana*, to study how the behavior of tentacles of different sizes affects the water velocities they experience in turbulent, wavy flow in their natural habitat. Videos made in the field (Gulf of Aqaba) of sea anemones illuminated by a sheet of laser light were used to measure simultaneously the ambient water flow (using particle-tracking velocimetry) and the behavior of tentacles of different lengths. Ambient flow was characterized by waves superimposed on a unidirectional current, and velocities varied on time scales of seconds to hours. When the current predominated, tentacles were bent over and fluttered at frequencies that were independent of tentacle length, but that matched wave frequency. Tips of long tentacles were held higher and fluttered at greater amplitude than short ones, and thus sampled a greater area of the water column. When waves predominated, tentacles were whip-lashed back and forth. Although *A. diaphana* can inflate or deflate their tentacles, length/diameter was independent of ambient velocity and tentacles scaled geometrically. Flexible tentacles moved with the flow, thus water velocities relative to their tips were different from their bases and could be higher or lower than ambient water speeds, and in the same or opposite direction. Our study showed that tentacle flexibility reduces forces on prey and tentacles, and these effects are more pronounced for long tentacles.

111.1 FUNG, JK*; FUKUNAGA, A; THOMAS, FIM; University of Hawaii, Manoa; *fithomas@hawaii.edu*

***Naturally occurring ranges in water quality affect early development in the sea urchin Tripneustes gratilla*: implications for distribution of invasive algae**

Kaneohe Bay, Hawaii has undergone rapid increases in invasive algal species. Along with this increase in algae has been the loss of a major algal grazer within the bay, the sea urchin *Tripneustes gratilla*. Numerous environmental factors could be driving the loss of *T. gratilla* across the bay that may act on different life history stages; however, little is known about these driving factors. Here we explore how naturally occurring differences in water across the bay influence *T. gratilla* fertilization. Results indicate using waters from some regions of the bay result in fertilization success that is 60% of that obtained using clean filtered seawater and water obtained in the open ocean. The data have shown that offshore onshore gradients exist in fertilization success. Fertilization in this species is sensitive to many environmental pollutants that are associated with terrestrial runoff, thus water quality may play a major role in the reproductive potential in these important grazers, which may cascade through the system resulting in increased algal cover and decreased coral reef health.

42.3 FUQUA, R.D.*; MONROY, J.A.; NISHIKAWA, K.C.; Northern Arizona University; *rene.fuqua@nau.edu*

Residual force enhancement: evidence for Ca^{2+}-activation of titin

When active muscles are stretched, tension increases and then settles to a steady state that is greater than the isometric force at the stretched length. The mechanism underlying this behavior, termed residual force enhancement (RFE), remains unknown. Previous studies have suggested that titin-based stiffness increases in the presence of Ca^{2+} and contributes to RFE. We hypothesized that the N2A region of titin binds Ca^{2+} to increase titin stiffness. To elucidate the role of the N2A region during active stretch, we tested soleus muscles from three genotypes of *mdm* mice, in which the mutant gene has a deletion in the N2A region. Muscles were actively stretched in two of three solutions, Krebs buffer then BDM, which prevents the formation of strongly-bound crossbridges, or Krebs buffer then dantrolene, which inhibits Ca^{2+} release. By comparing RFE of muscles in these solutions we isolated the effects of Ca^{2+} activation. BDM was used to determine if crossbridge interaction plays a role in RFE. Dantrolene was used to determine the roles of other elements in muscle that are also Ca^{2+}-dependent. In all three genotypes there was no difference in RFE following stretch in BDM, suggesting that the observed increase in force is not due to crossbridge interaction. However, both wildtype and heterozygous muscles showed a decrease in RFE following stretch in dantrolene, suggesting that RFE is Ca^{2+}-dependent whereas, *mdm* mutant muscles were not affected. Data from wildtype and heterozygous mice suggest that RFE is due to a non-crossbridge, Ca^{2+}-dependent mechanism. Data from *mdm* mutants suggest that this mechanism involves the N2A region of titin. Supported by NSF IOS-1025806.

92.1 FURIMSKY, M. M.; Westminster College - PA; *furimsmm@westminster.edu*

Taking time to teach scientific methodology and communication in a first year biology course

In addition to learning new information in the classroom, first year biology students are also developing important skills and competencies to carry forward into their upper level courses and beyond. Recent assessment of student learning has inspired revisions to existing curricula for the purpose of preparing the new generation of students for success in a competitive academic environment. The three hour per week lab component of our first year biology courses include one week skills workshops (e.g. solutions, microscopy, genetics), as well as three week lab modules. The lab module approach has permitted the careful stepwise use of the scientific method under the guidance of biology faculty, including gathering appropriate scientific literature, experimental design, data analysis and scientific writing. Details of the changes to our undergraduate curriculum will be discussed, with the primary focus being the experiential learning component of our first year biology courses.

P1.90 GABLER, M K*; FISH, F E; BENESKI, J T; MULVANY, S; MOORED, K W; West Chester Univ., Pennsylvania, Univ. of South Florida, Tampa , Princeton Univ. New Jersey; *mg731541@wcupa.edu*

The hydrodynamics of ground effect in relation to the head shape of the spotted eagle ray

Eagle rays are epipelagic batoids that forage on the ocean bottom. Unlike other members of the family Myliobatidae (e.g., *Rhinoptera*, *Manta*) that possess paired cephalic lobes around the mouth, the eagle rays have a prominent flattened bill-like rostrum. CT scans of the head of a spotted eagle ray (*Aetobatus narinari*) were used to define the external geometry to produce a scale model of the ray head with a 3D printer (ZPrinter 450). The model was tested in a flow tank over a range of flow speeds from 0.06 to 0.43 m/s. A multi-axis force transducer was used to measure lift and drag of the model head in mid-water and in close proximity to the bottom at angles of attack from -10º to 10º. At 0º angle of attack, a negative lift was generated by the model head when situated in the water column, but a slight positive lift was produced when the model was in close proximity to the bottom. Compared data from the model situated in the water column, the bottom produced a substantial ground effect which enhanced the lift production for both positive and negative angles of attack. The model head was modified with dye injection ports for flow visualization. The dye streams indicated that the rostrum acted like a delta wing. The delta shape makes wings less likely to stall and thus maintains lift production. When foraging, eagle rays swim with the head angled down in contact with the substrate. The increased negative lift from ground effect would aid in stabilizing the head to keep the sensory surface of the rostrum in contact with the substrate and counter any pitching motions induced by oscillations of the pectoral fins.

108.3 GAGNON, YL*; JOHNSEN, S; Duke University;
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Visual acuity in deep-sea fish and mollusks

The ocean can be a challenging environment for visually active animals. Downwelling light is absorbed by the water and decreases exponentially with depth. At epipelagic depths (0-200 m), targets reflect ambient light and create extended scenes. The most suitable lenses at these depths maintain high image contrast at the viewer's cutoff resolution (the highest spatial frequency that can still be registered by the viewer's retina). At mesopelagic (200-1000 m) and bathypelagic depths (>1000 m), bioluminescence is more common and the ambient light is many orders of magnitude dimmer than at shallower depths. The visual scene becomes dominated by point source targets requiring a different type of lens. Scenes become more binary (with less gray levels) and low contrast at the cutoff resolution does not necessarily affect the image quality. We looked at the optical characteristics of the lenses of 24 different species of deep-sea fish and pelagic molluscs. The lenses' radii, focal lengths, and focal capabilities were measured. Collimated light (550 nm) was focused on a camera CCD by adjusting the paraxial distance of the lens (suspended in buffer). We imaged the lens' point spread function (PSF) (quantifying the amount of blur introduced by the lens). The PSF was used to calculate image contrast of targets with varying spatial frequencies. These results were compared to known cutoff frequencies of the investigated species, their depth, and biology. The heteropod, *Pterotrachea coronata*, had distinct elongated and narrow PSFs matching the linear array of photoreceptors in its retina. The Hatchetfishes, *Argyropelecus aculeatus* and *Sternoptyx diaphana*, had the highest angular resolution and smallest full PSF width at half maximum (FWHM) of all the examined species. This matches well the predictions that these fish need high resolution for viewing silhouettes against the downwelling light at mesopelagic depths.

P1.65 GAI, L*; ELLIS, NA; MILLER, CT; Swarthmore College, Univ. of California, Berkeley; *lgai1@swarthmore.edu*

The roles of BMP6 and AP2 in tooth number determination in threespine stickleback

The overall objective of this project was to elucidate the genetic basis of naturally evolved tooth number differences in the threespine stickleback fish, *Gasterosteus aculeatus*. The threespine stickleback is well-suited for elucidating the genetic circuitry underlying tooth number variation, having undergone dramatic adaptive radiation as ancestral marine populations repeatedly colonized inland water bodies. Adaptive radiations are often associated with changes in trophic morphology, as populations adapt to new diets in new environments. In the threespine stickleback adaptive radiation, several trophic differences evolve upon freshwater adaptation, including increased tooth number in some freshwater populations. A recent study identified a number of quantitative trait loci (QTL) associated with tooth gain in a large forward cross between individuals from a high-toothed Paxton Lake freshwater benthic population and a low-toothed Japanese marine population. Our goal was to further elucidate the processes underlying evolved tooth gain using a combination of genetic and developmental approaches. Firstly, we hoped to determine which genomic regions are associated with tooth gain in lab-reared populations of Paxton Lake benthic stickleback. Secondly, we wished to characterize the expression patterns of candidate genes located near the peak QTL marker, as well as look for expression differences between high-toothed and low-toothed populations that could be responsible for tooth number divergence. In this presentation, I will give an overview of the findings and procedures resulting from this project.

P3.155 GALLAGHER, CA*; MURRAY, JA; CAIN, SD; CHOATE, BA; Cal. State U. East Bay, Eastern Oregon U;
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Distribution of ciliated cells and identification of putative olfactory receptors in a novel chemosensory organ in the nudibranch Tritonia diomedea

Tritonia diomedea has an a pair of rhinophores that are homologous to the posterior tentacles of the ancestral gastropods, and an oral veil that is derived from the anterior tentacles of ancestral gastropods. The rhinophores are distance chemoreceptors that detect odors emitted by prey, predators, and conspecifics. The oral veil is mechanosensory, can distinguish the taste of prey and predator, and has ~18 white tips, 2-5mm long, which serve as finger-like papillae oriented anteriorly that are used to explore items they contact by crawling. In contrast, the two most lateral tips are 5-10mm long, are oriented ventrally during crawling, and have a ciliated groove along the ventro-medial surface. The groove has motile cilia (10-20 micron long tufts of ~100 cilia; tufts at 500/mm^2) oriented to transport fluid from the tip towards the base at 2-4 mm/s. The groove is surrounded by skin with 5-10 micron long tufts of ~300 cilia on papillae separated by ~30 microns (~100 tufts per mm^2). The groove may be chemosensory and we observed an ~12% increase in the rate of transport of glass beads when the groove was exposed to the odors of prey or predator, but this change is not statistically significant (n=5). Genetic work was carried out to look for the presence of known *Aplysia californica* olfactory receptor sequences. Primers were designed for the gene sequence known as “olfactory receptor C”. PCR was carried out on the extracted *T. diomedea* DNA and a matching sequence was found. Cloning work is now underway to attempt to clone the gene sequence found in *T. diomedea*. Preliminary results indicate that type A and type C olfactory receptors are present in the oral veil and rhinophores. There is a greater concentration of receptors at the proximal base on the ciliary groove.

P3.88 GALLOWAY, K.A*; MEHTA, R.S; WARD, A.B; Univ. of California, Santa Cruz, Adelphi University ;
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Documenting the Mechanisms of Elongation Across the Ophidiiformes

Body elongation is pervasive throughout actinopterygian fishes; it has evolved multiple times independently, and over fifteen percent of the diversity has this body plan. Axial elongation can occur through a variety of morphological changes including increasing the number of vertebrae or lengthening the individual vertebral centra. Each morphological change has significant effects on body flexibility. Having a highly flexible body seems to offer many behavioral advantages such as the ability to fit into tight crevices and locomote both aquatically and terrestrially. Our study quantifies elongation in the diverse and little known teleost group, the Ophidiiformes and seeks to understand how elongation may lead to behavioral adaptations and specializations. The Ophidiiformes, collectively known as cusk eels, exhibit elongated bodies, but with varying degrees of flexibility. Pearlfishes (Carapidae) have the greatest degree of axial flexibility, enabling members of this group to enter and exit their invertebrate hosts, such as sea cucumbers. Through morphological metrics such as elongation ratio (ER) and axial elongation index (AEI), we compare the highly flexible axial skeleton of pearlfishes to members of four other ophidiiform clades. We find that pearlfishes and spotted cusk eels (Ophidiidae) have the highest ERs indicating more elongate body plans while the basketweave cusk eel and brotulas exhibit the lowest ERs indicating deeper bodies, albeit still elongate body plans. Our study shows that vertebral numbers in the caudal region of the axial skeleton are driving elongation in the Ophidiiformes. Pearlfishes, however, exhibit a two-fold increase in caudal vertebral numbers enabling them to be extremely flexible and probe small crevices to enter their invertebrate hosts.

126.1 GAMMILL, WM; ROLLINS-SMITH, LA*; Vanderbilt University School of Medicine; *louise.rollins-smith@vanderbilt.edu*

Antimicrobial peptide defenses of southern leopard frogs (Rana sphenocephala) against the pathogenic chytrid fungus, Batrachochytrium dendrobatidis

Southern leopard frogs (*Rana sphenocephala*) coexist in habitats in which the pathogenic chytrid fungus, *Batrachochytrium dendrobatidis* (*Bd*) is prevalent. Because this species is not in serious decline, it is likely that it possesses adequate skin defenses against this pathogen. One important innate defense is the production and release of antimicrobial peptides (AMPs) into the mucus of the skin. Four antimicrobial peptides have previously been described for this species, but their activity against *Bd* in growth inhibition assays has not previously been tested. We confirmed the presence of these four AMPs in *R. sphenocephala* adults collected in Tennessee by MALDI-TOF and tandem mass spectrometry. We showed that the natural mixture of hydrophobic peptides found in the skin mucus effectively inhibits *Bd* growth, and the individual pure synthetic peptides inhibited at micromolar concentrations. Injection of norepinephrine results in long-term depletion of skin peptides, and ongoing studies will determine whether peptide depletion results in greater susceptibility to *Bd* infection. These studies are designed to demonstrate whether AMP defenses are essential for protection of this species from *Bd* infections. Support: NSF grants 0843207 and 1121758 to LR-S.

33.3 GARB, J.E.*; HAYASHI, C.Y.; LANCASTER, A.K.; CORBETT, S.; AYOUB , N.A.; University of Massachusetts Lowell, University of California, Riverside, Whitehead Institute for Biomedical Research, Washington and Lee University; *Jessica_Garb@uml.edu*

Fresh Insights from RNA-Seq Analysis into Black Widow Spider Venom Composition and Evolution

Venoms are chemically complex secretions that have independently evolved in several animal lineages for the purposes of predation and defense. Venoms have attracted enormous interest because of their pharmacological applications, and because of their dynamic evolutionary histories, which can be directly linked to organismal ecology. Despite the biological importance of venoms, their molecular composition and evolution is poorly understood in many medically significant and ecologically interesting species. A case in point are the black widow spiders, representing several species in the genus *Latrodectus*, which have a potent neurotoxic venom that immobilizes both vertebrate and invertebrate prey. We assembled venom gland gene transcripts from the Western black widow spider (*Latrodectus hesperus*) using Illumina RNA-Seq libraries as well as traditional cDNA libraries. We compared these venom transcripts to Illumina-derived transcripts from *L. hesperus* silk gland and cephalothorax tissues. Our analyses identified large numbers of transcripts that are exclusively or primarily expressed in venom glands, including many novel toxin sequences. Our results show that black widow venom has far greater molecular complexity than previously realized, which is in part explained by dramatic expansion of toxin gene families. We are expanding this transcriptomic work across related species to further understand how changes in molecular composition and gene expression have led to the extreme toxicity of black widow venom.

P2.206 GARCIA, E.L.*; GRISWOLD, C.E.; CARMICHAEL, A; San Diego State University, Summer Systematics Institute, California Academy of Sciences, Summer Systematics Institute, California Academy of Sciences; *erika_garcia234@hotmail.com*

Phylogenetic investigation and species delimitation of South African araneoid spider genus Cyatholipus, Simon 1984

The forest biota of Africa is a biological diversity hotspot reflecting a heterogeneous landscape, suggesting centers of endemism and strong selective gradients in species richness. The existence of a disjunct montane region has been described as ‘archipelago-like’, which has led to high endemic diversity across many organisms including the araneoid spider family Cyatholipidae. The afrotropical cyatholipid fauna compromises fifteen genera. Here we focus exclusively on the South African genus *Cyatholipus* which encompasses six described species. Ranging from 1-2mm in body size, *Cyatholipus* are generally rare, but with recent efforts by the South African National Survey of Arachnida (SANSA), the number and quality of *Cyatholipus* collections has dramatically improved—this includes the *first* specimens preserved for molecular phylogenetic analysis. Integrating taxonomic information and phylogenetic methods, this project aims to describe, resolve, and understand interspecific relationships within *Cyatholipus*. To provide a detailed visualization of morphological characteristics, scanning electron microscopy (SEM), digital imaging, and female genitalia digestion methods were implemented. Using *Teemenaarus* as the outgroup hypothesis, molecular analyses of three molecular markers (H3, CO1, 28S) through Bayesian, Maximum Likelihood, and Parsimony were used to enable further resolution of the species limits within *Cyatholipus*. The congruence of the morphologic and phylogenetic data has suggested the synonymy of three species and one potential new species, reducing the number of valid species to four. *****We acknowledge generous support from the NSF REU program*****

77.2 GARCIA, MJ*; DOBBINS, M; VAUGHN, S; EARLEY, RL; Univ. of Alabama; *mjgarcia@crimson.ua.edu*

Variation Within and Among Populations in the Behavioral Types of Mangrove Rivulus (Kryptolebias marmoratus)

An individual’s fitness depends critically on their ability to obtain and retain resources, which may be linked to their willingness to leave shelter (boldness), explore novel habitats, or engage in aggressive encounters. These behavioral attributes often are consistent within but divergent among individuals; that is, individuals often exhibit consistent individual differences in behavior, or behavioral types. The aim of this study was to evaluate consistency of behavioral types (boldness, exploration, and aggression) within individuals and differences among individuals, genotypes, and populations in the mangrove rivulus. This fish is a self-fertilizing hermaphrodite and long bouts of selfing result in completely homozygous individuals capable of producing offspring that are genetically identical to parent and kin. This allows us to replicate at the genotype level, and to examine the genetic underpinnings of behavioral variation with greater resolution than in species with conventional reproductive systems (e.g., outcrossing). Thirty-three genotypes were derived from field caught individuals collected from seven geographic locations, which vary in both physical and community-level characteristics. Individuals of the F2 generation were collected from each genotype and were raised in standardized conditions. At 11-months of age behavioral assays of boldness, exploration, and aggression were performed. Behavioral types were then examined to determine differences within- and between-genotypes and populations. Given environmental variation among populations, we predicted that differential selection pressures would result in significant variation in behavioral types across populations while reducing within-population variation.

38.3 GARDINER, JM*; ATEMA, J; HUETER, RE; MOTTA, PJ; Mote Marine Laboratory, Boston University, University of South Florida; *jayne@mote.org*

Sensory switching in sharks: the role of multimodal stimuli in prey tracking and capture

Hunting involves a sequence of steps with increasing sensory information as the distance between predator and prey decreases. Little is known about multimodal aspects of hunting underwater, where prey can be visible, emit hydrodynamic disturbances, odors, sounds and/or electric fields. We investigated three shark species from different ecological niches: nurse sharks, bonnetheads, and blacktip sharks. We blocked olfaction, vision, the lateral line, and electroreception, alone and in combination, to elucidate their complementary and alternative roles in feeding. Interspecific similarities and differences exist among sharks in terms of which senses they focus on for particular phases of feeding behavior. In most cases, multiple senses can be used for the same behavioral task, allowing sharks to switch to alternative sensory modalities to successfully capture prey. Under our experimental conditions, nurse sharks rely on olfaction for detection and track using olfaction combined with vision, the lateral line, or touch. They orient to prey using the lateral line, vision, or electroreception, but will not strike without olfaction. Capture requires electroreception or touch. Bonnetheads normally use olfaction to detect prey, olfaction combined with vision or the lateral line to track, vision to line up a strike, and electroreception for capture. They can detect, orient, and strike visually in the absence of olfactory cues. Blacktip sharks also detect prey using olfaction or vision, and track using olfaction combined with vision or the lateral line. Long-distance orientation and striking is visually mediated but in the absence of vision, close-range orientation and striking can be lateral line-mediated. Capture requires electroreception or touch. Collectively, these results reveal species-specific sensory hierarchies for shark feeding behavior.

70.1 GARLAND, MA*; PAGANINI, A; STILLMAN, J; TOMANEK, L; California Polytechnic State University, San Luis Obispo, San Francisco State University; *mgarland@calpoly.edu*

The proteomic response of the porcelain crab, Petrolisthes cinctipes, following acclimation to fluctuating temperature, pH, and aerial exposure treatments

Petrolisthes cinctipes is a eurythermal porcelain crab that inhabits the mid- to high-intertidal zone along the Pacific coast between British Columbia and central California. Its localized niche results in exposure to fluctuating temperatures, changes in pH, and desiccating conditions according to seasonal, daily, and tidal cycles. We characterized the proteomic response to these dynamics by acclimating *P. cinctipes* to changes in temperature, pH, and aerial exposure. Crabs were acclimated to three conditions: (1) constant immersion at 11°C, (2) a daily emersion at 11°C, and (3) a daily emersion with an accompanying temperature increase up to 27°C. In each tank, half of the crabs were maintained at a constant pH of 8.0, and other half experienced a nighttime drop in pH to 7.6. Proteins from gill, hemolymph, and claw tissues were separated by 2D gel electrophoresis, and changes in protein expression patterns were analyzed using a general linear model. Proteins that changed significantly were digested with trypsin, mass fingerprinting was performed by tandem mass spectrometry (MALDI TOF/TOF), and identifications were made using an EST database. In claw tissue, crabs responded to thermal stress through changes in expression of several glycolytic enzymes, arginine kinase isoforms, and proteins involved in cytoskeletal restructuring. Proteins associated with the molt cycle, respiration, and other regulatory functions also played a role in characterizing the heat shock response, reflecting the major changes in homeostasis in response to environmental stress.

127.4 GARZA DE YTA, A.; Aquaculture Global LLC; *agarza@crm-agc.com*

Developing markets for a new product: Aquacultured Red Claw in Mexico

The number of farms, production and demand of Cherax quadricarinatus or Redclaw has had major shifts in the last fifteen years in Mexico. These shifts also have been caused by the marketing strategies for the organism and their source (aquaculture/fisheries) In 1996 there were around 20 active farms of redclaw in the States of Tamaulipas alone; by the end of 2001 there were just four. A major transformation in production practices and marketing occurred since then. There was the need to make the redclaw more accessible to the people and to expand the markets. More markets attracted more investors and the redclaw industry started to grow, more farms started operations in ten more states and redclaw looked like a booming aquaculture activity. The number of farms was over 40 again by 2007. Nobody thought there would be anything that could stop the booming of this industry. Unfortunately, illegal stocking in man-made dams and reservoirs occurred in Tamaulipas and suddenly the market was flooded with redclaw of all sizes at $60 MNX and sometimes $50 MXN so competition between farmers and fisherman started in 2007. Since then there has been a balance and producers that have been able to market their product through quality and consistency have succeeded and the ones that have not are struggling or have failed and closed operations. Farms by 2010 are reported to be 15 nationwide. Redclaw is in Mexico to stay, and it will depend on expanding the current markets that a new round of expansion occurs for the aquaculture farms or that innovative production systems can reduce the current production cost and make the farms competitive again.

P2.98 GAUDREAU, M.G.*; BERGMANN, P.J.; Clark University, Worcester, MA; *mgaudreau@clarku.edu*

Patterns of Abiotic Niche Evolution in Salamanders Along Different Niche Axis Spatial Scales

Niche evolution, or the tendency for ecological traits to diverge over time, is a process that can produce numerous patterns of niche trait distribution. These patterns may ultimately show how species distributions change in response to environmental changes, and how they diversify. Niche evolution occurs along course scale axes such as biome type and climatic attributes, and along increasingly finer scale axes such as habitat and microhabitat. Rates and modes at which course and finer scale niche axes evolve are likely to differ because of differing spatial heterogeneity of the underlying environmental variables. Here, we test whether courser scale niche axes display patterns of greater niche conservatism than finer scale niche axes. We quantified several abiotic niche axes of varying spatial scale (biome, canopy height, altitude, latitude, temperature, precipitation, and various aspects of the habitat and microhabitat) for over 300 species of adult salamanders. We used Pagel's κ, δ, and λ parameters to characterize patterns of niche evolution for each axis. We used κ to quantify the degree of gradual evolution for each niche axis, δ to determine whether most evolution along each niche axis occurred near the base of the tree (suggesting adaptive radiation) or the tips of the tree, and λ to evaluate whether changes in niche axes coincided with phylogenetic relationships of salamanders. We also estimated the Brownian Motion rate parameter, σ, to compare rates of niche axis evolution at different spatial scales. To our knowledge, this is the first investigation of the evolution of numerous detailed abiotic niche axes along different spatial scales in a large clade of organisms.

P1.59 GEBER, A*; SMALLS, T; PALMER, M; AMBROSE, B; Columbia University, The New York Botanical Garden; *abg2143@columbia.edu*

Transcriptome analyses of the rhizophore in Selaginella apoda

The lycophytes (Division Lycopodiophyta) comprise the oldest extant group of vascular plants at approximately 410 million years old. As such, they represent an archaic timepoint in the evolutionary history of plants, especially with regard to their modes of reproduction, their leaf morphology, and their meristem growth and branching patterns. Studies of stem morphology and anatomy have shown that most members of the genus *Selaginella* possess angle meristems, centers of developmental potential that arise *de novo* at stem branch junctions. While the axillary shoots of higher plants have fixed cell fates, the angle meristem has the capacity to develop in a context-dependent manner as either a new shoot or as a rhizophore, a root-bearing organ. The identity of the rhizophore is highly debated; it has been classified historically as a root, a shoot, and an organ in its own right according to lines of developmental and physiological evidence. Comparative transcriptomics of the root, shoot, and rhizophore tissues of *Selaginella apoda* have yielded insight into the nature of the rhizophore. Taken in conjunction with morphological and anatomical studies of the meristems in several species of *Selaginella*, these findings have potential implications for understanding the evolutionary history of root development.

P3.159 GEFEN, E.*; BERMAN, T.S.; University of Haifa-Oranim, Israel; *gefene@research.haifa.ac.il*

Neural control of gas exchange pattern is phase-dependent in the desert locust

The adaptive significance of discontinuous gas-exchange cycles (DGC) in insects is contentious. The recently proposed neural hypothesis suggests that DGC is expressed when insects conserve energy by reducing brain activity at rest, thus releasing thoracic ganglia from descending control of ventilatory activity. In accordance with this hypothesis, we predicted that the highly-responsive sensory pathways and considerably larger brain size in gregarious compared with solitary *Schistocerca gregaria* locusts would be reflected in higher DGC prevalence at rest in the former. Furthermore, cutting the connectives between the head and thoracic ganglia was expected to result in disappearance of phase-dependent variation in gas-exchange patterns, as well as in an overall increase in DGC expression. We used flow-through respirometry at 30°C for measuring metabolic rates (MR) and gas-exchange patterns in intact, connective cut (CC) and sham-operated adult male locusts of both density-dependent phases. DGC was not more common in gregarious locusts, although results may have been confounded by their significantly higher MR in comparison with solitary locusts. However, severing the connectives between head and thoracic ganglia did not increase DGC expression in gregarious locusts. Moreover, DGC was abolished altogether in CC solitary individuals, which switched to a distinctly continuous gas-exchange pattern (surgical treatments did not affect MR). These results are not consistent with predictions of the neural hypothesis, based on brain inhibitory effect on ventilatory centers in thoracic ganglia. Furthermore, a significant difference in DGC expression between gregarious and solitary CC locusts may point at neural plasticity of ventilatory control.

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Predation and parasitism: It's not all bad news

There are multiple theoretical studies predicting the outcome of the addition of predators in host-parasite systems. In a direct developing and castrating system, high levels of predation on infected individuals will likely lead to a reduction in parasite infections, but empirical data is currently lacking. The Rhizocephalan barnacle parasite *Loxothylacus panopaei* provides an ideal system for investigating parasite response to predation. *L. panopaei* is invasive from the Chesapeake Bay to Florida and infects the mud crab *Eurypanopeus depressus*. It has been hypothesized that *E. depressus* maintains a small size because it is able to escape predation by hiding in the interstitial space between oyster shells. *E. depressus* with adult *L. panopaei* infections carry a large externa, the external reproductive organ of the parasite, which increases the crabs size and could decrease mobility. I investigated whether infected mud crabs were more susceptible to predation by the native blue crab *Callinectes sapidus* than their healthy counterparts. In all treatments infected crabs were consumed at higher rates then healthy crabs, with some predators exclusively consuming infected crabs. On average, infected crabs were consumed three times as often as healthy crabs. With predators selectively feeding on infected hosts the parasite populations could be driven to extinction. In this system, a native predator may be helping to protect the native crab species from its invasive enemies.

2.5 GEORGE, A.B.*; DE BURON , I.; MCELROY, E.; College of Charleston; *abgeorge@g.cofc.edu*

The effects of the parasites, Cardicola laruei and Henneguya cynoscioni, on the swimming performance of spotted seatrout, Cynoscion nebulosus

Parasites are often associated with detrimental impacts on host physiology, but very few studies have examined the impact of parasites on the swimming performance of fish. In this study, we aimed to determine the impacts of two parasite species, *Cardicola laruei* and *Henneguya cynoscioni*, on the swimming performance of spotted seatrout, *Cynoscion nebulosus*. For 18 fish, we quantified burst swimming speed (U_{Burst}) and critical swimming speed (U_{Crit}) as indicators of anaerobic and aerobic swimming abilities, respectively. The effect of *H. cynoscioni* on swimming performance could not be determined because none of our experimental fish were infected with this parasite. 72% (13/18) of the fish were infected with *C. laruei*. Linear regression showed a significant (P = 0.02) positive relationship between *C. laruei* infection density and U_{Crit}, but no significant relationship (P = 0.17) between density and U_{Burst}. The unexpected positive correlation between *C. laruei* granuloma density and U_{Crit} may be explained by changes in heart muscle cell function as a byproduct of infection.

98.3 GERMAN, DP; Univ. of California, Irvine;
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Digestive enzyme activities elucidate the digestive strategies of prickleback fishes (family Stichaeidae) with different diets
The patterns of digestive enzyme activities along the digestive tract of an animal can reveal the strategy that an animal takes to acquire resources from their food. In this study I examined how the activity levels of carbohydrases, proteases, and lipase change along the guts of five closely related prickleback fish species with different diets: *Cebidichthys violaceus* (herbivore), *Xiphister mucosus* (herbivore), *X. atropurpureus* (omnivore), *Phytichthys chirus* (omnivore), and *Anoplarchus purpurescens* (carnivore). Digestive enzyme activities were measured in the pyloric caeca (which include pancreatic tissue in pricklebacks), and in the proximal, mid, and distal intestines of the fishes. All five species showed decreasing amylase activity moving distally along the intestine, whereas disaccharidase activities tended to peak in the mid intestines of the herbivores and omnivores, and decrease moving distally along the intestine of the carnivorous *A. purpurescens*. Collectively, these observations, in concert with moderate concentrations of short chain fatty acids in the fishes' guts, are consistent with the "plug-flow reactor" model of digestion, and suggest a reliance on endogenous digestive processes as opposed to microbial endosymbionts. Enzyme activity patterns (including proteolytic and lipolytic activities, which are in progress) will be discussed in the context of the fishes' feeding ecology and evolutionary history.

P2.44 GERRY, S.P.*; BISACCIA, M.; ELLERBY, D.J.; Fairfield University, Wellesley College; *sgerry@fairfield.edu*
Correlating Fast-Start Performance to Morphology in Juvenile Bluegill
Adult bluegill exhibit variation in their morphology and swimming performance based on habitat. The littoral form has a deeper body with fins located farther from the center of mass to aid in maneuvering among the vegetation. Pelagic bluegill have a streamlined, fusiform body shape associated with efficient steady-swimming. Additionally, this body shape is associated with greater fast-start performance based on peak velocity, acceleration and turning rates. This is significant since fish that perform faster-starts should have greater fitness because they are better able to evade predators. Juvenile bluegill of both body forms hatch in the littoral habitat and remain there until they are less susceptible to predation in the open water. It is not known if the variation in morphology and fast-start performance present in adult bluegill is also present in the juveniles or if there is a relationship between morphology and performance in juvenile fish. Therefore, we captured 100 juvenile bluegill over a range of size classes from 1-80 g. We analyzed their fast-start performance from high-speed video recordings and measured functionally relevant morphological variables including fin areas, body area and body depth. The smallest bluegill showed no association between morphology and performance. Body depth and the areas of the median fins are each negatively correlated with fast-start performance in larger juvenile bluegill (Pearson, $p < 0.05$). This divergence in form and function, as bluegill increase in size, may be related to a shift in foraging behavior between littoral and pelagic habitats. Juveniles with streamlined bodies and increased fast-start performance are better suited to sustained swimming, an advantage when capturing zooplankton and escaping predators in a pelagic environment.

S6-2.2 GHALAMBOR, C.K.*; HANDELSMAN, C.A.; RUELL, E.W.; Colorado State. Univ.; *cameron1@colostate.edu*
Plasticity, selection, and the potential for adaptation in newly established populations
Novel environments often impose directional selection for a new phenotypic optimum. However, new environments can also be a source of phenotypic variation by inducing plasticity and changing the distribution of phenotypes exposed to selection. Plasticity can either be cogradient, where the plastic response is in the same direction favored by selection, or countergradient, where the response deviates from the direction of selection. Cogradient plasticity is thought to be adaptive, as it provides a better pairing between the phenotype and local ecological conditions, but results in weaker directional selection. In contrast, countergradient plasticity is thought to be non-adaptive, as there is a greater mismatch between the expressed phenotype and the optimum favored by selection, resulting in strong directional selection. Thus, understanding how phenotypic plasticity and selection in new environments jointly shape suites of morphological, physiological, and behavioral traits is critical to predicting evolutionary responses and population differentiation. Here we review plastic responses in a diversity of traits for Trinidadian guppy populations adapted to high and low predation environments. Specifically, we examined plasticity in response to the presence or absence of predator cues during development and suggest that the type of plasticity a trait exhibits can be used to predict how it will respond to selection.

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Integrating animal behavior and conservation biology: a case study of invasive crayfish
Conservation behavior is a relatively new interdisciplinary field of study that aims at investigating how proximate and ultimate aspects of animal behavior can assist land managers in solving conservation problems (Blumstein and Fernández-Juricic 2010; Berger-Tal et al. 2011). However, its usefulness in promoting practical conservation matters is highly debated, with some scientists arguing that the importance of behavior in conservation practice is overemphasized (Caro 2007). I will show the role of behavioral studies in tackling the problem of the invasions by crayfish species. Two paradigmatic examples will be discussed: (1) the potential use of 'animal personality' studies in predicting the invasive potential of species (Gherardi et al. 2012) and (2) the importance of sexual selection, mating strategies, aggression, and other aspects of behavior in helping managers select appropriate techniques for the control of invasive populations (Gherardi et al. 2011). An important take-home message will be that ignoring behavioral data often leads to the failure of management programs (Knight 2001).
Berger-Tal O., Polak T., Oron A., Lubin Y., Kotler B.P., Saltz D. 2011. Integrating animal behavior and conservation biology: a conceptual framework. Behavioral Ecology 22: 236–239. Blumstein, D. and Fernández-Juricic, E. 2010. A Primer on Conservation Behaviour, Sinauer Press Caro T. 2007. Behavior and conservation: a bridge too far? Trends in Ecology and Evolution 22: 394–400. Knight J. 2001. If they could talk to the animals. Nature. 414: 246–247. Gherardi F., Aquiloni L., Diéguez-Uribeondo J., Tricarico E. 2011. Managing invasive crayfish: is there a hope? Aquatic Sciences 73: 185–200. Gherardi F., Aquiloni L., Tricarico E. 2012. Behavioral plasticity, behavioral syndromes and animal personality in crustacean decapods: an imperfect map is better than no map. Current Zoology 58: 566–578.

S3-2.4 GIBB, A.C.*; ASHLEY-ROSS, M.A.; HSIEH, S.T.; Northern Arizona University, Wake Forest University, Temple University; *alice.gibb@nau.edu*

How is a morphology that is under strong selection for swimming performance "repurposed" for terrestrial locomotion?

Non-amphibious teleost fish spend the vast majority of their lives in the water. Yet, individuals may become stranded during efforts to evade predators or colonize new habitats and must produce effective movements on land to return to the water. How is a morphology that is under strong selection for swimming performance "repurposed" to produce terrestrial locomotion? On a slope, a fish can produce head and/or tail oscillations that overcome inertia, enabling it to tumble or slide downhill. However, to effectively traverse overland, a fish cannot simply recapture potential energy, but must produce propulsive ground-reaction forces. To this end, many small, fully-aquatic teleosts employ a "tail-flip" jump when stranded on a flat surface. In this behavior, a fish, lying on its side, peels the head off the substrate, rolls the anterior body over the tail, and then straightens the body to launch into the air. We note that both down-slope and overland-transit behaviors in fully-aquatic fishes are markedly different from locomotor behaviors exhibited by many amphibious fishes; in amphibious fishes, the ventral (rather than lateral) surface of the body is in contact with the substrate, and bending movements are primarily parallel to the substrate. In addition, in several amphibious species, the body-bending component of the locomotor behavior is reversed, such that the tail curls towards the head (rather than the head toward the tail) with subsequent axial extension plus rotation contributing to effective thrust production. Thus, from observations of extant teleosts that represent a gradient of "terrestriality", we hypothesize that the transition to a "prone" position may be a key component of the evolution of a terrestrial habit.

19.1 GIBBS, AG*; RAJPUROHIT, S; PETERSON, LM; ORR, A; Univ. of Nevada, Univ. of Pennsylvania; *allen.gibbs@unlv.edu*

Testing the melanism-desiccation hypothesis using experimental evolution

Several *Sophophora* species on the Indian subcontinent show clinal patterns in pigmentation, with darker populations occurring in northern, drier locations. We used experimental evolution to test the 'melanism-desiccation' hypothesis, which proposes that dark cuticle in *Sophophora* is an adaptation for increased desiccation tolerance. We selected for dark and light body pigmentation in replicated populations of *S. melanogaster* and assayed traits related to water balance. We also scored pigmentation and desiccation tolerance in populations selected for desiccation survival. Populations in both selection regimes showed large differences in the traits directly under selection. However, after over 50 generations of pigmentation selection, dark-selected populations were only slightly more desiccation tolerant than light-selected and control populations. Body pigmentation of desiccation-selected populations did not differ from control populations after over 140 generations of selection. We also found correlated responses in carbohydrate amounts in both selection regimes. Our results do not support an important role for melanization in *Sophophora* water balance. Supported by NSF award EnGen-0723930.

30.4 GIBSON, Q.*; HOWELLS, E.; LAMBERT, J.; MAZZOIL, M.; O'CORY-CROWE, G.; RICHMOND, J.; University of North Florida, Harbor Branch Oceanographic Institute; *quincy.gibson@unf.edu*

Reproductive State Influence on Female Bottlenose Dolphin Ranging Patterns

Variation in mammalian home range patterns is often linked to energetic requirements, which likely differ depending on reproductive status. Yet, few studies have tested whether bottlenose dolphins (*Tursiops truncatus*) adjust their ranging patterns with respect to reproductive status. Using data from Indian River Lagoon, Florida (1997-2007), we compared the ranging patterns of nursing and non-nursing adult females with both longitudinal and cross-sectional analyses. The size of females' home ranges (HR) and core areas (CA) were not significantly different between reproductive states ($P>0.05$), presumably due to a lack of directional pattern among females. HR size varied greatly among individual females, 9.4–90.8km^2 nursing versus 20.9–186.1km^2 non-nursing. CA size ranged from 0.4–56.7km^2 nursing and 0.4–49.7km^2 non-nursing. Overlap between nursing and non-nursing ranges also varied greatly among individuals (HR: 13.9–95.0%, CA: 0–94.0%). Nursing females continued to utilize 52.0±5.1% of their non-nursing HR but only 19.1±5.45% of their non-nursing CA. In our cross-sectional analysis, a large portion (77.75±5.41%) of the non-nursing 95% utilization distribution was also used by nursing females across all seasons. However, overlap between nursing and non-nursing 50% utilization distributions was low (< 35%) in all seasons except summer. These findings suggest that variation in ranging patterns among individual females was greater than by reproductive state. Females continued to use a large proportion of their overall range, but concentrated in different areas depending on their reproductive status.

79.6 GIDMARK, N*; TARRANT, J; KONOW, N; BRAINERD, E; Brown University; *njg@brown.edu*

The role of muscle force versus work in trophic specialization of cyprinid fishes

Vertebrates feed on a wide variety of foods that vary in material properties, so biomechanical traits of their feeding systems should vary with diet. Cyprinidae is a trophically diverse fish clade that offers an opportunity to compare how muscle function varies with feeding ecology in a simple, conserved mechanical apparatus. Food is broken down exclusively by the pharyngeal jaws (tooth-bearing modified gill arches), where a single muscle elevates the jaw, pushing the teeth against an occlusal surface. We measured *in vivo* lengths of this levator muscle using XROMM in two cyprinid specialists: a molluscivore and a herbivore. We then used *in situ* electrical stimulation experiments to measure the force-length relationship of the same muscle. While masticating small foods, black carp (*Mylopharyngodon piceus*, molluscivore) used small muscle strains (<10%, 3 animals, 78 chews), whereas grass carp (*Ctenopharyngodon idella*, herbivore) used larger muscle strains (>15%, 4 animals, 196 chews). *In vivo* muscle strain differences translated into different physiological operating lengths: both species initiated occlusion at near-optimal muscle lengths (ca. $0.95L_o$), but the black carp levator shortened to a minimum length of $0.87L_o$, compared with $0.81L_o$ for grass carp. The slight operating length difference led to a striking force difference *in situ*: at $0.87L_o$, the black carp levator preserves much of its potential force (0.5-$0.7P_o$), but at $0.81L_o$, the grass carp levator only produces ca. 25% of its potential force (0.2-$0.3P_o$). We hypothesize that for black carp, force alone is the functional optimality criterion, whereas for grass carp, work (force x distance) is important for shearing plant matter. Thus, our results underscore the role of *in vivo* muscle operating lengths in shaping the diverse vertebrate trophic strategies.

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Methodological Refinements to Using Lugol's Iodine as a Contrast Agent in X-ray Micro-CT Imaging

Visualization methods vastly enhance our ability to appreciate and harness complex anatomical relationships for understanding the nature of morphological change. Most notably, the widespread use of non-destructive X-ray computed tomography (CT) and micro-CT (µCT) has greatly augmented our ability to comprehensively detail and quantify the internal hard-tissue anatomy of vertebrates. However, the utility of X-ray imaging for gaining similar paradigm-altering insights into vertebrate soft tissues has yet to be fully realized due to the naturally low X-ray absorption of non-mineralized tissues. In this study we detail how the soft-tissue anatomy of the head and neck—including differences between white and grey matter of the brain, individual fascicles of the cranial musculature, dural venous sinuses, glands, fat deposits, and the complete pathways of cranial nerves—can for the first time be fully visualized in post-embryonic vertebrates (*Alligator mississippiensis* and *Dromaius novaehollandiae*) using iodine-enhanced (i-e) µCT methodologies. To date, methods using Lugol's iodine (I_2KI) have been employed to study invertebrates, vertebrate embryos, and parts of adult rodents, rabbits, and a yearling alligator—in all cases yielding promising results. However, anatomical visualizations among the larger, post-embryonic specimens have remained incomplete. Our research builds on these previous studies by systematically testing for optimal staining using differences in contrast levels of resulting i-e µCT images from intact archosaur heads prepared under differing treatments of Lugol's iodine. We further demonstrate the utility of this method using computer rendering software to describe and quantify the 3-D anatomy of the brain, cranial musculature, and cranial nerves in *A. mississippiensis* and *D. novaehollandiae*.

P3.158 GILL, KP; RICE, JL*; MURRAY, JA; CAIN, SD; University of Mebourne, Eastern Oregon University, California State University, East Bay; *ricejl@eou.edu*

An investigation of the statocyst sensory system in Armina californica

Statocysts are a common type of gravireceptor within the invertebrate taxa. This system is analogous to the vertebrate auditory-vestibular system that utilizes the otolith. Within molluscan taxa, the statocyst is an epithelial sac filled with a fluid called statolymph. The epithelial wall is continuous with the statocyst receptor cells, each bearing several hundred sensory cilia and free-moving calcium carbonate stones or statoconia. Most information regarding the statocyst sensory system has been obtained from terrestrial snails such as *Helix* and *Lymnaea*. However, the statocyst sensry system has been described in only a few marine gastropod species. Most work into statocysts has involved opisthobranchs due to their large, re-identifiable neurons, as well as their symmetrical and relatively simple central nervous system (CNS) and stereotypic behaviors. In this study we investigated the statocyst sensory system in the nudibranch *Armina californica*. We used the righting response, initiated when the animal is rolled onto its back, to determine the role of the statocyst and the sensory neurons in this gravireceptor-initiated behavior. We used time-lapse video analysis to record and analyze the righting response. We used cell tracing techniques to determine the innervation pattern of the statocyst and investigated the neural response of pedal nerves to mechanical stimulation of both contralateral and ipsilateral statocysts by recording extracellularly from the pedal nerves innervating the foot. This study provides the initial steps in determining the neural pathways activated by the statocyst sensory system underlying righting behavior.

27.3 GILLIES, A G*; LIN, H; HENRY, A; REN, A; SHIUAN, K; FEARING, R S; FULL, R J; University of California, Berkeley;
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Gecko toe and lamella adhesion on macroscopically rough surfaces

The role in adhesion of the lamellae and toes - intermediate sized structures - found on the gecko foot remains unclear. Insight into the function of these structures can lead to a more general understanding of the hierarchical nature of the gecko adhesive system, but in particular how environmental topology may relate to gecko foot morphology. We sought to discern the mechanics of the lamella and toes by examining gecko adhesion on controlled macroscopically rough surfaces. Live Tokay geckos, *Gekko gecko*, were used to observe the maximum shear force a gecko foot can attain on an engineered substrate with sinusoidal patterns of varying amplitudes and wavelengths in sizes similar to the dimensions of the lamella and toe structures (0.5 – 6 mm). We found shear adhesion was significantly lower on surfaces that had amplitudes and wavelengths approaching the lamella length and inter-lamella spacing, losing 95% of adhesion over the range tested. We also found that the toes are capable of adhering to surfaces with amplitudes much larger than their dimensions even without engaging claws, maintaining 60% of adhesion on surfaces with amplitudes of 3 mm. Results suggest that gecko adhesion may be predicted by the ratio of the lamella dimensions to surface feature dimensions, and that macroscopic-scale features are necessary to maintain contact, and consequently, generate adhesion on macroscopically rough surfaces. Findings on the larger scale structures on gecko feet could provide the biological inspiration to drive the design of more effective and versatile synthetic fibrillar adhesives.

118.5 GILLOOLY, JF; University of Florida; *gillooly@ufl.edu*

Physiological Constraints on the Genome Size of Species

Biologists have long sought to explain the over 3000-fold variation in genome size among animals. Cell size is perhaps the only phenotypic trait that has been shown to be correlated with genome size across diverse taxa, but it remains unclear whether cell size constrains genome size or vice versa. Here I present a model that aims to predict genome size based on how physical chemistry constrains cell size, and cell size in turn constrains genome size. Data compiled from a broad range of species from diverse environments are presented in support of the model. Results suggest that much of the heterogeneity in genome size can be explained based on differences in organismal physiology.

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High cost of paternal care in the kit fox, Vulpes macrotis.

Cost of reproduction in mammals is usually estimated in females, with less attention to paternal investment in young. In many species of canids, males participate in rearing young by providing food to lactating females and older pups. The paternal cost of reproduction in the kit fox, *Vulpes macrotis*, was estimated from the cost of the increased daily movement distance of males provisioning lactating females and pups (4 - 6 weeks of age). Paired (n = 24) and unpaired (n = 7) foxes were radio-tracked and monitored in spring, summer, and winter over a 28-month period in the southern Mojave Desert of California. Most pairs were socially monogamous, with duration of mate relationship ranging from 1 – 28 months. Females serially associated with 0 to 3 males during the study: two of three solitary females did not produce pups. Two males each provisioned two dens simultaneously. The effect of provisioning mates and pups on male daily movement distance (DMD) was calculated from a repeated-measures model using monogamously paired animals: prey abundance, mean nighttime temperature, and reproductive status had significant effects on DMD, but body mass did not. When provisioning the lactating females, male DMD averaged 29.3 ± 1.1 km (LSMean ± SE), as compared with an average DMD of 17.5 ± 0.7 km during non-reproductive seasons. With an estimated field cost of locomotion of 15.6 kJ km-1 (Girard 2001), male cost of provisioning was 183 kJ d-1 or about 11% of total male field metabolic rate. In contrast, lactating females traveled only short distances away from the den. Maternal energetic investment in milk averaged 454 kJ d-1, or about 37% of a female's metabolizable energy intake. Thus, paternal effort is impressive (40% of maternal investment in milk) and plays an important role in providing food, reducing maternal activity costs, and allowing increased maternal vigilance.

11.6 GIRARDO, D.O.*; CITARELLA, M; KOHN, A.B.; MOROZ, L.L.; Univ of Florida; *dogirardo@wpi.edu*

Zero-click, Automatic Assembly, Annotation and Visualization Workflow for Comparative Analysis of Transcriptomes: The quest for novel signaling pathways

The rapid growth of genomic datasets is an enormous technical and conceptual challenge in data processing. To address this challenge, we developed an automated "zero-click" analysis pipeline with an integrated signaling peptide prediction system. This pipeline is compatible with all next generation sequencing platforms and it is capable of processing and visualizing RNA seq data in less than a day. This greatly improves the pipeline's computational throughput, keeping pace with the rapid advances of sequencing technology in recent years. The developed workflow has been validated with 60+ RNA-seq datasets obtained from 10 species of ctenophores (one of the most basal lineages of Metazoa) and 50+ species of molluscs, acoels, arthropods, and basal deuterostomes. All 60+ sequencing projects were designed to select organisms whose unique neural organization, development, cellular structures and behaviors aid in understanding the origins and evolution of nervous systems. As a result, we first identified the most evolutionarily conserved and fastest evolving subsets of genes underlying the origins of neuronal innovations. We hypothesize that secretory peptides can be the earliest intercellular signaling molecules. Consequently, the workflow is designed to simultaneously predict secretory signaling peptides across species. As an illustrated example, we investigated the effectiveness of our peptide prediction system in the quest for enigmatic signaling molecules in ctenophores. Importantly, we also validated our predictions by *in situ* hybridization to determine localization of the primary secretory cells. Our initial results suggest a diverse set of novel signaling peptides in ctenophores – most of them have no homologies across other phyla.

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Seasonal and altitudinal variation in fatty acid composition of native bees

Lipids are critical for organism physiology, both as key energy storage molecules (fatty acids), and as fundamental components of cell membranes (phospholipids and sterols). The quantity and quality of fat (the most important energy resource) stored strongly affects survival & fitness in many organisms. However, the structure and physiological functions of key lipid components (fatty acids) are strongly affected by temperature. In particular, low temperatures compromise the mobilization of energy from stored fats and reduce the fluidity of phospholipid cell membranes. In response to changing temperatures, organisms may also alter lipid and hence fatty acid composition to maintain fluidity, a hypothesis termed "homeoviscous adaptation". Small ectotherms like insects may be particularly susceptible to temperature induced shifts in lipid physiology but the homeoviscous adaptation hypothesis has rarely been tested in terrestrial insects, except in the context of diapause. We tested whether lipid content and fatty acid composition vary with seasonal (May to September) and altitudinal (2241 – 3151 m) variation in environmental temperature among eight species of native bees. We measured total lipid content and fatty acid composition using a vanillin assay and gas chromatography coupled with a flame ionization detector (GC-FID). Here, we discuss how fat physiology varies seasonally and with altitude among a diverse array of native bee species.

S2-1.6 GLASTAD, K M; HUNT, B G; YI, S V; GOODISMAN, M A D*; Georgia Tech; *michael.goodisman@biology.gatech.edu*

The function of DNA methylation in insects

Many organisms are capable of developing distinct phenotypes in response to ecological variation. This developmental plasticity is particularly prevalent in insects, which can produce alternate adaptive forms under different environmental conditions. Developmental plasticity often relies on epigenetic information, which affects gene function and is transmitted through cell divisions. One of the most important epigenetic marks, DNA methylation is found in many insect taxa, yet its function remains unclear. We have investigated the prevalence and patterns of DNA methylation in insect genomes. We have found that DNA methylation is preferentially targeted to genes showing active and uniform expression among insect phenotypes. Genes displaying DNA methylation also tend to be involved in particular biological functions and are conserved phylogenetically. Finally, we provide novel insight into the nature of DNA methylation in insects by contextualizing its role in the multi-layered epigenome.

34.6 GLAZIER, A.E.*; ETTER, R.J.; JENNINGS, R.M.; University of Massachusetts, Boston; *amanda.glazier001@umb.edu*

Bathymetric Patterns of Genetic Variation: Implications for Evolution in the Deep Atlantic

The deep-sea is a vast and complex ecosystem with a rich and highly endemic fauna. Most contemporary research has focused on the ecological mechanisms that allow coexistence of high alpha diversity. Few studies have considered how populations diverge or new species form to create this remarkable diversity. Recent work suggests that population divergence decreases with depth in response to reductions in biotic and abiotic heterogeneity below the continental shelf. Consistent with this hypothesis (referred to as the depth-differentiation hypothesis), species diversity, morphological divergence, and genetic differentiation all peak at bathyal depths, decreasing towards the abyss. Potential causes of this pattern include greater isolation of populations at bathyal depths due to topography, environmental heterogeneity, and depth-related variation in evolutionary rates. We test the depth-differentiation hypothesis in the western North Atlantic by comparing patterns of genetic variation between congeneric protobranch bivalve species pairs that have primarily bathyal (500-3000m) or abyssal (> 3000m) depth ranges. Comparing congeners controls for any taxonomic differences in evolutionary rates, ecology or life-history characteristics between more distantly related taxa. Multilocus analyses of both mitochondrial and nuclear loci are used to partition individuals into putative populations, estimate migration rates and test for divergence among these populations. Observed bathymetric patterns of genetic variation have important implications for evolution in the deep North Atlantic.

P1.185 GLEISS, A C*; WHITLOCK, R E; DALE, J J; CLARK, T D; BLOCK, B A; Hopkins Marine Station, Stanford University, Finnish Game and Fisheries Research Institute, Helsinki, Australian Institute of Marine Science, Townsville; *agleiss@stanford.edu*

Influence of Ambient Temperature on Specific Dynamic Action in Bluefin Tuna

Bluefin tunas are the most endothermic teleost fish. They have evolved the ability to elevate their muscle, viscera and brain temperature above ambient water temperatures and capture metabolic heat with counter-current heat exchangers. Pacific bluefin tuna (*Thunnus orientalis*) studied in captivity have a specific dynamic action (SDA) associated with metabolic rate elevated up to 2.3X routine metabolic rate and a doubling of heart rate in response to feeding. During SDA, the viscera warms as much as 8C° in juvenile Pacific bluefin tuna. Pacific bluefin showed an increased duration of specific dynamic action and heat increment of feeding as temperatures cooled both in captivity and the wild. This suggests four possibilities: a) increased heat conservation, b) increased meal size, c) decreased enzymatic performance, d) decreased cardiac performance and a limited aerobic scope. To examine this, we instrumented captive fish with temperature and acceleration data logging tags to capture information on thermal inertia, swimming speed and body temperature of fish digesting meals at different ambient temperature. Here we report on the physiological limitations to digestive performance in this endothermic fish. Our data are discussed in light of temperature limiting the range of these highly migratory fish.

S5-2.3 GODWIN, J*; SLANE, MA; GEMMELL, NJ; North Carolina State University, University of Otago; *John_Godwin@ncsu.edu*

Neuroendocrine regulation of sexual plasticity in fishes

The study of sex differences has produced major insights into the organization of animal phenotypes and the regulatory mechanisms generating behavioral variation from similar genetic templates. Coral reef fishes display an extraordinary diversity of sexual expression including simultaneous hermaphroditism and functional, socially-controlled sex change. These systems provide powerful models for understanding gonadal and non-gonadal influences on behavioral and physiological variation. The Caribbean bluehead wrasse, *Thalassoma bifasciatum*, shows a fully male sexual behavior phenotype can develop even in the absence of gonads, key influences of the neuropeptide arginine vasotocin on sexual and aggressive behavior, and a controlling role for estrogen biosynthesis in regulating female-to-male sex change. Transduction of social cues into reproductive responses by a sex-changing female wrasse is not understood, but patterns in mammals and some neuroanatomical findings in fishes suggest the potential for direct vasotocinergic and estrogenic influences on sexual function and sex change mediated through kisspeptin effects on GnRH neurons. Advances in next generation sequencing and bioinformatics are also creating opportunities to extend genomic approaches to 'non-model' species. We are using these methods to examine global gene expression patterns in brain and gonads and contrast these patterns between the sexes, between alternate male reproductive phenotypes, and over the course of sex change in the bluehead wrasse. We are also extending these studies to other sex changing wrasse species to determine whether there is an evolutionarily-conserved 'core set' of transcriptional changes associated with sex change.

S11-2.1 GODWIN, J*; LUCKENBACH, JA; HOLLER, BL; DANIELS, HV; BORSKI, RJ; North Carolina State University, National Oceanic and Atmospheric Administration; *John_Godwin@ncsu.edu*

Environmental influences on sex determination in flatfishes

Flatfishes of several genera display unusual sex determination patterns where both genetic and environmental influences play important roles. Two well-studied species of *Paralichthys* flounders (southern flounder, *P. lethostigma*, and Japanese flounder, *P. olivaceus*) exhibit approximately 1:1 sex ratios when reared at intermediate temperatures, but male-skewed sex ratios when reared at either high or low temperatures. These rearing temperature effects extend to somatic development with male-biased temperatures also producing poorer growth. These growth differences may be adaptive, as female *Paralichthys* flounder grow larger than males. The mechanisms underlying temperature effects on growth involve conserved pathways in vertebrate sex determination. Sex determination can be manipulated with sex steroid hormones and female development is associated with elevated expression of gonadal aromatase and the transcription factor FoxL2 mRNA while male determination is associated with expression of Mullerian inhibiting substance mRNA. Other environmental influences can also influence sex determination. Rearing of southern flounder juveniles in light blue tanks increases the proportion of males relative to that observed with darker backgrounds and is associated with higher whole-body cortisol concentrations. Consistent with a role in mediating environmental influences on sex determination, exogenous cortisol masculinizes sex ratios in both Japanese and southern flounder. This linkage between the endocrine stress axis and conserved sex determination pathways may provide a mechanism for adaptive sex ratio modification in a spatially and temporally variable environment.

P3.176 GOESSLING, J.M.*; MENDONÇA, M.T.; WILSON, A.E.; Auburn Univ.; *goessling@auburn.edu*

A meta-analytic approach to comparing indices of stress in vertebrates: Does heterophil:lymphocyte ratio reveal similar degrees of stress as circulating corticosterone concentration?

While a suite of assays is available to biologists interested in measuring physiological stress, there is not a consensus as to the most reliable biomarker indicating an individual is experiencing an environmental stressor, especially on a chronic basis. Additionally there are many constraints (i.e., timing, effort, and cost) that impact which measure(s) of stress to use. We used meta-analysis to synthesize and compare available data associated with the response of two commonly used assays of physiological stress: heterophil:lymphocyte ratio (H/L) and circulating glucocorticoid concentration (GC). Because the studies where both measures were obtained centered in groups (i.e., birds and reptiles) where the primary GC is corticosterone (CORT), we only analyzed studies using those species which use CORT as the primary GC. We compared paired values of H/L and CORT from control (i.e., "unstressed") and treatment (i.e., "stressed") populations to test for differences between the ability of the two measures to reliably indicate stress. Our analysis included two taxonomic classes (birds and reptiles) and 14 species across a broad range of stress types (e.g., food restriction, temperature stress, increased density, etc). In general, H/L and CORT responses to stress were similar and no differences between the stress indices were observed as a result of class, species, captivity status, or stress treatment type. Thus, we support the use of either measure as a reliable biomarker of stress, although H/L may represent a more practical assay due to logistical considerations.

88.4 GOETZKE, H.H.*; FEDERLE, W.; University of Cambridge; *hhg24@cam.ac.uk*

Jumping without slipping: spiders need sticky feet for take-off

Many insects and spiders can perform rapid jumps from smooth plant surfaces. If jumping arthropods relied only on classic friction, they should slip on smooth surfaces except for very steep take-offs. They can only overcome this biomechanical problem by using surface adhesion while accelerating. Most adhesive structures only grip when pulled toward the body, but jumping with hind legs requires pushing, against the usual direction-dependence. We studied how jumping spiders (*Pseudeuophrys lanigera* and *Sitticus pubescens*) leap from smooth surfaces. Both species accelerated with their 3rd and 4th leg pairs. In *P. lanigera* the jump was mainly powered by the 3rd legs, and 4th legs touched the surface only at the start of the jump. In contrast, *S. pubescens* mainly used the 4th legs while the shorter 3rd legs detached early. The different position of the leg pairs in both spiders resulted in a different orientation of the tarsus during take-off. While 4th-leg tips pointed backward in both species and pushed, 3rd-leg foot tips in *P. lanigera* were oriented forward and pulled. This opposite tarsus orientation led to the use of different attachment structures. High-speed video microscopy recordings of tarsi during take-off revealed that "pulling" 3rd legs in *P. lanigera* made brief (~9 ms) adhesive contact with their claw tuft setae. In contrast, the distal claw tuft setae of "pushing" 4th legs were lifted off the ground, and contact was only made by some setae of the proximal pretarsus. In *S. pubescens* the 3rd legs were oriented laterally and adhesive contact was only rarely visible, while "pushing" 4th legs made clear adhesive contact with proximal claw tuft setae. Experimental ablation of adhesive structures caused accelerating spiders to slip, confirming that adhesion is essential for jumps from smooth substrates.

P3.180 GOLOFF, B.M.*; GONZALEZ-GOMEZ, P.; WINGFIELD, J.C.; HIEBERT, S.M.; Swarthmore College, Univ. California, Davis; IFICC, Univ. California, Davis; *shieber1@swarthmore.edu*

Stress response of wild-caught rufous hummingbirds

The stress responses of wild-caught rufous hummingbirds (*Selasphorus rufus*) were characterized by determining the corticosterone (CORT) concentration in cloacal fluid (CF) collected noninvasively over 60 min of restraint. On the basis of previous studies of sparrows and tits, we hypothesized that social dominance would be inversely correlated both with baseline CF CORT concentration and with the response of CF CORT to restraint. After capture, restrained birds were held in the hand and fed for 45 min, during which a separate CF sample was collected over each of three 15-min periods. For the final 15 min, birds were moved to a flight cage and a fourth CF sample was collected without handling the bird; all samples were analyzed by direct RIA. In contrast to our predictions, baseline CF CORT (first 15-min sample) of all three age-sex classes did not differ. Although the predicted relation between previously published dominance status in this species (adult females > first-year males > first-year females) and CORT levels was not supported, young males tended to develop higher CF CORT concentration in response to restraint than did females of any age. Of six behaviors measured in the flight cage, one was inversely correlated with CF CORT concentrations in response to restraint: birds with higher CF CORT were significantly more restricted spatially in their exploration of the flight cage. In contrast to a previous study of restraint stress in captive rufous hummingbirds, the wild-caught birds in our study showed significantly increased CF CORT within 30 min of capture and no significant change thereafter, suggesting that the stress response can be quantified in the field in a shorter period of time with this noninvasive method than was previously thought.

P1.44 GOMEZ, S.F.*; TAKAGI, K.K.; WRIGHT, W.G.; Chapman University; *gomez131@mail.chapman.edu*

Hermit-crab assay reveals heterogeneity in deterrence by actively secreted chemical defenses in Aplysia californica

Chemical defenses against predators are a hallmark of physically unprotected prey. For example, the shell-less marine gastropods have a range of such defenses, including chemicals that are actively released in response to predation. The sea hare, *Aplysia californica*, releases two kinds of secretions; ink and a viscous opaline. This raises a question of their relative functions. Ink is generally a more effective deterrent against a variety of predators, whereas opaline is weakly deterrent at best (Nusnbaum and Derby 2010). Research on lobsters, however, demonstrated a significantly stronger deterrence of opaline than that of ink (Aggio and Derby 2008). These latter results suggest a heterogenous function of ink and opaline across consumer species. To further explore the relative deterrency of *Aplysia* ink and opaline, the present study utilized a powerful feeding assay using the hermit crab, *Pagurus samuelis*. Similar to lobsters, we found that hermit crabs were deterred significantly more by opaline than by ink. As a step toward identifying the deterrent chemicals in opaline, we obtained water soluble and insoluble fractions (Charles Derby, GSU, Atlanta). Hermit crabs were deterred by the water-soluble fraction only. Further separation (Derby lab) into a mycosporine-like amino acids (MAAs) fraction and a MAA-free fraction revealed that **both** had the same deterrent activity. These results support the hypothesis that the relative deterrency of ink and opaline is specific to the consumer. Such heterogeneity suggests two adaptive hypotheses: 1) Ink has evolved to deter fish predators, while opaline has evolved to deter crustaceans, or 2) Deterrents synthesized de novo, may be more tightly tuned to sympatric, co-evolving predators.

121.3 GONZALES, C.M.*; GOSLINER, T.M.; Duke University, California Academy of Sciences; *cgonzales@calacademy.org*

Resolving the genus Philine: Description and phylogenetic placement of six previously undocumented species (Gastropoda: Opisthobranchia)

Species of the genus *Philine*, one of the most species-rich genera of opisthobranchs, are predatory sea slugs who use their ability to secrete poisonous toxins to avoid being eaten by other organisms. Furthermore, they have few natural enemies, allowing them to be found anywhere from intertidal mudflats to deep sea bottoms in oceans all around the globe. Recently, the California of Sciences embarked on the 2011 Hearst Expedition to the Philippines. During the expedition, many *Philine* specimens were collected that were catalogued as unidentified species. This project analyzed the genus *Philine*, using molecular and morphological approaches to determine the number of new species found on the expedition. Each specimen was illustrated and carefully dissected. Then, key anatomical features were documented further through the use of a compound microscopy imaging system and Scanning Electron Microscopy, to obtain resolution images. In addition, DNA sequencing was conducted on the CO1, H3, and 16S genes of our specimens. These data were then edited and evaluated to yield a current phylogenetic tree of the known species of *Philine* that includes these recent discoveries. After finding some undigested food in the gizzard of a *Philine* individual and genetically sequencing the CO1 gene of this matter, we were able to compare it with certain bivalves of the family Mytilidae and determine if this family could be part of the *Philine* diet. From these studies, we have determined that the collection examined from the Philippines contains six undescribed species. Each has a unique set of morphological characters that distinguish them from their closest relatives and are representatives of at least three different lineages, based on molecular data.

68.5 GONZALEZ-GOMEZ, PL*; MERRILL, L; VENEGAS, C; PANTOJA, J; VASQUEZ, RA; WINGFIELD, JC; Univ. of California Davis, Oklahoma State University, Universidad de Chile, Universidad de Chile; *plgonzalezgomez@ucdavis.edu*

Seasonal modulation of testosterone and stress response in a highly stable environment

Birds inhabiting seasonal environments typically have well defined breeding seasons, adjusting the production of sex hormones such as testosterone accordingly. Glucocorticoid hormones, meanwhile, mediate physiological and behavioral responses to changing environmental conditions, allowing animals to respond by improving the chances to survive. We examined the relationship of these hormones to breeding and molting condition in a wild bird in a highly stable environment with no environmental cues limiting the breeding or molting seasons. We collected baseline testosterone (T) and baseline and stress-induced corticosterone (CORT) in blood samples from *Zonotrichia capensis* during one year in the Atacama Desert, Chile. We expected low levels of T and CORT year-round. We did not find seasonality in breeding stages, and consequently T levels were affected by breeding condition, but not season. Molt did not follow any pattern or seasonality and it was negatively correlated with stress-induced levels of CORT. Molt and breeding stages overlapped at population and individual levels. Our results suggest that in absence of environmental challenges and cues, the adrenocortical stress response is regulated by physiological constraints such as feather production. Further research is needed to assess the role of social cues on T in breeding stage.

60.1 GORSICH, EE*; EZENWA, VO; JOLLES, AE; Oregon State University; *eringorsich@gmail.com*

Consequence of co-infection for survival: immunity and disease persistence

In natural populations, hosts are infected with many, simultaneous infections, presenting a strong selection pressure on the host immune system. We studied brucellosis and intestinal parasite co-infections in a free-ranging African buffalo population during an experimental worm-removal study. Survival analysis shows that worm removal decreases mortality in buffalo co-infected with brucellosis but does not affect mortality in brucellosis negative buffalo. One hypothesis to explain this pattern is that co-infection with intestinal parasites affects the hosts' immunological response to brucellosis infection, thereby altering disease progression or persistence. In this talk, I test this hypothesis by examining two proxies for immunity, lymphocyte proliferation and cytokine levels, throughout chronic brucellosis infection.

57.6 GRACCEVA, G*; HERDE, A; KOOLHAAS, JM; PALME, R; ECCARD, JA; GROOTHUIS, TGG; Institute of Behavioural Neurosciences, University of Groningen, University of Potsdam, University of Groningen, University of Veterinary Medicine, Vienna, University of Groningen; *g.gracceva@rug.nl*

Turning shy on winter's day: effects of season on personality and stress response in Microtus arvalis

Many animals of temperate environments have evolved physiological and behavioural adaptations to cope with the cyclic seasonal changes. This may result in changes in personality: suites of behavioural and physiological traits that vary consistently amongst individuals. Winter, typically the adverse season challenging survival, may require individuals to have shy/cautious personality whether during summer, energetically favorable to reproduction and survival, individuals may benefit from a bold/risk taking personality. In order to test the effects of seasonal changes in early life and in adulthood on behaviour, body mass and stress response, we have manipulated the photoperiod and quality of food in two experiments to simulate the conditions of winter and summer. We used *Microtus arvalis* as they have been shown to display personality based on behavioural consistency over time and context. In both experiments we tested the voles for activity, exploration and risk-taking behaviours. Summer-born voles allocated to winter conditions at weaning had lower body mass, a higher corticosterone elevation after stress and a less active, more cautious behavioural phenotype in adulthood compared to voles born in and allocated to summer conditions. Behavioural consistency over time and context was unaffected. By contrast, adult females only showed plasticity in corticosterone-induced stress levels, which were higher in the animals placed in the winter condition than to those staying in summer conditions. These results suggest a sensitive period for season related plasticity of personality in which juveniles shift over the bold-shy axis as expected.

117.3 GRACE, J.K.*; ANDERSON, D.J.; Wake Forest Univ.; *gracjk7@wfu.edu*

Personality, stress, and fitness in a long-lived seabird

The relationship between the stress response and personality has recently become controversial. General "rules" of personality developed in laboratories appear to be less applicable in the wild or across species. Here, we test the hypothesis that shy individuals mount a greater corticosterone (CORT) stress response than bold individuals in free-living Nazca boobies. Incubating adults were tested in the field for personality, and CORT stress response. We compared structural equation models of personality and stress response using corrected Akaike Information Criterion values. Nazca boobies have a domain-specific personality syndrome (aggression, agitation, and anxiety), including reaction to a novel object, human intruder, and simulated conspecific (mirror), which is repeatable across years. Plasticity between tests was not correlated with any personality domain. Maximum CORT and the area under the CORT curve during a capture-restraint test were repeatable across years, but not baseline CORT. Personality had slight predictive power on the CORT stress response, but no trait was highly correlated with CORT concentration. This supports current research suggesting that links between personality and stress are more complicated in field than lab settings. In many cases, personality can affect mate choice and fitness. In Nazcas, aggressiveness of males and females were generally correlated within pair. However, assortative and dissasortative mating had no impact on fledgling production, within a year. The only personality trait associated with fledgling production was male aggression toward an intimidating novel object. Because this trait was repeatable across years ($r = 0.31$), this relationship is probably not due to changing behavior based on chick viability, but rather is a fitness consequence of a personality trait.

121.6 GRAJALES, A*; RODRIGUEZ, E; American Museum of Natural History; *agrajales@amnh.org*

Population genetics of the symbiotic sea anemone Aiptasia sp.

Sea anemones (Cnidaria: Anthozoa: Actiniaria) belonging to the genus *Aiptasia* have been used as a model organism in an increasing number of studies detailing mutualism of dinoflagellate-cnidarian symbiosis, bleaching mechanisms, and invertebrate reproduction. Despite its use in several disciplines of biology, many basic evolutionary and ecological aspects of the genus are still unknown. The latest taxonomic revision revealed 16 valid species distributed on tropical and subtropical shallow marine environments worldwide. However, current descriptions of most species are incomplete by modern standards and phylogenetic analyses are nonexistent. Preliminary studies including morphological analysis and molecular phylogenetics have revealed that this model organism is actually a single cosmopolitan, presumably invasive species. The genetic structure of the species was explored using 16 polymorphic microsatellite loci specifically developed for this project from a pyrosequencing EST library. More than 400 individuals within the genus *Aiptasia* have been collected through an extensive sampling effort that encompasses the entire distribution of the 16 currently described species. Specifically we aimed to discriminate distinct population across the globe, and to test different hypothesis that help explain its extreme widespread distribution.

P2.192 GRASSO, F W*; EVANS, M ; BASIL, J A; PRESCOTT, T J; BCR Lab, Brooklyn College CUNY, USA, ATLAS Lab, Uni Sheffield, UK, LIBE Lab, Brooklyn College CUNY, USA; *fwgrasso@gmail.com*

Toward a fusion model of feature and spatial tactile memory in the Australian crayfish Cherax destructor

Australian crayfish Cherax destructor (ACCD) use their haptic sense to navigate in enclosed spaces, use their mobile antennae to explore novel objects and in some manner remember the configuration of the surfaces in their environment. We report on parallel biological and robotic simulation studies intended to advance our understanding of the memory systems underlying this ability. Two streams of information useful for spatial mapping in ACCD, tactile input from the antennae and proprioceptive information from the legs were modeled in the control architecture of our robot models this system. In previous robot studies we demonstrated the plausibility of an interrupt-based cross-correlation (IBCC) mechanism using sensors mechanically fixed to the robot to account for some of the ACCD's spatial memory abilities. We extended those results using a pair of movable mechanical touch-sensors to inform both the IBCC and a second memory module to capture surface exploration ACCD behavior. Numerical correlation between the current sensor sweeps or 'antennation' sensation patterns (ASP) and stored previously experienced ASPs permit the classification of locations as familiar or novel. In the CTBR control system the IBCC and the ASP memory systems share information to enhance each other's performance. These in turn inform steering decisions in the CTBR during exploration. The combination of the ASP and IBCC memory systems is a novel computational approach that is constrained by the MPC connectivity. We report on animal and robot studies aimed at determining whether the behavior of the CTBR endowed with these interacting memory systems reproduces ACCD exploration behavior.

97.6 GRAVISH, N*; GOODISMAN, M.A.D.; GOLDMAN, D.I.; Georgia Institute of Technology, School of Physics, Georgia Institute of Technology, School of Biology; *nick.gravish@gmail.com*

Stabilizing falls in confined environments

Many organisms live and move in underground environments which they have excavated. Such environments may present challenges for locomotion, in part because organisms move within confined and crowded tunnels and chambers. We hypothesize that the ability to engineer underground habitats provides opportunities to facilitate movement. We studied subterranean locomotion of fire ants (*Solenopsis invicta*, body length $BL = 0.35 \pm 0.05$), which build networks of underground tunnels. In a laboratory experiment we challenged fire ants to climb through 8 cm long glass tunnels ($D = 0.1 – 0.9$ cm) that separated a nest from an open arena with food and water. During ascending and descending climbs we induced falls by a rapid, short, translation of the tunnels downward. We monitored induced falls over 24 hours in groups from five separate colonies. The confinement ratio ($BL/D = \alpha$) significantly influenced the ability of ants to rapidly recover from perturbations. The probability to arrest a fall (p_{arrest}) within the observed tunnel length fit a logistic equation with $p_{arrest} \approx 0$ for small α, $p_{arrest} \approx 1$ for large α, and $p_{arrest} = 0.5$ at $\alpha = 0.73$, comparable to natural tunnel diameter. The distance fallen prior to arrest (d_{arrest}) decreased with increasing α. At small α, ants fell large distances and rarely arrested. At large α, falls were arrested through the use of rapid jamming of limbs, body and antennae against the tunnel walls, arresting in as low 30 ms. We measured the upper bounds of d_{arrest} and found that the maximum arrest distance was consistent with scaling predicted from a model of falling in tunnels. Our data indicates that fire ants moving through natural tunnels can employ antennae, limbs, and body to rapidly stabilize falls.

P1.106 GREBE, E.M.*; GIENGER, C.M.; Austin Peay State University; *egrebe@my.apsu.edu*

Resting Metabolism of the Eastern Box Turtle, Terrapene carolina

Measuring the Standard Metabolic Rates (SMR) of ectotherms is key to understanding their thermal physiology and understanding the potential impacts of an altered global climate. We measured SMR of box turtles from a population in Tennessee (USA) to determine how variation in body size and temperature influence patterns of resting energy use. Our results indicate that across both juvenile and adult body sizes, individuals tested at 30C have approximately double the SMR as individuals tested at 20C. There is also no indication that a difference exists in male versus female SMR at the two temperatures. This information will also aid in assessing potential effects of global climate change on alterations of energy budgets of free-ranging box turtles.

P1.86 GREEN, P.A.*; CROFTS, S.; SIGWART, J.D.; Univ. Massachusetts, Amherst, Univ. Washington, Seattle, Queen's Univ. Belfast, Marine Station; *pagreen@bio.umass.edu*

Functional morphology in chitons (Polyplacophora): influences of environment and ocean acidification

Polyplacophoran molluscs show low morphological diversity compared to other marine invertebrates, yet chitons are important algal foragers that occupy distinct ecological niches. We investigated potential functional correlates of niche separation in three species of co-occurring mopallid chitons that have total ranges across differing environments (*Mopalia muscosa*, *Mopalia lignosa*, *Katharina tunicata*). We measured force required to fracture the protective valves of each species, and found significant variation between species. *Katharina tunicata*, considered to have "reduced" valves, is more fracture resistant than the two *Mopalia* species (mean *K. tunicata* = 31.5 N; mean *M. muscosa* = 22.6 N; mean *M. lignosa* = 13.9 N; F(2,30)=27.0, p<<0.01). Terminal valves in *Mopalia* spp. are significantly more fracture resistant than intermediate valves (F(1,370)=164.0, p<0.01), while all valves in *K. tunicata* appear to be functionally equivalent. To see if future pCO_2 changes predicted under ocean acidification (OA) will affect species differently, we measured the change in force to fracture valves after 10 days of exposure to raised pCO_2 (Control = 8.0pH [374.52+/-110.9 pCO_2], Raised = 7.5pH [1507.77+/-163.10 pCO_2). Although previous experimental OA work found significant impacts on mollusc shells over similar timescales, we saw no consistent reduction in total fracture resistance related to treatment in acidified water. Our data demonstrate functional implications of diversity in chiton valve morphologies, and show that physical changes in local topology and wave exposure may have stronger impacts on chitons than changes in ocean chemistry under future climate change.

P2.222A GREEN, E.*; MEDINA, M.; University of California, Merced; *ewindmeyer@gmail.com*

A high-throughput protocol to genotype Symbiodinium using ITS2, a ribosomal DNA marker, for Montastraea faveolata

Corals form one of the most complex and diverse ecosystems in the world. Their survival depends on an obligate endosymbiont to provide it with essential energy requirements, especially during stress events. Advancements in molecular genetic tools unveil increased species diversity in the genus Symbiodinium. A better understanding of the host-selection process of Symbiodinium and their general ecology is needed, but detecting clade diversity has many challenges. Previous gene targets using mitochondrial gene markers, such as cytochrome oxidase B and chloroplast gene markers such as cp23, have been less effective at distinguishing Symbiodinium species. We propose to optimize a high-throughput protocol to genotype Symbiodinium for internal transcribed spacer 2 (ITS2) to identify cryptic Symbiondinium genera. ITS2 is an ideal universal marker as it has successfully revealed sub-clade diversity in a suite of micro-organisms and has conserved base pair changes able to reveal cryptic species. We will genotype lineages of cultured Symbiodinium cells known to exist in Montastraea faveolata, an endangered Caribbean coral species. The protocol will be optimized on cultured cells and verified on up to 200 previously collected samples of Montastraea faveolata from variable health conditions and depth gradients. An effective universal molecular marker that reveals divergent lineages will enhance our understanding of the coral-dinoflagellate relationship and ability to protect endangered coral ecosystems throughout the world.

49.2 GREENE, MJ; University of Colorado Denver; *michael.greene@ucdenver.edu*

The organization of "wars" by pavement ants

The pavement ant (*Tetramorium caespitum*) is a tramp species commonly associated with human habitation in northern temperate regions. The species is well known for its ant "wars" in which thousands of workers from two colonies fight in a large group. Fighting appears to be ritualized; ants engage in fights by grabbing another ant's mandibles with its own and pairs undergo what can be described as a "push-of-war" while other ants recruit more workers. Few ants die during the battle. What are the rules that influence organization of these "wars"? I report that workers discriminate nestmates and non-nestmates by detecting cues coded in the mixture of cuticular hydrocarbons on the cuticle of ants they antennate. Nestmate recognition cues are coded in the relative abundance of methyl-alkane and alkene hydrocarbons. However, detection of cues on the cuticle of non-nestmate ants is not sufficient to stimulate fighting. Patterns of recent interactions with nestmate ants and the size of the group of ants fighting influence an ant's decision to fight. Workers respond to interactions with heterospecific ants using a different set of rules that do not depend on group size.

75.6 GREENLEE, K. J.*; SOCHA, J. J.; EUBANKS, H. B.; LEE, W.-K.; KIRKTON, S. D.; North Dakota State University, Virginia Tech, Jackson State University, Argonne National Laboratory, Union College; *kendra.greenlee@ndsu.edu*

Developmental changes in tracheal system structure and function in the caterpillar, Manduca sexta

Abdominal pumping in caterpillars has only been documented during molting. Using synchrotron x-ray imaging and high-speed flow-through respirometry, we show that *Manduca sexta* caterpillars also contract their bodies in response to hypoxia, which results in significant compression of the tracheal system. Tracheal compression induced by abdominal contraction appears to be the driving force for external gas exchange, as evidenced by the high correlation between CO_2 emission peaks and external body movements. Abdominal pumping was only observed in larger, older caterpillars (> 0.2 g body mass), suggesting that the hypoxia response varies with ontogeny. In caterpillars that exhibited abdominal pumping, neither the frequency of compression nor the percent change in tracheal diameter varied with body mass, suggesting that there is a threshold for this behavior. As insects increased in size, the fraction of tracheal system structures in the head increased, but not as much as would be predicted based on geometric scaling. The fraction of the body occupied by tracheae in the prothorax and last abdominal segment remain constant throughout ontogeny. Furthermore, the diameters of the major tracheae either did not vary with body mass or did not increase as much as expected, suggesting that trade-offs between non-respiratory structures result in smaller tracheae than would be expected based on geometric scaling.

101.1 GREETER, JSM*; HEDRICK, TL; Univ. of North Carolina at Chapel Hill; *jgreeter@live.unc.edu*

How the hawkmoth Manduca sexta moves left and right

Understanding flight control strategies in insects is essential for drawing a complete picture of the evolutionary and biomechanical underpinnings of flapping flight. Many flying animals can produce lateral "sideslip" maneuvers, which we investigate here in the moth *Manduca sexta*. We elicit maneuvers using phototaxis, whereby moths follow an oscillating low-intensity light source in a dark flight chamber. We measure angular and translational kinematics of the moth body and wings in flight with high-speed 3D videography. Our data show that sideslipping moths roll to redirect their body-weight lift vector, a reorientation which is sufficient to produce the lateral accelerations we observe. Using wingtip position, rather than body position, to calculate roll angle produces the strongest relationship between roll and lateral acceleration. Thus moths can, to some extent, actuate their wings independently of body roll. Still, larger lateral accelerations require whole-body roll in addition to wing stroke changes. Among the many possible ways to create roll acceleration, moths produce left-right wing asymmetries in both sweep amplitude and long-axis rotation angle. Conceptually, asymmetries in both quantities create yaw and roll torques. Preliminary data support a scenario in which a moth producing a roll to the right during upstroke alters its long-axis rotation angle so as to reduce the angle of attack of its left wing relative to that of its right. This angle of attack asymmetry also creates a yaw-left torque. The moth counters this yaw torque by increasing the relative sweep amplitude of its left wing during that upstroke and/or decreasing the relative sweep amplitude of its left wing during the subsequent downstroke.

P3.99 GRIECO, TM*; CAM, SB; HLUSKO, LJ; University of California, Berkeley; *grieco@berkeley.edu*

Variation and integration in amphibian dentitions: insights about sex and size from Silurana (Xenopus) tropicalis

The phenotypic variation expressed in populations is filtered through developmental and physiological processes occurring during individual lifetimes. Dental phenotypes allow us to study the relative influences of these processes because the functional constraints of the oral apparatus are superimposed on the development of the cranium. Amphibians, with their largely homodont, marginal dentitions spanning multiple jaw bones, provide a good model in which to study these various influences. Previous work in salamanders highlights size and/or shape differences in premaxillary teeth compared to maxillary teeth, and that this effect is sexually dimorphic (displayed in males only), suggesting that dental variation could be constrained by tooth bearing bones or could be differentially hormonally controlled. To examine this further, we turned to the sexually size dimorphic frog *Silurana (Xenopus) tropicalis* to look for evidence of these mechanisms in its dentition. Cranial linear measurement data suggest that overall head proportions are constrained to 1:1, and body length is less strongly correlated with the size of the jaw and dentition. Sexual dimorphism is apparent in all traits, but larger individuals/females appear to be more variable in maxillary length than smaller individuals/males. The consequences of this relationship for the dentition are further evaluated by tooth count data. We discuss the implications of these craniodental data for morphological integration in and evolvability of amphibian dentitions.

135.5 GRIECO, TM; University of California, Berkeley; *grieco@berkeley.edu*

Silurana (Xenopus) tropicalis as a model system for the evolution of odontogenesis

The highly conserved developmental mechanisms of odontogenesis illuminate the ways in which vertebrates have created highly adaptive and morphologically variable phenotypes from similar genetic underpinnings. The frog model *Silurana (Xenopus) tropicalis*, with its expanding genetic and genomic potential along with the large amount of comparative data derived from *Xenopus laevis*, provides a system to test hypotheses of tooth developmental mechanism function and evolution. I discuss how *S. tropicalis* lends itself to comparison across vertebrates when used with our extensive knowledge of mouse and fish tooth development, and how comparison between frogs allows us to understand what happens to the conserved mechanisms of odontogenesis when faced with a life history containing a prolonged, specialized larval stage. I use data from histological sections and gene expression during first generation tooth initiation to describe odontogenesis in tadpoles. First-generation teeth appear laterally before they appear medially, but alternation as reported by other researchers has been difficult to visualize in this study population. I consider evidence from these time series as it bears on hypotheses of dental patterning and initiation across vertebrates and within animals with late-developing dentitions.

P3.202 GRIFFIS, N.L.*; WILLIAMS, J.B.; Southern Illinois Univ.; *jasowil@siue.edu*

Cryoprotectant production has little effect on bound water content in the goldenrod gall fly, Eurosta solidaginis

Most freeze tolerant insects enhance survival to low temperature by producing high concentrations of cryoprotectants. These solutes enhance survival by reducing cellular osmotic dehydration during freezing. However, recent data suggest that cryoprotectants may also enhance freeze tolerance by increasing intracellular bound water content. Properties of bound water differ from bulk water in that its close association with subcellular structures prevents it from freezing at biologically relevant temperatures. To determine if cryoprotectant production is correlated with bound water content and increased freeze tolerance, we measured seasonal changes in all three parameters in *Eurosta solidaginis*, the goldenrod gall fly. As expected, whole body glycerol content seasonally increased as concentrations nearly doubled from larvae collected in October (228±30mM) to those measured in December (437±38mM). Similarly, freeze tolerance dramatically increased as only 25% of October collected larvae responded to tactile stimulation 48h after being removed from a diurnal exposure to -30°C while 95% of larvae responded after a similar stress in December. In contrast, bound water content did not change regardless of collection date (averaging 23.7±1.6%) and appeared unrelated to cryoprotectant levels. In a separate experiment, a January collected set of animals subjected to room temperature for four days prior to analysis. Interestingly, the experimental group had a trend of increased bound water content (28.6±2.0%) compared to all other groups that were analyzed immediately after collection. This may have been due to temperature induced conversion of sorbitol into glycogen, however glycogen content was the same or lower in these animals (0.309±0.08mg/mg dry mass) compared to groups analyzed immediately after collection (0.60 ± 0.12mg/mg dry mass).

70.3 GROOM, DJE*; TOLEDO, MCB; WELCH, KC; University of Toronto, Universidade de Taubate; *derrick.groom@mail.utoronto.ca*

The effect of elevation on hummingbird flight energetics: metabolic cost of flight in a changing environment

Global climate change is projected to impact species diversity and range. In particular, many species will move to higher elevations in an effort to track their environmental niche. However, for all organisms, moving upwards poses its own set of challenges. This is strikingly problematic for flying animals, as flight becomes difficult at elevation due to changes in air density and oxygen availability. Previous studies have demonstrated that highland hummingbirds are generally larger and have larger wings relative to body size compared to lowlanders, which allows them to fly at lower air densities and temperatures. We seek to elucidate the metabolic cost of flight for hummingbirds at different elevations, and how aerobic capacity changes with elevation and size. We hypothesize that elevation, and consequently low oxygen availability, exerts a metabolic constraint on hovering flight by limiting maximal aerobic output. As a result, species found at higher elevations will have a comparable hovering metabolic rate to similarly sized lowlanders. However, the metabolic rate of highlanders will rise more rapidly under increasing power output challenges than lowland species. This would indicate that hummingbirds have a metabolic limitation to the elevation they can inhabit. Hummingbirds were captured at three sites (0m, 1000m, and 1800m asl) in the Atlantic Forest in the state of Sao Paulo, Brazil by mist netting. Metabolic rate was assessed during normal hovering flight and during sustained weight lifting. Weight lifting is used to increase the power requirements of flight, independent of oxygen availability. Information regarding metabolic capacity will allow us to understand the implications of elevation on energetic performance.

S5-1.4 GROOTHUIS, T.G.G.*; GOERLICH, V.C.; DIJKSTRA, C.; University of Groningen, NL, University of Bielefeld D; *a.g.g.groothuis@rug.nl*

The role of maternal hormones in avian sex ratio manipulation

Avian species can manipulate the sex ratio of their offspring before these offspring hatch. In birds, mothers can not only affect the secondary sex ratio, but also the primary sex ratio of their offspring as the mother is the heterogametic sex. Avian sex ratios vary in relation to environmental or maternal condition. The production of maternal steroid hormones is sensitive to those conditions, and the hormones are also involved in reproduction and deposited in the egg before meiosis. Therefore, we explored to what extend and how maternal steroid hormones may be involved in affecting clutch primary or secondary sex ratio. We showed in the rock pigeon, as well as in a related wild pigeon species, the wood pigeon, both producing clutches of two eggs, a clear case of seasonal change in sex ratio in first eggs. In the homing pigeon, domesticated from the rock pigeon, testosterone treatment induced a clear male bias in first eggs, and corticosterone a female bias and we argue that this is in line with sex allocation theory. We next analysed treatment effects on follicle formation, yolk mass and yolk hormones, the latter both pre- and post-ovulatory, in order to test a diversity of potential mechanisms related to both primary and secondary sex ratio manipulation. In addition, we review the existing avian literature on correlative and experimental evidence for effects of maternal steroids on the primary and secondary sex ratio. We conclude that hormone levels in the mother may affect several pre-ovulatory mechanisms affecting offspring sex ratio, whereas egg hormones are probably involved in secondary sex ratio manipulation only.

P2.204 GROSS, V.*; MILLER, W.R.; HOCHBERG, R.; University of Masssachusetts Lowell, Baker University, University of Massachusetts Lowell; *Vladimir_Gross@student.uml.edu*

A New Genus of Marine Tardigrada (Arthrotardigrada) from the Southeastern United States

A new genus of Tardigrada (Heterotardigrada: Arthrotardigrada) is described from the southeastern United States based on unique digit morphology. This discovery was made from a population of tardigrades collected 7 km east of Hutchinson Island near Fort Pierce, Florida at a depth of approximately 10 m. The new genus is characterized by its unique suction pad/claw morphology. On legs IV, the two inner digits each have both a proximal suction pad and a distal claw with a single accessory point, while the two external digits have only suction pads. On legs I-III the two inner digits have both proximal suction pads and distal claws with an accessory point. The anterior external digit also has both a proximal suction pad and a distal claw, but the claw is smooth without an accessory point. The posterior external digit is identical to that of leg IV with only an adhesive pad. This morphology represents an intermediate state between clawless, suction pad-bearing tardigrades and those with claws but lacking suction pads. A related genus, *Paradoxipus orzeliscoides* Kristensen & Higgens, 1984, was discovered from the same locality, but differs from the one presented here by having both suction pads and claws on every digit of every foot. The nearly cosmopolitan distribution of *Orzeliscus* (a clawless, suction pad-bearing species) and recent DNA evidence suggest that the presence of suction pads and claws may be plesiomorphic conditions, but the combination of the two on the same foot is relatively derived.

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Rethinking theoretical gravity hypothesis of sexual size dimorphism and its effects on locomotor energetics

The gravity hypothesis (GH) predicts that sexual size dimorphism in spiders is mainly due to selection pressures that would favor smaller males because they possess higher climbing speeds to access the female. Theoretical and empirical evidence would show that the velocity of climb is not always related to size. Here, we propose an alternative hypothesis and expandable to all types of locomotion: energy expenditure hypothesis (EEH), where the velocity of climb is replaced by costs of transport as the main trait under selection pressure, which predicts that spiders with horizontal locomotion, also presented sexual dimorphism in size, associated with lower costs of transport in smaller males. If so, the EEH could replace the GH and explain the smaller size of males in all invertebrates which have sexual selection by scramble competition in their reproductive strategy.

55.4 GROVE, T.J.*; WHITTINGTON, A.C.; NIENOW, T.E.; WHITTINGTON, C.L.; FORT, T.J.; Valdosta State University, Florida State University, University of South Florida;
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From Muscle to Molecule: Function and Structure of the Calcium-Binding Protein Calsequestrin from a Eurythermal Teleost

Calsequestrins (CSQ) are Ca^{2+}-binding proteins in the sarcoplasmic reticulum (SR) of striated muscles that sequester calcium during muscle relaxation. CSQ undergoes conformational changes from a random coil at low levels of Ca^{2+} to highly ordered crystalline aggregates at high Ca^{2+} levels, but the underlying mechanism by which this structurally dynamic protein remains functional in eurythermal organisms is not known. The intertidal mummichog, *Fundulus heteroclitus*, provides an interesting study system for investigating thermal adaptation. Recorded twitch times of glycolytic skeletal muscle from *F. heteroclitus* decrease, while force increases, with increasing temperature (5-25ºC). Preliminary data indicate that force production decreases in the presence of the CSQ inhibitor, trifluoperazine, and this effect is more pronounced at higher temperatures. Recombinant CSQ from *F. heteroclitus* glycolytic muscle (FCSQ) is relatively insensitive to temperature changes in the physiological range (10-25ºC). At 35ºC, Ca^{2+}-binding ability of FCSQ decreases, correlating with a decrease in force production at this higher experimental temperature. Structural modeling of FCSQ reveals a highly conserved salt-bridge network critical for high-capacity Ca^{2+}-binding. The benefits of this work are two-fold: (1) we will be able to deliberately alter the physicochemical properties of FCSQ and measure the functional response to environmental perturbation, and (2) we will correlate the resulting *in vitro* functional changes with muscle function and whole organism performance. Supported by National Science Foundation grant IOS-0817805.

100.13 GRUBICH, JR*; HUSKEY, S; CROFTS, S; ORTI, G; PORTO, J; American University in Cairo, Western Kentucky University, George Washington University, INPA;
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Reconstructing the Bite of the Giant Miocene Piranha, Megapiranha paranensis

The evolution of gnathostome jaws, along with bite forces that can capture and masticate active prey is a key functional innovation underlying the diversification of early Devonian vertebrates. As a result of their fundamental importance to promoting the success of vertebrates, the jaws and bite forces of extinct species have been repeatedly investigated through computer modeling, bite simulations, and anatomical comparisons to living relatives. Here we present the first ever *in-vivo* bite forces recorded from wild piranhas (Serrasalmidae) and model their bite using 2-D lever and linkage mechanics. Integrating this empirical data with allometry, bite simulations, and 3-D finite element analyses (FEA), we are able to reconstruct the biting abilities and infer the feeding ecology of the extinct giant Miocene piranha, *Megapiranha paranensis*. An anterior bite force of 320 N from the black piranha, *Serrasalmus rhombeus*, is the strongest bite force recorded for any bony fish to date. Results indicate the extinct *M. paranensis'* bite force ranged from 1240 - 4749 N and reveal its novel dentition was capable of withstanding high bite stresses and crushing vertebrate bone. Comparisons of body size-scaled bite forces to other apex predators reveal that both *S. rhombeus* and *M. paranensis* have among the most powerful bites estimated in carnivorous fishes. Our results provide the first functional insights into the extraordinary biting abilities of piranha jaws as well as provide strong biomechanical inference that *M. paranensis* was a formidable osteophagous predator of the Miocene.

P1.208 GUARDADO , D*; BENTLEY, G.E; PERFITO, N; University of California, Berkeley ; *daisy.guard@gmail.com*

Melatonin and the reproductive axis of European starlings

Melatonin is secreted by the pineal gland at night and thus, for many organisms it provides a measure of day length throughout the year. Day length information is critical for seasonal breeders to time changes in their reproductive physiology that are costly in terms of time and energy. The melatonin signal in seasonally breeding mammals is essential for appropriate timing of changes in gonadal size and activity. Such a dependence upon the melatonin signal for reproductive timing is not as clearly defined in birds. Despite a handful of studies to the contrary, the current dogma is that melatonin does not influence the reproductive axis in birds. In our study, we investigated the effects of exogenous melatonin on the reproductive axis of European starlings *(Sturnus vulgaris)* housed in a semi-natural environment. Male and female adult starlings were given melatonin or control silastic implants during naturally increasing long days (March) and a second group of each sex was given implants or controls after the breeding season had ended but still during long days (August). Melatonin treatment did not affect testis volume or follicle development during either time period. Melatonin implants increased hypothalamic expression of GnIH only in photorefractory starlings. In addition, hypothalamic expression of GnRH, a stimulatory reproductive hormone, was not affected by treatment in either group, although it did change according to season. This study aims to understand how starlings under natural breeding conditions respond to exogenous melatonin and how this response relates to previous knowledge from laboratory studies.

P3.163 GUDENUS, V.*; LIBBY, T.; HALDANE, D.W.; FULL, R.J.; UAS Technikum-Wien, Univ. of California, Berkeley; *viktor.gudenus@chello.at*

Designing bio-inspired tailed robots to turn using bendable backs.

Typically, rapid-running, agile, legged robots have possessed rigid, single-segment bodies. Slower legged robots have employed modular bodies, but these segments have rarely been integrated into dynamic maneuvers. Recent efforts mimicking quadrupeds, such as the cheetah, have begun to include back bending in the sagittal plane. Our discoveries of lizards using tail motion in mid-air maneuvers that include righting and leaping have demonstrated the advantage of using the inertia of movable segments. Our recent research on the contribution of back and tail movement in the horizontal plane during the rapid escape maneuvers of lizards (*Agama agama*) has revealed the importance of body shape change, as well as the necessity of synchronization with leg-ground impulses. To this end, we began construction of a two-segment torso for a legged robot with an attached tail. We took advantage of an effective manufacturing process termed Smart Composite Microstructures (SCM) to fabricate the novel body that could bend laterally. The robot, with 6 degrees of freedom and two motors, coordinates tail motion, body bending and rear limb movements while allowing separate control of front limbs. When front and hind limbs are in phase, this arrangement allows the robot to turn rapidly by bending and pivoting about the rear feet. Reversing phase enables forward running. We contend that the coordination of body bending, tail curling and leg impulse forces will enhance the rate of rotation of turning in the horizontal plane and increase the controllability of terrestrial maneuvers in legged robots.

P2.200 GUERRA, V. I.*; COHEN, C. S.; Romberg Tiburon Center, Department of Biology, San Francisco State University ; *vguerracanedo@gmail.com*

Population genetic diversity of the cryptogenic invasive Ciona intestinalis sp A on the Pacific coast of America

The invasive basal chordate *Ciona intestinalis* sp. A has invaded coast regions around the world, including the temperate coasts of the Pacific side of America. Little is known about the genetic diversity of coastal invasive species of central South America, and few marine non-native species have been recorded to date, potentially due to lack of study or for other reasons including differences in amount of boat traffic. We characterize the population genetic structure of the globally invasive *Ciona intestinalis* sp A in two temperate coastal regions of the Pacific coast of America that differ in boat traffic (transport vector) and available suitable environment for establishment. We sampled 8 sites (n=172 individuals) in 2 regions north and south of the equator, including 4 sites in United States of America and 4 sites in Peru. Phylogenetic analyses using the mitochondrial cytochrome c oxidase I (COI) genes confirmed that the sub species of *Ciona intestinalis* found in the sampled sites in Peru were of Type A and included 19 haplotypes with haplotype diversity per population ranging from 0.714 to 0.937. Genetic differentiation was observed between, but not within, regions. Within region similarities may reflect common sourcing or frequent transport among sites. Additional loci may provide further resolution among sites. We are now using a highly polymorphic nuclear gene involved in a pre-zygotic reproductive mechanism to address questions within and between regions.

26.4 GUNDERSON, A.R.; Duke University; *arg12@duke.edu*

Testing common models of temperature-dependent activity: implications for predicting responses to climate change.

Understanding behavioral responses to thermal variation is crucial for our attempts to predict the biological impacts of climate change. Several models have been proposed to explain the temperature-dependence of activity, usually with reference to the preferred temperature range (i.e., the temperatures organisms assume in a thermal gradient). I evaluated the agreement between observed activity of the Puerto Rican lizard Anolis cristatellus under natural conditions and three models of temperature-dependent activity with varying levels of thermal constraint. Activity rates and body temperatures of 299 A. cristatellus were measured in two habitat types: wet and dry forest. The data were then transformed according to the assumptions of the following behavioral models: Model 1- organisms are only active when body temperatures are within the preferred temperature range, Model 2- organisms are only active if body temperatures are below the upper bound of the preferred temperature range, and Model 3- body temperature does not affect activity within the activity window (i.e., if you are active, body temperature does not matter). I found that Model 1 provided a poor representation of A. cristatellus activity. However, the agreement between Models 2 & 3 and A. cristatellus activity depended on habitat type. Both models provided good representations of activity patterns in the wet forest but not in the dry forest. Thus, even among populations of a single species occupying the relatively small island of Puerto Rico, models did not perform equally well. These results illustrate the need for more fine-scale studies to inform the development of models that accurately reflect behavioral patterns seen in nature. More generally, our knowledge of the behavioral consequences of thermal variation is extremely limited, a problem that must be tackled in order to better understand the consequences of rising global temperatures.

6.3 GUTMANN, A.K.*; LEE, D.V.; MCGOWAN, C.P.; University of Idaho, University of Nevada, Las Vegas; *agutmann@uidaho.edu*

Collision dynamics of bipedal hopping

Kangaroos and wallabies are able to maintain a nearly constant metabolic rate across a wide range of speeds when hopping bipedally. The anatomy of large, bipedal hoppers undoubtedly effects locomotion energetics – 30-70% of the mechanical energy required to hop is stored and returned by the long, compliant tendons of the ankle extensors. However, we wanted to determine the effects of collision dynamics. We compared the collision dynamics of two bipedal hoppers, tammar wallabies and desert kangaroo rats, and two quadrupedal trotters, domestic dogs and goats, across a range of speeds. We calculated collision angle (the angle between the ground reaction force vector and C.o.M. velocity vector) and collision fraction (the actual collision angle/maximum collision angle possible for a particular set of ground reaction force and velocity vectors) for all animals. Collision angle was substantially larger for wallabies than kangaroo rats(~6°) or dogs and goats (~9 °) across all speeds. A large collision angle may allow wallabies to take advantage of the potential for elastic strain energy storage and return in their ankle extensor tendons and, thus, allow them to bounce more economically than other species. Kangaroo rats may not use as large a collision angle as wallabies because their shorter, stiffer tendons are less suitable for elastic energy storage and return. Collision fraction was close to one (0.97) and remained constant for bipedal hoppers across all speeds but decreased with increasing speed for quadrupedal trotters. This suggests that bipedal hoppers are able to adjust collision geometry such that they can store and return elastic strain energy in a nearly ideal manner across a broad range of speeds, whereas quadrupedal trotters cannot store and return elastic strain energy as effectively at higher speeds.

P2.115 HACKMANN, A*; FEDERLE, W; University of Cambridge; *ah658@cam.ac.uk*

Functional morphology and efficiency of the antenna cleaner in Camponotus rufifemur ants

In the course of evolution insects have developed a variety of strategies to reduce surface contamination, which can inhibit physiological functions. For example, many insects regularly clean their antennae with specialized cleaning devices on their front legs. In *Camponotus rufifemur* ants, the antenna cleaner consists of a notch on the basitarsus facing a spur at the end of the tibia. Both components each bear a 'comb' and a 'brush'. Both combs consist of one row of stiff, regularly spaced cuticular outgrowths, whereas the brush structures bear multiple rows of flexible setae. Video recordings of the ants' cleaning behaviour showed that the spur is used to keep the antenna in contact with the tarsal notch. When the tibial spur was removed, insects were unable to clean the antenna. In order to investigate the detailed roles of spur and notch during antenna cleaning, we simulated cleaning movements using a motor positioning stage by stroking cleaning structures over antennae that had been artificially contaminated with fluorescent particles. Measurements of particle density on the antenna before and after simulated cleaning movements revealed that the tarsal notch removed particles more efficiently than the tibial spur, but both notch and spur removed more than 60% of the particles with the first cleaning stroke. Removal of brush and comb from the cleaning devices strongly reduced cleaning efficiency for both notch and spur, suggesting that these surface structures are essential for cleaning.

P3.147 HADJISOLOMOU, S. P.; Graduate Center of The City University of New York; *stavrosh@brooklyn.cuny.edu*

Behavioral Responses to Pulses of Light in the Longfin Inshore Squid, Doryteuthis Pealeii

The unshelled coleoid cephalopods (octopus, squid, and cuttlefish) are renowned for their rapid, adaptive camouflage which is under direct neural control. This anti-predatory mechanism is extremely efficient at deceiving the visual system of predators and also allows for communication within and between species. This behavior is driven by a sensorimotor system, which receives and then integrates information from the eyes and selectively activates intradermal color-pigmented skin cells called chromatophore organs. The question of how cephalopods control their chromatophores has received considerable attention from the perspectives of color modulation and contrast in ethology. While the anatomical arrangement of the neuro-muscular components of chromatophores and the sensory contributions of the visual system has been studied, the computation underlying the information processing of the chromatophore control system that enables such behavior is still unknown. The impulse-response system identification technique was used to test the hypothesis that a sudden, intense visual stimulus (pulse of light) can trigger chromatophore responses in Longfin Inshore Squid, *Doryteuthis pealeii* (Lesueur, 1821). A camera recording at 240 Hz was used to capture behavioral responses before and after the pulse of light. There was an immediate, brief activation of the chromatophore organs following the pulse of light and this behavior was extremely reliable across pulses with a 3-second interstimulus interval, without signs of habituation. The results reported here provide a description of the timing relationships in the dynamics of brain function that control the chromatophore system response to light input. This study seems a natural increment to proceed attempting to understand color control in cephalopod chromatophore systems.

S8-1.6 HAJDU, E.*; LôBO-HAJDU, G.; COSME, B.; DE PAULA, T.; REDMOND, N.E.; COLLINS, A.G.; THACKER, R.W.; Universidade Federal do Rio de Janeiro, Universidade do Estado do Rio de Janeiro, Smithsonian Institution, University of Alabama, Birmingham; *eduardo.hajdu@gmail.com*

Towards an Evolutionary Classification of Mycalina and Latrunculina (Poecilosclerida)

A cladistic assessment of familial relationships on the basis of morphological characters obtained low support for the monophyly of Mycalina, with Isodictyidae and Desmacellidae included (Bayesian Analysis - BA), or left out of it (Maximum Parsimony – MP; and Neighbor Joining - NJ). BA retrieved no clades within the suborder, while MP and NJ shared only slight congruence in assigning Hamacanthidae and Merliidae to the same clade, a trichotomy with Podospongiidae in NJ. No morphological cladistic study of Latrunculina affinities has been carried this far. Mycalina and Latrunculina are rather poorly represented in molecular studies. Recent highlights are the non-Mycaline affinity of the polyphyletic Desmacellidae (28S) and Podospongiidae (*Diacarnus*, 28S & COI), as well as the confirmation of *Abyssocladia*'s assignment to Cladorhizidae (28S & COI). The PorToL project 18S tree confirms the non-Mycaline affinity of both former families, and suggests that Esperiopsidae (*Amphilectus*) may be a sister of Isodictyidae (*Isodictya*), both being sister of Podospongiidae (*Diacarnus, Negombata, Neopodospongia*). This project also suggests that *Desmacella lampra* may actually belong in *Mycale*, that Mycalidae (*Mycale*) and Guitarridae (*Guitarra*) may be sister groups, and that Latrunculina (*Latrunculia, Tsitsikamma*) may be monophyletic and belong in the Poecilosclerida. Important taxa of Mycalina and Latrunculina still missing in molecular trees are Hamacanthidae and Merliidae, further genera of Esperiopsidae, Guitarridae and Latrunculiidae, and additional subgenera of *Mycale*. It is also important to add Cladorhizidae into more comprehensive trees.

72.2 HALDANE, D. W.*; FEARING, R. S.; University of California, Berkeley; *dhaldane@berkeley.edu*

Using dynamic similarity scaling to inspire the design of a high-speed hexapedal millirobot.

The cockroach, *Periplaneta americana*, is a highly dynamic running insect, exhibiting a variety of robust and high speed gaits that we used as a model to study for the design of a highly dynamic robot. Using dynamic scaling from the cockroach, we determined the system parameters such as mass, leg stiffness and operating frequency for VELOCIRoACH, a 10cm long hexapedal millirobot, fabricated using our Smart Composite Micro Structure process. The robot weighs 30g, operates in a frequency range of 2 – 26Hz, and shows spring-mass like ground-reaction forces, like the insect. Noting that *P. americana* has very slender legs, we minimized the mass of the running appendages and all moving transmission components, to reduce the energy required for limb recycling. Surprisingly, the scaled legged robot was capable of locomotion at speeds up to 26 body lengths per second, making it, relative to size, the fastest running robot to date. This performance is comparable to the expected top speed of the scaled model system. In addition, using a novel application of an analysis based on the comparison of the three dimensional angular momentum of the robot and animal, we discovered significant similarities between the stable periodic angular rotations of the two systems during locomotion. All three components of rotation are comparable in magnitude, phase and frequency when mapped over a stride. The robotic model system successfully maintained the dynamic properties of the animal. These findings offer significant evidence for the power of using dynamic similarity as a design tool. Moreover, we demonstrated the degree to which -- even unaccounted for -- dynamic oscillations are preserved when a dynamically scaled system is implemented on a robotic platform.

100.7 HALE, M. E.*; WILLIAMS IV, R. ; Univ. of Chicago; *mhale@uchicago.edu*

Fish fins function as dual sensory and motor neuromechanical systems.

The roles of fin movement in behaviors have been studied widely across the broad diversity of jawed fishes, both living and extinct. Fins serve diverse behavioral functions. They propel and brake, maneuver and stabilize, clasp, threaten and defend. In tetrapods, such behaviors require considerable feedback from mechanosensors in the limbs that provide proprioceptive information on limb position and movement. Without such input limb movements and the behaviors that include them are greatly impaired. We have found that fish fins used extensively in locomotion and for stability receive proprioceptive feedback from several types of sensory nerve fibers. Afferents run distally along the fin rays and into the fin membranes. With physiology on the pectoral fins of bluegill sunfish, a species that uses its pectoral fins extensively during swimming, we determined that these nerve fibers respond both to bending and to static position of the rays. Surveying several taxonomically distant species suggests that a proprioceptive response to fin ray bending is common. Transection of the pectoral fin ray nerves of bluegills alters fin use in locomotor behaviors, indicating that the sensory feedback these nerves provide is important for motor function. Together these data demonstrate that pectoral fins with significant roles in locomotion and other behaviors also need to be examined as potential sensory structures. Considering pectoral fins used in locomotion as dual sensory and motor systems has implications for studies of their morphology and movement, as changes in fin shape, size, stiffness and movement pattern could impact the sensory input received. We suggest that other fins likely use similar feedback and that mechanosensory function and sensorimotor integration should be considered in studies of fin functional morphology and evolution.

P2.118A HALL, MI*; KAMILAR, JM; KIRK , EC; CARRANO, MT; IWANIUK, AN; Midwestern University, UT Austin, Smithsonian Institution, University of Lethbridge; *mhallx1@midwestern.edu*

The relationship between scleral ring morphology and activity pattern in birds and dinosaurs

Activity pattern, the time of day when an animal is awake and active, is highly associated with that animal's ecology. Extinct bird and dinosaur activity patterns are presently poorly understood but would provide important contributions toward understanding their paleoecologies. Soft-tissue studies of eyeball measurements show that extant birds exhibit characteristic eye shapes associated with their activity pattern. Specifically, nocturnal bird eyes are optimized for visual sensitivity with a relatively large corneal diameter and diurnal bird eyes are optimized for visual acuity with a relatively large axial diameter. Orbit morphology reflects eyeball shape and activity pattern can be interpreted from measurements of the scleral ring plus the orbit. Recent studies utilizing a new statistical technique suggest that measurements of the scleral ring even without a complete orbit are sufficient to make activity pattern interpretations for fossil birds and dinosaurs. Here, we analyze scleral ring measurements of over 500 species of extant birds and lizards within a phylogenetic context, and apply the results to interpret dinosaur scleral rings. Several factors preclude reliable interpretation of activity pattern from measurements of the scleral ring, and we conclude that these measurements are not sufficient to interpret activity pattern. Instead, more measurements of the orbit are required, especially orbit depth, to infer activity pattern with any certainty.

81.5 HAMLET, C. L.*; MILLER, L. A.; RODRIGUEZ, T.; Tulane University, University of North Carolina at Chapel Hill, University of California Berkeley; *chamlet@tulane.edu*

To Pause or Not to Pause: Effects of Pauses and Grouping on Fluid Flow around the Bell of the Upside-Down Jellyfish, Cassiopea spp.

The sessile nature of the upside-down jellyfish *Cassiopea spp.* makes it an ideal organism for gathering large sets of data on the kinematics of bell pulsations. Previous experiments and simulations have demonstrated the important role secondary structures play in directing flow around the bell. Here we present numerical simulations examining the effects of pulse timing and of spacing between organisms. We develop a discrete time Markov chain model based on pulse patterns of laboratory specimens to drive the bell kinematics. Effects of observed grouping of similar size and of different size specimens are explored in conjunction with the Markov chain model. Immersed boundary methods are used to solve the resulting coupled fluid-structure interaction problem. Our preliminary results show that variability of pauses between muscle contractions result in very different bulk flow patterns around the bell with implications for particle capture and exchange efficiency. Simulations of paired jellyfish indicate grouping has the potential to enhance opportunity for particle sampling, particularly for smaller specimens.

44.2 HANAUER, RE*; KETTERSON, ED; Indiana University; *rhanauer@indiana.edu*

Does corticosterone deposited in feathers in autumn predict circulating corticosterone during breeding?

The adrenal steroid hormone corticosterone (CORT) is involved in the regulation of energy balance, behavior, and stress responses. Individuals differ in the degree to which they elevate CORT in response to acute stress, and in some species this has been shown to be a stable trait over the individual's lifetime. In birds, CORT is generally measured by taking blood samples immediately after capture and again 30 minutes later. Interest has grown in measuring CORT extracted from feathers because it is not affected by the process of capture, and it provides a longer-term measurement integrated over the time it took the feather to grow. Feather CORT has been found to correlate with an individual's elevated circulating CORT in response to an acute stressor. However, previous work reported circulating CORT during feather growth. It is unknown if this relationship holds in birds whose feathers grew months earlier. I compared hormone levels from feathers and blood samples to determine whether feather CORT might be a reliable predictor of circulating CORT during the breeding season. Wild male dark-eyed juncos (n=80) were captured during the breeding season at two sites in southern California. Blood samples were collected at 0 and 30 minutes after capture. One tail feather, which had grown the previous autumn during molt, was collected, along with measures of endo- and ecto-parasites. Results will reveal whether circulating CORT correlates with feather CORT deposited several months earlier in a wild passerine and which measure of CORT is a better predictor of the prevalence of parasites. This study will be useful to researchers interested in less-invasive methods, and will inform future research in the fields of animal personalities, eco-endo-immunology, and conservation.

21.1 HANES, S D*; KEMPF, S C; MEYER, E; Auburn University, Oregon State University; *shanna.hanes@gmail.com*

Profiling gene expression responses of the symbiotic anemone, Aiptasia pallida, to elevated temperature and light conditions using RNA Seq

Coral reefs have dramatically declined over the past few decades as a result of mass mortality bleaching events. Bleaching functions as a stress response to elevated temperature and/or light conditions resulting in the loss of intracellular dinoflagellates (*Symbiodinium*) from host gastrodermal tissues. This process involves a complex series of events that occur throughout the duration of the bleaching episode and involve cellular interactions between both symbiotic members. However, few studies have investigated the early host stress response when symbiotic breakdown is initiated. In this study, molecular techniques were employed to characterize the host response during the first 48 hours of heat and light stress in *Aiptasia pallida*. Both symbiotic and aposymbiotic anemones were exposed to stress conditions of ~32.5ºC at 140 umols irradiance for 12 hours daily followed by 12 hours of darkness at ambient temperature. Differential gene expression was measured at various time points (0, 3, 12, 24, and 48 hours) using an RNASeq procedure. Additionally, ultrastructural examinations of tentacle tissues at 0 and 48 hours were conducted using transmission electron microscopy in order to monitor cellular activities. Results from this investigation indicate that the gene expression profile of *A. pallida* changes during early stages of bleaching, and several key genes are identified that are involved in the host stress response. This study provides a better understanding of the genetic determinants of stress tolerance in a host anthozoan, and offers further insight into the cellular processes that underlie coral bleaching.

5.2 HANLON, S/M*; PARRIS, M/J; University of Memphis; *hanloc2107@gmail.com*

Taking the good with the bad: Varying effects Roundup® on amphibian health.

Organisms are exposed to a variety of perturbations in natural communities. In aquatic systems, pesticides are a common anthropogenic pressure that can negatively affect non-target organisms such as amphibians and alter larval anuran behavior, morphology, or life histories. Glyphosate, especially the commercial formulation Roundup®, is the most widely applied herbicide worldwide and is known to reduce amphibian performance and survival; however, the mechanism of such reductions is currently unknown. We conducted three separate studies on two anuran species to test how: 1) Roundup affects tadpole foraging behavior, 2) application timing alters the effect of Roundup on life history traits, and 3) Roundup affects tadpole mouthpart damage (a potential mechanism for reductions in life history traits). In experiment 1, Roundup significantly altered tadpole foraging behavior. In experiment 2, tadpoles exposed to Roundup later in development experienced increased growth and accelerated development compared to subjects in non-Roundup treatments. In experiment 3, tadpoles exposed to Roundup experienced significantly increased tadpole mouthpart damage (specifically to jaw sheath structures) in a dose-dependent manner. Additionally Roundup at higher concentrations significantly slowed development. Our results suggest that factors such as concentration and application timing may play an important role in understanding how anthropogenic disturbances (e.g. pesticides) affect non-target organisms.

11.5 HANNA, B.SK*; CHANG, PK; MEDINA, MM; University of California, Merced; *bkamel@ucmerced.edu*

Tissue specific gene expression in the fresh water snail Biomphalaria glabrata: implications for biominerlization and shell formation

The lack of good manipulatable models to study biomineralization in molluscs led us to investigate the potential use of the fresh water snail *Biomphalaria glabrata*. Using comparative bioinformatics on several molluscan mantle transcriptomes from previous studies, we were able to detect conserved transcripts responsible for biomineralization. We conducted RT-PCR based experiments for a subset of the genes (n=70) in order to explore specific expression patterns in four different *B. glabrata* tissues: Mantle edge, foot, hepatopancreas and ovotestis. Six out of the 70 novel transcripts showed exclusive expression in the mantle edge. While 19 genes showed significant over expression in the mantle edge over the other tissues. Using a combination of in-situ hybridization and RNAi we are currently trying to understand the functional role of these novel biomineralization-related genes.

P3.9 HANSEN, B.K.*; KRIST, A.C.; MARTINEZ DEL RIO, C.; University of Wyoming; *bhanse11@uwyo.edu*

Is more really merrier? A case for increased success under high conspecific densities in the New Zealand mudsnail, Potamopyrgus antipodarum.

Although in its native range *Potamopyrgus antipodarum* (the New Zealand mudsnail) occurs in populations of sexual and asexual individuals, as an invasive species this snail occurs only as asexual, polyploid females. Asexual *P. antipodarum* should have a high demand for dietary phosphorus (P) because of high somatic P, high growth rates and increased ploidy. This demand for P may be impacted further by the high population densities that can occur in the invaded range and by the P limitation common in freshwater habitats. Although high densities typically reduce fitness, recent studies suggest *P. antipodarum* benefits from high densities of conspecifics through increased fecundity. To determine whether conspecific density also affects foraging, we compared preference for high quality food and foraging behavior under increasing densities of conspecifics. Preliminary experiments did not support the hypothesis that *P. antipodarum* preferred high quality food, but did suggest that feeding activity increased with conspecific density. Consistent with preliminary results, we found no evidence that *P. antipodarum* preferred high quality food. Previous experiments established that they compensate for low quality food by increasing feeding rate. The probability of *P. antipodarum* feeding activity increased with conspecific density. Unexpectedly, few *P. antipodarum* fed in our trials, possibly due to an inability to locate food patches. However, preliminary experiments with an alternate food source suggest that it is more likely that animals found our food unpalatable. Our results may provide insight into the natural history and invasion success of this species.

139.5 HARDEN, L.A.*; WILLIARD, A.S.; Univ. of North Carolina, Wilmington; *lah4492@uncw.edu*

Seasonal variation in osmotic and metabolic status of diamondback terrapins

Estuarine ectothermic vertebrates are faced with highly variable, tidally-influenced conditions, and many aspects of their biology reflect their ability to withstand and respond to the challenges posed by this environment. Diamondback terrapins *Malaclemys terrapin* experience broad fluctuations in temperature and water availability during the summer, and sub-zero temperatures and low oxygen availability while buried in the mud during the winter. The physiological adjustments necessary to maintain water and salt balance and the metabolic adjustments that accompany seasonal changes in activity and behavior have not been well-characterized for terrapins under field conditions. To investigate seasonal changes in terrapin osmotic and metabolic physiology, we obtained repeat blood samples from 10 radio-tagged female terrapins maintained in a semi-natural open-air salt marsh enclosure that encompassed their typical habitat and allowed them to experience natural shifts in temperature, salinity, and photoperiod. From September 2011 to May 2012 we measured monthly plasma concentrations of inorganic and organic osmolyte concentrations (Na+, K+, Cl-, uric acid, urea, glucose, total Ca2+, Mg2+), osmolality, and lactate. Monthly changes in blood parameters were analyzed using repeated measures ANOVA and Tukey's post-hoc analysis with sample collection date, terrapin size, and environmental variables (e.g. rainfall, salinity, behavior, tide, and mud, water, and air temperatures) included as model covariates. This study will provide unprecedented insight into the physiological strategies of terrapins exposed to natural environmental fluctuations throughout the year and provide baseline blood composition data for diamondback terrapins.

P3.36 HAROLD, AS*; ZURLO, D; TOLINE, CA; DOTY, S; MCDONOUGH, V; College of Charleston, Charleston, South Carolina, National Park Service, Charleston, South Carolina, Biscayne National Park, Homestead, Florida; *harolda@cofc.edu*

Diet of Red Lionfish (Scorpaenidae) from Biscayne Bay, Florida, based on gut content analysis

Introduced Red Lionfish (*Pterois volitans*) have become established throughout much of the warmer inshore waters of the western Atlantic. Several studies have looked at the impacts of this voracious species on communities of reef fishes and those of other shelf habitats. The present study was undertaken by the National Park Service in order to ascertain the possible effects of Red Lionfish on the fish assemblage in Biscayne Bay, Florida. One of the questions is directed towards determining possible impacts on the top predators and other large bodied, economically important fish species. Complete stomach content samples were obtained from a total of 567 lionfish, ranging in total length from 32 to 310 mm. A total of 916 prey items were identified, including 406 fishes (in twelve families), 509 crustaceans, and one gastropod. All prey items were identified to the lowest taxonomic level possible, although for present purposes we focus on the family level. Of the fishes identifiable to at least family gobies (Gobiidae) and triplefins (Tripterygiidae) were the most common prey, together accounting for about 48.6% of that component. Other common prey fishes, in decreasing order of occurrence, were blennies (Blenniidae), grunts (Haemulidae), and damselfishes (Pomacentridae). These preliminary observations indicate that lionfish in the Biscayne Bay area feed mainly on benthic fishes and crustaceans, but are also opportunistic. The relationship between body size of lionfish and the type of prey consumed is also discussed.

P2.7 HARRIS, BN*; DE JONG, TR; YANG, V; SALTZMAN, W; University of California, Riverside; *bharr002@ucr.edu*

Effect of Chronic Variables Stress on Paternal Behavior in California Mouse Fathers

Stress and chronically elevated glucocorticoid levels have been shown to decrease parental behavior in mothers; however, almost no studies have investigated this effect in fathers. We predicted that exposing California mouse (*Peromyscus californicus*) fathers to a chronic variable stress (CVS) paradigm would decrease paternal behavior and alter development and/or survival of pups. First-time fathers were subjected to a 7-day CVS protocol consisting of 21 total stress events (7 different stressor types in semi-random order) administered every 6-10 hours (chronic stress group, CS, n=8). Control fathers were separated from their mate and pups for the stressor duration (separation controls, SC, n=7), or were left unmanipulated (undisturbed controls, UC, n=8). Body mass, plasma corticosterone (CORT) concentrations, paternal behavior and pup development were monitored across the study. Immediately after CVS, all fathers were exposed to a novel stressor and blood samples were collected for CORT; animals were sacrificed and organ masses were determined. CS fathers lost body mass over the course of the experiment and had higher CORT levels on day 4 compared to UC and SC fathers. Additionally, CS fathers had smaller thymi than both UC and SC fathers, and larger adrenals than UC fathers. CS fathers showed several behavioral differences from SC and UC fathers, including more time away from pups, more time autogrooming, and less time huddling with the mate and pups. Nonetheless, no significant differences in pup developmental measures were found. These results demonstrate that CVS does alter paternal behavior in *P. californicus* fathers, but effects were subtle and did not alter pup development under these circumstances. Supported by NIH 1R21MH087806.

P3.173 HARRIS, C.M.*; MADLIGER, C.L.; LOVE, O.P.; University of Windsor, Ontario; *harris2c@uwindsor.ca*

Feather corticosterone: an accurate integrated measure of stress?

Glucocorticoid measurement in outer integuments (e.g. hair, feathers) has become increasingly popular as a non-invasive physiological measure of stress. It is currently assumed that corticosterone (CORT) levels in feathers represent a long-term integrated measure of glucocorticoids over the time of feather growth. However, recent results call into question the mechanisms by which CORT may be deposited in feathers, complicating the conclusions that can be drawn from interpretation of their concentrations. Here we experimentally test whether CORT levels are subject to change following completion of feather growth in primary flight feathers obtained from a wild population of Tree Swallows (*Tachycineta bicolor*). Our results will provide considerations for the appropriate interpretation of feather CORT and provide insight into the mechanisms underlying CORT deposition and resiliency in feathers.

P3.143 HARRISON, J.F.*; WATERS, J.S.; CEASE, A.J.; VANDENBROOKS, J.M.; CALLIER, V.; KLOK, C.J.; SHAFFER, K.; SOCHA, J.J.; Arizona State University, Virginia Tech; *j.harrison@asu.edu*

How hoppers breathe

Insect tracheal-respiratory systems achieve high fluxes, great dynamic range and are light-weight and energetically efficient. Because they have been improved by natural selection for millions of years, they represent new and potentially important models for bioengineers interested in developing microfluidic systems. Here we focus on the best-known insect respiratory system, the abdominal pump of the locust. Functional valves of unknown mechanisms appear to allow hemolymph to resist gravity and permit segment-specific pressures. Each segment contains two fluids with very different properties (air and water) separated by a flexible membrane. Muscle-driven volume changes in abdominal segments generate volume changes in the tracheal system of that segment, producing pressure changes that drive flow both within the body and through spiracles. Differential compression of air sacs and tracheae create local regional flows. Velocities through the major longitudinal tracheae are high and convection dominates over diffusion as a transport mechanism in these parts of the tracheal system, but Reynolds numbers suggest viscous effects remain important. This research was partially supported by NSF EFRI BSBA 0938047 to JJS and JFH.

34.1 HART, M*; SUNDAY, J; POPOVIC, I; LEARNING, K; KONRAD, C; Simon Fraser Univ.; *mwhart@sfu.ca*

Selection and gene flow in gamete recognition molecules: daughters of immigrants meet sons of locals in a sexual conflict

Conflict between male and female reproductive interests can lead to a local arms race between male adaptations and female countermeasures within populations. Divergence between populations in male and female traits can lead to reproductive isolation and speciation, unless this outcome of the arms race is diluted by immigration and gene flow. Gamete recognition proteins (GRPs) of broadcast spawning marine animals are promising targets for selection, sexual conflict, and reproductive isolation, but few studies have looked at population-level divergence. We recently found strong positive selection that produces population divergence (and partial reproductive isolation) in the sperm acrosomal protein bindin between northern and southern populations of the bat star *Patiria miniata*. Here we analyze GRPs expressed in eggs. We modelled both positive selection and gene flow for these loci (as well as background rate of gene flow for loci not involved in sex). We found high amino acid substitution rates (a response to selection favoring new or rare or better alleles) for egg surface proteins. However, selection acts differentially on immigrant alleles for male- and female-expressed GRPs. Bindin gene flow is zero (less than background), but gene flow for the egg bindin receptor is high and asymmetrical: in the population that experiences the strongest selection for high rates of bindin evolution, immigration of egg bindin receptor alleles is ~80-fold higher than background. We conclude that selection in this system favors the daughters of immigrants (and their egg-expressed alleles) as a response to selection created by fast bindin evolution among the sons of locals. The evolutionary outcome of selection in such a system (and the potential for speciation) may be hard to predict.

35.4 HARVEY, TA*; PRUM, RO; Yale University; *todd.harvey@yale.edu*

3D Imaging Spectroscopy for Measuring Organismal Hyperspectral Patterns

The color phenotype of an organism consists of a complete description of the variation in spectral reflectance over the entire organismal surface. Scientific description of the color phenotype requires detailed documentation of both the spectral variation and spatial variation of the surface of the organism. Because many organisms use color in communication and crypsis, the color phenotype should be described over the visible spectrum of the organisms themselves, their predators, or ecological interactors. From flowers and fishes to birds and butterflies, organisms have evolved integuments of astounding beauty and diversity, including brilliant color and dramatic pattern. Research into the evolution of color, size, shape, and distribution of reflectance is limited by current technology. Therefore, we developed novel methods to capture simultaneously a 3D virtual model of organismal surface geometry and the NUV-Vis-NIR spectral reflectance over the organism's surface. Example data sets demonstrate how we integrate 3D laser scanning, hyperspectral imaging, range image/hyperspectral image registration, and surface mesh-texture integration to capture the color phenotypes of a diversity of bird plumages. Using physiological models of tetrachromatic avian color vision, we then calculate avian color channels for each pixel on the surface of the 3D virtual model of the bird and project these color channels back on to the 3D virtual model. We anticipate that an entirely new standard in visual ecology, behavioral ecology, and evolutionary biology will be established as new methods exploit the advantages of 3D, whole organism, and hyperspectral data sets to test hypotheses about coloration, function, and evolution within populations, between sexes, and among species.

P1.95 HARVEY, TA*; BOSTWICK, KS; MARSCHNER, S; Yale University, Cornell University; *todd.harvey@yale.edu*

Spatially- and Directionally-varying Reflectance of Milli-scale Feather Morphology

Birds have evolved diverse plumage through complex morphological modifications. Plumage is fundamental to how birds interact with their world; the signaling function of plumage plays a role in an organism’s social interaction and is a determining factor in an organism’s overall visual identity. Previous case studies have established the vast morphological modifications of individual, specialized feathers, and the millimeter-scale topography generated by the shape and orientation of feather sub-structures. We present investigations into a previously understudied aspect of avian visual signaling: directional reflectance and its relationship to milli-scale structure, namely its barbs and barbules. We hypothesized that structural modifications produce anisotropic reflectance, the direction of which may be predicted by the orientation of the milli-scale structure of the vane. We developed non-destructive tools and methods to investigate the signaling potential of the feather. We correlated measurements of directional light scattering to the milli-scale morphology of select samples of structurally-colored bird plumage. The results of these analyses lead to a more thorough understanding of the relationships between directional reflectance and the structure of the feather itself. Having found the reflectance to be anisotropic, we demonstrated that the change in the direction of the reflectance over the surface of the vane could in fact be predicted from the orientation of the different branches of the barb. The improved understanding of the variation in directional reflectance over the surface of the feather should allow for better comprehension of avian behavior, evolution of morphological adaptations, and the synthesis of more accurate predictive models.

P3.200 HASANEINI, SJ; BERTRAM, JEA*; Univ. of Calgary, Calgary; *jbertram@ucalgary.ca*
Evaluating models of locomotion dynamics: What complexity is adequate?
One approach to understanding biological legged locomotion is to use theoretical mechanical models as a test bed to evaluate theories of why humans and animals move as they do, or as a means to predict their response to new environments. Simple models are more amenable to interpretation and are computationally fast, while comprehensive models have complexities that can obscure the underlying principles. Minimal analytical and numerical models (e.g. Kuo (J Biomech. Eng., 2002) and Srinivasan (Nature, 2006)) have shown good success in explaining some aspects of human and animal locomotion. However, the capability of the minimal models is limited, and thus greater complexity is necessary for such models to provide insight into the more subtle aspects of locomotion dynamics. The question remains as to what level of complexity is required in order to produce a functionally reliable model. Obviously the answer depends on the specific question at hand and the characteristic that is being investigated. Here we explore the required level of complexity in the human response to walking and running in simulated reduced gravity. Two different models that self-optimize for mechanical energy cost, each with a different level of complexity, are explored. The predicted optimum behavior for these models as gravity changes is compared with observations of human gait in reduced gravity. It is found that the model's ability to predict human response to an unusual gravitational environment is often counter-intuitive. Through comparison of model and human in an experimentally manipulated physical environment, it is possible to determine the consequences of model simplicity and complexity.

P1.150 HASLETT, S.*; PROUDFOOT, G.; CRESPI, E.; WARNE, R.; Southern Illinois University Carbondale, Vassar College; *smhaslett@siu.edu*
Integrating stress physiology across breeding and migrating life stages in owls
Understanding the cumulative effects of reproduction, molt, migration and environmental conditions during each of this life stages on the stress physiology and immune function of migrating vertebrates is exceedingly challenging. Inclement weather and/or poor environmental conditions coupled with the high energetic demands during each of these life stages may result in elevated levels of physiological stress and reduced immune responsiveness. Here we used integrated measures of glucocorticoid stress hormones, parasite loads and deuterium stable isotopes of fall migrating Saw-whet owls (Aegolius acadicus) to estimate breeding locations and stress levels during two different time frames. To these ends, deuterium isotopes measured in the feathers of these birds were used to determine the region in which they bred and molted their feathers. Glucocorticoid levels (stress hormones in vertebrates) were also measured in feathers and blood, which provided an index of physiological stress profiles of these owls during two time frames: feather molt and migration. Last, blood parasite loads and identities were measured as an index immune competence. Integrating these measures can provide insight into how environmental or regional climate conditions at breeding locations, as well as migratory distance and path are associated with the stress profiles and immune competence of migrating animals.

147.2 HATTON, R. L.*; DING, Y.; CHOSET, H.; GOLDMAN, D. I.; Oregon State University, Georgia Institute of Technology, Carnegie Mellon University; *Ross.Hatton@oregonstate.edu*
Influence of Deformation Geometry on Sand-swimming Performance
Many animals move within granular media such as desert sand. Studies of an undulatory sand-swimmer, the sandfish lizard, showed that the grains around the organism form a frictional fluid in which inertial effects are small and kinematics dominate. To examine the kinematics of swimming in granular media (GM) we have adapted, from our work in robotics, a geometric model for swimming in viscous fluids. This model relates the net displacement induced by a stroke to an area integral in the stroke parameters. It also gives rise to a visualization that allows us to better understand the performance of the system, whether it be an animal or a robot. For each component direction - forward, lateral, and rotational - this visualization can be viewed as a graph of a function or a "terrain map." A closed loop in this space represents a cyclic motion, i.e. a stroke. If a stroke encompasses a large positive "mountain" or deep negative "valley," then it accrues positive or negative displacement, respectively, in its component direction. If the stroke encloses as much positive as negative area, then it produces no displacement; it has enclosed a self-canceling region.

Previously, we demonstrated the principles of the geometric approach on a reduced system, the three-link swimmer. Here, we extend them to continuous systems that can still be modeled by two internal degrees of freedom. In particular, we look at traveling waves of body curvature. The resulting visualizations highlight both the fundamental similarities between various modes of swimming and the differences in their effectiveness.

139.4 HAVIRD, J. C.*; HENRY, R. P.; SANTOS, S. R.; Auburn University; *jhavird@auburn.edu*
Using RNA-Seq and gene-specific methods to examine salinity-induced gene expression changes in an anchialine shrimp
Understanding how organisms respond to environmental variation is critical in order to comprehend how they function in their niches. Taxa from the coastal anchialine ecosystem represent good candidates for studying responses to environmental variation since their habitats undergo wide oscillations in physical and chemical properties, like temperature and salinity. Currently, little is known on how anchialine organisms cope with the environmental variation experienced in these habitats. To address this, we investigated how the Hawaiian anchialine shrimp *Halocaridina rubra* responds to changing salinity via analyses of gene expression. Illumina technology was first used to sequence transcriptomes from two *H. rubra* genetic lineages (from East Hawaii and Windward Oahu) previously identified based on divergence in their mitochondrial COI. Six known crustacean osmoregulatory genes were identified from this transcriptomic data and targeted for expression analyses using qPCR. The expression levels of these genes remained relatively constant, or decreased, when shrimp were transferred from iso-osmotic conditions (32‰) to either hyper-regulatory (15‰ and 2‰) or hypo-regulatory (45‰) conditions. This is in contrast to previously studied crustaceans, which tend to upregulate these genes during salinity transfer. These and previous results suggest that alternative or novel osmoregulatory genes, pathways, or mechanisms may be utilized by *H. rubra* to cope with the rapidly changing salinities experienced in anchialine habitats. Ongoing experiments utilizing RNA-Seq will investigate salinity-induced gene expression changes across the entire *H. rubra* transcriptome and shed light on this possibility.

94.5 HAWKINS, M.B.*; JANDZIK, D.; CRUZ, A.; STOCK, D.W.; Harvard University, Cambridge, MA, University of Colorado, Boulder; *michaelbrenthawkins@fas.harvard.edu*

The evolution of fish barbels by the co-option of fin developmental mechanisms

Barbels are sensory projections from the head that are found in 27 of the 62 orders of fishes, ranging from hagfishes to goatfishes. The phylogenetic distribution of barbels and substantial differences in their structure among groups suggest that they have arisen independently numerous times. The repeated evolution of complex structures may be facilitated by the co-option of existing developmental mechanisms. We tested this hypothesis for barbel origins by examination of gene expression and function during barbel development in the Channel Catfish, *Ictalurus punctatus*. We found that the maxillary barbels of this species likely deploy two developmental genetic mechanisms that are also used to pattern paired fins: an Fgf/Hh positive feedback loop driving outgrowth, and the Hh-regulated expression of posterior group HoxD genes controlling morphological asymmetry along the anterior-posterior axis. We also compared the development of maxillary barbels to that of the other barbel pairs present in the Channel Catfish, the chin and nasal barbels, which arose in catfish (siluriform) evolution after the appearance of maxillary barbels. While evidence for similar outgrowth and anterior-posterior patterning mechanisms was observed in all barbel pairs, the different pairs are divergent in the expression of Fgf, Dlx, and Hox gene family members. We propose that barbels first arose in catfishes by the co-option of paired fin developmental genetic mechanisms, with the resulting barbel program similarly deployed during the origin of the chin and nasal barbels. In addition to providing insight into the origins of barbels in catfishes, our findings identify candidate mechanisms for the independent origins of these structures in other vertebrate groups.

1.9 HAZARD, L.C.; Montclair State University, NJ; *hazardl@mail.montclair.edu*

Integrating physiology and conservation: Lessons from the Nagy lab

The developing field of conservation physiology has roots in field studies in physiological ecology, including techniques and approaches pioneered by Ken Nagy. Some recent research projects illustrate the increasing relevance of physiological ecology for conservation issues. Threatened desert tortoises in the Mojave Desert are incorporating non-native, sometimes invasive plant species into their diets. In a laboratory study, we examined the nutritional impact of this shift and found that food type (forb vs. grass) was a better predictor of nutritional value than food origin (native vs. exotic). However, in some areas native forbs are being replaced by less nutritious exotic grasses, leading to a potential shift in available nutrients. This may be of conservation concern if tortoises must forage longer or farther to find suitable foods, and will help determine habitat needs of this declining species. In the temperate forests of the northeastern U.S., anthropogenic salinization of freshwater habitats directly impacts some amphibian populations. We are integrating physiology, behavior, and ecology to evaluate how adults of several sympatric amphibian species respond to increased salinity of their breeding habitat. We have found significant variation in salinity aversion among species, suggesting that adults of some species may not avoid salinities that would be detrimental to them or to their eggs/larvae, and may therefore be more likely to suffer population declines. Knowledge of the physiological basis for these interspecific differences in behavioral salinity tolerance may help predict susceptibility of other species. To conserve declining species, a physiological approach will be critical in predicting, measuring, and hopefully mitigating the effects of local or global anthropogenic influences on populations at risk.

P2.138 HEAD, T. B.*; MUDRON, M. R.; CHANG, S. A.; CHANG, E. S. ; MYKLES, D. L. ; Colorado State University, UC Davis Bodega Marine Laboratory, UC Davis Bodega Marine Laboratory; *talhead@rams.colostate.edu*

mTOR-dependent protein synthesis is required for ecdysteroid synthesis in the crustacean molting gland

Molting in crustaceans is regulated by two endocrine organs: the X-organ (XO)/sinus gland complex in the eyestalks and a pair Y-organs (YOs) located in the thoracic region. The XO produces molt-inhibiting hormone (MIH), which inhibits synthesis of molting hormones (ecdysteroids) by the YO. Our model of the MIH signaling pathway in the YO involves a cAMP/calcium-dependent "triggering" phase and a NO/cGMP-dependent "summation" phase. A potential downstream target is mechanistic Target of Rapamycin (mTOR), a protein kinase that regulates translation of mRNA into protein. This ongoing study determines the effects of recombinant MIH and reagents that target components of MIH and mTOR signaling on YO ecdysteroidogenesis. YOs from the green shore crab, *Carcinus maenas*, were cultured in the presence or absence of a compound and ecdysteroids secreted to the medium were quantified by ELISA. cPTIO (NO scavenger) ($p = 0.022$) and ODQ (NO-dependent guanylyl cyclase inhibitor) ($p = 0.039$) increased ecdysteroid secretion. Cyclohexamide (RNA translation inhibitor) ($p = 0.0003$) inhibited ecdysteroid secretion. Actinomycin D (mRNA synthesis inhibitor) had no significant effect. Previous work showed that the mTOR antagonist rapamycin is a potent inhibitor of YO ecdysteroidogenesis. The data suggest that MIH signaling inhibits mTOR and that translational control by mTOR is necessary for maximal ecdysteroid synthesis by the YO. Supported by NSF (IOS-0745224).

144.6 HEAD, J.J. *; POLLY, P.D.; University of Nebraska-Lincoln, Indiana University; *jhead2@unl.edu*

Conservation of primaxial regionalization in the evolution of the snake body form

Shifts and reduction in *Hox* gene expression domains have been proposed as a primary mechanism in the evolution of the elongate, "deregionalized" axial skeleton of snakes and other squamates. Mapped domains do not show a consistent change in expression in the axial skeleton of snakes, however, and the extent of morphological homogenization has not be examined separately for the primaxial and abaxial regions of the skeleton. To test for morphological changes along the primaxial skeleton and their implications for inferring *Hox* patterning in the snake body form, we quantified vertebral shape in a sample of amniotes including taxa with highly differentiated axial regions and resolved *Hox* boundaries (*Mus*, *Alligator*) and representatives of all major squamates clades including elongate taxa. Geometric morphometric analyses of intracolumnar changes in vertebral morphology along the anterior-posterior axis were used to test against models of differing regionalization and to search for regional boundaries. Testing the method on *Mus* and *Alligator* produced perfect correspondence between *Hox* boundaries and quantified shape variation for a four-region model representing cervical, anterior thoracic, posterior thoracic and lumbar regions. Morphometric variation in squamates, including elongate taxa, also best fit a four-region model, despite the absence of additional regional morphologies. Comparisons of morphometric regions in the snake skeleton with mapped domains revealed an exact correspondence between *Hox* gene expression and morphometric boundaries in the cervical and thoracic regions and a loose correspondence in the lumbar region. These results strongly suggest that primaxial regionalization is retained in the evolution of elongate body forms, and that "deregionalization" results from reduction or loss of the abaxial skeleton.

P3.30 HEALY, F.*; PARK, D.; BERGAMINI, R.; DANIELS, K.; PROPPER, C.R.; Northern Arizona Univ., Flagstaff; *fh52@nau.edu*

Evaluating naturalized populations of western mosquitofish, Gambusia affinis, in the Verde River watershed for biomarkers of endocrine disruption

Invertebrate and vertebrate aquatic organisms exhibit a number of responses to xenobiotics, making them excellent bioindicators of environmental contamination. Rivers in the arid Southwest may be particularly vulnerable to chemical pollution as there is limited availability of surface water for dilution effects. Based on a prior study of benthic macroinvertebrate community structure in the Verde River watershed, Arizona, we identified five sites that may represent different pollution loads and a site that receives only spring-fed water. To determine whether these sites may also affect endocrine function in aquatic vertebrates, we used naturalized populations of western mosquitofish (*Gambusia affinis*) as a bioindicator for estrogenic or androgenic markers of pollution. There were no significant intrasex differences in anal fin lengths among all sites, suggesting that fish raised in these waters did not experience feminization or masculinization during development. However, body length in females and mass in males differed among sites, but these were not related to predicted pollution levels. The lack of differences in anal fin length suggests that there is no overt disruption of androgen activity in these sampled reaches. However, the differences in body size and mass may be related to complex biotic and abiotic interactions within the watershed. Our results suggest that water in the areas sampled may not affect androgenic activity in these fish. Furthermore, this study illustrates that within a watershed's geographic microscales there are differences in population traits. These differences need to be taken into account when trying to find correlations between pollution and physiological outcomes in natural populations.

S7-2.2 HEATH-HECKMAN, Elizabeth A.C.*; PEYER, Suzanne M.; MCFALL-NGAI, Margaret J.; University of Wisconsin - Madison; *heathheckman@wisc.edu*

Symbiont luminescence entrains daily host-tissue rhythms through direct regulation of a host cryptochrome gene

All animals exist in the presence of beneficial microbial symbionts, however the extent to which these microbes control, or are controlled by, host circadian rhythms has not been addressed. We studied the role of bacterial partners in regulating biological rhythms in the symbiosis between the squid *Euprymna scolopes* and its luminous symbiont *Vibrio fischeri*. This binary model for the chronic bacterial colonization of animal epithelia is characterized by daily transcriptional rhythms in both partners, as well as by daily rhythms in symbiont luminescence. Two transcripts encoding cryptochromes, blue-light receptors that entrain circadian rhythms in all invertebrates, were identified in the host. We first determined whether these genes, *escry1* and *escry2*, cycle in host tissues. Whereas both cycled in the head with a similar pattern to that found in other animals, *escry1* cycles in the symbiont-colonized light organ with an 8-fold up-regulation coincident not with environmental light but with the rhythms of bacterial luminescence. Manipulating the colonization process revealed that *escry1* transcription patterns in the light organ were dependent upon the presence of symbionts. Mutants of *V. fischeri* defective in luminescence (*Δlux*) failed to induce *escry1* expression to wild-type levels, providing evidence that bacterial luminescence entrains host cryptochrome expression. In addition to being the first known characterization of cryptochromes in a mollusc, this study demonstrates that bacterial symbionts have the potential to be active participants in the setting of host biological rhythms. The conservation of both epithelial-bacterial interactions and circadian gene regulation across the metazoa suggests that symbiont-induced circadian rhythms may be widespread.

19.4 HEDRICK, MS*; HILLMAN, SS; DREWES, RC; HANCOCK, TV; University of North Texas, Portland State University, California Academy of Sciences, Eastern Washington University; *michael.hedrick@unt.edu*

Physiological vagility, vertebrate dispersal and population genetic structure of amphibians

Physiological vagility (m h^{-1}) is the ability to move sustainably. We provide a quantitative metric for vagility that incorporates aerobic capacity (VO_{2max}), body mass, body temperature and the minimum cost of transport (C_{min}). A meta-analysis of four vertebrate classes was used to test our vagility metric with data for dispersal distance (D_{max}) and body mass. We also tested our metric with data for genetic heterogeneity (F_{ST}') for amphibians and reptiles. Vagility increased with increasing body mass in amphibians (r^2=0.73), reptiles (r^2=0.59) and terrestrial mammals (r^2=0.81), but was independent of body mass (P=0.99) in flying birds. Within terrestrial locomotors, endothermic mammals have greater vagility at equivalent body masses than amphibians or reptiles owing to greater VO_{2max}. Vagility is higher in reptiles at equivalent body masses than amphibians owing to greater VO_{2max} at higher body temperatures. D_{max} was significantly related to body mass for amphibians, reptiles and terrestrial mammals, but was not related to body mass for flying birds. Vagility and D_{max} were correlated and both scaled similarly with body mass. There was a significant negative correlation ($P<0.001$) between F_{ST}' and vagility for amphibians with vagility accounting for 56% of the observed genetic heterogeneity. The degree of genetic differentiation with distance (F_{ST} km^{-1}) was greater for amphibians compared with reptiles ($P<0.001$) and likely due to reduced activity duration or lower VO_{2max} at lower operating temperatures. Recent studies with amphibian populations validate our vagility hypothesis. Our results suggest that interspecific differences in vagility resulting from physiological and anatomical phenotypes play a significant role in limiting or enhancing genetic exchange among amphibian populations.

143.5 HEDRICK, MS*; CROSSLEY II, DA ; University of North Texas; *michael.hedrick@unt.edu*

Development of the cardiac and peripheral limbs of the baroreflex in embryonic chickens

The baroreflex is the primary short-term compensatory mechanism to buffer arterial pressure (Pa) changes and maintain cardiovascular homeostasis. Compensatory adjustments in mechanisms include both parasympathetic and sympathetic efferent activity acting on the heart (cardiac limb) as well as sympathetic efferents that modify vascular resistance and perfusion. Although the afferent and efferent limbs of the baroreflex are well-characterized in adult vertebrates, the developmental onset of function in most vertebrates is poorly characterized. Moreover, measurement of the baroreflex in fetal animals is normally limited to the cardiac limb of the reflex in response to changes in Pa. We sought to measure both cardiac and peripheral limbs of the baroreflex using fetal chickens as a model to examine the onset and development of the baroreflex. Fetal chickens were instrumented with chorioallantoic membrane (CAM) arterial catheters to measure Pa and heart rate (fH), Doppler flow probes to measure peripheral blood flow (femoral artery) and miniature bipolar electrodes to measure whole vagal (parasympathetic) nerve activity and peroneal (sympathetic) nerve activity. These measurements were made in day 18/19 (of 21 day development) in white leghorn embryos. Pa was altered using the Oxford method with drugs injected into the CAM artery to increase (Phenylephrine; Phe) or decrease (sodium nitroprusside; SNP) Pa. Injection of SNP resulted in reductions in Pa and vagal afferent activity and increased fH. Nerve activity in the peroneal nerve was associated with increases in Pa and fH, indicating an intact sympathetic limb of the baroreflex at day 18/19 of development. These are the first data to characterize the peripheral limbs of the baroreflex in a developing chicken and show that afferent and efferent components of the baroreflex are functional by day 18/19.

114.3 HEERS, A M*; DIAL, K P; University of Montana;
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Wings versus legs: mechanistic underpinnings of variation in locomotor strategies among birds

Among the 10,000 species of living birds and their extinct dinosaurian ancestors, relative musculoskeletal investment in wings versus legs is highly diverse, varying both across species and throughout ontogeny. Such variation likely has profound effects on locomotor performance and many related aspects of bird ecology, including habitat preferences, foraging strategies, migration patterns, and parental care. During aerial locomotion, high leg investment may hinder wing performance. Likewise, high wing investment may hinder leg performance during terrestrial locomotion. Given these potential relationships between body modules, do tradeoffs between wings and legs influence locomotor ontogeny and evolution? To explore this question and better understand the ecological ramifications of how wings and legs function both independently and cooperatively during ontogeny and evolution, we used published and new data to compare wing and leg morphology and locomotor performance (i) across adult birds of different species and (ii) during ontogeny, in three precocial anseriform-galliform species with distinctly different sequences of locomotor development. Our findings suggest that birds with high wing investment may have reduced mass-specific leg performance and rely on wing-dominated locomotor behaviors, while birds with high leg investment may have reduced wing performance and rely on leg-dominated locomotor behaviors. For example, among adults, wing and leg investment are negatively correlated. Similarly, ontogenetic increases in wing investment and performance can compromise leg investment and performance, and vice versa. Collectively, these results provide new insight into the mechanistic underpinnings of variation in locomotor strategies among birds, and suggest that performance tradeoffs between different body modules may be important during ontogeny and evolution.

P2.189 HEESY, C.P.*; KAMILAR, J.M.; Midwestern University, Midwestern University and Arizona State Univ.;
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Relative brain size decreases with limb loss in squamates

Most variance in vertebrate brain size is explained by its relationship to body size. However, the underlying biological mechanism that relates brain to body size in vertebrates continues to be debated. One potentially valuable clade that can be used to study vertebrate brain:body size allometry is lepidosaurs (tuataras, lizards, and snakes) within which relatively large brain size has evolved multiple times among presumably distantly related lizard groups. Additionally, brain size has been suggested to be smaller in elongate, and/or limbless vertebrates, including snakes and some lizards. In this study, we examine the relationship between digit and limb loss on brain:body size scaling in lepidosaurs. We combine data on brain and body mass from multiple sources and also collate data on digit and limb number in these taxa. Lastly, we employ modern phylogenetic statistical approaches to the analysis of these data. Our analyses are consistent with the hypothesis that relative brain size decreases with digit and limb loss, and the relationship between brain:body size ratio and limb loss has evolved multiple times within lizards as well as in snakes. We also find that relative cerebellum volume decreases with digit and limb reduction and loss. Relative brain size reductions in squamates with limb loss can be interpreted as reflecting lower innervation demands by body wall structures.

38.2 HEIN, A. M.*; MCKINLEY, S. A.; University of Florida;
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Sensory signals and predator search performance at the low prey density limit

Organisms of all types collect sensory measurements from their environments. In some cases, these measurements contain information about the locations of resources such as prey. We show how simple mathematical models of predator sensing and search decision-making can be scaled up to describe one of the fundamental rate functions associated with predator-prey interactions: the predator functional response, which describes how the per-capita rate at which predators encounter and consume prey depends on prey density. Most classic models of functional response assume that, until a predator locates a prey item, the predator moves through its environment in a manner that is independent of the locations of prey. We show that relaxing this assumption and allowing predators to detect and modify search behavior in response to noisy sensory signals emitted by prey causes a qualitative change in functional response. Predators that alter their movement behavior in response to prey signals encounter prey more frequently than predators that search without using information about prey positions. Interestingly, this difference in search performance is strongest at low prey densities, where predators that utilize even minimal noisy prey signals have a huge advantage over predators that forage without using sensory data. We suggest that evolution of long-range prey sensory mechanisms such as sensitive olfaction and the corresponding decision-making machinery may be driven by the need to reliably locate prey when prey density is extremely low. More generally, our methodology provides a means of scaling up individual-level sensory processes to describe a fundamental population-level rate parameter that has bearing on species interactions, population dynamics, and food web stability.

P1.14 HEIN, S.R.*; JACOBS, M. W.; Mcdaniel College;
srh001@mcdaniel.edu

Decoration preference and habitat selection in early stage juveniles and megalopae in the decorator crab Oregonia gracilis

Often referred to as decorator crabs, many species from the family Majoidea (Decapoda; Brachyura) adorn their bodies with decorations by attaching pieces of algae, sponge, or other items from their habitats onto hooked setae. *Oregonia gracilis* is a wide ranging cold water Pacific decorator crab. We investigated carapace morphology of and habitat selection by megalopae and juveniles, as well as juvenile decoration preferences. Hooked setae were absent in megalopae, but appeared in first instar juveniles, and were arranged in distinct sparse rows of single setae. As the crabs progressed in size the number of rows increased and setae began to occur in clusters. The young crabs began to decorate during their first instar. When presented with a choice of three materials commonly found attached to adults (sponges, erect bryozoans, and red algae), juveniles preferred to decorate with unidentifiable debris found free floating in the water or stuck to offered decorating materials. The sparsely arranged setae or weak chelae of very young juveniles may make it easier for the juveniles to attach debris over other more robust materials. When given habitat choices using the same aforementioned materials plus a mixture of all three, both megalopae and juveniles favored bryozoans. We think this behavior may be related to crypsis. Compared to other potential habitats, erect branching bryozoans have a great deal of structural complexity and a large attachment of debris for decoration, both qualities that could be exploited by the young crabs who likely rely on crypsis as a means of survival.

P2.1 HEINIGER, J*; DICKMAN, C; WILSON, R S; The University of Queensland, University of Sydney; *r.wilson@uq.edu.au*

The life and times of a sex addict in northern Australia: understanding the breeding dynamics of the world's largest semelparous mammal

The northern quoll (Dasyurus hallucatus) is a medium-sized (approx. 1 kg) predatory marsupial previously common across the entire top-end of Australia. It is the largest known semelparous mammal in the world, which means mating is highly synchronous, males live for only one year, and males undergo total die-offs soon after the mating season. Such population-wide male die-offs are presumably due to the physiological stress of procuring copulations and the intense fighting among males. Despite large population declines on mainland Australia a thriving population is found on Groote Eylandt, an Indigenous-managed island off the coast of the Northern Territory that is free of the invasive species linked to the rapid decline in mainland populations. During the past year a mark-recapture study was conducted on Groote Eylandt to determine the population dynamics, ecology, reproductive output and performance of 150 individuals found within a 125ha area on the island. We have found that this high-density population is sex-biased towards females and there are large morphological differences among males with consequences for their biting and running performance. Interestingly, some of the males of this population survive for an extended period past the breeding season (previously extremely uncommon in this species) and their condition appears to recover after the abrupt weight loss and decline in condition that accompanies the intense mating bout. In the upcoming field season we wish to determine the parentage of all pouch young and discover what combination of male traits (morphology and performance) equates to a siring a greater number of young. We also aim to determine why some males die immediately after the breeding season while others have the ability to live past this point.

30.2 HEINIGER, J*; DICKMAN, C; WILSON, R S; The University of Queensland, University of Sydney; *r.wilson@uq.edu.au*

The frenetic sex life of male northern quolls: does performance degrade when the sex becomes too demanding?

The northern quoll (Dasyurus hallucatus) is a medium-sized (approx. 1 kg) predatory marsupial previously common across the entire top-end of Australia. It is the largest known semelparous mammal in the world, which means mating is highly synchronous, males live for only one year, and males undergo total die-offs soon after the mating season. Such population-wide male die-offs are most likely due to the physiological stress of procuring copulations and the intense fighting among males. Given the importance of procuring mates in such a short period (approx. 2 weeks), the ability for males to win fights and cover long distances to find reproductively mature females is presumably of critical importance. As such we would expect the performance of males of high quality males to be high throughout the breeding season while those of poor quality males rapidly decrease. We explored this idea using a mark-recapture study of more than 150 individual northern quolls located within a 125ha area on Groote Eylandt. For each individual, we measured the morphology, growth, maximum bite force and maximum running speed throughout their life cycle. We found that not only are there large changes in both male performance throughout their life cycle but there are also substantial variation among individuals that may profoundly influence their reproductive success.

85.2 HEINRICH, EC*; BRADLEY, TJ; Univ. of California, Irvine; *eheinric@uci.edu*

Temperature dependent variation in respiratory patterns and spiracular control in Rhodnius prolixus

Our current understanding of insect respiratory control indicates that spiracular activity is regulated by two interacting feedback loops which monitor and respond to changes in internal pCO_2 and pO_2. Spiracles open when pCO_2 reaches a critically high threshold (2-6 kPa) or when pO_2 becomes critically low (4-5 kPa). Given that the spiracles open in response to a specific pCO_2, the volume of CO_2 released in a burst by a discontinuously respiring insect should remain constant independent of metabolic rate. However, previous studies which manipulated metabolic rate via temperature found that burst volume decreases at higher temperatures. We used *Rhodnius prolixus* to determine if this variation is caused by changes in metabolic rate or by an effect of temperature on spiracular control. We increased metabolic rate by either increasing ambient temperature or by feeding Rhodnius a bloodmeal. Burst volume decreased significantly as temperature increased from 18°C to 38°C (ANOVA, F=89.58, $p<0.001$) but showed no relationship to metabolic rate in fed animals measured at 24°C (BV= -0.0016MR + 0.0243, R2=0.0015). Burst duration and time between bursts decreased in both treatment groups. Additionally, insects that experienced temperature variation abandoned discontinuous respiration at lower metabolic rates than those in the fed treatment group. Our study suggests that the set point at which the spiracles open in response to CO_2 is dependent on ambient temperature. It is clear that the respiratory patterns produced by insects are influenced by both temperature and metabolic rate. These results provide a window for examining the mechanisms by which insects sense and respond to pCO_2 and pO_2. This work was supported by the NSF grant IOS-0920683 (TJB).

77.4 HEISS, E*; VAN WASSENBERGH, S; University of Antwerp, Belgium; *Egon.Heiss@ua.ac.be*

Prey capture throughout the seasons: functional demands of a multiphasic lifestyle in the Alpine newt Ichthyosaura alpestris (Salamandridae)

Evolutionary transitions between aquatic and terrestrial environments were – and still are – significant steps in vertebrate evolution. These transitions require major changes in most biological functions, including feeding. The Alpine newt, *Ichthyosaura alpestris* is known to show a "multiphasic lifestyle" where the adult newt changes from a terrestrial to an aquatic life, and again to its terrestrial habitat every year due to its breeding activity. These seasonal transitions induce dramatic changes in morphology, resulting in a distinct aquatic and terrestrial morphotype. We hypothesized that the morphological change between both phases goes along with changes in prey-capture mechanics to maintain performance in both environments. We provide a reconstruction of the complex cranio-cervical myo-skeletal system and simulate its movements during prey-capture. We also analyze the prey capture kinematics in two natural modes (aquatic strike in aquatic phase, terrestrial strike in terrestrial phase) and two induced modes (aquatic strike in terrestrial phase, terrestrial strike in aquatic phase) and perform a multivariate comparison between all 4 modes. In the terrestrial phase, *I. alpestris* uses its quickly protruding tongue to capture prey, but a suction mechanism when feeding in water. In the aquatic phase, it uses a jaw-based grasping mode on land, but suction feeding underwater. We conclude that *I. alpestris* shows a so far unknown amount of behavioral plasticity during prey-capture, and that the functioning of its prey-capture system is tuned to seasonal performance demands.

P2.76 HELFRICH, LW*; JOHANSSON, KB; DIAMOND, J; FISCHER, AHL; LYONS, D; HENRY, JJ; SMITH, J; Marine Biological Laboratory, Duke University, University of Illinois at Urbana-Champaign; *kimberly.johansson@gmail.com*

From Transcriptome to Interactome: Getting the Slipper Snail Ready for the Ball

How did the animal body plan arise? What are the underlying molecular mechanisms driving the diversification of animal forms? The slipper snail *Crepidula fornicata* serves as an excellent model organism to explore these questions. Like the majority of the members of the "forgotten phylum" Lophotrochozoa, *Crepidula* develops according to a spiral cleavage pattern. Though this mode of early development is distinct from embryogenesis in other animals, spiralians also form body axes and germ layers common to bilaterians. In other words, different modes of development create a similar body plan. In order to gain a molecular understanding of the processes of early development, we prepared cDNA libraries at 20 time points from early cleavage stages through the onset of gastrulation for sequencing on the Illumina HiSeq1000. Additionally, we treated embryos at the four-cell stage with the MAPK inhibitor U0126, a drug shown previously to induce a loss of dorsoventral axis formation, and prepared and sequenced cDNA libraries from these embryos. Results from our combined RNA-seq experiments establish a reference transcriptome, providing a community resource of *C. fornicata* gene models. Ongoing analyses from our time series and perturbation data will identify zygotic regulatory transitions and potential gene-gene interactions, and thus provide a basis for further gene network studies into the origins of diversity and uniformity in animal body plans.

P1.58 HELM, R/R*; DUNN, C/W; Brown University ; *Rebecca_Helm@brown.edu*

The evolution of direct development in Scyphozoa

Scyphozoan jellies (Cnidaria) provides an excellent opportunity to study lifecycle evolution from the perspective of the evolution of development. Within Pelagiidae, a clade of scyphozoans with indirect life cyles that include both a benthic polyp and pelagic sexually mature jelly (termed medusa), one species, *Pelagia noctiluca*, has done away entirely with polyps and has a direct lifecycle wherein the embryo develops into a medusa. While the closest relatives of *P. noctiluca* are being cultured through full life cycles in public aquaria, because *P. noctiluca* does not have a polyp stage it is more difficult to collect. Very little published information is available on the morphological development of *P. noctiluca*, making it impossible to compare its direct development to that of sister species. Here we will discuss our efforts to culture *P. noctiluca* and characterize its morphological development.

64.5 HELMS IV, J.A.*; KASPARI, M.; University of Oklahoma; *jackson.a.helms-1@ou.edu*

Found or Fly: flight, reproduction and biomechanical tradeoffs in ant queens

Because of a diversity of reproductive strategies, the ants [Formicidae] are an ideal system to study reproductive tradeoffs. In a typical species, a young queen performs two competing, yet intimately related tasks. First, in the flight phase, she must fly to mate, disperse and locate a new nest site. Second, in the foundation phase, she must found a colony, lay eggs and rear the first batch of workers. Many colony foundation strategies are known, but we lack a quantitative framework linking reproduction to flight morphology. Here we introduce the Found or Fly (FoF) Hypothesis, which posits a fitness tradeoff in ant queens between colony foundation and flight performance, manifest through investment in gaster mass. We investigated queen morphology of a common Neotropical species, *Azteca instabilis*, to evaluate the assumptions of FoF. Gaster mass varied among queens, with time of year, and independently of body size, consistent with individual or colony level manipulation. Several measures of flight ability- flight muscle ratio, wing loading, and drag- were adversely affected by increased gaster mass. Second, we characterized the flight morphology of a hyperdiverse tropical assemblage. Flight morphology accurately predicted colony foundation strategy among the ants. Due to gaster investment, several species carried extremely large loads relative to flight muscle mass, pushing theoretical limits of insect flight. These results confirm the tight relationship between foundation and flight, and suggest that biomechanical flight requirements may constrain reproductive strategies in the ants.

86.3 HENDERSON, J.J.*; GERHARDT, H.C.; University of Missouri, Columbia; *jhenderson@mail.missouri.edu*

Rescuing of call attractiveness using novel acoustic appendages in gray treefrogs, Hyla versicolor

Acoustic signals vary from simple, repeated elements to a combination of diverse elements that create a complex signal. Complex calls are found in a variety of taxa, from the multi-note calls of songbirds to the syntax of human speech; however, call complexity is relatively rare in the widely studied anuran amphibians. To study questions regarding complex call evolution, it is critical to understand the mechanisms of the sensory system and its inherent biases in order to establish "rules" affecting the attractiveness of novel complex signals. The gray treefrog (*Hyla versicolor*) serves as a powerful model system for examining the rules that determine the effectiveness of novel complex signals. One such rule, temporal order, is an important factor in novel call attractiveness as females often preferred complex calls consisting of the pulsed advertisement call of the species followed by a novel acoustic appendage. This observation may be explained by a class of interval-counting neurons that are selective for interpulse interval. These neurons fire after a number of intervals with correct duration. The most selective of these neurons can be reset after one incorrect interval. The results of this study show that calls with one or more inappropriate intervals or pulses with short duration are discriminated against when presented with normal advertisement calls. In addition of a novel acoustic appendage often "rescued" call attractiveness for these inappropriate calls. These results suggest that the interval-counting neurons do affect call attractiveness and that appendages may lessen discrimination of an unattractive call.

P1.186 HENEN, BT; United States Marine Corps; *bthenen@yahoo.com*

It's About Time: Chelonian Physiological Ecology and Conservation

Rate phenomena are central measures of the physiological and ecological exaptations and adaptations of many vertebrate endotherms and ectotherms. For Agassiz's Desert Tortoises, *Gopherus agassizii*, physiological and ecological rates help demonstrate advantages of ectothermy in a harsh, variable environment, and vulnerability on a conservation timescale. The ability to temporally relax or abandon homeostasis with regards to osmoregulation, body condition, metabolic rate, and water flux helps them endure short or extended droughts in their desert clime. Their morphology, behavior, and physiology, including follicular atresia and long-term vitellogenesis, support their long, iteroparous lives and a bet-hedging reproductive strategy. However, this combination makes them less than ideal 'canaries in the coal mine' or indicators of habitat quality and degradation. Their ability to persist and reproduce for long periods under harsh conditions and degraded landscapes, at individual and population levels, suggest that range-wide declines for *G. agassizii* portend considerable habitat degradation and community and biodiversity loss. The physiological and ecological rate phenomena, including the slow reproduction and low juvenile survivorship of *G. agassizii* and other chelonians, indicate that these species require extended periods to recover from anthropogenic-based threats.

140.4 HENNIN, H.L,*; DESCAMPS, S.; FORBES, M.R.; GILCHRIST, H.G.; BÊTY, J.; SOOS, C.; LOVE, O.P.; University of Windsor, ON, Norwegian Polar Institute, Tromsø, Carleton University, Ottawa, ON, Environment Canada, Ottawa, ON, Université du Québec à Rimouski, Environment Canada, Saskatoon, SK; *hennin@uwindsor.ca*

The survival cost of reproductive investment: higher fattening rates lead to increased risk of mortality to a novel disease

In mixed (income-capital) breeding birds that reproduce in a seasonal environment, a combination of arrival date and arrival condition on the breeding grounds, as well as the rate of gain in condition following arrival, influence the timing of reproduction. Individuals that gain in condition the quickest lay earlier, invest in larger clutches and generally incur higher fitness. However, it has recently been shown that in the presence of a highly virulent disease higher reproductive investment is associated with higher mortality risk, although the exact mechanism(s) for this link is unclear. We studied the pre-breeding energetic physiology of an Arctic-nesting colony of Common Eiders (*Somateria molissima*) at East Bay Island, Nunavut during an ongoing avian cholera (*Pasteurella multocida*) outbreak first beginning in 2006. We collected blood samples from arrival female eiders, tracked them through reproduction, and recorded mortality in high and low cholera outbreak years. We used energetic metabolites (plasma triglycerides - TRIG) as a measure of the rate of condition gain and examined its relationship to breeding propensity, lay date and the downstream effects these traits had on survival. Higher TRIG individuals were more likely to breed and had earlier laying dates. However, individuals with higher TRIG had an increased risk of mortality regardless of breeding propensity or whether they timed reproduction to the peak of cholera outbreaks. We demonstrate that increases in physiological investment in reproduction can trade-off with survival in the presence of a highly virulent disease.

95.5 HENNINGSEN, J.P.*; HUSAK, J.F.; IRSCHICK, D.J.; University of Massachusetts Amherst, University of St. Thomas; *justinh@bio.umass.edu*

Dewlap displays and predation risk in green anole lizards

In some animals, signals are consistently correlated with another trait and are thus considered reliable. Theory predicts that signal reliability is maintained via costs imposed upon the signaler. One such cost may be increased risk of predation. Male green anole lizards (*Anolis carolinensis*) use the dewlap as a reliable signal of maximum bite force capacity. However, the costs that maintain signal reliability in dewlaps are unknown. We tested whether dewlap displays increase predation risk by disabling dewlap displays in a sample of adult male green anoles. We compared the recapture rates of these males against animals given a sham treatment and found that recapture rates did not differ between the groups. We also used clay models to test how dewlaps and their color profile affected predation attempts. We found that models with naturally colored dewlaps (pink with UV reflectance) were struck by predators more often than models with green dewlaps and models with no dewlaps. We explore hypotheses that could explain the apparent contradictory evidence between sedentary models and free living animals.

101.3 HENNINGSSON, P.*; BOMPHREY, R. J.; Univ. of Oxford, UK; *per.henningsson@zoo.ox.ac.uk*

Efficiency of lift production in six species of hawk moths

The efficiency of lift production is important for all flying animals because it directly influences the limits of performance. For both fixed-wing vehicles and flapping animals the efficiency of lift production, span efficiency (e_i), can be estimated using quantitative flow diagnostics and fundamental aerodynamic theory. Wings generating lift in the most aerodynamically efficient way do so by deflecting the oncoming airflow uniformly across the span, creating a uniform spanwise induced flow distribution. Any deviation from uniformity is associated with an extra cost as induced drag increases. By quantifying how large this deviation is, the increase in drag and the reduction in span efficiency can be calculated. We used high speed stereo Particle Image Velocimetry (stereo-PIV) with a repetition rate of 1 kHz to capture the near wake from six species of hawk moths flying tethered in a wind tunnel in forward flight. The selected species represent a range in wingspan from 40mm to 110mm (2.75 times) and in mass from 0.2g to 1.5g (7.5 times). From the high spatio-temporal resolution flow fields we extracted downwash distributions behind the animals and calculated instantaneous values of ei throughout the wingbeat cycle as well as multi-wingbeat averages. Here we present how span efficiency differs between the six moth species and discuss the effect of force generation and kinematics.

146.2 HENSON, J.R.*; FREEMAN, D.A.; Univ. of Memphis; *jrhenson@memphis.edu*
Different neural target tissues mediate melatonin-dependent regulation of the RFamides, kisspeptin and gonadotrophin-inhibitory hormone, in Siberian hamsters
Siberian hamsters exhibit seasonal rhythms in physiology and behavior that aid in their ability to cope with annual changes in the environment. These include intra-annual changes in reproductive function, body mass, energy balance, and pelage coloration that are driven by changes in day length. For example, short day lengths inhibit, whereas long day lengths stimulate the reproductive axis. Day length is encoded by the duration of nocturnal pineal melatonin (Mel) secretion, which acts at several neural Mel target tissues to alter reproduction via changes in the release of hypothalamic gonadotrophin-releasing hormone (GnRH). Interestingly, GnRH neurons do not express Mel receptors, suggesting that regulation of GnRH by Mel is mediated by factors upstream of GnRH neurons. We assessed the effect of Mel on two up-stream GnRH regulators, kisspeptin (Kiss1) a positive regulator, and gonadotrophin-inhibitory hormone (GnIH, also termed RFRP-3) a negative regulator. We extended the Mel rhythm locally within specific target tissues in male hamsters housed under long day length by employing Mel-containing cannulas implanted into either the suprachiasmatic nucleus (SCN) or the nucleus reuniens (NRe). Extending the Mel duration at either target tissue elicited the expected testicular regression, and evoked site-specific effects to the RFamides. Mel administered to the SCN resulted in a reduction in Kiss1-immunoreactivity (-ir) in the anteroventral periventricular nucleus and Mel localized to the NRe resulted in a reduction of GnIH-ir in the dorsomedial hypothalamus. The results indicate that these two RF-amides are regulated independently by Mel acting at distinct target tissues.

P2.77 HERATH, B. J.*; BOWSHER, J. H.; North Dakota State University, Fargo; *bodini.herath@my.ndsu.edu*
Are Hox genes involved in the genetic regulation of the novel abdominal appendages in male Sepsid fly, Themira biloba?
Evolutionary novel structures often provide a new function to the organism, but do not have a known homology. Even though modern insects lack any abdominal appendages in segments one through seven except for genitalia and cerci, some species of male sepsid flies (family Sepsidae) have evolved abdominal appendages on their fourth abdominal segment. These appendages are thought to be used during mating to stimulate the females. Research on the sepsid *Themira biloba* has found that their abdominal appendages are derived from ventral histoblast nests on the fourth segment. However, initial specification of the development of abdominal appendages in Sepsids has not been evaluated. Hox genes are important in segment specification in arthropods and defining antero-posterior axis of embryos. Further Hox genes are involved in regulating the expression of a variety of target genes which then may involve in significant developmental changes in organisms. Due to the Hox gene function in segment identity and histoblast specification in *Drosophila*, we propose that the bithorax complex of Hox genes are potential candidates for the development of abdominal appendages in the sepsid species, *T. biloba*. We hypothesize, (1) a shift in expression pattern of a bithorax gene may occur at the fourth abdominal segment making the phenotype different in *T. biloba*, and (2) there will be a change in the downstream targets of any of the three bithorax genes (Ultrabithorax, abdominal A, and Abdominal B) which resulted in the evolution of the abdominal appendage development in *T. biloba*.

S2-1.5 HERB, Brian R.; WOLSCHIN, Florian; HANSEN , Kasper D.; ARYEE, Martin J.; LANGMEAD, Ben; IRIZARRY, Rafael; AMDAM, Gro V.*; FEINBERG, Andrew P.; Johns Hopkins University , Norwegian University of Life Sciences, Arizona State University; *Gro.Amdam@asu.edu*
Reversible switching between epigenetic states in honeybee behavioral subcastes
Female honey bees provide a model of social organization and behavior, with developmental separation of castes into reproductive queens and workers, the latter of which emerge as nurses caring for the brood, and then often shifting behavior to become foragers which gather pollen and nectar outside the hive. Epigenetics, or non-sequence based information heritable during cell division, is an attractive potential substrate for these caste differences and behavioral changes, and we tested the hypothesis that differential DNA methylation might distinguish the brains of queens from workers, or foragers from nurses. Using CHARM microarray analysis and whole genome bisulfite sequencing, we found no evidence of worker-queen differences, but substantial changes were detected in the brains of foragers compared to nurses, in genes involved in chromatin remodeling and RNA processing. To test the link between these changes and worker subcaste phenotypes, we reverted foragers to nurses by a technique of hive trickery. Half of these reprogrammed loci were among the nurse-to-forager subset (P-value < 2.2 x 10-16), and included genes for nuclear transport and organization. These data provide the first evidence of reversible epigenetic changes associated with behavior in a model organism.

79.1 HERNANDEZ, LP; George Washington Univ, Washington DC; *phernand@gwu.edu*
Widespread distribution of the palatal organ across Cypriniformes suggests multiple roles in feeding
The cypriniform palatal organ has long been thought to play a role in selectively feeding on the benthos. Composed of a dorsal mass of muscle fibers that spans the entire buccal roof it is strongly tied to the branchial elements laterally. Previous work on carp and goldfish has shown that this taste bud-studded muscular pad produces localized protrusions that are used to sort and select edible items while bottom feeding. While the neurobiology and physiology of palatal organ function in the goldfish has been well described, there is little data on palatal organ functional morphology across Cypriniformes. While previous reports have suggested that this important feeding structure is limited in its distribution these data show it is present in nine subfamilies of Cypriniformes. Importantly, an obvious palatal organ was present in species that are known to feed within the water column. Ontogenetic data show that this structure forms early in development. Moreover, data from miniaturized species (e.g. *Paedocypris*), in which many morphological structures are commonly lost, show that even these species have a patent palatal organ. To date the palatal organ is proposed to function solely to selectively feed on the benthos. While sorting during benthic feeding may have been the primitive function, it is likely that the palatal organ has secondarily become adapted for suction generation during the course of cypriniform evolution. Data is presented on muscular architecture and myosin composition of palatal organs of species within 9 subfamilies. Contrary to previously published results all species examined have some type of palatal organ. Although not as well developed or highly innervated as that of goldfish, a complex mesh of predominantly fast muscle fibers characterized nearly all cypriniform palatal organs.

P1.156 HERNANDEZ, D*; SCHUMAN, M; TOMANEK, L; Cal Poly, San Luis Obispo; *dherna07@calpoly.edu*

Proteomic changes in gill tissue during acute aerial heat stress in tidally entrained Mytilus californianus

The rocky intertidal mussel species *Mytilus californianus* is native to the Pacific coast of North America. It is frequently exposed to temperatures that can induce the cellular stress response due to the tidal rhythm. Mussels were collected just prior to the experiment in a location with recorded thermal history and immediately placed in an artificial tidal cycle so as not to interrupt the entrainment. These mussels were selected to test the hypothesis that oxidative stress is a co-stressor of acute heat stress and triggers the production of a number of metabolic proteins to deal with the production of reactive oxygen species under naturally occurring conditions of aerial exposure. Immediately before the second artificial low low tide, mild (25 °C) and severe (35 °C) heat stresses were induced by increasing the air temperature at a rate of 6 °C per hour. Once reached, the target temperatures were held for one hour while a control group was left at 10 °C under aerial conditions. Gill tissues were sampled from individuals immediately after heat stress or placed back in the tidal cycle and sampled immediately prior to the next low low tide. Tissues from all individuals were prepared for analysis using 2D gel electrophoresis and subsequent 2D gel image analysis (two-way ANOVA; $p<0.02$). 21% of the proteins showed time-dependent heat stress (interaction) effect; 32 and 17% showed a heat stress or time (main) effect, respectively. A partial suite of the significant proteins have been identified using matrix-assisted laser desorption ionization (MALDI) tandem time-of-flight (ToF-ToF) mass spectrometry. Present data suggests that tidally-entrained *M. californianus* may be acclimatized to the possible occurrence of cellular damage through heat shock because of adjustments to hypoxia episodes that accompany low low tide episodes and also generate reactive oxygen species.

100.6 HERREL, A.*; PERRENOUD, M.; ABDALA, V.; MANZANO, A.; POUYDEBAT, E.; CNRS; *anthony.herrel@mnhn.fr*

The effect of substrate diameter and incline on locomotion in arboreal frogs

Frogs are characterized by a unique morphology associated with their saltatory lifestyle. Yet, arboreal species show morphological specializations relative to other ecological specialists allowing them to hold on to narrow substrates. Here we study the limb and brain morphology in arboreal frogs of the genus *Phyllomedusa*. In addition, we quantified the 3D kinematics of forelimb movement for frogs moving across branches of different three diameters (1, 4, 40mm) and two different inclines (horizontal and 45 degrees). Our data show anatomical differences between arboreal species compared burrowing, terrestrial and aquatic species in the forelimb anatomy and the size of the cerebellum. Moreover, our results show that grip types differed across diameters and inclines. The kinematics of the wrist, elbow and shoulder as well as the body position relative to the substrate showed significant effects of individual, diameter and incline. Kinematic differences involved the durations, velocity of movement and angular excursions with differences being more pronounced for the distal joints. Interestingly, the effects of diameter and incline on both grip type and kinematics are similar to what has been observed previously for primates suggesting. Thus the mechanics of narrow substrate locomotion appear to drive the kinematics of movement independent of morphology and phylogeny.

95.1 HEWS, DK*; VITAL, C; ZÚÑIGA-VEGA , JJ; MARTINS, EP; Indiana State University, Universidad Autonoma de Ciudad Juarez, México, Universidad Nacional Autónoma de México, Indiana University; *diana.hews@indstate.edu*

Staged territorial intrusions and aggressive visual signaling in males of three Sceloporus lizard species that differ in abdominal patches

As in many animals, *Sceloporus* lizards use multicomponent visual signals involving color and motion. Most *Sceloporus* are sexually dichromatic: only males have paired blue abdominal patches and use posture to emphasize the abdominal color during male-male aggression. However, there are several independent evolutionary losses or reductions of the blue belly patches in *Sceloporus*. We examined behavioral responses of males to standardized staged territorial intrusions (STIs), in two white-bellied *Sceloporus* species, which also differ in lineage age (*S. virgatus* "recent white", *S. siniferus* "older white"), and in a third species with partially-blue abdominal patches and which is in a relatively old lineage (*S. merriami* "older partial blue"). Previous work found that male *S. virgatus* (recent white) were less likely to escalate to using aggressive visual displays in standardized STIs compared to males of a blue-bellied species, *S. jarrovii*. Here we report that male virgatus (recent white) were more likely to use broadcast displays (push-ups) and less likely to use more aggressive displays ("fullshow", "fullshow hold"). By contrast, males in both *siniferus* (older white) and *merriami* (older partial blue) were less likely to use broadcast displays (push-ups) and more likely to use highly aggressive postures (full show), although usually only after moving towards the intruder male. We discuss these species differences in use of broadcast display versus high-intensity aggressive display in the context of considering differences in habitat complexity and in the risk of predation.

P3.130 HIATT, M*; KILLPACK, T; CROUCH, W; FASSBINDER-ORTH, C; Creighton University, University of Wisconsin-Madison; *mjh13972@creighton.edu*

Alphavirus infection impairs growth and development of altricial nestling birds

Arboviral infections have been recorded in wild avian nestlings, but the physiological impacts of the infections on avian growth and development have not been well studied. House sparrows (*Passer domesticus*) are one of two species of wild birds that serve as avian hosts for Buggy Creek virus (BCRV), an alphavirus transmitted by swallow bugs (*Oeciacus vicarius*). To study the impact of BCRV on developing birds, 7 day old house sparrow nestlings were inoculated with 3.5 $\log_{10}$ plaque forming units (PFUs) of two different lineages of BCRV (lineage A or B), or a vehicle control, and the infection was followed for 4 days post inoculation (DPI). Measurements taken post-infection revealed that there were no significant differences in body mass growth among the BCRV-A, BCRV-B, and control groups. However, a significant reduction ($P<0.02$) in tarsus length was seen in both BCRV-A and BCRV-B infected birds compared to the control group (14.7% reduction and 15.9% reduction, respectively). Furthermore, data taken post-mortem showed the average wing length to be significantly shorter in BCRV-infected birds compared to control birds ($P < 0.05$). Culmen length was also significantly lower ($P<0.002$) in BCRV-B birds compared to the controls, with mean culmen lengths of 0.58 ± 0.012 cm and 0.61 ± 0.009 cm, respectively. Lastly, water content of tissues (a measure of tissue maturity) was significantly higher in BCRV-A infected birds compared to controls ($P<0.04$), indicating relative tissue immaturity of BCRV-A infected birds. These results suggest that BCRV infection leads to a reduced capacity for growth in developing house sparrows. This impairment likely contributes to the high mortality rates observed in BCRV-infected house sparrow nestlings in the wild.

136.2 HIEBERT, T. C.*; VON DASSOW, G.; HIEBERT, L. S.; MASLAKOVA, S. A.; Oregon Institute of Marine Biology, University of Oregon; *terrah@uoregon.edu*

Long-standing larval mystery solved —Pilidium recurvatum is the larva of Riserius sp., a basal heteronemertean (Heteronemertea; Pilidiophora; Nemertea)

The typical pilidium larva of nemertean worms looks like a hat with earflaps. *P. recurvatum* looks like an athletic sock, swimming around heel first with the toe trailing behind. It was discovered in 1883 in the NW Atlantic off Rhode Island, and has since been reported from Gullmarfjord (Sweden), the Bay of Nha Trang (Vietnam), the Sea of Japan (Russia) and the NE Pacific off Washington and Oregon, but its identity remained mysterious until now. We identified *p. recurvatum* larvae from Coos Bay, OR based on molecular phylogenetic evidence and the morphology of the metamorphosed juveniles as belonging to the genus *Riserius*, an unusual mesopsammic heteronemertean. Gösta Jägersten suggested that *p. recurvatum* may represent an evolutionary intermediate between the planuliform nemertean larva and the typical pilidium. The fact that *Riserius* is basal within the Pilidiophora supports the evolutionary significance of this larval form. We found two morphologically distinct kinds of *p. recurvatum* larvae in Coos Bay. Based on the 16S rDNA sequence divergence they represent two separate species, each distinct from the only described species of *Riserius*, with which they form a monophyletic clade. We have yet to find the adults of these two apparently undescribed species of a previously monotypic genus. We also report on the remarkable choice of prey by the juveniles of *Riserius* sp. They feed exclusively on the larvae and juveniles of the hoplonemertean *Carcinonemertes errans*, which itself is an egg predator and parasite of the Dungeness crab, a commercially important species.

124.4 HILL, G. E.*; JOHNSON, J. D.; Auburn Univ.; *ghill@auburn.edu*

The biochemical basis for honest signaling via carotenoid pigments

Tradeoffs in allocation of carotenoid pigments between use in immune defense versus use in ornamentation have been widely stated as the means by which the honesty of ornamental coloration is maintained. While this Resource Tradeoff Hypothesis has been supported in some empirical studies showing loss of carotenoid pigmentation following immunostimulation, alternative explanations are equally plausible. Moreover, the quantities of carotenoids used by leukocytes is five orders of magnitude lower than the quantities of carotenoids in circulation, a disparity that is hard to reconcile with a direct tradeoff in carotenoid allocation. An alternative to this Resource Tradeoff Hypothesis is the Shared Pathway Hypothesis, whereby production of ornamentation is linked to the biochemical efficiency of vital cellular processes. We present a biochemical model for regulation of ornamental coloration based on interdependencies of carotenoid and retinoid biochemistry. We propose that vitamin A regulatory mechanisms, redox systems, and carotenoid pigmentation pathways link carotenoid coloration to oxidative state and to a host of important aspects of performance such as immune function. Finally, many animals oxidize dietary pigments to produce ornamental coloration. We hypothesize that these oxidation reactions occur in the inner mitochondrial membrane and that pigmentation ultimately reflects the efficiency of cellular respiration.

21.2 HILL, M*; HILL, A; COTMAN, C; FRIDAY, S; HEIST, T; MCCAULEY, M; PETERSON, K; RICHARDSON, C; RIESGO, A; STREHLOW, B; Univ. of Richmond, Univ. of Richmondq, Univ. of Mississippi, Univ. of Virginia, CEAB, Spain; *mhill2@richmond.edu*

Evolutionary and ecological significance of sponge-Symbiodinium symbioses: genetic regulation of uptake and maintenance in sponges.

Symbioses involving *Symbiodinium* are arguably the most important ecological interaction on coral reefs because zooxanthellae energetically subsidize the entire community. These algal symbionts also enhance rates of calcification, and thus facilitate the creation of three-dimensional structure for all organisms. Nonetheless, we have a remarkably limited understanding of the symbiont's niche (e.g., why is zooxanthella distribution so restricted among sponge hosts?). We will present two novel hypotheses derived from our work with sponges (the Magnesium Inhibition Hypothesis and the Arrested Phagosome Hypothesis) that help explain well-known aspects of *Symbiodinium* associations regardless of taxonomic status of the host. We will argue that sponges afford unique methodological opportunities and broad-reaching insights into the associations found in all other *Symbiodinium*-based symbioses. We will present research examining the genetic regulation, physiological integration, and ecological/evolutionary significance of *Symbiodinium* symbioses involving sponge hosts. We will present data from suppressive subtractive hybridization and transcriptomic-based approaches that identify genes differentially regulated during zooxanthella uptake. Gene expression profiles will be correlated with various stages of reinfection as aposymbiotic sponge hosts re-acquire their algal partners. The physiological integration of partners and capacity of Clade G *Symbiodinium* to tolerate stressful conditions will be presented. Finally, we will evaluate *in hospite* "residence time" as a useful heuristic for studying zooxanthella symbioses.

116.8 HILL, A.*; RIVERA, A.; WINTERS, I.; RUED, A.; DING, S.; POSFAI, D.; GENTILE, L.; WEBB, E.; TROK, W.; Univ. of Richmond, Richmond, VA, Univ. of the Pacific, Stockton, CA, Stanford Univ. School of Medicine, Stanford, CA, Univ. of Pittsburgh Medical Center, Pittsburgh, PA, Univ. of Oxford, Oxford, England; *ahill2@richmond.edu*

The freshwater sponge, Ephydatia muelleri, as a model to study the evolution of developmental regulatory programs

Sponges possess an extensive repertoire of animal specific transcription factor, signal transduction and structural genes that first appeared at the dawn of animal multicellularity and continued to expand and diversify as the animals evolved ever increasing levels of complexity. We are using the emerging freshwater sponge model, *Ephydatia muelleri*, to study the evolutionary origins and functions of developmentally important gene families and networks. Through the development of methodologies (e.g., RNAi and expression vectors) as well as directed studies on specific genetic pathways, our lab is contributing to the growing body of knowledge and resources for this model organism. For example, expression studies as well as gene knockdown experiments demonstrate a role for Pax and Six genes in the endothelial lining of the canal system and the development of the choanoderm in these freshwater sponges. Current work is exploring the regulatory relationships and downstream targets of a putative Pax-Six (PS) component of the evolutionarily conserved Pax/Six/Eya/Dac (PSED) gene regulatory network.

S4-2.3 HILLER , M; BEJERANO , G*; Stanford University; *bejerano@stanford.edu*

A "forward genomics" approach links genomic and phenotypic evolution in a clade of related species

Genotype to phenotype association is a holy grail of the genomic era, hampered by the lack of clear mappings between the millions of genomic changes and thousands of trait differences apparent even when comparing closely related species such as human and chimpanzee. Efforts to link DNA base pair changes to whole organism phenotypes have recently focused on experimentally mapping genomic regions involved in a given trait or testing genomic regions that show accelerated changes between lineages. Here we introduce a computational "forward genomics" strategy to detect phenotype – genotype associations by matching a phylogenetic pattern of trait evolution with a corresponding pattern of orthologous genomic regions evolution. Simultaneously searching dozens of mammalian genomes we are able to correctly associate individual genes with the phenotypic traits to which they contribute. We show that our method is robust to missing phenotypic data, and applicable for both discrete and continuous, monogenic and polygenic traits. Using simulation studies, analysis of existing phenotype surveys and the coming availability of genomes of many additional species we show that "forward genomics" can be applied to many phenotypes, including those relevant for human evolution and disease. A portal allowing researchers to query their phenotypes of interests for matching genomic regions is developed at http://bejerano.stanford.edu/phenotree/

96.1 HODIN, J.*; FERNER, M.C.; GAYLORD, B.; Hopkins Marine Station, Stanford Univ., Pacific Grove, CA USA, Romberg Tiburon Center, San Francisco State Univ., CA USA, Bodega Marine Laboratory, Univ. of California at Davis USA; *seastar@stanford.edu, mferner@sfsu.edu*

Shake, Settle and Hold: Turbulent shear stimulates settlement in sea urchin larvae

For nearshore invertebrates with dispersing larvae, the greatest set of challenges facing such larvae is to return to and recognize suitable nearshore habitat, to successfully settle there, and to do so at a developmental stage that maximizes the likelihood of survival to reproduction. Much progress has been made identifying environmental cues that larvae use to identify settlement sites; such cues typically operate at or around the scale of a larva. Is it possible that larvae are also sensitive to habitat-scale cues –on the order of meters to kilometers– that would indicate approach to potentially rare settlement sites? Here we show for the first time that marine invertebrate larvae increase their settlement rate following exposure to intense turbulent shear characteristic of high-energy nearshore habitats. We exposed purple urchin larvae (*Strongylocentrotus purpuratus*) to turbulent shear spanning the range found in open ocean conditions to levels they would experience when approaching wave-swept rocky shores. We then immediately subjected the larvae to a settlement test using elevated KCl in seawater. We found that exposure to strong turbulence causes previously refractory, pre-competent larvae to respond to KCl and settle. In other words, turbulent shear appears to trigger these larvae to enter the competent state, thereby allowing them to respond to chemical or other surface cues if they arrive in a suitable area, and then complete settlement and metamorphosis. We discuss a planned comparative approach to further explore turbulence as a habitat indicator, as well as functional tests of settlement timing on juvenile performance.

91.3 HODIN, J.*; MILLER, P.; EPEL, D.; Hopkins Marine Station, Stanford Univ., Pacific Grove, CA USA; *seastar@stanford.edu*

Virtual labs and activities: Tools for students and an opportunity to broaden your Broader Impacts

Our team facilitates educational outreach at the high school and college level by producing high quality, topical, freely-accessible digital tools designed to complement classroom and laboratory experiences in biology and environmental science. The enormously popular *Sea Urchin Embryology* site (launched in 1997) exploits the numerous possibilities of using sea urchins and their embryos in the classroom. Its modern counterpart, *VirtualUrchin*, offers interactive activities and tutorials ranging from microscopy skills to an ocean acidification (OA) experiment, where students explore a current research issue by entering our 'virtual lab bench,' setting up an OA experiment (using real data from our colleagues Thorndyke & Dupont) and measuring the effects on urchin larval growth. We designed our lab bench in a modular fashion, and are modifying it for a lab involving embryo manipulations and microinjection. We have also designed activities on salmon migration, and, most recently, an international high school project allowing students to calculate, explore and discuss their carbon footprints. The modular design of our tools allows us effective dissemination of a wide range of research topics while addressing their broader impacts, now a strict requirement of many funding agencies, notably NSF. We propose a partnership with SICB members, where our media design and curriculum staff works with researchers to develop and disseminate high quality educational outreach activities based upon their research. We discuss possibilities for funding such activities, including inclusion in individual research grant proposals.

48.1 HOEKSTRA, LA*; SIDDIQ, M; MONTOOTH, KL; Indiana University; *lhoekstr@indiana.edu*

Physiological mechanisms of pleiotropy revealed by the accelerating effect of temperature

Organisms respond to environmental change with coordinated changes in metabolic processes. Plasticity in metabolic performance can create a dynamic context for the effects of mutations, particularly for mutations affecting energy use. Here we use *Drosophila melanogaster* nuclear genomes paired with divergent *Drosophila* mitochondrial genomes to explore the effects of mitochondrial-nuclear genetic variation across different thermal environments. Previously, an incompatibility between a particular *D. melanogaster* nuclear genome and *D. simulans* mitochondrial genome was identified that significantly impacts several life history traits when reared under normal laboratory conditions. Mapping the causal mutations revealed that this incompatibility compromises mitochondrial protein translation and oxidative phosphorylation activity. Here we demonstrate that the phenotypic effects of this mitochondrial-nuclear incompatibility are conditional on environmental temperature. Development time and pupation height, both traits associated with energy state, are adversely affected by interactions between mitochondrial-nuclear genotype and increasing developmental temperature. Using flow-through respirometry to measure larval metabolic rate, we find that mitochondrial-nuclear genotype significantly affects the ability of larvae to match their metabolic rate to their thermal environment. Overall we find that the deleterious effects of mitochondrial-nuclear incompatibility increase with temperature, but also that developmental plasticity provides some homeostasis for metabolic rate. Together these results demonstrate thermodynamic constraint on performance via energy limitation, such that inefficiencies in metabolic processes are revealed when temperature accelerates the rate of life.

P2.66 HOESE, W.J.*; SANDQUIST, D.R.; California State University Fullerton; *bhoese@fullerton.edu*

NSF Undergraduate Research and Mentoring in Biology at CSU Fullerton: Southern California Ecosystems Research Program

The Southern California Ecosystems Research Program (SCERP) is a two-year undergraduate research training program funded by NSF - Undergraduate Research and Mentoring in Biology (previously Undergraduate Research and Mentoring in Environmental Biology) that supports annual cohorts of 5. Our goal is to engage underrepresented minority and urban-raised students in understanding the ecology of changing southern California ecosystems via field research, while preparing scholars for graduate school. The program has three major components: an intensive summer field course, independent research with faculty mentors, and weekly group research and professional training meetings during the academic year. The summer field course builds a community of scholars through skills training and social bonding. Faculty mentor individual scholars through independent research that culminates in a senior thesis. First-year scholars present research at national undergraduate conferences (e.g., SACNAS) and advanced scholars present research at discipline-based conferences. Scholars participate in ethics training and prepare for graduate programs. Our annual research showcase celebrates accomplishments and offers family and friends insight into the SCERP experience, which has been critical for developing family support for our underrepresented students. Institutional support provides release time, a room where scholars gather, field vehicles, and a collaborative atmosphere where faculty are recognized and rewarded for their ongoing mentoring of undergraduate research. Career paths are diverse and over the past 10 years, 39 students have completed the program; 35 are active in biology/ecology, 27 students have been accepted to, enrolled in, or completed graduate degrees; 8 PhD and 19 MS.

S9-1.7 HOFMANN, Gretchen/E; UC Santa Barbara; *hofmann@lifesci.ucsb.edu*

Physiological response and local adaptation of marine invertebrates to natural variation in the ocean acidification seascape

Understanding how marine ecosystems will respond to future anthropogenic change – e.g., ocean warming and ocean acidification - is a critical priority for the research community. Central to this goal is knowing whether marine organisms possess the physiological plasticity or adaptation capacity to adjust in a rapidly changing environment and thus avoid extinction. In this presentation I will overview results from our research program that examines physiological plasticity and local adaptation in populations of marine invertebrates along the U.S. Pacific coast. Here, variation in upwelling regimes from Washington to southern California generate spatial and temporal gradients in concentration of CO_2 that shoal to surface waters during upwelling events, bringing cold, low pH waters to benthic populations near shore. These episodic events of natural acidification likely act as a selection regime where some populations may have more resilience to future ocean acidification due to local adaptation. In order to identify the mechanistic underpinnings of calcifying marine invertebrates to acclimatize or adapt to increasing CO_2, we co-located oceanographic sensors for pCO_2 and pH with biological measurements to examine physiological plasticity (e.g., metabolic rates, change in body size and transcriptomic responses). Additionally, genetic surveys have been done to identify genetic variation. The results of the project suggest that there is heterogeneity in seawater conditions across this large biogeographic space – the California Current Large Marine Ecosystem (CCLME) – and that the performance of two invertebrates, sea urchins and mussels, varies with this variation in a manner that suggests local adaptation and differential responses amongst species.

54.6 HOFMEISTER, J.K.K.; University of California, Berkeley; *jenkkhof@berkeley.edu*

Factors influencing distribution and abundance of octopus inside and outside of a marine protected area in a kelp forest rocky reef ecosystem

Anthropogenic influences on the marine environment can result in altered community interactions and food web dynamics. Most research about this topic focuses on keystone or apex predators, but studies focusing on mid-level predators can reveal interspecific competition and predator-prey interactions, resulting in a better understanding of how a certain ecosystem has been altered by anthropogenic activities. Octopuses are important mid-level predators but little is known about octopus population response ecosystem change. This study focused on the factors influencing octopus distribution and abundance inside and outside a marine protected area (MPA) on Santa Catalina Island, CA. It was hypothesized that octopus abundance would be greater in the non-MPA sites, as the removal of fish predators should relieve some predatory influence on their populations. Octopus, fish, lobster, and gastropod distribution and density surveys were completed in 10 sites during Jun-Aug 2012. Rock formation type and percent algae cover data were also collected. Contrary to my hypothesis, preliminary analysis of the data suggests that within similar rock formations, there are more octopuses inside the MPA than outside. Moray eels, a major predator of octopus, are more abundant outside the MPA, possibly explaining this result. Furthermore, when a variety of rock formations are included in the analysis, this trend disappears. This suggests a possible hierarchy of factors influencing octopus distribution in a rocky reef kelp forest, where habitat type is more important than predator abundance. This study highlights the complex interplay of ecological factors that influence where octopus are found in their environment, and calls for further research to understand how octopus will respond to a changing world.

P1.103 HOGAN, BM*; WILCOXEN, TE; HORN, DJ; Millikin University; *bhogan@millikin.edu*

The impact of bird feeding actvities on antioxidant capacity and stress physiology of Central Illinois birds.

Antioxidants are essential to the health of vertebrates through their protection from free-radical damage. Bird feeding is a popular activity in the United States and little is known about the true impact of hobbyist bird feeding activities on the health of wild birds. We hypothesized that total antioxidant capacity would differ between birds that were fed supplemental commercial bird food versus those that were not given supplemental food. Also, we hypothesized that there would be an interaction between stress physiology and total antioxidant capacity. Specifically, we examined antioxidant levels and baseline corticosterone levels over an 18-month period in common feeder-using birds of the Eastern United States - Black-capped Chickadees, Downy Woodpeckers, Northern Cardinals, and White-breasted Nuthatches. We found a significant effect of supplemental food on total antioxidant capacity, but only after birds at the feeder sites had received supplemental food for more than two months. Further, there was a significant correlation between antioxidant levels and baseline corticosterone levels, supporting other vertebrate studies that have revealed a link between antioxidants and corticosteroid activity.

121.1 HOLLEY, J.C.*; WILD, A.L.; SUAREZ, A.V.; Univ. of Illinois, Urbana-Champaign; *jholley@life.illinois.edu*
The pattern of colony structure evolution in the ant genus Linepithema
The Argentine ant, *Linepithema humile*, is one of the most prolific ant invaders worldwide. The success of this invader has been attributed to specific biological characteristics including its expansive colony structure and extreme polygyny; individual nests can contain hundreds of queens and colonies made up of interconnected nests can extend over large areas. While the Argentine ant is well studied, it is unknown whether these same colony traits also occur in other members of the genus *Linepithema*. This information is essential to test hypotheses about why some species become invasive while their close relatives do not. To examine the evolution of colony characteristics in the genus *Linepithema*, we examined nest number and dispersion, and estimate queen number for colonies of eight species in the genus from Argentina, Ecuador and Brazil. Our observations revealed significant variation in colony size, nest number, and estimated queen number both within and between the eight *Linepithema* species. However, *L. humile* was the only species to have colonies with nests dispersed over 250 meters. Polydomy occurs at larger distances in a stepwise fashion within the 'humile' clade, suggesting species have incrementally increased their colony size sequentially, rather than an abrupt change in colony structure evolving solely in *L. humile*. Queen number estimates from field data and Microsatellite analysis suggest a similar pattern; many species within the 'humile' clade have colonies with multiple queens, but none possess as many egg laying queens as often seen in *L. humile* colonies.

142.6 HOLLIDAY, CM*; GANT, CA; NESBITT, SJ; University of Missouri, University of Washington; *hollidayca@missouri.edu*
Form, function, and evolution of archosaur mandibular symphyses.
Archosaurs radiated into numerous trophic niches during the Mesozoic, resulting in a diversity of cranial adaptations and feeding behaviors. The mandibular symphysis is a poorly understood cranial joint which may offer significant insight into cranial development and function, feeding ecology, and evolution in these vertebrates. Using imaging, histology, and dissection data from extant and fossil sauropsids, we investigated the anatomy and evolution of archosaur symphyses with a focus on *Alligator mississippiensis* and crocodyliforms. Adapting Scapino's classification scheme, character complexes of specific clades were identified and their evolution was mapped using a current phylogeny of archosauriforms. During ontogeny, alligators rapidly develop a complex, interdigitated, Class III symphysis coupled with fused Meckel's cartilages. This morphology is a derived for mesoeucrocodylians as protosuchians possess non-interdigitated Class II symphyses. Extinct taxa with the simple Class I condition (e.g., proterochampsids, rauisuchians), rugose Class II (aetosaurs, silesaurids, derived dinosaurs), and interdigitating Class III symphyses (e.g., phytosaurs, crocodyliforms, basal birds) and finally fused Class IV (Neoaves) build the joints in expected ways, though they differ in contributions of bony elements and Meckel's cartilage. Optimization of the different classes of symphyses across a archosauromorph clades indicate that major iterative transitions from plesiomorphic Class I to derived, rigid Class II-IV symphyses and beaks occurred along the lines to phytosaurs, aetosaurs, poposauroids, crocodyliforms, pterosaurs, ornithischians, and birds. These transitions in symphyseal morphology appear to correlate with changes in dentition, the origin of beaks, and potentially inferred diet.

P3.92 HOLLIDAY, CM; SELLERS, KC*; Univ. of Missouri; *kcsty5@mail.missouri.edu*
Enamel thickness as an indicator of feeding behavior in crocodyliforms
Many craniodental features are known to be under selective pressures; thus, insights into dental anatomy may shed light on feeding evolution. Tooth size, complexity, and enamel thickness provide information on dietary adaptations in living and fossil taxa. Fossil crocodyliforms display a wide diversity in dental forms, including the conical teeth of the predatory Alligator, giant molars of durophagous species, and the complicated cusps of putatively herbivorous, chewing species. However, enamel thickness of these specimens remains unmeasured and little is understood about the evolution of internal dental features in crocodyliforms. To test the hypothesis that enamel thickness varies among crocodyliforms with potentially different feeding habits, we investigated the enamel thickness of teeth of different ontogenetic stages and locations in *Alligator mississippiensis*, and then the molariform teeth of two protosuchians, the stem eusuchian *Iharkutosuchus*, the extinct globidont alligatorid *Allognathosuchus*, and finally the extant squamate *Dracaena*. Measurements of enamel thickness, enamel-dentine junction length, and volumes were obtained from analysis of microCT data. Crocodyliform enamel thickness is substantially lower than that recorded for primates. *Iharkutosuchus*, with the most complex cusp morphology, has the relatively thickest enamel, whereas the other taxa possess similar enamel thicknesses, even the megadont *Allognathosuchus*. This suggests that crocodyliform enamel thickness may track with derived chewing behaviors and dietary regimes. More data are necessary to better understand the ontogenetic and phylogenetic patterns of the dentition as it relates to diet and the feeding apparatus.

131.6 HOLMAN, S.D.; GERMAN, R.Z.*; Johns Hopkins University; *rz.german@jhmi.edu*
Sensorimotor interactions in mammalian feeding
The mammalian swallow is considered distinct from oral processing (transport and mastication), involving separate sensorimotor pathways and distinct peripheral sensory nerves. We tested the hypothesis that anterior, oral sensation impacts pharyngeal function by selectively removing sensation to the hard palate. In 8 infant suckling pigs we recorded (1) normal feeding, (2) a long-lasting anesthesia treatment, blocks to the nasopalatine and greater and lesser palatine nerves, and (3) a sham treatment, with saline injection. We recorded 240 swallows, and over 400 suck cycles, with videofluroscopy (60 fps). We tested for differences in the timing of tongue, hyoid and epiglottis movements during swallowing using mixed-model repeated measures ANOVA. In the anesthesia treatment, the timing of hyoid and epiglottis movement was delayed, and the epiglottis took longer to get to its "flipped" position, covering the airway than in the control. In the sham treatment, the hyoid elevated more quickly, and the epiglottis stayed in its flipped position for longer than in the control. The differences in the sham treatment are likely due to discomfort from the injection, whereas the differences due to anesthesia are likely from a reduced sensory signal. These results suggest that integration occurs, in the brainstem or in the cortex, between afferent and efferent signals that govern sucking and swallowing.

P2.170 HOLSINGER, RC*; COOPER, RL; University of Kentucky; *rcholsinger@uky.edu*
The effect of regional phenotypic differences of Procambarus clarkii opener muscle on sarcomere length, fiber diameter, and force development
The opener muscle in the walking legs of the crayfish (*Procambarus clarkii*) is innervated by only one excitatory motor neuron although there are regional differences across the muscle. The distal, central and proximal muscle fibers have varied biochemistry and physiology associated with them, including synaptic structure, presence of troponin T, EPSP amplitudes and facilitation, fiber diameter, sarcomere length, and force generation. Because the differences in synaptic structure and physiology have previously been described, here we will present how the EPSPs and force generation vary between the muscle fiber regions. Innervation of the proximal fibers produced larger excitatory postsynaptic potentials (EPSPs) than those of the central fibers with distal fibers' EPSPs showing intermediate levels. These differences in EPSP amplitudes were correlated with differences in short-term facilitation between the three regions, as various stimulation frequencies of the excitor motor nerve produced different amounts of force in each of the regions as well as the whole muscle, with the proximal developing force most quickly. The proximal muscle fibers were also found to have the shortest sarcomeres when measured with the claw relaxed. These data support the idea that the proximal region of the opener muscle is phasic-like tissue and central is tonic-like tissue.

43.3 HOLT, NC*; MIARA, M; WAKELING, JM; BIEWENER, AA; Concord Field Station, Simon Fraser University; *natalie.c.holt@gmail.com*
The effect of muscle fibre recruitment on force-velocity properties and the implications for Hill-type models
Hill-type muscle models, which are broadly used in human applications, provide a simple way to predict muscle forces based on fibre length and force-velocity properties. However, muscles are not, as these models assume, homogenous and maximally activated. Instead, they are composed of mechanically distinct fibre types; a subset of which is recruited to meet mechanical demand. Therefore, a muscle's force-velocity properties depend on its instantaneous activation state. Failure to account for this is likely to lead to errors in the prediction of dynamic forces. However, no data exist to show the effect of recruitment of fast and slow-twitch fibres on muscle force-velocity properties. This study aims to determine the force-velocity properties of a muscle with selective activation of different muscle fibre types and to evaluate the effect of accounting for recruitment in Hill-type models. The plantaris muscles of anaesthetized rats were stimulated, *via* the sciatic nerve, to activate all muscle fibres or, selectively activate slow-twitch fibres. Isometric and after-loaded isotonic tetani were performed, muscle force and muscle length change recorded, and electromyography performed. Preliminary data show that activation of only slow muscle fibres resulted in lower maximum isometric force (1.98 Ncm^{-2} vs. 4.49 Ncm^{-2}) and maximum shortening velocity (1.11 Ls^{-1} vs. 4.10 Ls^{-1}) reflecting the lower number of active fibres and their mechanical properties. These data will be incorporated into a Hill-type model which accounts for muscle fibre recruitment and the predictions of this model validated against *in vivo* measures of muscle force. (Supported by NIH AR055648)

21.4 HOLT, A.L.*; GAGNON, Y.; VAHIDINIA, S.; MORSE, D.E.; SWEENEY, A.M.; UCSB, Duke University, NASA-Ames, Univ. of Pennsylvania; *holt@lifesci.ucsb.edu*
Photonic enhancement of symbiotic photosynthesis in giant clams
Giant Tridacnid clams, like reef-building corals, harbor and exchange nutrients with the photosynthetic dinoflagellate *Symbiodinium*. These clams are also notable for their bright color patterns, caused by clam cells called iridocytes. These cells are photonically unique, having a structure that is a superposition of sub-wavelength scale layers with a super-wavelength scale sphere, suggesting that they may serve an undiscovered optical function. Here we show that these iridocytes function to reshape and propagate incident sunlight deep into the clam tissue, in spite of the presence of the strongly absorbing algae, producing a remarkably deep photic zone inside the animal. This expanded photic zone likely increases the photosynthetic capacity of the clams, contributing to the animals' storied size. In field experiments in Palau, we used custom-built fiber optic microprobes to measure scalar irradiance with ~10 μm spatial resolution inside the tissue of several species of *Tridacna*. Non-iridescent individuals occur occasionally in wild populations of the species *Tridacna crocea*; these animals allowed us to compare the optical performance of an iridocyte-bearing clam to one without iridocytes. Clams with iridocytes had five-fold more photons available for photosynthesis within their tissues than did clams without iridocytes. This relative enhancement of photosynthesis increases with clam tissue depth. To explain the optical performance of iridocyte-bearing clams, we developed a model of radiative transfer in clam tissue using the discrete dipole approximation to estimate the scattering of a single iridocyte, and Monte Carlo simulation of photon transport. Our models demonstrate that the unique scattering function of the iridocytes is likely responsible for the optical performance of the real clam.

P2.176 HOLTZ, S B*; DICKSON, K A; California State University Fullerton; *sholtz@fullerton.edu*
Extraocular muscles as a potential heat source for cranial endothermy in tunas
In endothermic tunas (family Scombridae) counter-current heat exchangers, *retia mirabilia*, associated with the prootic region of the skull conserve metabolic heat, allowing cranial temperatures to be elevated above ambient water temperature (cranial endothermy). In tunas, although the *retia* have been described, little is known about the source of metabolic heat used in cranial endothermy. We hypothesized that one or more of the six extraocular muscles serve as the source of heat for cranial endothermy in tunas. The specific activity of the enzyme citrate synthase (CS units g^{-1} of muscle) and muscle mass were measured as indices of heat production potential in all six extraocular muscles of five scombrid species: three endotherms– Pacific Bluefin (*Thunnus orientalis*), Yellowfin (*T. albacares*), and Skipjack (*Katsuwonus pelamis*) – and two ectotherms– Eastern Pacific Bonito (*Sarda chiliensis*) and Pacific Chub Mackerel (*Scomber japonicus*). The extraocular muscle with the greatest CS specific activity and relative mass within each species varied interspecifically. The medial rectus muscle in *T. orientalis* was the only extraocular muscle to have both a greater CS activity and mass relative to the other extraocular muscles. In the majority of comparisons, the extraocular muscles of the ectothermic *S. chiliensis* had a CS activity and relative mass greater than or equal to that of endothermic scombrids. Overall, this study did not provide evidence that tunas have evolved an elevated heat production capacity in their extraocular muscles for cranial endothermy. Furthermore, no histological evidence of modification for heat production was observed. Therefore, the presence of *retia mirabilia* alone may be sufficient to elevate cranial temperatures above ambient water temperatures.

S1-2.3 HOLZMAN, Roi; Tel Aviv University; *holzman@post.tau.ac.il*

Suction feeding mechanics and hydrodynamics in fishes

Predation by fish is a major ecological force in aquatic ecosystems, with fish targeting prey from diverse functional groups and taxonomic affiliations. This remarkable trophic diversity presumably underlies the diversity of skull morphologies and predatory behaviors in fishes. However, making implicit connections between specific aspects of morphology or behavior and their effect on feeding can be difficult. This is because prey capture in fishes is mediated by the viscous medium in which they operate. In such medium, the effects of prey's and predator's form and behavior are often non-monotonous and non-intuitive. Recently, an approach emerged that treats the aquatic predator-prey encounter as a hydrodynamic interaction between a solid particle (representing the prey) and the unsteady suction flows around it (produced by the fish). Using first principals and engineering theory, it is possible to integrate the effects of morphology, physiology, skull kinematics, ram, and fluid mechanics on suction feeding performance. I review how this approach, manifested in the Suction Induced Force Field model (SIFF), can be used to study the adaptive significance of prey morphologies, behaviors and sensory abilities. SIFF can also illuminate how different prey types impose different challenges on the predator, and how prey escape response can be modified to maximize prey escape probabilities. Including the hydrodynamic interaction between the suction flows and the prey strengthens the general theory of aquatic predator-prey interactions, and augments our understanding of the evolution of aquatic feeding performance.

P2.144 HONG, T.*; MIRY, S.; CISNEROS, B.; FUSE, M.; San Francisco State University; *tiffanyihong@yahoo.com*

Quantifying hemocyte population changes in Manduca sexta larvae after x-ray irradiation damage

Hemocytes, or insect blood cells, are comprised of about five classes of cells that play key roles in an insect's life cycle and in its immune responses. Immune responses include phagocytosis of invading microbes in a similar fashion to the actions of human macrophages, encapsulation and melanization of larger invaders like parasitic wasp eggs, and cell signaling through the JAK/STAT pathway in response to general tissue damage. The larval tobacco hornworm *Manduca sexta* is a holometabolous insect whose hemocyte population has been quantified under different developmental and immune cues, largely through the use of manual hemocytometry. We therefore sought to (i) develop a flow cytometry technique in the lab to easily quantify hemocyte populations, by comparing our data to that derived by manual hemocytometry, and (ii) quantify changes in the hemocyte population after selectively damaging the highly proliferating imaginal discs using x-ray irradiation. We noted hemocyte populations on the order of 10^6-10^7 cells, using both methods. Moreover, the population was significantly reduced after tissue damage through x-ray irradiation, but not after manual fracturing of the discs. These differences suggest that x-rays may do more than damage imaginal discs, as was previously suggested.

P3.60 HOOKS, AP; Stony Brook University; *hooksap@gmail.com*

Prey Plasticity and Life History Responses to a Native and Nonnative Predator

Phenotypic plasticity in response to environmental stimuli is exceedingly common across systems and taxa. For instance, predation risk in many gastropods can induce a variety of defenses including growing thicker shells, growing shells of different shapes, and developing apertural teeth. Along with changes in shell morphology, gastropods can also delay reproduction when in the presence of predators, reproduce at a larger size, and produce fewer young. However, the role of coevolution between species that produce these defense responses and their consumers is not well known. My study examined the responses of ovoviviparous gastropods (*Littorina saxatilis*) from three different populations (marsh habitat, boulder habitat, and cobble stone habitat) to the presence of a native (*Panopeus herbstii*) and nonnative (*Hemigrapsus sanguineus*) crab predators to investigate the role of coevolution in shaping phenotypically plastic responses. The morphological responses I tested for include differences in shell shape, shell thickness, and shell and soft tissue growth. The life history characteristics I studied include size at first reproduction, fecundity, and offspring survivorship.

S8-1.7 HOOPER, J.N.A.*; HALL, K.A.; EKINS, M.; ERPENBECK, D.; WÖRHEIDE, G.; JOLLEY-ROGERS, G.; Queensland Museum, South Brisbane, Australia, Ludwig-Maximilians-University, Munich, Germany, CSIRO Plant Industry, Canberra, Australia; *john.hooper@qm.qld.gov.au*

Managing and sharing the escalating sponge "unknowns": the SpongeMaps project

Collections of sponges in the Indo-west Pacific have escalated substantially due to pharmaceutical discovery, national bioregional planning, and compliance with international conventions on claims over the seabed and its marine genetic resources beyond existing national jurisdictions. These partially processed OTU collections now vastly outweigh the expertise available to make them better "known" via complete taxonomy, yet for many bioregions they represent the most significant body of knowledge. Increasing numbers of cryptic species are also being discovered from molecular and chemical studies, undetected morphologically, and the uncoordinated and fragmented collection efforts mean that knowledge and expertise gained from a particular project is often lost to future projects without a biodiversity informatics legacy. Integrating these diverse data (GIS, OTUs, images, molecular and other datasets) required a two-way iterative process so far unavailable for sponges with existing biodiversity informatics tools. SpongeMaps arose from the need for online collaboration to integrate morphometric data with barcodes for the MarBOL and SBD projects. It provides: interrogation of existing data to better process new collections; create new OTUs; publish online species pages to interpret GIS and other data for SBD, EoL, ALA, OBIS and other databases; and link automatically to external datasets for taxonomic hierarchy (WPD), specimen GIS and mapping (via OZCAM), molecular (via SBD and Genbank), and images (via Morphbank).

P3.103 HOPKINS, SSB*; ORCUTT, JD; DAVIS, EB; U. of Oregon; *shopkins@uoregon.edu*

Body size reconstruction in a saber-toothed cat from the Late Miocene of North America

The Late Miocene is a critical interval in felid evolution in North America, falling at the end of the "Cat Gap" and encompassing the immigration of the saber-toothed *Machairodus* from Eurasia, the evolution of the enigmatic, endemic *Nimravides*, and the appearance of the continent's first true conical-toothed cats. Because of their value in reconstructing evolutionary trends and behavior, much of the research on Late Miocene felids has focused on cranial and dental remains. However, postcrania are also valuable tools in reconstructing the diversity and ecology of felids from this interval. Limb bones from the Northwest and Great Plains indicate the presence of an aberrantly large felid during the Hemphillian land mammal age. The morphology of these bones is similar to that of *Machairodus*; however, they are up to 35% larger than known specimens of North American *Machairodus*. Length of a complete humerus from McKay Reservoir, Oregon yields a body mass estimate of 228 kg, making it larger than all but a few captive individuals of extant lions and tigers, but an estimate based on circumference (415 kg), suggests that the robust forelimbs of machairodontines may overpredict body size. Regardless of its precise mass, the McKay felid was undoubtedly much larger than its contemporaries, and was in a size class without precedent on the continent. It is unlikely that the difference in size between the large felid and *Machairodus* reflects regional variability, as both have been recovered from the same sites. The large felid may indicate the presence of sexual dimorphism in *Machairodus*, or it may indicate the presence of an as-yet unrecognized species of felid. In either case, it has important implications for the diversification of felids in North America and underscores the importance of postcrania in understanding taxa previously known described mainly from skulls.

P3.46 HOQUE, R.*; JEANLOUIS, A.; CARROLL, M.A.; CATAPANE, E.J.; Medgar Evers College; *catapane@mec.cuny.edu*

Octopamine Has a Dual Effect on Heart Rate of Crassostrea virginica

Octopamine (OA) a biogenic amine first identified in octopus has been well studied in arthropods and gastropods being as a neurotransmitter and hormone. Functions of OA have rarely been reported in bivalves. Previously, we identified OA in cerebral and visceral ganglia (VG), gill, palps and hemolymph of the oyster *Crassostrea virginica*. We found OA is cardio-acceleratory when applied to whole animals and speculated it is a neuro or endocrine agent. We tested OA on heart rate of *C. virginica* by applying OA to VG of whole animals (*in situ*) or isolated hearts. Rate was monitored with a Narco Systems Physiograph. Data were collected and analyzed with a DATAQ DI-700 Data Acquisition System. Average basal heart rate of whole animal preparations was 5.5 beats/min. Superfusion of OA (10^{-6} - 10^{-3} M) to VG increased rates to 9.3 beats/minutes in a dose dependent manner. Average beating rates of isolated heart preparations was 13.4 beats/min. Bath applications of OA (10^{-6} - 10^{-3} M) decreased rates to 0 in a does dependent manner. Actions of OA were prevented by the OA antagonist phentolamine. The study shows OA affects heart rate in 2 different fashions, depending on site of application. Bath applications to isolated heart reveals it decreases heart rate at that site. When applied to VG OA increases rates. A possible explanation for the divergent results is if OA is activating different receptors in the different locations. Superfusing OA to VG causes it to stimulate receptors on different neurons at the same time. The end result would be due to the various nerves being simultaneously stimulated, which is not what happens in the animal's normal physiological actions. Under normal conditions OA would be discretely released to stimulate discrete neuronal circuits at a particular time.

P2.39 HORNER, AM*; JAYNE, BC; Brown University, Univ. of Cincinnati; *angela_horner@brown.edu*

The axial motor pattern and kinematics of terrestrial locomotion of the African lungfish, Protopterus annectens

Transitions between water and land have occurred numerous times in the evolution of vertebrates, but these transitions also occur frequently in the ontogeny and daily behavior of many taxa. Primarily aquatic organisms such as lungfish occasionally move on land to escape unfavorable conditions. Although the African lungfish has diminutive paired fins that aid in slow, benthic locomotion, most aquatic locomotion is powered by axial musculature during lateral undulatory swimming. Previous studies of lateral undulatory swimming in many diverse elongate vertebrates found that axial muscle activity propagates posteriorly and alternates between left and right sides, with onset tending to precede muscle shortening. Eels, snakes , and ropefish also use lateral undulation to move in both terrestrial and aquatic environments, with some adjustments to the timing of muscle activity. We hypothesized that lungfish would similarly exhibit posteriorly propagated alternating waves of unilateral muscle activity during terrestrial lateral undulation on a mud surface. We determined the kinematics and axial muscle activity of terrestrial locomotion in the African lungfish (*Protopterus annectens*) and found that 1) lungfish do not use the path-following terrestrial undulations common to snakes, eels, and ropefish but rather pivot with their heads; and 2) muscle activity in the trunk is nearly synchronous rather than showing a clear posterior propagation. Thus, rather than resembling the terrestrial locomotion of other elongate limbless vertebrates, the standing wave of axial muscle activity observed here is more similar to walking salamanders.

P3.41 HOTARD, K; ZOU, E*; Nicholls State Univ, Thibodaux, LA; *em.zou@nicholls.edu*

Crustacean ethoxyresorufin O-deethylase activity varies during the molting cycle

Ethoxyresorufin O-deethylase (EROD) activity has widely been used as a biomarker for organic pollution. However, since much of crustacean physiology is cyclic, EROD activity could also fluctuate during the molting cycle, which would call into question the use of crustacean EROD as a biomarker for organic pollution without distinguishing molt stages of crustacean specimens. This study aimed to address a fundamental question in crustacean toxicology, that is, is crustacean EROD activity influenced by the molting physiology? Using the fiddler crab, *Uca pugilator*, as the model crustacean, we investigated whether microsomal EROD activity in the hepatopancreas fluctuates during the molting cycle. Results showed that microsomal EROD activity varies significantly during the molting cycle, with the lowest enzymatic activity occurring in late premolt stage. These results clearly show that crustacean EROD activity is influenced by the molting physiology, suggesting that when using crustacean EROD assays in evaluating pollution, only individuals from the same molt stage should be used. Based on an inverse relationship between EROD activity and ecdysteroid titers, we propose that the high level of EROD activity in postmolt and intermolt stages is an additional mechanism used by crustaceans to prevent any untimely rise in ecdysteroid levels.

P1.109 HOULTON, C.*; KNOLL, J.; GLADKOWSKI, L.; RICH, D.; HOLFORD, K.; Purdue University North Central; *choulton@pnc.edu*

Affects of eyestalk ablation on hemolymph protein levels in the crayfish, Procambarus clarkii

Eyestalk ablation (ESX) of crustaceans has been shown to induce molting, vitellogenesis, and sexual maturation. Unfortunately, there is little information available concerning the effects of full (bilateral) or partial (unilateral) ablation on total hemolymph protein concentrations in freshwater crustaceans. In order to examine the general effects caused by ESX on total protein levels, a series of experiments were conducted on the crayfish *Procambarus clarkii*. For this study, only male crayfish were used to avoid fluxes in protein concentration caused by vitellogenesis alone. Crayfish were divided into three groups which were bilaterally ablated, unilaterally ablated, or left intact (control). Hemolymph samples were drawn multiple times over a two week period and the Bradford method was utilized to determine total hemolymph protein concentration. Protein levels peaked at day 7 (13.1 ±3.8 mg/ml) and then again at day 18 (15.0 ±1.1 mg/ml) in all groups, with the highest levels observed in control animals. Protein levels gradually decreased following each peak period suggesting a cyclical pattern in mobilization. Multiple experiments were conducted to investigate this observation (e.g. temperature modification, staggered bleeding, food supplementation), but the putative cause remains elusive.

P3.156 HOWELL, DB*; DICKERSON, BH; DYHR, JP; SPONBERG, SN; DANIEL, TL; University of Washington; *howelld@uw.edu*

Extracellular recordings of wing campaniform sensilla of Manduca sexta demonstrate encoding properties similar to intracellular recordings of haltere neurons.

Insects rely on an array of sensory organs to maintain stable flight. For the hawkmoth *Manduca sexta*, both visual and antennal mechanosensory systems have established roles in flight control. The wings, however, are also imbued with a rich set of mechanosensory structures (campaniform sensilla). Wings experience forces that arise not only from aerodynamic lift and thrust, but also from inertial processes resulting from wing flapping and body maneuvers or perturbations. Sensory information from the wings, therefore, could provide information about body inertial dynamics. Thus, wings may function as both actuators and sensors. Previous intracellular recordings have shown that the campaniform sensilla can encode wing bending with frequencies exceeding 200 Hz, sufficient for reporting rapid inertial events. But intracellular methods limit the number of cells that can be studied. To examine the encoding dynamics of multiple campaniform sensilla simultaneously, we developed methods for recoding multi-unit extracellular activity while mechanically oscillating the wing with a white noise stimulus. Using spike sorting algorithms, we identified single neuron responses within the multi-unit recordings and constructed spike triggered ensembles and the corresponding spike triggered averages (STA), i.e. the average mechanical stimulus that precedes a spike. A subpopulation of extracellular STAs from three animals were similar to those observed in prior intracellular studies of haltere and wing nerves having waveforms with peak deformation stimulus occurring approximately 5 ms prior to spikes. We suggest that this neural information can be used to detect perturbations in the body trajectory, giving wings both sensor and actuator roles.

128.1 HOWEY, C.A.F*; ROOSENBURG, W.M.; Ohio University; *chris.howey@gmail.com*

The Effects of Prescribed Burning on the Landscape and Reptile Abundance

Prescribed burning has become a popular management tool throughout North America; a tool that creates a landscape representing an earlier successional forest. However, little is known regarding how reptile abundances may respond to these landscape changes. Over the past three years, we measured structural and thermal characteristics in addition to the abundance of reptiles in four burned plots and four unburned plots at Land-Between-The-Lakes NRA, Kentucky. We compared habitat characteristics and reptile abundances within plots between years and among plots within years using nonmetric multidimensional scaling and ANOSIM. We determined that habitat characteristics differed for all comparisons (P = 0.001). Burn plots had an increased percentage of grasses and forbs and less canopy cover than control plots. Snakes were able to achieve warmer body temperatures in burn sites. Whereas this was beneficial earlier in the year, it would constrain reptile activity later in the summer. Relative reptile abundance differed between treatments (burn vs. unburned; P = 0.029) and between years within the burn treatment (P = 0.010). In addition to a treatment effect, some reptile abundances were correlated to the thermal and habitat characteristics of plots. As abundance of leaf litter and percent canopy increased, abundance of *Agkistrodon contortrix*, *Thamnophis sirtalis*, *Pantherophis spiloides*, and *Scincella lateralis* increased. Additionally, as percent canopy and vegetation density decreased and percent grass, bare ground, and ground temperatures increased, abundance of *Diadophis punctatus*, *Storeria dekayi*, and *Sceloporus undulatus* increased. These changes also correlate to preferred body temperatures measured in the lab. We suggest that reptiles may not necessarily respond to the actual disturbance, but to the changes in habitat characteristics within the landscape.

100.10 HRISTOV, N.I.*; ALLEN, L.C.; CHADWELL, B.; Winston-Salem State Univ., Winston-Salem, WSSU, Winston-Salem, N.E. Ohio Med. Univ., Rootstown; *nickolay.hristov@centerfordesigninnovation.org*

Flight modalities in the group behavior of free-tailed bats.

From the seemingly chaotic movement of unicellular organisms to the grandiose migrations of ungulates, the collective behavior of organisms belongs to some of the most striking displays in nature. Based on the characteristics of the individual but meaningful in the context of the group, the behavior of animal groups poses an evolutionary paradox – how to balance the proximal and ultimate costs and benefits of grouping. Bats are excellent models for studying collective behavior displaying a range of collective patterns that can offer insight about why and how organisms group. Studying the group behavior of bats poses significant challenges; nevertheless, recent advances in visualization methods give new opportunities to study the natural group behavior of bats in the field. Using an array of high-speed video cameras we recorded (at their natural roost) the emergence and return of a large colony of Brazilian free-tailed bats (*Tadarida brasiliensis*). Three-dimensional reconstructions of the flight kinematics and behavior of individual bats in the column, paired with a reconstruction of the group formation indicate significant differences in the flight behavior and grouping pattern of individual under these two different flight regimes. Emerging bats emerge utilize powered flight, fly slower, are spaced closer and interact more with each other. The group displays characteristics of a formation for predator defense (avoidance). Bats returning to the roost predominantly glide/dive, move faster, space themselves further apart, and rarely contact each other. The formation appears organized by the need to avoid collisions. How morphology, ecology, and flight performance of bats affect these two flight regimes remains to be studied.

110.2 HU, Y.*; PARSONS, K.J.; ALBERTSON, R.C.; Univ. of Massachusetts, Univ. of Glasgow; *Yinan@cns.umass.edu*

Evolvability of the cichlid jaw: New insight into the genetic basis of phenotypic integration

Phenotypic integration refers to the pattern and magnitude of covariation among a set of traits, and is thought to substantially influence evolvability. Theory predicts that relatively low levels of integration will facilitate evolution as it allows distinct anatomical units (i.e., modules) to evolve independently from each other. On the other hand, high levels of integration may constrain the rate and/or direction of evolution as it presets a pattern of correlation among traits. To evaluate the genetic basis of phenotypic integration and its role in evolutionary processes, we developed a new method that estimates an individual's integration level as the relative contribution of each individual to a population's integration level. We then applied this metric to the lower jaws of an F2 hybrid population derived from a cross between two Lake Malawi cichlid species with alternate feeding strategies in order to genetically map integration levels. Our analysis detected two QTLs and two epistatic interactions that potentially contribute to integration within the cichlid mandible. Notably, alleles from the phenotypically derived and ecologically specialized species, which has significantly higher level of integration than the more generalized species, increase integration level in the F2 population. Our results suggest that integration of the cichlid jaw has a tractable genetic basis. They are also consistent with the hypothesis that ecomorphological specialization may arise at the expense of evolvability (i.e., high integration), shedding new light on the mechanisms that both promote and limit craniofacial diversity within this group.

P1.110 HUBBLE, CN*; WILCOXEN, TE; HORN, DJ; Millikin University; *chubble@millikin.edu*

Using multiple measures of individual condition to examine the impact of commercial bird food on wild birds.

Many metrics have been used to assess the health of free-living vertebrates, with conflicting findings and differential support for these metrics. We examined the impact of bird feeding activities on individual condition in Central Illinois feeder-using species of birds. Specifically, we examined hematocrit, total plasma protein, fat deposition, and a body condition index that incorporates multiple structural measurements and mass to examine effects of commercial bird food on the condition of birds relative to birds at similar, nearby sites without feeders. In this 18-month study, we captured approximately 1200 birds of 11 species that are known to regularly use feeders. We found that feeders had a positive or neutral effect when it came to each of the measures and there was no evidence of a negative effect relative to control sites, at least in these measures of condition. There were also differences between the sexes and among species and our findings lend some support to certain measures of condition over others. Understanding differences in individual condition among songbirds and using multiple measures of condition allow us to understand the complex effects of an abundant and predictable food source in the natural habitat of birds.

115.1 HUBEL, T.Y.*; USHERWOOD, J.R.; Royal Veterinary College; *thubel@rvc.ac.uk*

Torques in running and feet in walking - how deviations from point mass models give insight into bipedal locomotion

Reductionist point mass models are useful in understanding the underlying mechanical principles of walking and running. However, they are inevitably incomplete representations of true animal gaits. Exploring simple deviations from the point mass model can be give useful insights into human locomotion. Here we consider the implication of two small deviations from pure point mass models. In walking, foot structure and function deviates considerably from the point-foot assumption of point-mass compass-gait models. We suggest that the human heel-sole-toe stance during walking, and the structure of the lower limb, allows calf and shin muscles to be loaded when needed but largely unloaded during the passive vaulting phase, reducing the energetic costs of opposing isometric forces. While power is not, fundamentally, required to provide isometric force, the metabolic costs of resisting forces with muscle can be considerable, and the human foot provides a mechanism for limiting this cost. In running, the ground reaction forces pass close to the center of mass; pitching torques and motions are small. However, sending the GRF through the CoM comes at a price: the resulting fore-aft forces require mechanical and muscular work. Humans actually run with measurable – albeit small – torques, with GRFs missing the CoM. This allows a near-optimal compromise between reducing kinetic energy fluctuations and avoiding spinning, but is only possible because we are not point masses. While "torque-based" energy savings are small in humans, other animals such as kangaroos with their peculiar long-head/long-tail structure could benefit considerably from a non-zero-CoM-torque strategy.

P3.172 HUBER, SJ*; WILCOXEN, TE; HORN, DJ; Millikin University; *shuber@millikin.edu*

Stress physiology of songbirds in response to bird feeding activities.

The purpose of this study was to observe stress physiology and its interaction with reproductive endocrinology in relation to variation in food availability among communities of common feeder-using birds. Over an 18-month period, we observed two measures of stress physiology, heterophil to lymphocyte ratios and baseline corticosterone levels, and made comparisons among birds captured at natural areas with feeders of commercial bird food and similar sites without feeders. We also tested for correlations between the indicators of stress and the sex steroids testosterone and estradiol in males and females respectively. We hypothesized that in the presence of supplemental food, there will be a lower heterophil to lymphocyte ratio and lower corticosterone levels in birds, exemplifying stress-reducing effects of an abundant, predictable food source. Further, we predicted that greater stress would correlate with decreased levels of sex steroids. Overall, our findings offer new information on the relationship between variation in food availability, stress and reproductive physiology in a songbird community.

130.3 HUBER, D.R.*; NOAKER, D.E.; STINSON, C.M.; TATE, E.E.; ANDERSON, P.A.; BERZINS, I.K.; The University of Tampa, University of South Florida, Mystic Aquarium, One World, One Water, One Health; *dhuber@ut.edu*

Etiology of spinal deformities in captive sandtiger sharks Carcharias taurus

Spinal deformities plague captive sandtiger sharks *Carcharias taurus*. Husbandry practices, animal behavior, nutritional physiology, and spinal biomechanics were explored to identify the causes of spinal deformities to develop better husbandry guidelines and reduce dependence on wild stocks for exhibit specimens. Spinal deformity is associated with collection locale and method and usually manifests within 4 years of captivity with affected sharks characterized by lethargy. Aquarium size is negatively associated with disease prevalence and captive sharks (regardless of condition) spend 95.5 % of their time actively swimming and only 0.5 % gliding, suggesting abnormal locomotion that lacks equivalence of phases. Affected sharks spend less time gliding than healthy sharks, which is coupled with constant lateral stress on the spine due to non-linear swimming that accounts for 99.7% of locomotion (regardless of condition). Blood chemistry revealed that affected sharks are deficient in potassium, zinc, and Vitamin C, which play critical roles in skeletal development and maintenance. Biomechanical analyses revealed that the flexural stiffness of spinal columns from healthy sharks was greater than that of affected sharks due to greater second moment of area. The force required for spinal buckling, as well as the compressive stiffness, yield strength, yield strain, ultimate strength and mineral content of individual vertebrae were significantly greater in healthy sharks. However, the compressive stiffness and ultimate strength of vertebrae from healthy specimens were lower than those of other species, suggesting an inherent predisposition for spinal deformity in captive settings.

1.8 HUEY, R.B.*; KINGSOLVER, J.G.; Univ. of Washington, Seattle, Univ. of North Carolina; *hueyrb@uw.edu*

Thermal sensitivity of ectotherm growth: interactions of food quantity and food quality with climate change

How will the thermal sensitivity of growth rates of ectotherms be altered by climate warming? For predators fed ample food, growth rate increases with body temperature up to an optimum level and then drops rapidly at high temperature. But for predators fed restricted food, their growth at all temperatures is reduced; and the optimal temperature shifts **lower**, because energy gain at high temperature is insufficient to compensate for elevated metabolic rates. A simple energetics model (dating to J.R. Brett) predicts that if food levels decline, then ectothermal predators should preferentially select lower body temperatures. Note, however, that if food quantity declines as climate warms, then predators are caught in an energetic bind: climate warming may force them to be active at elevated body temperatures, even though energetics favors lower body temperatures: “metabolic meltdown” will result. But for herbivorous insects, the limiting resource is often nitrogen, not energy. When feeding on abundant but low-nitrogen plants, insects can grow fastest at relatively high body temperatures, because this facilitates compensatory consumption. Thus if food quality declines as climate warms and as atmospheric CO_2 increases (likely reducing leaf nitrogen and increasing secondary defensive compounds), then herbivores may achieve highest growth rates at elevated body temperatures. For herbivores then, climate change may increase consumption rates, growth rates and optimal temperatures. Thus, the effects of climate change on the thermal sensitivity and magnitude of ectotherm growth may reflect complex interactions with tropic level, food quantity, and food quality. Supported by NSF grants to RBH and to JGK.

30.3 HUFFARD, CL*; CALDWELL, RL; California Academy of Sciences, University of California, Berkeley; *chuffard@gmail.com*

Female proceptive behavior in octopus (Abdopus aculeatus d’Orbigny 1834)

During extensive observations of the octopus *Abdopus aculeatus in situ*, we recorded a postural proceptive display given by females engaged in sexual activity. Nearly half of all mating females raised their dorsal arms and coiled them at the tips, typically once mating had already begun. Females that gave this display procured matings more quickly than did non-displaying females, however its use was not associated with males remaining in association with the female for extended guarding. This display was most frequently given by small females, perhaps to obtain additional matings with males despite male preference to spend time guarding and mating large females, in a population where many small females are aggressive with males.

86.1 HUMFELD, S. C.*; SCHWARTZ, J.; MARSHALL, V. T. ; University of Missouri, Pace University, University of Scranton; *humfelds@missouri.edu*

Call timing preferences in gray treefrogs, Hyla versicolor

In a variety of animal taxa, females often show preferences based on the relative timing of sexual advertisement signals produced by different males. Such preferences may be important selective forces on communication systems, leading to phenomenon such as synchronous displays or avoidance of overlap. In a preliminary study, we examined the preferences of female gray treefrogs for calls broadcast with different timing relationships. We systematically modified the interval between the onset of calls. At the longest intervals (900 and 500 ms), calls did not overlap but exhibited a distinctive leader-follower timing relationship. At the shorter delays (225 and 25 ms), calls overlapped in time. With the overlapping calls, we further experimented with pulse overlap, in which pulses were interleaved or overlapped so that pulses also exhibited leader-follower timing relationships. The results of two-speaker choice tests show that females increasingly preferred the leading call as the interval between signal onset was shortened, and this effect was more distinctive with shorter-than-average calls. However, this preference for a leading call could be reversed if the pulses of following calls were positioned in a leading position relative to the pulses of the other call. Finally, by testing calls of different durations, we conclude that the preference for leading calls was fairly weak compared to the preference for longer call duration. We discuss the possibility of significant geographic variation in this preference.

23.4 HUNT, K.E.*; ROLLAND, R.; KRAUS, S.; New England Aquarium, Boston MA; *tweedoo@gmail.com*
Respiratory vapor sampling for endocrine studies of free-swimming baleen whales
Physiological studies of baleen whales have been severely hampered by the inability to capture and sample living animals. Recent developments in noninvasive sampling methodology, including fecal sampling and blow sampling, have improved this picture. Here we focus on blow sampling (sampling of respiratory vapor) and its potential application for endocrine studies of free-swimming baleen whales. We present data from a preliminary study on a well-known population of North Atlantic Right Whales (NARW, *Eubalaena glacialis*) in the Bay of Fundy. Our initial questions were (1) whether blow sampling is feasible for routine use at sea, and (2) whether any steroid or thyroid hormones are detectable in NARW blow samples using standard immunoassay techniques. Using a pole-sampling method, we collected 55 blow samples from individually known NARW during 7 days at sea in 2011. In good conditions, sampling rate ranged between 10-22 samples per day, and most samples were large enough to test for multiple analytes. Using RIA and EIA methods, we detected cortisol, progesterone, testosterone, estrogens, and thyroid hormones in NARW blow. Parallelism validations were successful. Thus, it appears that most hormones that are present in whale blood are also present in whale blow. Our next goal is to develop methodology for quantifying hormone concentration relative to a control substance that is secreted at constant rate in lung fluid, in order to control for variable water content. Additional benefits of this technique are that individual animals can be sampled repeatedly, and the sampling is entirely noninvasive. Though many validations remain to be done, blow sampling holds considerable promise for opening the black box of baleen whale physiology.

P3.168 HUNT, N/H*; STERGIOU, N; University of California, Berkely, University of Nebraska, Omaha; *nathaniel.hunt@berkeley.edu*
Manipulation of the Structure of Gait Variability with Rhythmic Auditory Stimulus
Gait is a rhythmic behavior that may be analyzed via discrete measures taken once per cycle, such as inter-stride time interval. Nonlinear analyses of the dynamics of a series of discrete measures identifying power law scaling or entropy are complements to more traditional linear analyses. These nonlinear measures quantify a specific temporal structure of gait variability in young healthy walkers that deviates systematically with the onset of aging or gait pathology. While gait therapies often focus on restoration of linear measures such as mean step length or the standard deviation of toe clearance, no studies investigate the effects of restoration of nonlinear measures of gait. We approach the restoration of nonlinear measures by *driving gait rhythms with individualized rhythmic auditory stimulus*. A strong, natural auditory motor coupling in humans promotes walking in synchrony with an external auditory stimulus. Taking advantage of this synchronizing phenomenon we designed individualized rhythmic auditory stimulus with a target temporal structure that was prescribed by one of three colored noise distributions (white, pink or brown noise). Ten subjects walked overground to each auditory stimulus for at least 612 strides. The monotonically increasing entropy and power law scaling patterns in the rhythmic auditory stimulus conditions were mirrored in the inter-stride time interval variability patterns of the subjects. This result opens the opportunity for experimental manipulation of these nonlinear measures, thus an investigation of a possible causal relationship between these measures and beneficial characteristics of gait.

102.1 HUNT VON HERBING, I.*; PAN, F.; MAYORGA, M.; University of North Texas, Denton, University of Southern California, Los Angeles, Autonomous University of the State of Mexico, Toluca; *vonherbing@unt.edu*
When Metabolic Scaling Relationships Collapse: The Thermodynamic Nightmare of Development
In a series of unique experiments in which developing *Danio rerio* were exposed to a combination of chronic and acute high temperature and hypoxia treatments, metabolic scaling relationships collapsed in most conditions. Given the unexpected results, non-equilibrium thermodynamics was applied to understand the underlying mechanics. In this study, larvae were reared in a 2 (28 & 31°C) x 2 (PO_2 of 10 & 21 kPa), factorial design from fertilization to 7 days post-fertilization. Larval oxygen consumption was measured at: 1) normoxia (PO_2 of 21 kPa at 28°C); 2) acute hypoxia (PO_2 of 10 kPa at 28°C); 3) acute high temperature (PO_2 of 21 kPa at 31°C); and 4) acute hypoxia & high temperature (PO_2 of 10 kPa at 31°C). Larvae reared in normoxia when exposed to acute hypoxia showed steep allometric scaling relationships; b of 1.79 ± 0.28 (28°C) & 1.33 ± 0.37 (31°C) compared to b of 0.80 ± 0.29 (28°C) and 0.69 ± 0.23 (31°C). In contrast, larvae reared in chronic high temperature and hypoxia had no significant metabolic scaling relationships. As living systems rely on vascular networks for heat and energy input and dissipation, power law relationships between metabolism and mass may be expected. In development, vascular systems are immature, and rapid changes occur across many gradients (chemical, thermodynamic and pressure), which affect the equilibrium of a dynamic, open (non-linear) system. In our experiments rapidly developing larvae exposed to acute and/or chronic abiotic change may experience energy inputs that exceed rates of dissipation. Thermodynamic gradients and their coupled transport processes may begin to break down resulting in disorder and collapse of metabolic scaling relationships creating conditions inimical to life.

115.2 HUNTER, A*; WILSON, R S; The University of Queensland; *r.wilson@uq.edu.au*
Can we improve a footballer's kicking performance using optimisation theory?
How much effort should an individual use when executing a physical task? And how much effort should one use if a physical task or skill relies on both accuracy and power? In this study, we explored the idea that individual animals possess the capacity to optimise their effort when performing a physical task and their effort is individual-specific. To achieve this, we used soccer players shooting a football at a goal as our model study system as this task simultaneously requires both power and accuracy; such that, the shooter needs to accurately kick the ball towards the corner of the goal and fast enough to beat the goalkeeper. However, when more effort is put into striking the ball harder it is likely to lead to a compromise in accuracy. Players of different skill level/experience were directed to kick balls at a target using different levels of effort. We used 3D-motion digital video cameras to record foot velocity at 100 Hz during each kick, which was utilised as our index of kicking effort. Based on these data, we could then determine each individual's trade-off between accuracy and power so that we could calculate their optimal kicking effort for a given distance from the goal. All individuals also completed a game relevant task in which they were asked to kick the ball using a level of effort of their choice - with the aim to successfully hit the target and beat the goalkeeper. We then tested whether individuals accurately optimised their kicking effort by comparing their predicted optimum effort with their self-selected effort. We will discuss our results in the context of optimal performance theory and the application of these techniques for studying human performance and evolution.

P1.1 HUNTER, A*; WILSON, R S; The University of Queensland; *r.wilson@uq.edu.au*
Power, accuracy & deception: using evolutionary theory to improve scoring success in soccer penalties
A successful penalty can mean the difference between winning and losing in the world cup final and can potentially earn professional clubs millions of dollars with a single kick of the football. But what performance traits underlie a player's ability to be a great penalty-taker? Is it their kicking accuracy or power, their nerves of steel or maybe their artful ability to deceive others? During my project I am investigating the underlying basis of penalty success in soccer players using both analyses of performance and deceptive strategy. The soccer penalty represents a simplified game between the penalty-shooter and the goalkeeper and offers a novel system for studying the evolution of human performance and deception. Using models of performance optimization and deception, I am exploring this idea in an attempt to both predict and improve scoring success during penalty-taking. My early PhD work has focused on the trade-offs between power and accuracy during the penalty kick but during this poster presentation I will be discussing my planned future experiments over the next year.

P1.181A HUSAIN, DI*; MAXKWEE, K; MEKDARA, PJ; LENT, DD; GOTO, JJ; MULLER, UK; California State University, Fresno; *dhusain@csufresno.edu*
Assessing the Role of Glutamate in Insect Motor Control
Glutamate is a major excitatory neurotransmitter in the nervous system of insects with receptors in locomotory control areas, such as the central complex in the central nervous system (CNS) and the neuromuscular junctions in the peripheral nervous system. While the role of glutamate at the neuromuscular junction is well understood, we know less about its role in the CNS. To explore the role of glutamate in locomotory control, we treated fruit flies (*Drosophila melanogaster*) with the glutamate agonist beta-Methylamino-L-alanine, which has been shown to affect locomotory control centers. We quantified the walking behavior of fruit flies during straight climbing in an incline walking arena and while maneuvering around obstacles in a corner walking arena. We found that treated flies have poorer locomotory ability than control flies (they lose their footing during incline walking) because their foot placement was affected by the glutamate agonist. During the stance phase, treated flies placed their feet closer to their body, which resulted in smaller triangles of support and reduced stability. We did not find that foot placement was more erratic – just like the control flies, treated flies generated a nearly equilateral triangle of support and the shape of the triangles of support was not more variable than in control flies. Preliminary data also suggested that walking speed, walking motivation, and maneuverability were affected.

138.1 HUSAK, J. F.*; KEITH, A. R.; WITTRY, B. N.; Univ. of St. Thomas; *jerry.husak@stthomas.edu*
Making Olympic lizards: The effects of sprint and endurance training in lizards
Exercise training is well known to affect a suite of physiological and performance traits in mammals, but training effects are less clear in other vertebrate groups. We examined performance and physiological differences among green anole lizards that were trained for sprinting or endurance, or not trained at all. Trained lizards underwent an increasingly rigorous training regime over 8 weeks, whereas untrained lizards were handled as a control. Sprint-trained lizards were run an increasing number of times per day, three days a week, on an inclined racetrack. Endurance-trained lizards were run for 30 min per day, three days a week, on a treadmill that was progressively increased in incline. All three groups improved in endurance capacity by at least 10% on average, and all groups decreased in sprint speed on average, but there were post-treatment differences in performance capacity. Lizards trained for endurance had significantly higher post-training endurance capacity compared to the other treatment groups, but groups did not show post-training differences in sprint speed. Acclimation to the laboratory environment and training explain some of our results, but we explored potential mechanistic explanations for these results as well, including differences in hematocrit, heart size, muscle masses, proportion of muscle fiber types, and response of different muscle fiber types to specialized training. Our results offer some caveats for researchers, but they reveal insights into how muscles and performance are impacted by training.

P2.90 HUSSAIN, Y.H.*; RIFFELL, J.A.; University of Washington; *hyasmeen@uw.edu*
Finding the Path Between Sperm Chemotaxis and Fertilization Success
Reproduction is arguably the most critical point in an organism's life history, yet many details of this process are still not fully understood. A critical step in fertilization is a sperm's requirement to locate a conspecific egg while out-competing sperm from other males. This is particularly important for marine invertebrates that broadcast their gametes into the ocean environment, where there is only a short window of time to interact. One mechanism that facilitates gamete interactions is a sperm's ability to perform chemotaxis to egg-derived compounds, a phenomenon in which sperm orient to an attractant gradient around an egg. However, it is not clear how much chemotactic ability differs in the sperm between males, and whether these differences affect fertilization success. To address these knowledge gaps, we use gametes from the sea urchins *Arbacia punctulata* and *Strongylocentrotus purpuratus*, both well-studied models for sperm chemotaxis. Using a microfluidic laminar-flow device, we established a chemical gradient with known chemoattractants and simultaneously imaged sperm motility, orientation, and calcium responses under simulated hydrodynamic conditions. We ran fertilization assays in conjunction with these chemotaxis studies in order to assess the reproductive consequences of the sperm's response to chemical signals. Preliminary results comparing the motility of males before and after chemoattractant exposure suggest a trend towards significance as well as a large range of motilities within and between individual males. Fertilization assays also show a tentative correlation between these substantially different sperm motilities and the subsequent reproductive outputs, suggesting that differing responses to the same chemoattractive stimulus may influence reproductive success.

89.4 HUTCHINSON, JR; The Royal Veterinary College, Structure and Motion Laboratory; *jrhutch@rvc.ac.uk*

Assessing the evidence for the evolution of asymmetrical gaits in Crocodylomorpha

Some Crocodylia use asymmetrical gaits, including bounding and galloping, at near-maximal speeds. This ability is commonly assumed to have evolved in stem Crocodylomorpha, related to changes in limb/axial morphology. Body size is typically assumed to limit the capacity to use asymmetrical gaits, but it is unknown how size might mechanistically constrain such athleticism. I report on collaborative efforts to reconstruct these constraints and how they shaped locomotor evolution in the crocodile lineage.

Experimental data (50-100 Hz video; also limited forceplate data) were collected from 189 near-steady strides of 32 individuals from 15 species of Crocodylia across a broad speed range (0.15-4.4 m s-1). Locomotor parameters were quantified for each stride and compared statistically. These experimental data reveal the absence of asymmetrical gaits in Alligatoroidea, whereas Crocodyloidea >2-4m total length do not use asymmetrical gaits. Otherwise, many aspects of crocodylian locomotion vary more within species than among them.

Additionally, for 6 taxa, we conducted scaling analyses of anatomical data for the 78 limb muscles of 18 individuals (0.13-278 kg) (e.g. physiological areas calculated from muscle mass, pennation and fascicle length) to examine whether limb muscles showed structural changes for supporting faster gaits at larger sizes. Alligatoroidea and Crocodyloidea lack any strong evidence for allometry of limb muscle architecture. Similarly, while axial “bracing systems” could constrain/enable such gaits, their biomechanics remains only qualitatively explored. Better evidence for limb/axial function-form linkages in extant Crocodyloidea, as well as quantitative morphology of fossils, could resolve this mystery and reconstruct when, how and why asymmetrical gaits evolved in Crocodylomorpha.

80.5 HUYNH, TL*; EVANGELISTA, D; MARSHALL, CR; Univ. of California, Berkeley; *huynhtony@berkeley.edu*

Analysis of the fluid flow through the complex internal respiratory structures of an extinct Paleozoic echinoderm

Blastoids were a group of stalked, sessile echinoderm preserved in rocks that span the middle Ordovician (~470 mya) to the end of the Permian (~250 mya). These extinct echinoderms possessed hydrospires, uniquely complex internal thecal structures with putative respiratory function. Here, we present measurement and visualization of flow within the hydrospires using a 3D-printed and Reynolds-similar physical model of the interior of a hydrospire of the blastoid *Pentremites rusticus*, to examine in further detail possible functions of the hydrospire. Specifically, the model allows examination of the extent to which the pattern of flow within the hydrospire kept oxygen-rich incurrent water separated from water that had already been depleted of oxygen. If the flow pattern within the hydrospire fails to keep these two bodies of water separate, this would suggest some other function for the hydrospires. In addition, the model also allows for determination of whether active pumping would have been required to achieve optimal respiratory function, or whether passive pumping alone was sufficient. Furthermore, the model allows for testing of the hypothesis that the need for removal of digestive waste, thought to be associated with the hydrospires, is responsible for some unusual aspects of the hydrospires, such as the conical shape of the putative excurrent canals and the presence of cover plates over the remarkably large excurrent openings.

64.1 IAMS, SM*; BEATUS, T; GUCKENHEIMER, J; COHEN, I; Bowdoin College & Cornell University, Cornell University; *smi6@cornell.edu*

Roll-based sideways motion of mosquitoes in free flight

The mosquito body plan and flight characteristics are qualitatively different than those of other well-studied Dipterans. Mosquitoes have a long and slender body, and often fly with a sideways velocity component, so that their body heading does not align with their flight track. They produce substantial sideways accelerations during flight. While flight kinematics and control have been characterized for moths and for many flies, they have not been studied for mosquitoes. Here we report the first quantitative study of mosquito flight kinematics during free flight. We use high speed video and novel image analysis methods to extract the position and orientation of body, wings and legs. We show that mosquitoes generate sideways thrust almost entirely by banking their bodies, and quantify this relationship to show that the sideways deflection of flight forces is driving this sideways acceleration. We find that mosquitoes are almost always generating some sideways thrust due to roll, making roll stability and control critical to their overall flight control. Although yaw control and pitch control have both been carefully explored in many Dipterans, roll control is not commonly explored. However, for mosquitoes, understanding roll generation and roll dynamics is particularly essential to understanding how they move.

61.5 IRIARTE-DIAZ, J.*; ROSS, C.F.; University of Chicago; *josdiiri@gmail.com*

3D kinematics, motor control and bone strain during feeding in non-human primates

In recent years substantial advances have been made in our understanding of the feeding mechanics of non-human primates. On one hand, researchers have investigated the relationship between the three-dimensional displacement of the mandible and food material properties as well as species-specific differences. Muscle activation patterns have also been recorded in multiple species and patterns of variation have been identified at different hierarchical levels suggesting the importance of intra and inter-individual variability. This variability derives in part from the structural complexity and redundancy of the masticatory muscles. However, little work has been done on evaluating how differences in patterns of muscle activation relate to differences in mandibular movement, and how this interplay affects the forces applied on the mandible. Such interaction, although often ignored due to lack of data, is essential to understand how the masticatory apparatus in primates adapts to changes in food material properties and how this affects feeding behavior. Using a large dataset of 3D mandible kinematics, muscle activation patterns and, in some cases bone strains, recorded simultaneously, we investigate the relationship between all these factors in two species of non-human primates, *Macaca mulatta* (macaques) and *Cebus sp.* (capuchins). Our data suggest that differences in loading regimes in the mandible are not driven as much by differences in food material properties as by differences in feeding behavior, and its associated variation in muscle activation patterns and mandibular movement.

27.2 IRSCHICK, D.J.*; CROSBY, AJ; FEDERLE, W; Univ. Massachusetts Amherst, Cambridge University, UK; *irschick@bio.umass.edu*

The evolution of Gecko adhesion: An integrative perspective

Gecko adhesion has received a great deal of attention in the popular media and among scientists aiming to mimic their adhesive properties for human use. However, while there has been a general neglect of both an evolutionary perspective and one that integrates synthetic and empirical data. Our approach is to examine gecko adhesion on a wider perspective by examining the wide evolution of toepad anatomy, and to understand how the scaling of adhesion can be predicted by morphological and anatomical features. We place this approach in the context of the recent discovery of GeckskinTM, which unites anatomy and a whole-organism perspective, and which represents a breakthrough in synthetic gecko adhesion. This approach differs markedly from other approaches that examine only setae, and which largely ignore the integrative organismal features of the gecko foot. We then provide a prospectus for the future of gecko adhesion through a more integrative perspective.

125.4 ISERI , V.J. ; KLASING, K. C.*; Univ. California, Davis; *kcklasing@ucdavis.edu*

The cost of an immune response to Escherichia coli in Gallus gallas

There are a variety of costs associated with an immune response to potential pathogens. These costs were quantified in a model using the domestic chicken challenged with an i.v. dose of dead E. coli that was sufficient to cause a vigorous innate immune response and protective levels of immunoglobulins, but did not trigger immumopathology. In young growing chicks, a systemic E. coli challenge results in a 29% decrease in growth. About 2/3 of this decrease is due to decreased food consumption and about 1/3 is due to the immune response and accompanying metabolic inefficiencies that include impaired digestion and increased metabolic rate. Quantification of the amount of lysine, which was used as a sentinel for nutrient flux, in the cells and proteins of the systemic immune system indicates that they contain only 0.39% of the chicken's entire lysine content; however this amounts doubles during the acute phase response to E. coli (first day). The adaptive response (cellular and antibody) occurs much later, is much smaller and is fueled by the decline in the innate response. To put this in perspective, the additional lysine needed to support the acute phase response is equivalent to 5% of the lysine in the two major pectoralis muscles. Thus, the costs of a protective immune response are very high but they are not dominated by direct consumption of nutrients by the systemic immune system.

P2.127 ISRAEL, S.*; DEBAN, S.M.; Univ. of South Florida, Tampa; *segalli@mail.usf.edu*

Functional morphology of the smallest ballistic tongue

An elastic-recoil mechanism in the tongue-projection system has evolved independently in three lineages of plethodontid salamanders. This mechanism increases performance and provides thermal insensitivity to projection, allowing an advantage over muscle-powered movements at lower temperatures. We hypothesized, based on its morphology and phylogenetic relationships, that the miniaturized bolitoglossine *Thorius*—one of the smallest vertebrates—uses an elastic tongue-projection mechanism like other bolitoglossines (e.g., *Bolitoglossa*). We asked if its small adult size (~20 mm SVL) limits its ability to modulate its tongue movements as do other plethodontids or has other performance consequences. Morphological examination revealed a reduced number of myofibers in its tongue muscles (e.g., 6-8 fibers in the retractor muscle), and unusual folding of the hyobranchial apparatus. High-speed imaging (15 kHz) and inverse-dynamics analysis of the tongue projection and retraction movements revealed that tongue projection in *Thorius* is ballistic and elastically-powered, and shows low thermal dependence (Q_{10} of peak velocity <1.5), while retraction is muscle powered and non-elastic. *Thorius* modulates its tongue movements in response to prey distance and appears to suffer no significant performance consequences of its reduced body size.

103.2 IYENGAR, E.V.; Muhlenberg College; *iyengar@muhlenberg.edu*

The function of shell wiping in the marine snail Calliostoma ligatum

Individuals of the marine snail *Calliostoma ligatum*, similar to other congeners, are unusual in that they can extend their foot over the apex of their shells and use the back of the foot to wipe the entire surface of the shell. Shell-wiping leaves behind a thin film of mucus; the removal of the mucus using a paper towel renders the shell less slippery. Various functions have been proposed for the purpose of shell-wiping in *Calliostoma* spp., including defense from predators and procurement of food. Because of this wiping behavior, *Calliostoma ligatum* shells are typically cleaner than surrounding surfaces. However, certain epibiotic species, most notably the slipper limpet *Crepidula adunca*, specialize on this host species. In choice experiments, individuals of *Crepidula adunca* were neither more or less likely to attach to wiped compared with unaltered shells of *Caliostoma ligatum*, nor did predators (sea stars and crabs) discriminate based on this parameter. Host snails wipe their foot over the shell of established epibiotic *Crepidula adunca*. At the end of a wiping bout, individuals of *Calliostoma ligatum* retracted their foot before it passed over the mouth, so procurement of food is an unlikely reason for shell wiping. Time lapse video documented that animals did not increase their rate of shell-wiping after the mucus had been removed from the shell. After contact with predators, snails were more likely to increase their rate of movement and did not seem to increase the frequency of shell wiping, but there was variation in this response. Thus, the shell wiping behavior in *Calliostoma ligatum* is more likely to have evolved to remove non-specialist fouling organisms than to encourage or discourage specialist epibionts, discourage predators, or provide food to the snail.

39.1 JACKSON, BE*; HEDRICK, TL; Univ. of North Carolina at Chapel Hill; *jacksobe@live.unc.edu*

Hovering with a high speed wing: How cliff swallows push the envelope of wing shape

The energetic demands of flight impose strict constraints on the morphology of flying animals. As a result, functional morphologists often predict tight form-function relationships between wing shape and flight ability, and place wings into shape-performance categories based primarily on fixed-wing aerodynamic theory. For example, swallows possess wings in the high-speed flight category with a narrow and pointed shape predicted to reduce drag while producing sufficient lift at high speeds as the birds chase insects on the wing. Such high-speed performance should come at the cost of reduced force production, and hence limited behaviors, at low speeds. Like most birds however, swallows have a vast array of flight behaviors. Their elaborate elevated mud nests require precise low speed maneuvering and hovering during construction and nestling feeding. How do swallows perform such a diversity of flight behaviors with an apparently single-purpose wing? We filmed cliff swallows (*Petrochelidon pyrrhonota*) in the field with high speed video while they foraged at speed and while they hovered near nests. Here, we present the first field 3-dimensional kinematic comparison between these extremes of flight in a single species. When hovering, the swallows increased both stroke amplitude (from less than 120° in steady flight to greater than 170° in hovering) and wing beat frequency (from 6-7 Hz to 9.5 Hz). They also use very high geometric angles of attack (>40°) during hovering. Together, these results suggest that wing-shape categories based on fixed-wing theory do not accurately describe the aerodynamic capacity of flapping wings, nor constrain the diversity in flight behaviors within species even in cases where aerodynamic predictions appear to match aspects of flight ecology.

P1.68 JACKSON, J.M.; LENZ, P.H.*; University of Hawaii at Manoa; *petra@pbrc.hawaii.edu*

Selectivity and Capture Success in Larval Clownfish Amphiprion ocellaris Preying on Evasive Copepods

Predator-prey interactions shape pelagic communities and are drivers for evolutionary adaptation. Survival through the larval stages is particularly risky for most marine fishes, which start life as zooplanktivorous ichthyoplankton. Little is known about the feeding behavior of coral reef fish larvae during this critical phase, but gut analyses suggest that they feed on a wide variety of prey including copepods. Larvae of the clownfish *Amphiprion ocellaris* and the evasive copepod prey *Parvocalanus crassirostris* were used as a model system to investigate larval reef fish predatory behavior during the planktonic phase. Larval fish were presented with multiple copepod life stages in both mixed and single prey-type assemblages, and their predatory behavior was recorded on video and analyzed frame-by-frame to evaluate predator-prey encounters. *A. ocellaris* growth characteristics were measured and compared to prey size. First feeding larvae were able to detect and capture *P. crassirostris* nauplii, but could not capture copepodites. On day 3 post-hatch copepodites were captured with an initial success rate of 22%, while adult copepods were first captured on day 8 post-hatch with an initial success rate of 4%. Early in development, *A. ocellaris* preferentially attacked nauplii and failed to attack adults. By 10-14 days post-hatch, the larvae attacked all copepod life-stages equally, however, capture rates were skewed towards nauplii. *A. ocellaris* mouth gape size was a poor predictor of prey size and would have predicted consumption of all *P. crassirostris* life stages by day 2 post-hatch. This study provides novel insights into the developmental progression of fish predatory behavior from first feeding to age of settling.

3.3 JACOBS, H.O.; Imperial College London; *h.jacobs@imperial.ac.uk*

On the interpretation of swimming as a limit cycle

When the wind blows through the venetian blinds in your house, it is not uncommon for them to flutter. The next time this happens, note two things. Firstly, the fluttering is really the sound of a periodic oscillation at a fixed frequency. Secondly, if you hold one of the blinds between your fingers and then releases it, the fluttering will stop and then restore itself. This stable oscillatory behavior is known by mathematicians as a limit cycle. Given the complex dynamics which are possible in fluids, it is remarkable that fish, frogs, tadpoles, and humans can obtain regular motion in a given direction by periodically flexing muscles. Perhaps motion in a fixed direction is stable under the influence of a periodic force. In other words, perhaps swimming is a limit cycle. The stability of a limit cycle implies that locomotion in a fixed direction can be achieved by exploiting passive physical dynamics and relatively simple motor patterns. In this talk I will provide a sketch of the physics and mathematical proofs which suggest this to be the case for neutrally buoyant bodies of arbitrary shape immersed in a Newtonian fluid in the middle Reynolds number regime (Re ~ 100 to 10,000). The theory should be of interest to those wishing to understand and mimic the orderliness of swimming in this regime or understand the robustness of fluid locomotion across body type and size.

P2.151 JAECKLE, W.B.; Ill. Wesleyan Univ, Bloomington; *wjaeckle@iwu.edu*

Seawater flow into the digestive system of actinotroch larvae (Phoronida)

Collection of particle foods by actinotroch larvae involves the cilia of the larval tentacles, the muscular elevation of the preoral lobe, and the ciliature of the vestibular epithelium. Particles, ingested by larvae, are likely to be contained within a volume of seawater that enters the digestive system. However, the existence of this seawater flow in the absence of particulate foods is unknown. To test for the presence of a constitutive flow of seawater into the digestive system, larvae of *Phoronis architecta* were exposed to the iron-containing protein, ferritin (0.5-1.0 mg/mL), for < 5 h. Larvae were collected from plankton tows, transferred into 0.2 µm-filtered seawater, and then incubated in filtered seawater containing ferritin. The presence and distribution of the iron-containing label in experimental and control larvae was detected using the ferrocyanide reaction. The blue reaction product was present in the digestive system of all larvae exposed to ferritin; no label was detected in the digestive system of control larvae. In whole mounts and sectioned larvae, the label was located within apparent vesicles in cells of all regions of the digestive system except the distal proctodaeum. In the lumen of the proximal proctodeum the reaction product was also found within a consolidated, acellular mass. The presence of an iron-containing label in larvae previously incubated in particle-free seawater containing ferritin supports the existence of a constitutive flow of seawater into the digestive system. The appearance of the label in vesicles within cells of the digestive system indicates pinocytosis of the dissolved protein and presents potential alternate sites in feeding larvae for the assimilation of dissolved organic materials present in seawater.

P1.131 JAFFE, A.L.*; SLATER, G.J.; ALFARO, M.E; Harvard University, Univ. of California, Los Angeles; *alexanderjaffe@college.harvard.edu*

The evolution of island gigantism and body size variation in tortoises and turtles

Extant chelonians (turtles and tortoises) span almost four orders of magnitude of body size, including the startling examples of gigantism seen in the tortoises of the Galapagos and Seychelles islands. However, the evolutionary determinants of size diversity in chelonians are poorly understood. We present a comparative analysis of body size evolution in turtles and tortoises within a phylogenetic framework. Our results reveal a pronounced relationship between habitat and optimal body size in chelonians. We found strong evidence for separate, larger optimal body sizes for sea turtles and island tortoises, the latter showing support for the rule of island gigantism in non-mammalian amniotes. Optimal sizes for freshwater and mainland terrestrial turtles are similar and smaller, although the range of body size variation in these forms is qualitatively greater. The greater number of potential niches in freshwater and terrestrial environments may mean that body size relationships are more complicated in these habitats.

74.2 JAMES, C.J.*; MCELROY, E.J.; College of Charleston; *ccjames@g.cofc.edu*

The effect of autotomy on locomotor performance in the green anole, Anolis carolinensis.

Autotomy is the practice of losing the tail in an effort to escape a predator. Though the immediate threat of predation is avoided via autotomy, the costs of tail loss may have a significant impact on locomotive performance; this could jeopardize the animal's ability to feed, escape from future predators, and reproductive capacity.Many studies have examined the impact of autotomy on running performance, but few studies have looked at other aspects of performance capacity. This study examined locomotor ability in the green anole, *Anolis carolinensis,*to better understand the effects of tail autotomy on both climbing and running performance. Maximum speed and acceleration were measured as lizards burst from a standstill to maximum speed and these measures were repeated before and after autotomy. Autotomy was found to have a significant impact on climbing performance, while terrestrial locomotion was unaffected. These results implicate a significant role for the tail in climbing locomotion in anoles, as has been previously reported for geckos.

53.2 JANZEN, F*; WARNER, D; BRONIKOWSKI, A; MILLER, D; Iowa State Univ., Univ. Alabama, Birmingham, Penn State Univ.; *fjanzen@iastate.edu*

Miles to go before I sleep: reduced fitness at older ages in a long-lived reptile

Theory predicts that senescence will evolve when selection operates less strongly on traits that are expressed at an old age relative to those expressed at a young age. Although identifying reproductive deterioration and reduced survival at old ages provides an indication of senescence, how age-related changes in reproductive output and survival translate to actual fitness is largely unknown. We quantify the strength and direction of age-specific natural selection and its temporal consistency concerning reproductive output and survival of >1000 mature female painted turtles (*Chrysemys picta*) across 20 field seasons to further our understanding of how selection affects deterioration of reproductive function and/or survival (or lack thereof) in long-lived organisms. Clutch size and choice of vegetation cover over nests did not differ with maternal age, but older females laid larger eggs and nested more frequently, earlier in the season, and farther from water than younger females. Despite this moderate increase in reproductive function at old ages, fitness declined with advancing age, particularly for individuals with relative high egg output. Moreover, demographic analyses revealed fairly low mortality across reproductive ages, yet detected an unmistakable acceleration in mortality rate with age in these female turtles. To our knowledge, these findings provide the first evidence of reduced fitness at old age in putatively "immortal" reptiles, and suggest that senescence may be observed in populations that exhibit long chronological life spans.

12.3 JASZLICS, A.*; PARDO, J.D.; University of Texas at Arlington, University of Nebraska at Lincoln, University of Calgary; *jaszlics@huskers.unl.edu*

Patterns of development and diversity in the crocodilian skull

Variation in ontogenetic trajectories plays a critical role in shaping morphological diversity of the vertebrate skull. Crown group crocodilians are a potentially informative research group for this phenomenon because they demonstrate extensive morphological diversity in the skull despite conservative ecologies. Previous studies of crocodilian skull morphology suggest that variation correlates to biomechanical constraint during feeding. In order to test whether the diversity of crocodilian skull morphologies reflects variation in developmental trajectories, we constructed ontogenetic trajectories in all four major extant crocodilian lineages (Alligatoridae, Crocodylidae, *Tomistoma* and *Gavialis*), using geometric morphometric analysis of growth series within and between lineages. We found that the entire skull is tightly integrated throughout ontogeny for all taxa. Differences in adult skull shapes between crocodilian genera primarily reflect variations in juvenile morphology, as well as variation in the overall length of the ontogenetic trajectory. Although skull development in *Gavialis* is tightly integrated, the observed pattern of growth differs significantly from that seen in all other crocodilian genera. Because this divergent trajectory is associated with landmarks in the rostrum and suspensorium, we hypothesize that the unique feeding mechanism of true gharials constrains morphology throughout ontogeny, which shapes both the aberrant ontogenetic trajectory and adult morphology of this species. These results suggest that divergent morphologies can evolve despite ontogenetic constraint.

109.1 JAWOR, J.M.*; HOOKER, J.D.; University of Southern Mississippi; *jodie.jawor@usm.edu*

Influence of temperature on non-breeding HPG-axis activity in northern cardinals.

In seasonally breeding birds, change in day length is a very common cue used to track seasonal change and initiate breeding, however, not all species use changing day length as their primary environmental cue. Many species rely on resources that are irregularly spaced in time and location for reproduction and these non-photic cues can be more influential than changes in day length. Northern Cardinals (*Cardinalis cardinalis*) show year-round levels of testosterone as well as broad timing in when they initiate reproduction and the behaviors associated with reproduction, suggesting that they may not use changes in day length as the sole control for transitions between non-breeding and breeding states. Here we used exogenous gonadotropin-releasing hormone (GnRH) challenges to investigate hypothalamic-pituitary-gonadal (HPG) axis activity and compare HPG axis activity with daily temperature prior to the winter solstice, when day lengths begin to increase. We found that male response to GnRH did not co-vary with temperatures in a predictable pattern. In females response was more complex and tended to co-vary with temperature. We suggest that in male cardinals, once they have an active HPG axis, no further modification of activity may be beneficial, while females may benefit by having a physiological response system that can more closely track environmental change.

89.5 JAYARAM, K*; SPRINGTHORPE, D; HALDANE, D; MCKINLEY, S; DIROCCO, A; FULL, R.J; University of California Berkeley; *kaushikj@berkeley.edu*

Running in confined spaces by the American cockroach

A composite exoskeletal system with an integrated array of sensors and muscles enables arthropods to locomote through the most restrictive environments. Here we found that the tough yet compressible exoskeleton of the cockroach, *Periplaneta americana*, enabled the animal to run through confined spaces less than a third of its standing height (12-15mm). We ran animals through a variable ceiling height rectangular tunnel at 4, 6, 9 and 12mm heights. Surprisingly, animals ran within the vertically restricted space with equal ease at high speeds (52.15±2.68cm/s), only showing a decrease at the lowest height of 4mm (12.56±2.45cm/s, $P<0.01$). Further, animals maintained a tripod gait at all heights except 4mm when feet often slipped on the surface (medium-grit sandpaper) and stereotyped leg trajectories were altered. Kinematic analysis revealed no significant change of leg cycling frequency (16.12±1.24Hz, $P>0.05$) across the ceiling heights. However, cockroaches used significantly ($P<0.01$) shorter stride lengths at 4mm. At the smallest ceiling height, animals chose a more serpentine path of travel and lost foothold traction in 40.2±3.49% ($P<0.01$) of the strides leading to significantly less effective propulsion. Although navigating through confined spaces likely increases the normal load, remarkably animals showed limited adjustments of the tarsal (hind leg) extreme positions relative to the body centerline, contrary to our expectations. Insights obtained into strategies of high-speed, confined space navigation not only increases our understanding of the mechanical design principles of these organisms, but it also is inspiring the development of novel robots that will go where no robot can at present.

S10-1.2 JéKELY, G; Max Planck Institute for Developmental Biology, Spemannstrasse 35, 72076 Tübingen, Germany; *gaspar.jekely@tuebingen.mpg.de*

Mechanism of phototaxis in marine zooplankton and origin of simple visual circuits

Eyes and nervous systems evolved in a marine environment at the dawn of animal life and diversified during the Cambrian explosion, one of the most spectacular events in the history of life. Little is known about early stages of eye and visual circuit evolution. Simple marine planktonic organisms, in particular ciliated larvae of various marine invertebrates, can give us insights into how simple eyes and circuits of marine organisms function and may have evolved. We investigate the nervous system of the marine annelid model, Platynereis dumerilii. The ciliated, planktonic larvae of Platynereis have three pairs of eyes forming simple reflex circuits. The eyes control phototactic swimming, a key behavior regulating larval depth in the water column. We use a combination of behavioral, molecular genetic and ultrastructural studies to map and characterize phototactic circuits in Platynereis larvae. We believe that the simple circuitry we uncover in these ciliated larvae could give us insights into how neural circuits function and may have evolved.

80.2 JENSEN, M.M.*; DENNY, M.W.; Hopkins Marine Station, Stanford University; *mmjensen@stanford.edu*

Do Wave Impact Forces Limit the Size of Intertidal Organisms?

Although intertidal organisms are generally much smaller than their terrestrial and subtidal counterparts, the biological and physical mechanisms that limit size have not been determined. While hydrodynamic forces due to breaking waves are theorized to limit size, models based on drag and accelerational forces are poor predictors of maximum sizes in the field. However, these models may be incomplete: the transient force occurring at wave impact -- the impingement force -- is neither well-characterized nor included in current size-prediction models. Impingement may limit organism size through differing scaling exponents: tenacity is generally proportional to attachment area (the square of characteristic length). If the largest force experienced by the organism also scales with area, there is no theoretical size limit as the organism grows isometrically. If maximum force is proportional to organism volume, force increases with the cube of characteristic length as the organism grows. In this case, force increases at a faster rate than attachment strength, potentially limiting the organism's size. While scaling behavior of other hydrodynamic forces is known, the scaling exponent of impingement has remained unstudied. To test the scaling behavior of impact forces, rectangular prisms of various sizes were exposed to impingement forces using simulated waves from a gravity-driven water cannon. Data show that impingement scales with both area and drag coefficient of shapes tested. Analysis of the water cannon jet shows a spike in jet velocity concommittent with measured impingement forces, further suggesting that transient wave impacts are caused by brief increases in drag. Thus, impingement is not likely to limit organism size -- leaving intertidal size limitation a mystery.

P2.120 JEONG, J.*; DARAKANANDA, K.; HITCHCOCK, A.; CONNOLLY, E.; QUIST, A.; ROBBINS, A.; ELLERBY, D.; Wellesley College; *dellerby@wellesley.edu*

Behavioral Thermoregulation Not Accompanied by Locomotor Performance Acclimation in the Medicinal Leech

Medicinal leeches adjust their temperature preference in relation to their nutritional status: low temperatures are preferred when energy reserves are low, reducing metabolic costs, while higher temperatures are preferred after feeding to support higher metabolic rates and rapid food processing. Although energetically favorable, low temperatures may reduce locomotor performance. In many vertebrate ectotherms continued cold exposure triggers compensatory changes in muscle contractile properties and metabolic capacity that support performance recovery. However, the capacity for locomotor acclimation in invertebrates is less well understood. Medicinal leeches were acclimated to 21˚ C and their swimming and crawling speed and kinematics quantified by video analysis. This was repeated during acute exposure to 12.5˚ C, the preferred temperature for unfed leeches, and at regular intervals while being held at this temperature over the course of 6 weeks. Acute cold exposure significantly reduced performance. Mean swim velocity and swim cycle frequency were reduced by 40% and 37%, respectively. There was no detectable recovery of performance during prolonged exposure. The kinematic viscosity of water increases with decreasing temperature and at relatively low Reynolds numbers may alter swimming performance independently of any temperature effects on muscle contraction or metabolism. To separate these effects, swimming performance was quantified at 21˚ C with the kinematic viscosity of water increased to that of 12.5˚ C water by addition of methyl cellulose. The altered viscosity reduced swimming speed by 15%, indicating part of the performance change can be ascribed to viscosity effects.

S3-1.7 JEW, C.J.*; WEGNER, N.C.; GRAHAM, J.B.; University of California, San Diego, Scripps Institution of Oceanography; *cjew@ucsd.edu*

Physiology in deep time: Using extant vertebrates to model behavioral and functional aspects of the Devonian land transition

Extant air-breathing fishes can be used to infer the physiological and behavioral changes that occurred during the fish-tetrapod land invasion (early Middle to Late Devionian) that otherwise could not be studied due to the lack of living stem tetrapods. Here we describe two such projects from the laboratory of the late Jeffrey B. Graham. Mudskippers (Teleostei: Gobiidae), which possess many respiratory and locomotive specializations for amphibious life, were used to study how changing atmospheric O_2 concentrations in the late Paleozoic may have influenced the emergence and subsequent radiation of the first tetrapods. Japanese mudskippers (*Periophthalmus modestus*) exercised on a treadmill under 7, 21, and 35% atmospheric O_2 revealed that hyperoxia increased both terrestrial endurance and aerial O_2 uptake efficiency in the buccopharyngeal chamber following exercise. Extrapolated to early tetrapods, this suggests higher lung efficiency in hyperoxia that may have allowed for increased aerobic performance on land and a decreased reliance on skin respiration, permitting the skin to become more resistant to water loss and allowing for prolonged excursions farther from water. In a second study, we examined bimodal (lung and gill) breathing in *Polypterus*, a basal ray-fin fish. Structural, behavioral, video, and pressure data show that under unstressed conditions *Polypterus* uses it spiracles (dorsally located openings on the skull) for up to 93% of its air breaths. Similarities in size and position of polypterid spiracles with those of some stem tetrapods suggest the use of spiracles for breathing air during the fish-tetrapod land transition.

P2.18 JI-HYUN, L.*; HYUN-WOO, K.; Department of Marine Biology, Pukyong National University, Busan 608-737, Republic of Korea; *ellen3235@gmail.com*

Characterization of low density lipoprotein receptor (LDLR) gene superfamily members in decapod crustaceans

As low density lipoprotein receptor (LDLR) gene superfamily members, the vitellogenin receptor (VgR) or lipophorin receptors (LpR) play an important role in oocyte development via receptor-mediated endocytosis of yolk protein precursors such as vitellogenin (Vg) or lipophorin (Lp). In the present study, we identified five cDNAs encoding the putative VgR/LpR/LDLRs from the morotoge shrimp (*Pandalopsis japonica*) and the chinese mitten crab (*Eriocheir sinensis*) by the combination of EST database analysis and tranditional PCR-based cloning strategy. First sequences (PJ-VgR) exhibited the highest similarity to the VgR from *Macrobrachium rosenbergii* (52%). Second PJ-LpR 1 was similar to LpR from *Aedes aegypti* (44%). Third PJ-LpR 2 turned out to be homolog of LpR from *Tribolium castaneum* (53%). Fourth PJ-LDLR exhibited highest similarity to LDLR from *Aedes aegypti* (57%). Finally, fifth ES-VgR appeared to be ortholog of VgR from *Penaeus monodon* (37%). They all exhibited conserved domain organizations as LDL receptor family members : ligand binding domain(LBD), epidermal growth factor (EGF) – like domain, YWTD domain, transmembrane domain, cytoplasmic domain. In order to understand an evolutional relationship among different VgR/LpR/LDLR family members in arthropod, a phylogenetic and structural analysis were also performed. Hepatopancreatic or gonadal expression of each gene was also determined by both qualitative and quantitative PCR strategy. The relationship between gonadosomatic index (GSI) and transcriptional level of five receptor genes was also determined.

141.4 JIMENEZ, A.G.*; VAN BROCKLYN, J.; WILLIAMS, J.B.; The Ohio State University; *jimenez.102@osu.edu*

Cellular metabolic rate is influenced by life-history traits in tropical and temperate birds.

Tropical and temperate bird species tend to live on opposite sides of the life-history continuum, with tropical birds falling on the “slow” end of the spectrum characterized by low annual reproductive output and low mortality rate, and temperate birds on the “fast” end characterized by rates of reproduction and mortality that are high. Although it is thought that physiological processes underlie many life-history trade-offs, the precise linkages between an organism’s life history and the function of its organs, tissues, and cells remain unclear. Previous work in our lab has demonstrated that tropical birds have a significantly lower basal metabolic rate and peak metabolic rate compared with their temperate species counterparts. We have also found that a contributing factor to the reduced rate of metabolism in tropical birds is that they have smaller metabolically-active organs, such as heart, liver, kidneys, and pectoral muscles, compared with similar-sized temperate species. However, a fundamental challenge facing physiological ecologists is an understanding on how variation in life-history at the whole-organism level might be linked to cellular function. Here, we compared various parameters of cellular metabolism in 34 species of phylogenetically paired tropical and temperate bird species. Using an XF24 Seahorse extracellular oxygen analyzer, we measured basal and maximal cellular oxygen consumption (OCR) and the rate of glycolysis (ECAR). We found that in most bird pairings, there was a lower basal and maximal oxygen consumption in tropical species, which is in accordance with a slower pace-of-life.

115.3 JINDRICH, DL*; QIAO, M; California State University, San Marcos, Arizona State University; *djindrich@csusm.edu*
Compensations for increased rotational inertia during human cutting turns
Locomotion in a complex environment is seldom steady-state, but the mechanisms used by animals to power and control unsteady locomotion (stability and maneuverability) are not well understood. We used a morphological perturbation (increased rotational inertia) to determine the compensations used to perform sidestep cutting turns during running. Previous studies have argued that because humans have low yaw rotational inertia relative to body mass, braking forces are used to prevent body over-rotation during turns. We tested the hypotheses that increasing body rotational inertia would allow for decreased braking forces during stance. We recorded ground reaction force and body kinematics from seven participants performing 45 degree sidestep cutting turns and straight running at 5 levels of body rotational inertia, with increases up to 4-fold. Braking forces remained consistent at different rotational inertias, facilitated by anticipatory changes to horizontal plane body rotational speed. Moreover, increasing inertia revealed that the opposing effects of several turning parameters (i.e. initial rotation and rotation due to medio-lateral forces) result in a system that is robust to changes in rotational inertia. These results suggest that in submaximal effort turning, legged systems are robust to changes in morphological parameters, and that compensations can involve relatively minor adjustments between steps to change stance initial conditions.

63.4 JOHN-ALDER, H.*; POLLOCK, N.; PAZDZIOR, D.; FEIGIN, S.; Rutgers Univ., New Brunswick; *henry@sebs.rutgers.edu*
Dihydrotestosterone Reduces Growth in a Female-Larger Lizard
Sex differences in adult body size (sexual size dimorphism; SSD) are widespread, and both male- and female-larger SSD is observed even among closely related species. Earlier investigators focused largely on sex differences in the balance of selective forces on body size, but more recent workers have investigated proximate regulation of growth leading to SSD. A growing body of evidence in squamate reptiles has shown a correlation between patterns of SSD and effects of testosterone (T) on growth, wherein T stimulates growth in male-larger species and inhibits growth in female-larger species. These data have given rise to the bipotential growth regulation (BPGR) hypothesis to explain SSD in squamates and perhaps more broadly. However, mechanism(s) of BPGR, including possible conversions of T to estradiol and dihydrotestosterone (DHT), are conjectural. The present study tests whether growth inhibition by T in a female-larger lizard (*Sceloporus undulatus*; Eastern Fence Lizard) is an androgenic effect not involving aromatization of T to estradiol. Experiments were conducted on yearling males and females of *S. undulatus*. DHT was administered via implanted Silastic tubules in intact females and in intact and surgically castrated males. Body size was measured at regular intervals for six weeks. Compared to controls, growth rate was reduced by DHT in females and in males. Body condition, measured by regressing log mass on log snout-vent length, was unaffected by DHT, indicating that growth reduction was not caused by negative energy balance. Our results help to clarify the androgenic mechanism(s) of BPGR, wherein T inhibits growth in males of female-larger lizards.

37.3 JOHNSEN, S.*; NILSSON, D.-E.; WARRANT, E.J.; Duke Univ., Lund Univ.; *sjohnsen@duke.edu*
Why do giant squid have giant eyes?
Giant and colossal deep-sea squid (*Architeuthis* and *Mesonychoteuthis*) have the largest eyes in the animal kingdom, but there is no explanation for why they would need eyes that are nearly three times the diameter and 27 times the volume of those of any other extant animal. While these eyes may simply be scaled-up version of the eyes of smaller squid, studies from vertebrate species show there is a significant negative allometry for eye size, with eye diameter peaking at roughly 9 cm and pupil diameter peaking at 3 cm. Here we develop a theory for visual detection in pelagic habitats, and demonstrate that such giant eyes are unlikely to evolve for detecting mates or prey at long distance, but are instead uniquely suited for detecting very large predators, such as sperm whales, either as shadows against the dim ambient light or via bioluminescence stimulated by the motion of the animals. We also provide photographic documentation of an eyeball of about 27 cm and a pupil diameter of 9 cm in the giant squid *Architeuthis*, and predict that, below 600 m depth in clear oceanic waters, it would allow detection of sperm whales at distances exceeding 120 m. With this long range of vision, giant squid can monitor a surrounding sphere of more than 7 million m^3 of water, and get an early warning of approaching sperm whales. Interestingly, the distance at which giant squid are predicted to detect sperm whales visually is comparable to the sonar range of the whales. Our results thus suggest that the enormous eyes of giant squid may have evolved in an arms race with the sonar of large toothed whales. The equally enormous eyes of certain ichthyosaurs are also discussed in the context of the detection of large deep-sea targets in low-light conditions.

P2.187 JOHNSON, J/I*; FENSKE, B/A; BUCHANAN, K/J; YALAMARTHY, A/S; Michigan State University; *johnij@aol.com*
The Puddling Claustrum
The claustrum is so named for its appearance as a thin layer of cells narrowly enclosed between the corpus striatum and the overlying insular cortex. However, in comparative study of a diversity of mammalian species we found a good portion of the claustrum forming “puddles” of tissue that appear to be spilling out from the enclosed claustral lamina in various locations. In the domestic pig, a huge egg-shaped mass projects out from the posterior edge of the lamina. In carnivores, a large pyramidal shaped mass of claustrum pours out the top of the lamina. In primates (humans included), a large globular puddle protrudes anterior and inferior from the lamina. We propose that claustral morphology depends on available space in the developing brain which leads to different “puddles” of claustrum pouring out from the lamina in different places in different mammalian species. These distinctive developments warrant further study as to possible correlations with distinctive behavioral specializations of mammalian phyla.

P3.98 JOHNSON, K.E.*; ANDRUS, C.J.; MIDDLETON, K.M.; California State University San Bernardino, Western University of Health Sciences, University of Missouri; *katiejay1987@gmail.com*

Comparative anatomy of flight and contour feathers in aquatic birds

The evolutionary transition from aerial to aquatic flight in penguins and alcids involved long-appreciated and well-studied changes in anatomy and physiology, and prior studies have addressed locomotor kinematics and muscle physiology in these clades. For underwater flight, the wing, including feathers, must be stiff enough to resist a fluid reaction force sufficiently large for propulsion in a dense and viscous fluid. Recent discoveries of basal penguins with anatomically "modern" feather morphology have highlighted the need for a better understanding of feather biomechanics and evolution. To explore the role of the physical environment in shaping the mechanical design of feathers, we compared cross-sectional anatomy of flight and contour feathers in fourteen species of seabirds, including aerial fliers, foot-propelled divers, wing-propelled divers, and flightless wing-propelled divers. Serial histological sections of the feather rachis were measured to determine cross-sectional areas and indices of flattening and resistance to bending and torsion. Two measurements, including aspect ratio (a measure of dorsoventral flattening) and standardized resistance to torsion, reveal that penguin contour feathers are significantly flatter and more resistant to torsion than closely related or ecologically similar birds, even after accounting for phylogenetic relationships. Despite differences in ecology, flight feathers showed similar scaling patterns across species, when corrected for rachis position. Short feathers are geometrically and biomechanically similar to the same lengths of the distal ends of large feathers. These results suggest a general mechanism for feather construction in which feather length is the main determinant of geometry. (NSF DEB 0949945)

P3.175 JOHNSTON, NR*; LOPES, PC; GOLDSMITH, GR; BENTLEY, GE; DAWSON, TE; Univ. of California, Berkeley, Univ. of California, Berkeley and GABBA, Univ. of Porto, Helen Wills Neuroscience Institute and Univ. of California, Berkeley, Center for Stable Isotope Biogeochemistry and Univ. of California, Berkeley; *njohnston@berkeley.edu*

Do prolonged elevations of corticosterone influence the stable isotope ratios of blood in zebra finches?

Stable isotope analyses can be a powerful tool for determining animal diet, food web relationships and habitat quality. Changes in the stable isotope ratios of carbon and nitrogen are known to be associated with shifts in the quality, availability or source of food being consumed. To test whether other, previously unconsidered factors can cause changes in tissue stable isotope ratios, we implanted corticosterone capsules into female zebra finches (*Taeniopygia guttata*). Corticosterone is a hormone involved in carbohydrate metabolism often released in response to stressful stimuli. Prolonged elevations of this hormone can lead to catabolic effects on muscle protein. Blood samples for stable isotope analysis were collected prior to inserting the capsules and following 14 days of treatment. We also quantified food intake, body mass and plasma levels of corticosterone. We predicted that birds exposed to elevated corticosterone would demonstrate altered stable isotope ratios in blood despite the fact that food availability and quality remained the same. The experimental treatment induced reduced food intake and significant body mass loss, as well as a significant change in the carbon content (%) in blood plasma, indicating effects of corticosterone on bird metabolism. Although the treatment was maintained long enough for these birds to experience blood turnover, we found no evidence for the effects of prolonged corticosterone exposure on stable isotope ratios.

P3.107 JONES, K E*; GERMAN, R Z; Johns Hopkins University; *kjone108@jhmi.edu*

Differential vertebral growth produces variations in adult thoracolumbar proportions in half-bounding mammals

Vertebrae are serially homologous structures that are tightly integrated through their development and evolution. However, in mammals the dorsal vertebrae are split into thoracic and lumbar vertebrae that are morphologically and functionally differentiated. The lumbar region tends to be specialized for locomotion via well developed epaxial musculature which may be used for producing thrust during quadrupedal jumping. Here we test the hypothesis that half bounding taxa exhibit a longer lumbar region than non-specialists. Further, the relative role of growth rate of individual vertebrae versus vertebral number in altering adult proportions is tested using longitudinal data. Lateral x-rays of 38 specimens from two half-bounding (*Oryctolagus cuniculus* and *Chinchilla lanigera*) and two non-specialized (*Cavia porcellus* and *Monodelphys domestica*) species of similar size were the source of centrum length measurements on individual vertebrae. The repeated measurements design included the same individuals soon after birth and again at adult size. The half-bounding species had both more lumbar vertebrae and a longer lumbar:thoracic region than the non-specialists. This correlates with suggestions that the lumbar epaxial muscles are important in producing thrust during saltatorial behavior. This relatively longer lumbar region was apparent in new-borns but longitudinal data indicated that the difference also increased during postnatal growth. Lumbar vertebrae consistently grew twice as fast as thoracic vertebrae in all taxa. Therefore, evolution of additional, fast-growing, lumbar vertebrae in half-bounding taxa is key to increasing the rate of post-natal growth relative to the thoracic region, and ultimately varying adult regional proportions.

117.2 JONES, B.C.*; BEBUS, S.E.; SMALL, T.W.; BATEMAN, P.W.; SCHOECH, S.J.; Univ. of Memphis, Archbold Biological Station; *bcjones8@memphis.edu*

Corticosterone responsiveness and behavioral phenotype reveal learned antipredator behavior is sex specific in Florida scrub-jays (Aphelocoma coerulescens)

The extent to which antipredator behavior is learned, and the mechanisms that facilitate this learning, remain largely unexplored. Glucocorticoids, corticosterone (CORT) in birds, are released in response to stressful stimuli, including perception of a predator. Elevated CORT facilitates physiological and behavioral changes that enhance survival and memory, thus, CORT may mediate antipredator behavior learning. Florida scrub-jays (FSJ) exhibit repeatable intraspecific variation in plasma CORT levels in response to a stressor, which correlates with degree of neophobic behavior. Flight initiation distance (FID; the distance from an approaching intruder at which an individual flees) is used to investigate an animal's response to an intruder, but may also reflect an aspect of an individual's personality. We tested two hypotheses: 1) FSJs have the capacity to learn antipredator behavior and 2) CORT responsiveness and behavioral phenotype are predictive of antipredator behavior. We developed a model to test for, and compare CORT responsiveness and behavioral phenotype to, learned antipredator behavior in free-living FSJs. Forty-six individuals, who were previously exposed to an artificial novel "predator", displayed greater FIDs than forty-five naïve controls. Further, FID and the degree of neophobia were positively correlated in males, yet negatively correlated in females. Preliminary analysis of CORT responsiveness suggests a negative correlation with FID. These data indicate FSJs can learn to associate a novel threat after a single exposure, and that behavioral phenotype and antipredator behavior covary in a sex-specific manner.

S4-1.1 JONES, Corbin; University of North Carolina; *cdjones@email.unc.edu*

RNAseq on draft genomes; perils and pitfalls

High throughput genomic sequencing is revolutionizing biological research and is rapidly expanding the number of organisms with genomic and trancriptomic (RNAseq) data. These new sequencing technologies produce large numbers of short (<100 bp) reads, which are best suited for assembling unique regions of a genome or transcriptome. These short reads also have inherent technical weaknesses. Short reads perform poorly when assembling repetitive regions of the genome and are problematic when measuring gene expression across members of gene families. These problems are compounded when short reads are used to assemble a genome, annotate genes within that genome, and measure the expression of the genes within that genome. Using a combination of synthetic and experimental data, we illustrate some common pitfalls of measuring the transcriptome using a draft genome. Not surprisingly, gene families are particularly problematic. Our data also suggest that isoform prediction – one of the strengths of RNAseq over microarrays – can be erroneous when applied to draft genomes. Based on these data, we define a set of "good practices" that can improve the quality of inference from RNAseq experiments applied to draft genomes. However, polishing and closing of draft genomes will ultimately be the critical step to preparing them for highly accurate RNAseq analysis.

P3.198 JONESON, J.R.*; OWERKOWICZ, T.; ELSEY, R.M.; California State University, San Bernardino, Rockefeller Wildlife Refuge, Louisiana Dept. of Wildlife and Fisheries, Grand Chenier; *corbettj@coyote.csusb.edu*

Tenotomy of the caudofemoralis longus has no effect on alligator locomotion

The caudofemoralis longus muscle (CFL) - a major retractor and medial rotator of the thigh - is particularly well-developed in reptiles with a long tail and a sprawling gait. The CFL originates on the transverse processes and chevrons of the caudal vertebrae and inserts on the fourth trochanter of the femur. As determined by electromyography in the American alligator (*Alligator mississippiensis*), the CFL is consistently active during the stance phase of walking, while other synergists are not. Evolutionary changes to hindlimb orientation and tail morphology among the theropod dinosaurs have been ascribed to a reduction in prominence of the CFL to locomotion, but no experimental alteration to CFL function has been attempted. In order to discern the role of the CFL in locomotion, we filmed juvenile American alligators walking on a level grid trackway before and after bilateral CFL tenotomy. We found no significant differences between surgically-tenotomised alligators (n=6) and sham-operated controls (n=6) in average speed, stride length or hip height during steady locomotion on the trackway. These preliminary results suggest that either (i) the CFL is not an important contributor to hindlimb stance and movement, or (ii) other hip muscles are able to compensate for lack of CFL function during slow and steady locomotion. Monitoring of bone growth following CFL tenotomy will allow us to investigate the effects of CFL function on femoral and vertebral morphology. Understanding the CFL-driven phenotypic plasticity of the alligator skeleton may elucidate the role of musculoskeletal strain in shaping the evolutionary transformation of the hindlimb/tail module in archosaurs.

P1.102 JOOSTE, E.*; BOYLES, J.G.; HALLAM, T.G.; MCCRACKEN, G.F.; Southern Illinois Univ., Univ. of Tennessee, Univ. of Tennessee; *ejooste@siu.edu*

Feeding, foraging, and energetics of small bats at high latitudes

Small insectivorous bats that spend summers at very high latitudes experience a suite of bioenergetic constraints including cool nighttime temperatures, long daylight periods which limit foraging, and a short summer. Thus, they are likely to display feeding and foraging patterns unlike those of congeners and conspecifics at lower latitudes. We evaluated the feeding patterns of small myotine bats roosting in buildings in Wrangell-St. Elias National Park, Alaska (~62-63°N) during summer and autumn 2012. During the summer sampling period (June and July), there was no true darkness and twilight lasted for approximately 2-3 hrs. We captured bats exiting buildings and held them to collect feces. Diet was later determined through standard analytical techniques. We also collected free-flying insects, including mosquitoes, to analyze energetic content of the prey available to bats. We used ultrasonic detectors during the entire period from June to October to estimate the foraging periods and activity as the amount of daylight drastically changed. Finally, we used the energetic estimates of the sampled insects and previously published data to estimate energy budgets assuming the diet sampled in the feces.

P3.52 JORGENSEN, D.*; BRYANT, M.; HINLICKY, A.; Roanoke College; *jorgensen@roanoke.edu*

Hydrostatic pressure is unequally distributed in the branchial chambers of lobsters, Homarus americanus, and Atlantic blue crabs, Callinectes sapidus

Lobsters and crabs have two sets of gills each enclosed in a branchial chamber (BC) located on either side of the thoracic body region. Each BC contains a scaphognathite (scaph), a muscularly-driven pump, which moves cyclically, generating a Negative (suction) pressure in the BC to pull water unidirectionally past its gill set, bringing hemolymph and ventilatory water into close apposition. It has been assumed previously that pressure resulting from scaph movement is equally distributed in the BC. We wished to determine the validity of this assumption. We measured hydrostatic pressure at different locations along the longitudinal axis of the BC in American lobsters and Atlantic blue crabs using catheters attached to strain gauge transducers. Our data indicate that pressure is unevenly distributed in the BC in resting animals, being 2-3X more negative in the anterior and posterior regions of the BC as compared to that in the mid-longitudinal region. Previous work has shown that BC pressure decreases (i.e., increased BC suction) during periods of exertion when increased scaph activity is invoked to drive increased BC ventilation. We found that pressure decreased below resting levels by 2-3X in all regions of the BC of exercising lobsters and crabs (steady state walking on a submerged treadmill), but to a greater extent in the anterior and posterior BC regions. This unequal pressure distribution may affect a range of gill functions that relate to transmural hydrostatic pressure, including the movement of hemolymph through individual gill vascular circuits.

P3.208 JOST, JA*; ABOU-HANNA, JJ; Bradley University; *jjost@bradley.edu*

AMPK activity as an indicator of seasonal temperature acclimation in the zebra mussel, Dreissena polymorpha

Invertebrate temperature stress has been widely examined in the context of climate change and there is a strong interest in measuring thermal stress for invertebrate species. Previous work on crustaceans shows that AMP-activated protein kinase (AMPK) activity can indicate high temperature stress and detect sublethal temperature ranges where survival is possible but growth and reproduction may be limited. The freshwater zebra mussel, *Dreissena polymorpha*, is an invasive aquatic species capable of biofouling hard substrates, including organisms, boat ramps and industrial equipment. Previous work indicates zebra mussels are capable of thermal acclimation depending on incubation temperature. However, little is known about the cellular mechanism of temperature stress, thermal acclimation or sublethal temperature range for this species. In this study, we investigated the potential for AMPK activity to indicate (a) sublethal temperature stress in the zebra mussel and (b) thermal acclimation relative to seasonal variation in river temperature. Mussels were collected every 30 days for 1 year, exposed to progressive temperature increases and harvested every 2°C until lethal temperature was reached. Results indicate that AMPK activity increases as temperature stress occurs and that maximum AMPK activity levels vary with river temperature. Mussels collected in winter show dramatic increases in AMPK activity at low temperatures while AMPK activity increases in summer mussels only near the lethal temperature. Our results suggest that zebra mussels are acclimating seasonally and that this response is detectable using a cellular stress marker. This research is the first step in determining sublethal temperatures and the abiotic factors that may limit future invasions.

35.3 JUDGE, J. L.*; HASZPRUNAR, G.; UC Berkeley, Ludwig-Maximilians University Munich; *jennajudge@berkeley.edu*

A 3D investigation of the morphology of lepetellid limpets (Lepetella sierrai): hypotheses on feeding ecology and symbiosis

The Lepetelloidea, a clade of small limpet-shaped gastropods, represents a case study in continental margin and deep-sea diversification. Lineages in this clade have been found associated with various substrates, including hydrothermal vents, seeps, wood, whale bone, polychaete tubes, elasmobranch egg cases, seagrass rhizomes, algal holdfasts, crab carapaces, and sponges. It is unclear how each lineage utilizes its substrate; as a food source, a grazing surface, or a substrate that positions them in a reducing environment suitable for chemoautotrophic symbionts. Symbiosis is an obvious trait that would provide a lineage with a clear advantage in a nutrient-poor environment like the deep-sea, indicated by the prevalence of chemosymbiotic animals at hydrothermal vents. One lepetelloidean family, Lepetellidae, lives specifically on or inside empty polychaete tubes of the genus *Hyalinoecia*. The detailed morphology of a Mediterranean species, *Lepetella sierrai*, has been reconstructed from serial sections using the 3D modeling software AMIRA, and compared to other members of the genus. A unique alimentary tract, with huge oesophageal pouches, no true stomach, and an extensive multi-lobed midgut is shown. Additionally, a bacteriocyte system surrounding the entire mantle rim has been revealed via light microscopy and TEM. This is the first recognized evidence for microbial symbiosis in lepetelloidean limpets. A feeding ecology combining nutrition from the sugar phosphate polymer worm tube and chemoautotrophy is likely. Further investigation of this and other lepetelloidean feeding ecologies will contribute to revealing the drivers of evolutionary success in this limpet clade that lives on a high diversity of substrates utilized by few other lineages.

74.4 JUSUFI, A.*; BYRNES, G.T.; FULL, R.J.; Univ. of California, Berkeley; *ardianj@berkeley.edu*

Gliding Geckos Perch on a Tree Trunk Assisted by Active Tails

Laboratory studies of air-righting and equilibrium gliding revealed that geckos could use tail movements for maneuvering (Jusufi et al. 2008, 2010). We measured geckos, *H. platyurus*, in a Southeast Asian rainforest to study tail function during aerial descent and gliding in nature. Field video revealed that geckos traveled horizontal distances from tree to tree of up to 4m with gliding speeds ranging from 5.4 to 7.5m/s and angles of attack of approximately -15° to -20° at mid-glide. Preparing to land, geckos pitched their body up to 32° to 35° and decelerated to speeds ranging from 4.4 to 6.3m/s. Gliding geckos initiated their perching maneuver with a 15° angle of attack relative to horizontal. Near head-on collisions with the tree trunk pitched the torso vertically as high landing forces were absorbed by the body and tail. After vertical alignment with the tree trunk, the anterior section of the body pitched up to 100° away from the trunk, anchored by only the hind limbs and tail. Tail forces allowed recovery from the extreme pitch back angles by reducing stress on the rear legs. Of the gliding geckos that reached the tree target (n=7), the majority (86% of trials) alighted safely on the vertical target. By contrast, tailless geckos experienced catastrophic falls in 75% of trials after crashing into the tree (n=4). Results reveal geckos use tails as shock-absorbers and stabilizers to reduce and control high impact forces acting on the limbs allowing effective landing at high speeds. Gecko’s perching behavior could be initiated by the same reflex discovered during climbing where forefoot slippage stimulates tail depression. Strategies incorporating tail assisted responses can improve the vertical landing performance and stability of both animals and robot planes.

P3.78 KACZMARCZYK, A.N*; PATEL, N.; Univ. of California, Berkeley; *ankaczmarczyk@berkeley.edu*

The molecular mechanisms of germline regeneration in Parhyale hawaiensis

Germline cells play a unique role in sexually reproducing organisms – these cells form the gametes that maintain the continuity of genetic information across generations. The molecular mechanisms responsible for the specification of the germline are well understood in several genetic model organisms. However, studies on the adult germline stem cell (GSC) niche are limited to model organisms such as *D. melanogaster*, *C. elegans*, and *M. musculus*. The crustacean *Parhyale hawaiensis* displays a remarkable property of germline development; ablation of the germline (g) blastomere in the embryo can be compensated for during a later post-embryonic period, resulting in fertile animals and normal offspring. Currently, the molecular mechanisms involved in this germline replacement are unknown. I hypothesize that in germline ablated juvenile *Parhyale*, cell-cell signaling in the intact, but empty (no germline cells) somatic gonads, possibly mediated by Dpp signaling, can recruit somatic cells and induce them into germline fates. This phenomenon makes *Parhyale* an attractive model to study germline specification, the germline stem cell niche, and ultimately germline regeneration.

54.5 KAHN, A.S.*; YAHEL, G.; TUNNICLIFFE, V.; LEYS, S.P.; Univ. of Alberta, Edmonton, Ruppin Academic Center, Michmoret, Israel, Univ. of Victoria, British Columbia; *kahn@ualberta.ca*

Glass sponge reefs significantly impact water properties in a marginal sea, the Strait of Georgia

Glass sponges form unique reef habitats similar to coral reefs in the Strait of Georgia (SOG), a marginal sea surrounded by major cities such as Seattle and Vancouver. Individual sponges can affect localized water properties; since reefs are so vast, they may alter water properties on a regional scale. Reef sponges in the SOG (some 11 million oscula) filter over 6 billion liters of water per hour, removing bacteria and other particulates while adding ammonium to the water. We used SIP samplers to compare ambient water near reef sponges with water exhaled from oscula of *Aphrocallistes vastus*, the dominant reef-forming species in the SOG. Whether living in reefs or solitarily, each osculum adds ~ 200 nmol/l of NH_4^+ to expelled water, independent of differences in ambient NH_4^+ concentrations. Similarly, bacteria were removed at about the same efficiency whether sponges were in a reef or solitary. Each reef sponge drew down 0.5609 µM oxygen, or used 241 mJ per liter pumped to filter feed. Our calculations show that the 12 known reefs in the SOG remove hundreds of kilograms of carbon per year in the form of bacteria, and lesser amounts of *Synechococcus*-like and large eukaryotic cells. Though they are live habitats and their effects are not nearly as great as Fraser River inputs, the sponge reefs alter water properties by removing bacterioplankton and oxygen, and adding ammonium. Our findings suggest that the water properties of the SOG may depend heavily on sponge reefs being present just as the reefs rely on SOG water properties.

P3.179 KAISER, K.*; JONES, C.G.; MARENTES, A.A.; WEICKUM, R.M.; SALTZMAN, W.; Univ. of California, Riverside; *kristinekaiser@gmail.com*

Diel rhythm of plasma corticosterone in White's treefrog, Litoria caerulea

Although widely thought of as stress hormones, glucocorticoids have myriad functions, and in most organisms are secreted in a diel cycle. The circadian rhythm of circulating corticosterone (CORT) concentrations has been characterized in several amphibians; however, treefrogs (family Hylidae) have been generally overlooked, despite the variety of CORT studies performed on this species-rich group of frogs. We characterized the pattern of basal circulating CORT concentrations over the 24-hour cycle in White's treefrogs (*Litoria caerulea*). We sampled blood by cardiac puncture once per week from nine male, captive-reared frogs from October to December, 2011, with six collection time points over the course of the day. Plasma was extracted and CORT levels were determined using a radioimmunoassay kit that was validated for this species. We found that male *L. caerulea* exhibit a diel rhythm, with a significant trough at the 08:30 h sample and a slight peak at 12:30 h. CORT levels in *L. caerulea* were lower than those observed in most other amphibians; however, sampling occurred outside of the breeding season, when circulating CORT levels generally are lower in frogs, and a repeat of this study during the breeding season when social stimuli are present would likely yield higher basal levels. We provide the first characterization of the CORT diel rhythm in a hylid frog, and suggest that such data provide an important foundation for proper interpretation of any stress or CORT study.

P1.74 KANE, E.A.*; HIGHAM, T.E.; University of California, Riverside; *ekane001@ucr.edu*

Predicting three-dimensional predator accuracy during dynamic capture events in centrarchid fishes

Strike accuracy is likely a key aspect of prey capture success and can be altered by both the predator and prey. Accuracy is commonly measured using methods that do not account for hydrodynamics, use immobile prey, or constrain predators to a small area. Using data from a PIV analysis of accuracy in centrarchids, the shape of the ingested volume of water (IVW) was predicted in 2D using predator ram speed and peak gape. We have expanded this model to 3D kinematics, and applied it to dynamic prey capture events where both predators and prey are able to perform more natural feeding and escape behaviors. A 3D diamond shape, with the predicted length and height (height was also used as depth) of the IVW, approximated the rounded shape of the parcel of water. The center of the IVW was determined, and distance to the prey (dp) and the boundary (db) were used to calculate accuracy index as AI = 1 - (dp/db). Compared to published 2D data for centrarchids, predator ram speeds determined from 3D kinematics were greater when capturing live, untethered fish prey in an unconstrained environment. These factors resulted in lower AI scores than those published previously. However, the shape of the ingested volume became longer and narrower with increased speed, representing a continuation of the relationship found at lower ram speed in 2D. Therefore, the predicted accuracy determined from 3D unconstrained trials is valid. This method represents an innovative way to determine predator accuracy that not only accounts for the hydrodynamics of suction, but can also be used in the absence of PIV techniques. Predicting accuracy during natural feeding events offers the ability to relate functional consequences to behavior, and is important for future analyses of predator-prey interactions in fishes.

P1.209 KANGAS, K.A.*; GUERRERO , V.; BENTLEY, G.E.; Univ. of California, Berkeley, Univ. of California, Berkeley; Integrative Biology and Helen Wills Neuroscience Institute; *k_kangas@berkeley.edu*

Awaking a sleeping dogma: de novo hypothalamic melatonin synthesis in passerines

Annual fluctuations in photoperiod, associated with seasonal availability of resources, mediate physiological and behavioral changes across vertebrate taxa. Variations in the duration of nocturnal melatonin secretion in temperate zones provide information about the time of day and year. Changes in photoperiod regulate gonadal growth and regression in seasonal breeders, and administration of melatonin has profound effects on mammalian gonadal status. Unlike in mammals, there is a long-standing dogma that pineal melatonin is not involved in avian seasonal reproduction. Recent evidence suggests hypothalamic melatonin synthesis *de novo* in galliform birds. Hypothalamic melatonin could well be involved in the timing of reproduction in birds. Our preliminary data indicate that passerine birds *Sturnus vulgaris* are likely to produce hypothalamic melatonin, causing us to reconsider the role of melatonin in avian seasonal reproduction. This project investigates if melatonin can be synthesized de novo in the avian hypothalamus by confirming the expression of all four enzymes of the melatonin biosynthesis pathway: tryptophan-5-hydroxylase (TPH), 5-hydroxytryptophan decarboxylase (DDC), aralkylamine N-acetyltransferase (AANAT), and hydroxyindole-O-methyltransferase (HIOMT). This is the first time the expression of these four enzymes has been identified in the songbird hypothalamus. By comparing the diurnal and nocturnal expression levels of these enzymes in the hypothalamus relative to other tissues known to synthesize melatonin de novo, we demonstrate the potential for daily fluctuations of encephalic melatonin to influence avian photoperiodic responses. This will better our understanding of the crucial role of melatonin in the evolution of photoperiodic responses across vertebrates.

96.2 KAPLAN, M.B.*; MOONEY, T.A.; Woods Hole Oceanographic Institution; *mkaplan@whoi.edu*

Adverse effects of elevated CO_2 concentrations on squid (Doryteuthis pealeii) development and early life

Increasing quantities of anthropogenic carbon dioxide (CO_2) are being absorbed into the ocean, altering seawater chemistry and impacting diverse marine life in many ways. At particular risk may be the early life stages of fish and invertebrates with internal and external aragonite structures. Impacts on cephalopods are of major concern because of the central role they play in many ocean ecosystems and because of their importance to global fisheries. The objective of this work was to determine whether elevated CO_2 concentrations impact squid and the manners in which potential effects may be exhibited. Atlantic longfin squid (*Doryteuthis pealei*), an ecological and economical valuable taxon, were reared from eggs to hatchlings (paralarvae) in ambient (390 ppm) and elevated (2200 ppm) CO_2 concentrations in replicated experimental trials. Animals raised under elevated pCO_2 demonstrated developmental changes. The distribution of the proportion of paralarvae hatching by day differed significantly between treatments in both trials. In addition, body (mantle) length differed significantly between treatments. Aragonite statoliths, used for balance and detecting movement, were significantly shorter, had decreased surface area, and were typically malformed in paralarvae reared under elevated pCO_2. These results indicate that squid may be adversely impacted by ocean acidification conditions in multiple ways. These effects could impact squid paralarvae behavior and survival in the wild, which raises concern for direct and indirect consequences to marine food webs and commercial fisheries.

P3.192 KARAGIANNIS, EE*; MAYNARD, EM; VICKOWSKI, FB; MACESIC, LJ; GILLIS, GB; Mount Holyoke College, Wheaton College; *ggillis@mtholyoke.edu*

What goes up must come down: Forelimb kinematics in cane toads during jumping and landing

Jumping anurans have long been a model for addressing questions in locomotor biomechanics. However, most research has focused on take-off, while landing remains less well explored. Cane toads (*Bufo marinus*) exhibit coordinated landing, using their forelimbs to decelerate and stabilize the body after impact. We've shown previously that forelimb muscle use in these animals is distance-dependent, with EMG signal timing and intensity varying predictably with hop distance. To better understand how these differences in muscle activity translate into forelimb movements, we studied elbow angle excursions during jumping and landing in six toads. We were interested in testing whether toads undergo similar amounts of elbow flexion after impact regardless of hop distance. We digitized joint landmarks and processed 3D coordinate data using custom Matlab routines to determine elbow angle excursions as well as rates of elbow extension and flexion before and after landing. During hopping, toads exhibited a consistent pattern of forelimb movements. First, as a hop started, the elbow extended (mean = 8°). After this initial extension the elbow flexed roughly 30° as the hands left the ground and were swung forward. In mid-air the toad re-extended the elbow prior to impact (mean = 41°). After impact, the elbow flexed 38° on average. Impact-related elbow flexion increased with hop distance, however, the amount of elbow extension that preceded impact also typically increased with distance. Thus, the final elbow angle reached after impact varied little, regardless of hop distance, suggesting that cane toads modulate mid-air elbow extension to compensate for impending impact-related flexion and prevent over-stretching of elbow extensors during landing.

1.3 KARASOV, WH; Univ. of Wisconsin, Madison; *wkarasov@wisc.edu*

Research paradigms in nutritional ecology inspired by Ken Nagy

Although the majority of Ken Nagy's work focused mainly on energy expenditure in free-living vertebrates, more than 20% of his journal publications were concerned with nutritional ecology. His highly empirical studies involving detailed budgets of energy, mass, and specific elements and nutrients advanced knowledge about topics such as the cost of growth, the digestibility of foods of wild vertebrates, the mechanistic bases for observed digestibilities, and the nutritional qualities of whole diets. A hallmark of the work was the way it was integrated with the ecological and sometimes evolutionary contexts of the animals he studied, resulting in in-depth understanding of the nutritional ecology of diverse organisms such as ectothermic and endothermic desert herbivores, marine iguanas, and tropical howler monkeys. I will elaborate on how the work was also foundational for development of new tools and research directions in ecology. For example, the water economy index (ratio of water influx to field metabolic rate) became a new tool to indicate the likelihood of surviving without supplemental water. The estimates of the ecological cost of growth can advance models of growth in the emerging field of metabolic ecology. The budgeting approach lent itself to the subsequent integration of how natural toxins and contaminants relate to animal energetics and nutritional ecology.

52.4 KASPARI, M*; CLAY, NA; YANOVIAK, SP; REVZEN, S; CZEKANSKI-MOIR, J; LUCAS, J; KAY, A; University of Oklahoma, University of Michigan, University of St. Thomas; *mkaspari@ou.edu*

On the evolution of ant thermal performance: clues from a Neotropical forest

Thermal performance curves quantify the ability of an individual to interact with its environment across a range of temperatures. Thermal performance curves reflect critical thermal minima and maxima, thermal range, and the activity energy (or Q10) of behavior. They have implications for both ecosystem services and the future of biodiversity in a warming world. We report thermal performance of worker tempo for 92 species of ant from the Neotropical forest of Barro Colorado Island Panama. Consistent with the Thermal Adaptation Hypothesis canopy ant populations averaged Thermal ranges that were 7 °C higher than populations from the understory (n=69), brought about by higher Critical Thermal Maxima. Consistent with the Size-Inertia hypothesis, CTmax and CTmin increased and decreased respectively ca. 2.5 °C for every 10-fold increase in body mass; a pattern repeated within dimorphic species. Moreover, a second mechanism adapting canopy ants to the warmer canopy was suggested by the 3.5 °C greater mass-corrected CTmax for canopy populations. Average ambient temperatures are predicted to increase by 5 °C in this Panama forest by 2080, suggesting a pre-adaptation for canopy ants to a warming world. However the temperatures of surfaces, and not open air, are those experienced by tiny cursorial organisms. The number of sunny hours may be a more important, and far less understood, driver of thermal ecology for invertebrates that live on terrestrial surfaces. Finally, the Q10 of activity ultimately arises from the concerted action of enzymes, most of which require metal atoms. We test the Q10-Bioaccumulation hypothesis that posits that species with lower concentrations of these metals have commensurately higher Q10s.

P2.186 KATAGI, A*; DRAUD, M; SANTAGATA, S; Long Island University-Post, Brookville; *ayakokatagi@hotmail.com*

Brain Development of Amatitlania nigrofasciata and the Onset of Aggressive and Territorial Behaviors

Animals often secure resources, such as food and mates, through the expression of a suite of behavior collectively referred to as aggression. Aggressive behaviors are likely finely honed by evolution because of their impact on lifetime reproductive success. Fishes in the family Cichlidae are a prominent example of animals that exhibit aggressive behavior. We used the convict cichlid, *Amatitlania nigrofasciata*, as a model species to study the role of brain development and brain growth in the ontogeny of conspecific aggressive behaviors. Our behavioral experiments were based on the responses of a resident fish to a new intruder. We measured the growth of developing brain regions in embryos, larvae, and juvenile fish with epifluorescence and light microscopy using image analysis software. We then explored how changes in brain development and growth correlated with the onset of rudimentary aggressive behaviors (poking and biting), coordinated aggressive behaviors (tail beating and mouth wrestling), and territorial behaviors (approach and territory entry). Although not previously documented for juvenile stages, the resident fish's simple aggressive behaviors towards intruders began immediately after the wiggling stage, when the fry (6 mm) become able to swim. More advanced (adult-like) aggressive behaviors such as tail beating and mouth wrestling were also observed in juvenile fish and become more complex in juveniles 2 cm in length. Of the seven measured brain regions, growth of the cerebellum, and, more notably, the telencephalon are best positively correlated with the onset of territorial behaviors and both categories of aggressive behaviors in convict cichlids.

P3.165 KATZ, H*; LEVIN, E; MACESIC EKSTROM, LJ; GILLIS, GB; Univ. of Chicago, Tufts University, Wheaton College, Mount Holyoke College; *ggillis@mtholyoke.edu*

Making a Splash: The effect of environment on landing preparation in Lithobates catesbeiana

During a step or a jump, limb muscles are activated before the foot actually makes ground contact to help coordinate landing and counteract ground reaction forces. In humans and a number of other mammals, both the timing and amplitude of this "pre-landing" muscle activity are variable and shift with the expected time and force of impact. Recent work with various anuran species, including the American bullfrog (*Lithobates catesbeiana*), has shown that they too produce pre-landing muscle activity in the forelimbs that is tuned to the time and magnitude of impact. In order to test if this pre-landing muscle activity is conserved regardless of landing environment we took electromyographic recordings from the *m. coracoradialis* (an elbow flexor) and the lateral head of *m. anconeus* (an elbow extensor) during jumps into water as well as onto land. Results indicate that similar patterns of activity are present in these muscles regardless of the landing medium. However, in some animals pre-landing muscle activation intensity in the *m. anconeus* was lower when the animal was hopping into water than when it was hopping onto land. Further, pre-landing intensities in the *m. coracoradialis* were positively correlated with distance during both types of hop, although they increased at a greater rate with hop distance when animals were landing in water compared to on land. Our data suggest that pre-landing forelimb muscle activity in bullfrogs can be subtly modulated depending on the landing environment.

29.5 KATZ, S.*; TRESGUERRES, M.; ROUSE, G.W.; Scripps Institution of Oceanography, UCSD, San Diego; *skatz@ucsd.edu*

Drilling for nutrition: The physiological mechanism of bone penetration by Osedax

Annelids belonging to Siboglinidae lack a gut and obtain nutrition via bacterial symbionts housed in a specialized organ called the trophosome. While most siboglinids host chemoautotrophic symbionts, which allow them to thrive in reducing habitats such as hydrothermal vents or methane seeps, *Osedax* exploits vertebrate bones lying on the seafloor. Furthermore in contrast to other siboglinids, *Osedax* house heterotrophic Oceanospirillales bacteria in their posterior body, which is modified into so-called 'roots'. These roots penetrate and ramify through the bone, which serves as their food source (Goffredi et al., 2007). However, *Osedax* lack any obviously bioabrasive structures and the physiological mechanism of bone erosion and nutrient absorption has been virtually unknown. The ultrastructure of the root epidermis suggests secretory/absorptive functions of this region and we hypothesized *Osedax* demineralize the bone by secreting acid, followed by absorption of bone collagen and lipids for nutrition. Our analysis of putative acid-secreting proteins, namely vacuolar H^+-ATPase (VHA) and carbonic anhydrase (CA), by immunohistochemistry and quantitative immunoblotting, shows preferential location and high abundance of VHA in the root epidermal cells. Analysis of transcriptome data of the root vs. the trunk region also confirms this pattern. CA is co-occuring with VHA in the root epidermis, and additionally found in other cells and body regions, suggesting CA is also involved in maintaining acid/base balance throughout the worm. These results support our hypothesis on bone erosion via acid secretion by *Osedax*, which is similar to chemical mechanisms employed for boring by some gastropods and for bone demineralization by human osteoclasts.

94.4 KAVANAGH, KD*; WINSLOW, B; LEARY, B; Univ. of Massachusetts Dartmouth; *kkavanagh@umassd.edu*

Evolutionary and Developmental Modularity in the Digits of Vertebrates

The toe bones of most tetrapods include the metatarsal followed by a series of phalanges bones. In the embryos, these bones develop in sequence as chondrogenic condensations that grow out distally and segment behind the growing tip to position the joints. By the time the tip is formed, the final adult proportions of the toes are achieved. Among taxa, phalanges' sizes covary in a highly predictable way, with variations ranging from equal-sized to a proximodistal gradient. The metatarsal variation does not follow this rule, indicating separate evolutionary modules. However, evidence of developmental modularity that establishes independence of MT and phalanges has been elusive. Previous analyses of gene expression and morphogenetic processes consistently show no differences between formation of metatarsal and phalanges. Here, we have found evidence of emergent modularity in the digit. Using experimental perturbations and DiI cell tracing in the chick, we establish the timing of very early separation of MT and phalanges compartments. In contrast, formation of individual phalanges remains plastic until late phalangeogenesis. We propose a two-stage evolutionary scenario for the tetrapod digit.

S3-2.3 KAWANO, S.M.*; BLOB, R.W.; Clemson Univ.; *skawano@clemson.edu*
Comparative appendicular function during terrestrial locomotion: implications for the invasion of land
The invasion of land was a pivotal event in vertebrate evolution that was associated with major appendicular modifications. Although fossils indicate that the evolution of fundamentally limb-like appendages may have occurred in aquatic environments, the functional consequences of using early limbs, rather than fins, for terrestrial propulsion have had little empirical investigation. Moreover, while many fossil specimens have indicated that terrestrial adaptations first arose anteriorly in tetrapodomorphs, some experimental data have suggested a greater antiquity to "hindlimb driven" locomotion. To examine these aspects of vertebrate locomotor evolution during the invasion of land, we measured three-dimensional ground reaction forces (GRF) produced by isolated pectoral fins of mudskipper fishes (*Periophthalmus barbarus*) during terrestrial crutching and compared these to isolated walking footfalls by the fore- and hindlimbs of tiger salamanders (*Ambystoma tigrinum*). As a proportion of body weight, isolated fins of mudskippers bear similar peak net GRF magnitudes as salamander limbs, but fin GRFs are inclined more medially. Comparing salamander fore- and hindlimbs, although the peak net GRF occurs later in stance for the forelimb, both limbs experience nearly identical mediolateral and vertical GRF components, suggesting they make comparable contributions to support. Thus, a major locomotor role for the forelimb may have persisted extensively among basal tetrapods. However, the salamander forelimb was typically deceleratory at peak GRF, whereas the hindlimb and mudskipper pectoral fin were mainly acceleratory. Together, data from these extant taxa help clarify how structural change may have influenced locomotor function through the evolutionary invasion of land by vertebrates.

P2.152 KEHR SMITH, A. J.*; JAECKLE, W. B.; Illinois Wesleyan University; *akehrsmi@iwu.edu*
Feeding modes by planulae of Nematostella vectensis (Cnidaria: Anthozoa)
We assessed the ability of larvae of the starlet sea anemone, *Nematostella vectensis*, to assimilate dissolved organic material (DOM) and ingest artificial and natural particles from seawater. Planulae were exposed to the proteins ferritin and labeled bovine serum albumin (FITC-BSA) and the polysaccharides iron dextran and labeled dextran (FITC-dextran) at solute concentrations between 0.25-1.0 mg/mL for 1-5 hours at 22°C. Other larvae were incubated with polystyrene beads (0.5 µm, 10^6 beads/mL and 4.5 µm and 6 µm, 10^3 beads/mL) or with algal cells (*Dunaliella tertiolecta*, 5 x 10^3 cells/mL) for 2.5-5 h. The label from all provided macromolecules was detected only within the gastrovascular cavity. In intact and sectioned (1µm) larvae assimilation of ferritin was detected within cells of the pharynx and the endoderm. Assimilation of BSA-FITC was inferred from the presence of a diffuse fluorescence visible only in endodermal cells. The label from iron dextran and FITC-dextran was not detected within cells. Control larvae not exposed to provided macromolecules showed no detectable label. We found no particles in the gastrovascular cavity of larvae. These data indicate that particulate foods do not contribute to the energetics of larval development of *N. vectensis*. In contrast, planulae assimilated some forms of DOM (proteins) but not others (polysaccharides), suggesting that specific DOM could contribute to the energetics of larval development.

57.3 KEISER, C.N.*; MONDOR, E.B.; University of Pittsburgh, PA. Georgia Southern University, Statesboro, GA, Georgia Southern University, Statesboro, GA; *cnk21@pitt.edu*
Maternal predation risk induces transgenerational behavioral plasticity in a parthenogenetic insect
It is becoming increasingly evident in many organisms that cues of immediate and latent predation risk in one generation can induce defensive phenotypes in the next generation. This predator-induced transgenerational phenotypic plasticity has been widely documented in the induction of defensive morphologies in naïve offspring, though relatively little is known about transgenerational plasticity in offspring behavior. To address the possibility of transgenerational behavioral plasticity in the pea aphid, *Acyrthosiphon pisum*, a group-feeding parthenogenetic insect, we exposed pre-reproductive individuals of two clonal lines ("green" and "pink" color morphs) to the aphid alarm pheromone (E)-&beta-Farnesene (EBF), a reliable cue of increased predation risk. Compared to controls groups, offspring of aphids exposed to a single alarm pheromone emission altered their feeding site choices relative to the location of the maternal aphids, occupying lower-risk feeding sites. The two clonal lines responded differently; green juveniles occupied "safer" feeding sites in the natal colony, while pink offspring were more likely to disperse to feeding sites on neighboring plant leaves. Offspring responses were also different depending on the cultivar of broad bean, *Vicia faba*, upon which they were feeding. This may indicate an influence of host-plant quality on aphid defensive behavior. Further studies are needed to clarify the association between the transgenerational induction of morphological and behavioral defenses, and how transgenerational behavioral plasticity augments survival of the clonal lineage.

P2.136 KELLER, EK*; TAMONE, SL; RAY, L; University of Alaska Southeast; *ekkeller@uas.alaska.edu*
Temporal secretion of ecdysteroids over the premolt period in two life histories of Tanner crab Chionoecetes bairdi
Chionoecetes bairdi (Tanner crab) and *C. opilio* (snow crab) are commercially important crabs that inhabit the North Pacific. Unlike many other crustaceans, *C. bairdi* and *C. opilio* undergo a terminal molt before becoming mature adults. Studies showed that *C. bairdi* and *C. opilio* males do not undergo their terminal molt at a particular size or developmental stage. Because Tanner crabs are harvested according to size, the fishery could be selecting for smaller sized crab at maturity. Understanding environmental or hormonal regulators of molting is important for understanding growth which is important for managing a sustainable fishery. Molting is coordinated by ecdysteroids (molting hormones) and methyl farnesoate which is similar to the developmental hormone in insects. It is likely that MF influences the terminal adult-differentiating molt. The objectives of this study were to determine the duration of pre-molt in *C. bairdi* and improve our understanding of how hormones influence the terminal molt. Hemolymph samples were collected from 47 adolescent male *C. bairdi* over a six month period until the crab molted. Most of the crab terminally molted during the sample period, but some also molted to larger adolescents. Hemolymph ecdysteroids were analyzed using an ELISA. Ecdysteroids at the onset of pre-molt were 357.1 ±67.5 ng/ml. Ecdysteroids peaked at 2056.5 ±435.2 ng/ml, then dropped to 79.6 ±96.0 ng/ml during molt and remained low (<20 ng/ml) post-molt. *C. bairdi* spend approximately 120 days in pre-molt and this is independent of crabs undergoing a terminal molt.

47.3 KELLEY, AL*; DERIVERA, CE; Portland State University;
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Intraspecific variation in heat shock response and cell-cycle modulation in the invasive Carcinus maenas, the European green crab, on the west coast of North America

Physiological studies have long been utilized to understand the role of abiotic features in the distribution of native organisms within marine communities. For the invasive decapod *Carcinus maenas*, environmental temperature has been implicated as the main predictor of establishment success across temperate regions. Therefore, investigations into the regulation of thermotolerance are paramount to identifying those physiologic mechanisms that may facilitate invasion success. A comparative laboratory analysis of *Carcinus maenas*, the European green crab, sampled from the northern, cold acclimated (British Columbia-BC), and southern, warm-acclimated (California-CA), investigated how these disparate thermal environments resulted in differential expression of proteins involved in the heat shock response and cell-cycle regulation when given heat and cold stresses. This work clearly illustrates that a divergence in physiological phenotypes exist across this meta-population despite having the smallest degree of genetic diversity of all invasive and native populations, and a relatively short invasion timeline of only 20 years.

46.5 KELLY, M.W.*; PADILLA-GAMINO, J.L.; HOFMANN, G.E.; Unversity of California, Santa Barbara;
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Natural variation, and the capacity to adapt to ocean acidification in the sea urchin Strongylocentrotus purpuratus

There is a rapidly growing body of literature documenting potential negative effects of CO2-driven ocean acidification (OA) on marine organisms. However, nearly all of this work has focused on the effects of future conditions on modern populations, ignoring the role of adaptation. We measured the capacity to adapt to OA in two populations of the ecologically important purple sea urchin *Strongylocentrotus purpuratus* by using a breeding experiment to estimate additive genetic variance for larval size under future high pCO2/low pH conditions. Although larvae reared under future conditions were smaller than those reared under present-day conditions, there was also abundant genetic variation for body size under elevated pCO2, indicating that this trait can evolve. Accounting for the observed genetic variation in models of future larval size and demographic rates substantially altered projections of performance for this species in the future ocean. There were also subtle differences in larval size between populations of this species under high pCO2 rearing conditions in the laboratory, consistent with local adaptation to carbonate chemistry in the field. These results suggest that spatially varying selection may help to maintain genetic variation necessary for adaptation to future ocean conditions.

63.6 KELLEY, K.M.*; REYES, J.A.; California State University, Long Beach, Pacific Coast Environmental Conservancy;
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Contaminant Effects in Fish: Development of Multiple Measures Screening Approaches

In studies in urban California waters, observed environmental effects in wild fish often reflect specific types of environmental conditions, including presence of chemical contaminants. Since different types or classes of chemicals typically act through distinct phenotypic pathways, development of multiple phenotypic measures have strong potential to serve as screening and diagnostic tools to predict types of active environmental constituents and their health effects. It has been the goal of these studies to develop multiple-measures approaches using proteomics technologies combined with measures of endocrine and physiological status. Proteomes of liver and other tissues are being characterized to discover proteins whose expression is altered in relation to different kinds of contaminant exposures and endocrine system status (endocrine disruption). Since all parameters are measured within the same individuals, it is possible to evaluate contaminant exposures, effects, and endocrine system status using correlative and multivariate statistical analyses. Identification of new protein biomarkers and their expression differences point to changes in toxicological processes, oxidative stress response, hepatic fuel metabolism, and altered signaling (endocrine, intracellular), among others. The multiple-measures approach is providing new insight on the phenotype of animals affected by different kinds of environmental contaminants, and shows promise as a powerful, integrative diagnostic tool to evaluate environmental effects.
[Supported by NOAA/USC Sea Grant Program]

40.2 KENALEY, C. P.*; LAUDER, G. V.; Harvard University;
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BassBot: A Biorobotic Model of the Teleost Feeding System

Comparative morphologists have studied aquatic prey capture in fishes for nearly two centuries. Although current approaches will continue to yield fruitful insights into the relationships between form, function, and performance, studies of live fishes are limited in their ability to isolate and manipulate individual variables. Biorobotic models of vertebrate systems have risen to the fore as valuable and transformative tools that permit investigators to study comparative biomechanics in entirely new ways. Here we present a biorobotic model of the teleost feeding system based on the largemouth bass (*Micropterus salmoides*), a combination RAM-suction feeder. “BassBot” incorporates a three-dimensional armature of the bass head fabricated from poly(methyl methacrylate) plastic. The hard anatomy of the model represents the functional units of the teleost head including the neurocranium, maxillary apparatus, lower jaw, hyoid, suspensorium, and opercular apparatus, with an overlay of skin cut from ultra-thin latex. Constrained by the properties and positions of joints found in the bass skull and powered by DC linear motors representing the levator operculi, adductor mandibulae, hypaxial, and epaxial muscles, the three-dimensional kinematic profiles of these functional units are precisely controlled. Programing of linear motors permits repeatable and precise simulation of behaviors (e.g., hyoid depression and lateral expansion of the suspensoria). We also present preliminary results of BassBot feeding experiments that focus on kinematic profiles and suction performance. These results demonstrate a relatively accurate match between feeding in BassBot and live bass and illustrate the promise that robotic models have in understanding the relationship between morphology and performance in fish feeding systems.

8.5 KENKEL, CD*; ALMANZA, AT; MATZ, MV; Univ. of Texas at Austin; *carly.kenkel@gmail.com*
Physiological and genetic underpinnings of local coral adaptation in the Florida Keys
Coral reefs throughout the world, and especially in the Caribbean, are experiencing declines attributable to direct anthropogenic impacts on reef ecosystems exacerbated by the effects of global climate change. However, the relationships between environmental parameters and coral reef health are far from clear. In the Florida Keys, offshore reefs experience seemingly benign environmental conditions yet exhibit consistently lower coral cover and lower coral growth rates than mid-channel and inshore patch reefs that are subject to higher nutrient loads and thermal extremes. We preformed reciprocal transplants of the mustard hill coral, *Porites astreoides*, between two inshore and two offshore reefs to identify patterns of local adaptation and the physiological and/or genetic mechanisms that enable this species to inhabit both reef environments. Each of the four locations was represented by 15 genotypes (individual colonies), which were fragmented and outplanted at local and foreign sites. Samples of each individual were collected after six months and one year. Microsatellite analysis of the coral host revealed subtle but significant genetic subdivision between inshore and offshore populations, potentially facilitating local adaptation. Following the first six months of transplantation, offshore-origin corals exhibited higher growth rates and higher protein content than inshore corals at all sites. In addition, all coral genotypes tended to grow less at offshore sites compared to inshore, suggesting the presence of some unidentified stressor(s) that might explain lower coral cover at offshore reefs. Ongoing analysis of additional metabolic parameters in both the host and symbiont together with host global gene expression profiling with RNAseq will provide further insight into physiological and molecular mechanisms underlying these patterns.

P3.206 KENKEL, CD*; MATZ, MV; PARTICIPANTS OF THE 2010 AND 2011 GENE EXPRESSION BIOMARKERS WORKSHOPS, ; Univ. of Texas at Austin; *carly.kenkel@gmail.com*
Gene expression biomarkers of acute and chronic heat stress in a reef-building coral
Coral reefs are declining worldwide due to increased incidence of coral bleaching, which will have widespread biodiversity and economic impacts. While the environmental conditions that promote bleaching are known, how climate information relates to the actual stress experienced by corals at any particular reef site is not well understood. Gene expression analysis based on quantitative PCR (qPCR) can be used as a diagnostic tool to determine coral condition *in situ*, providing means of linking physiology with putative environmental stress. First, we performed a graded heat-stress experiment to assess the sensitivity of our previously published acute stress markers in the mustard hill coral, *Porites astreoides*. Four candidates showed correspondingly graded expression, as well as the simplified double-gene assay, which relies on the non-normalized expression values of only two genes, Hsp16 and Actin. However, when these acute stress candidates were tested in response to a natural bleaching event, no expression differences between bleached and non-bleached individuals were observed. A second experiment subsequently exposed *P. astreoides* fragments to chronic heat stress (six weeks under elevated temperature), which did induce bleaching responses. A subset of these bleached individuals were used in an RNAseq analysis to identify chronic stress candidates. Nine candidate genes were validated in the remaining experimental individuals using qPCR. Two of them showed significant (adjusted, $p<0.05$) down-regulation under stress, a carbonic anhydrase and an anion transporter, while two more showed noticeable trends (adjusted $p<0.1$). The anion transporter demonstrated a particularly large dynamic range, with down-regulation of 26-fold, rendering it a viable marker of chronic heat stress.

P3.190 KENNEDY, N.K.*; BHATT, R.; VAN VALKENBURGH, B.; Univ. of California, Los Angeles; *natalia.k.kennedy@ucla.edu*
A Geometric and Kinematic Backbone Model of the Cheetah, Acinonyx jubatus
Cheetahs are the fastest land animals, partly due to their spinal flexibility. Surprisingly, there has never been a detailed study of the musculoskeletal anatomy and function of their vertebral column despite the obvious contributions it makes to cheetah speed through extreme flexion and extension. Using anatomical data, radiographs, and 3-D laser scanning, a geometric and kinematic computer model of the vertebral column of the cheetah was created. This model allows a clearer understanding of the spinal flexibility of the cheetah, as well as which specific areas are fundamental in providing the vertebral column flexibility necessary for fast running.

45.3 KENNEDY, L.V.*; GUGLIELMO, C.G.; University of Western Ontario; *lkenne2@uwo.ca*
DYNAMICS OF FAT AND LEAN MASS IN REFUELLING MIGRANT PASSERINES MEASURED USING QUANTITATIVE MAGNETIC RESONANCE
Although fat deposition during stopover in migrating passerine birds has been extensively studied, changes in lean mass during refuelling are not well understood. I used quantitative magnetic resonance (QMR) analysis to measure the deposition of fat and lean mass for both recaptured and single capture migrant passerines in spring and fall at Long Point, Ontario. Both the recapture analysis and single capture regression analyses indicated a substantial contribution of lean mass to overall increases in total body mass across 18 species. Lean mass contribution to changes in total body mass is substantial, ranging anywhere from -35 to 113 % of mass increase and in some cases, was more dynamic than fat mass deposition during refuelling at stopover sites. The results of both regression and recapture analyses also suggest that smaller birds deposit relatively less lean mass and more fat per gram gained than larger birds. Our results support recent studies suggesting that lean mass is a dynamic body component during migration in all short-, medium- and long-distance migrant passerines. Thus, the accumulation of protein, and not just energy is an important driver in the foraging ecology of migratory birds.

77.1 KERNEY, R R*; BRITTAIN, A L; HALL, B K; BUCHHOLZ , D R; Gettysburg College, University of Cincinnati, Dalhousie University; *rkerney@gettysburg.edu*
Cartilage on the Move: Cartilage Lineage Tracing During Tadpole Metamorphosis
The reorganization of cranial cartilages during tadpole metamorphosis is a set of complex processes. The fates of larval cartilage-forming cells (chondrocytes) and sources of adult chondrocytes are largely unknown. Individual larval cranial cartilages may either degenerate or remodel, while many adult cartilages appear to form de novo during metamorphosis. Determining the extent to which adult chondrocytes/cartilages are derived from larval chondrocytes during metamorphosis requires new techniques in chondrocyte lineage tracing. We have developed two transgenic systems to label cartilage cells throughout the body with fluorescent proteins. One system strongly labels early tadpole cartilages only. The other system inducibly labels forming cartilages at any developmental stage. We examined cartilages of the skull (viscero- and neurocranium), and identified larval cartilages that either resorb or remodel into adult cartilages. Our data show that the adult otic capsules, tecti anterius and posterius, hyale, and portions of Meckel's cartilage are derived from larval chondrocytes. Our data also suggest that most adult cartilages form de novo, though we cannot rule out the potential for extreme larval chondrocyte proliferation or de- and re-differentiation, which could dilute our fluorescent protein signal. The transgenic lineage tracing strategies developed here are the first examples of inducible, skeleton-specific, lineage tracing in tadpoles.

BERN.1 KETTERSON, Ellen D.; Indiana University; *ketterso@indiana.edu*
Synthesizing research on the adaptable snowbird: geographic variation, seasonality, and evolutionary endocrinology
Evolutionary endocrinology explores the role of endocrine systems in adaptive evolution by relating hormones to phenotypes to fitness. Three key concepts include hormonal pleiotropy, phenotypic integration, and hormones as agents of change and stasis. The dark-eyed junco, a songbird species, has played historically important roles in our understanding of speciation and seasonality, and continues to provoke curiosity about what a species is and how populations respond to long- and short-term changes in the environment. This talk will consider how selection acts on experimentally induced and naturally varying hormonal phenotypes. It will also address the role of variation in hormonal signal strength and target sensitivity in accounting for varying degrees of phenotypic integration. Populations will be compared to assess the role of timing of reproduction and migration in population divergence, and recent examples of juncos entering novel habitats will demonstrate how endocrine-mediated plasticity can promote successful colonization and adaptation to changing environments. The contributions of many individuals will be highlighted and video clips will serve to illustrate birds, habitats, and history.

P1.121 KHALILI, S.; WHALEN, W.; MAGIE, C.R.*; California State University, Fresno, Quinnipiac University; *craig.magie@quinnipiac.edu*
Rho GTPase function during early development in the cnidarian, Nematostella vectensis
Gastrulation is a central event in metazoan development and the first morphogenetic process in the embryo, resulting in the formation of a multilayered embryo from a monolayered blastula. Gastrulation strategies involve many different cellular behaviors that require the precise control of cell dynamics, making gastrulation an excellent context in which to study the molecular mechanisms underlying morphogenesis. In addition, understanding how morphogenesis is controlled in early-branching metazoans will help clarify the evolution of these processes. To this end we have examined the expression and function of the Rho family of small GTPases (including Rho, Rac, and Cdc42) during gastrulation in the cnidarian, *Nematostella vectensis*. Rho GTPases have been shown to be important regulators of cellular behavior through their effects on a variety of processes, including actin cytoskeletal rearrangement, transcriptional activation, and regulation of cell adhesion. One of the pathways through which Rho is thought to act is downstream of the Wnt/planar cell polarity (PCP) pathway. In *Nematostella*, morpholino oligonucleotides that block function of the PCP cell surface molecule Strabismus also block invagination. Because of this, we hypothesize that Rho GTPases may be involved in the regulation of invagination during gastrulation in *Nematostella*. We are currently utilizing a morpholino-based approach to perturb function of Rho, as well as a pharmacological approach to inhibit the function of downstream Rho effectors. We have observed that Rho, Rac and Cdc42 are ubiquitously expressed at the gastrula stage in *Nematostella*, with a higher level of expression in the endoderm at the planula stage. Preliminary functional data suggest that the molecular mechanisms underlying Rho function in *Nematostella* may be distinct from those in bilaterian taxa.

P2.52 KHORSHIDCHEHR , DM*; RYAN , DS; FEITL , KE; MCHENRY , MJ; MULLER , UK; California State University Fresno, University Wageningen, University of California Irvine, University of California Irvine; *dariusmk@mail.fresnostate.edu*
Escape trajectories of larval zebrafish to vertical and horizontal suction stimuli
Fish execute a C start when they escape from a predator. Previous studies suggest that fish randomize their horizontal escape trajectories, but bias the response away from the stimulus. The few studies that looked at the vertical trajectory found that fish larvae respond to a horizontal stimulus with a downward escape trajectory. This study quantifies the escape trajectories of fish larvae in three dimensions. We use a vertical and a horizontal suction stimulus to explore the effect of stimulus direction on the escape trajectory. We found that zebrafish larvae (age 3 to 12 days post-fertilization) consistently responded to a horizontal stimulus with a downward trajectory. For the horizontal stimulus, out of 70 video recordings, 54 showed escape responses (77.1%). 52 of those responses showed a downwards trajectory (96.3%). Current qualitative data suggests that the same trend holds true when we use a vertical stimulus, simulating a benthic predator. Given the age range of the larvae, the downward trajectory cannot be explained by asymmetry of the body due to the presence of a yolk sac; the yolksac is absorbed usually at age 5 to 6 days. So the downward trajectory might be a hardwired response (zebrafish larvae are demersal) or indicate that fish have less control over their pitch than their yaw angle – the body movements during an escape response might be able to generate a wide range of yawing moments, but not pitching moments, leading to the observed bias in the trajectories.

S1-3.4 KIøRBOE, Thomas; Technical University of Denmark; *tk@aqua.dtu.dk*

Attack or attacked: The sensory and fluid mechanical constraints of copepod predator-prey interactions

Most animals are both predators and prey. This dual position represents a fundamental dilemma because gathering food often leads to increased exposure to predators. The optimization of the trade-off between eating and not being eaten depends strongly on the sensing, feeding, and motility mechanisms of the parties involved. I here describe the mechanisms of sensing, predator escape, and prey capture in pelagic copepods. Copepods can remotely sense their predators and prey from hydromechanical and chemical cues, they can capture evasive prey in efficient attack strikes or sense and collect prey that are arriving in their feeding current, they have unparalleled escape performances (the ‘strongest animal in the world’) and they can propel themselves with unusually high efficiencies (propulsion efficiency > 95 %) while minimizing their hydrodynamic footprints. I will describe all this by means of high speed video, flow visualization, and simple fluid dynamical experiments and models. I will conclude by presenting a mechanistically underpinned model that predicts optimal foraging behaviors and rationalizes observed size scaling and magnitudes of zooplankton clearance rates.

142.4 KIENLE, SS; San Diego State University; *sarah.stachura@gmail.com*

Hungry, Hungry Pinnipeds: The Comparative Feeding Morphology of Phocid Seals

Pinnipeds (seals, sea lions, and walruses) evolved specific feeding strategies to capture and consume prey underwater. Most are generalist feeders, employing pierce or suction feeding. Grip-and-tear and filter feeding are specialized strategies exhibited only by the crabeater seal and leopard seal. Phocids (true seals) are a model group for this study as they are the most diverse pinniped lineage with 18 extant species and employ all four feeding types. The objectives were 1) to determine the feeding strategies used by extant phocids, and 2) to compare generalist and specialist feeding strategies in an evolutionary and ecological context. Three dimensional landmark data were collected from 220 specimens representing all extant phocids. A total of 58 cranial and 24 mandibular landmarks were taken per specimen. Principle Component Analysis and Discriminate Function Analysis were performed. Coalescent-based methods were utilized to generate a molecular phylogeny, and comparative phylogenetic methods determined the ecological factors driving the evolution of each feeding type. The results show that grip-and-tear and filter feeders have evolved distinct feeding characteristics. These morphological adaptations have allowed crabeater and leopard seals to exploit novel niches. However, it has resulted in increased dependence on one or a few prey sources, which could affect survival if prey abundance changes. In contrast to previous studies, the generalist feeding strategies do not correlate with predicted feeding characters. These findings suggest that pierce and suction feeding are not distinct feeding categories or that there are more feeding categories than hypothesized. These results provide a framework to better understand the feeding modes employed by phocids, enabling us to predict how phocids will respond to changing environments.

P3.105 KILBOURNE, B.M.; Friedrich-Schiller-Universität Jena; *brandon.kilbourne@uni-jena.de*

Proportions and distribution of mass in the hindlimbs of neognath birds

While scale effects on avian hindlimb segment lengths and proportions have been studied in depth, the influence of size upon the proportions of segment masses remains unexplored. Furthermore, it is also unknown how individual segment masses contribute to the mass distribution of the overall hindlimb. To understand the influence of body and hindlimb size upon the mass proportions of avian hindlimbs, I collected data on body mass, hindlimb segment masses, and hindlimb length in 22 species of neognath birds. The species sample contains at least one representative of seven major neognath lineages and reflects a range of ecological specializations, and masses were recorded from the femoral, tibiotarsal, and tarsometatarsal segments, as well as the digits. Prior to dissecting limb segments from one another, I measured the center of mass (COM) position of the entire hindlimb relative to the femoral head. To understand the scaling of hindlimb COM position and segment masses, I tested empirical scaling relationships against the null model of geometric similarity. COM position scales with positive allometry relative to body mass but does not deviate from geometric similarity when scaling against hindlimb length. Thus, hindlimb mass shifts distally relative to body mass as body size increases in neognaths. Segment masses scale with isometry relative to both body mass and hindlimb length. The allometric exponent (0.41) when scaling hindlimb length against body mass is well above the prediction of geometric similarity (0.33), and the relationship between hindlimb length and body mass determines how COM position scales with body mass. Specifically, the results suggest that the positive allometry COM position is due to large-bodied neognath species having more extended hindlimbs than small-bodied neognaths and not due to differences in the mass of individual hindlimb segments.

102.3 KILBOURNE, B.M.; University of Chicago; *brandon.kilbourne@uni-jena.de*

Scale effects and rotational inertia in the limbs of quadrupedal mammals

Recent biomechanical studies have revealed that the metabolic cost of swinging the limbs is a significant portion of the total metabolic cost of terrestrial locomotion. Such studies suggest that limb rotational inertia, which reflects gross limb morphology, is relevant to understanding the mechanical cost of terrestrial locomotion. Yet scant data on limb inertial properties currently exist. Limb inertial properties – moment of inertia (MOI), mass, and radius of gyration – were measured from the fore- and hindlimbs of 44 species of quadrupedal mammals (representing eight major clades) to understand how limb rotational inertia varies with body and limb size. Muscles were left *in situ* on limb bones in order to measure limb inertial properties for the entire appendicular musculoskeletal system. Relative to body mass, limb length is positively allometric, with larger mammals having longer limbs relative to their body mass than smaller mammals. Fore-and hindlimb MOI is negatively allometric with limb length, with an allometric exponent of ~ 4.45 being significantly less than the predicted slope (5.0). Though the difference in actual and predicted exponents seems small, the negative allometry of hindlimb MOI results in a considerable decrease in MOI in larger limbed mammals relative to the predictions of geometric similarity. Thus, relative to limb length, larger mammals have limbs that consume less energy to swing than smaller mammals. Fore- and hindlimb mass scale with negative allometry relative to limb length. Radius of gyration – a measure of limb shape – scales with negative allometry (hindlimbs) or isometry (forelimbs) relative to limb length. Thus, hindlimb mass shifts proximally relative to hindlimb length with increasing limb size in mammals. Positive allometry of limb length and the negative allometry of limb inertial properties have a high potential to reduce the locomotor costs of large mammals relative to their size.

125.3 KILLPACK, T.L.*; CARREL, E; KARASOV, W.H.; Univ. of Wisconsin, Madison, MMSD High School Science Internship Program; *tkillpack@wisc.edu*

Impact of food restriction on immune function in altricial house sparrow nestlings

If resources are limiting, then trade-offs may occur between immune defense and life history components such as growth and development. We tested for such trade-offs in food restricted (FR) nestling house sparrows and, particularly, that immune function would be more reduced in a defense considered costly, like the acute phase response to lipopolysaccharide (LPS), compared with one considered less costly, like complement-mediated lysis. We tested birds both early in the nestling period, when growth demands are high, and late in the nestling period, when growth has reached a plateau. We examined the long-term effects of early FR on birds refed and tested late in the nestling period. Masses of alimentary organs and heart were significantly reduced in both early and late FR birds, yet reductions resulting from early FR were reversible in refed birds. Reduced skull length and lean flight muscle mass and maturity were observed with early FR, and refed birds had persistent reductions in muscle size and maturity. As predicted, FR did not significantly impact complement-mediated lysis, a constitutive component of immune function, yet levels of acute phase protein haptoglobin (Hp), an inducible component of the innate immune system, were reduced in early and late FR birds. Early FR had no long-term impact on Hp response, as refed birds challenged with LPS late in nestling period did not significantly differ in Hp response compared with late controls. Thus, innate immune function, like organ growth, appears to be flexible to resource supply during the nestling period, and early FR during the nestling period does not permanently stunt development of the innate immune system. Support: NSF-GRFP, AOU, USDA-Hatch, Birge Fund, GWIS-Ruth Dickie.

P3.129 KILVITIS, H.J.*; BORUTA, M.; RICHARDS, C.L.; MARTIN, L.B.; University of South Florida; *hkilviti@mail.usf.edu*

Does early-life exposure to bacteria have enduring effects on the immune system of zebra finches?

Environmental stimuli experienced within critical periods of development can have profound effects on adult phenotype. In rodents and birds, infection early in life can impact disease susceptibility into adulthood, particularly aspects of the acute phase response and immunoglobulin (Ig) responses to novel antigens. Although investigations have been heavily biased towards mammalian systems, a recurring observation is that enduring effects of early-life experience are often mediated by changes in glucocorticoid regulation. In a few cases, alterations in glucocorticoid regulation are orchestrated by molecular epigenetic mechanisms (e.g. methylation of glucocorticoid receptor promoters). Here we examined how early-life exposure to bacterial components and corticosterone influence immunoglobulin response to antigens in the zebra finch (*Poephila guttata*) in adulthood. Immunoglobulin Y (IgY) responses mediate memory of infection and are sensitive to glucocorticoids, thus they could be important mediators of changes in disease coping mechanisms that endure to adulthood. In summary, this project represents an initial foray into the behavioral epigenetics of avian immunity, particularly sickness behaviors, in which we will use methyl-sensitive AFLPs and pharmacological manipulations of epigenetic state to parse the roles of genes, environments, and epigenetic effects on critical elements of disease cycles.

26.3 KIM, TW*; TAYLOR, J; LOVERA, C; BARRY, JP; Monterey Bay Aquarium Research Institue; *ktwon@mbari.org*

Ocean acidification impairs olfaction and elevates respiration in deep sea hermit crabs, with high variation between individuals

Future ocean pH is projected to drop considerably at all depths as surface water continues to absorb rising levels of atmospheric CO_2; the pH at bathyal depths (200-2000 m) is expected to be lowered by 0.2-0.4 units by the end of this century. Still the ability of organisms to adapt to lower pH has been far less explored in deep water species than shallow water species. To test the effect of environmental acidification on deep-sea animals, we compared behavioral and physiological features of the deep-sea (~900 m) hermit crab *Pagurus tanneri* between pH 7.6 (ambient control) and pH 7.1 (low-pH experimental) lab conditions. No significant difference was detected between treatments for some parameters, such as oxygen consumption and the “boldness” of crabs, measured as time spent in shell after attack by a potential predator (octopus). At lower pH, however, hermit crabs decreased their rates of antennular flicking (the equivalent of “sniffing”) and also tended to have a slower speed of prey detection, indicating that lower pH can impair olfactory function. Respiration rates transiently increased in response to higher CO_2 level at 4 weeks after treatments but returned at 9 weeks. Furthermore, hermit crabs at lower pH showed higher individual variation in antennular flicking rates, prey detection speeds, and respiration rates. This pattern suggests that, although ocean acidification impairs some abilities linked to survival, the ability of *P. tanneri* to cope with lower pH appears to vary considerably among individuals, potentially promoting population survival by natural selection.

P1.137 KIM, T.L.*; NEUFELD, C.; Northwestern University, University of Washington; *tk12@u.northwestern.edu*

Variation in thermal tolerance between life stages of the intertidal copepod Tigriopus californicus

Predicting the impacts of climate change on species ranges is essential for global conservation efforts. Recent studies suggest thermal tolerance can vary considerably among geographically isolated populations within a single species. However, it is not clear whether similar variation in heat tolerance exists between life stages of organisms with complex life cycles. In this study, we test the thermal tolerance (LT_{50}) of each life stage in five populations of copepod Tigriopus californicus, spanning 18 degrees in latitude. Copepodites (juveniles) were able to tolerate 1-2°C higher temperatures than adult males or females within four of the five populations, on average. Furthermore, across all life stages, the southernmost population exhibited a 2°C higher heat tolerance than the least-tolerant population. The presence of biologically significant variation in thermal tolerance across some (but not all) populations and life stages suggests both factors should be included when forecasting climate change impacts on species ranges.

P1.179 KIM, G.R; PuKyung National University, Republic of Korea; *arctickkl@pknu.ac.kr*

Cloning and Expression Study of the Five Pandalopsis japonica (the Morotoge shrimp) Nicotinic Acetylcholine Receptor Subunits

The Nicotinic Acetylcholine Receptor (nAChR) is a diverse family of neurotransmitter-gated ion channels which contain five transmembrane subunits arranged around a central pore. It mediates synaptic transmission at the junction between nerve and muscle cell. It is also involved in several neurological pathologies. The basic linear sequence of all nAChR subunits appears as a large extracellular domain, four transmembrane domains, and a cytoplasmic domain of variable size that resides between transmembrane domain 3 and 4 (TM3 and TM4). Subunits are classified by the presence of two adjacent cysteines in c-loop which are important for acetylcholine binding. A Cys-Cys pair is identified only α-subunits. Compared with vertebrate, relatively less has been studied about the invertebrate nAChR, especially Crustacean's nAChRs. This study will help an understanding of Crustacean's nAChRs. Pandalopsis japonica (morotoge shrimp) is one of the important shrimp in East Asian countries, including Korea and Japan. From the previous Expressed Sequence Tag (EST) project, we identified 5 subunits that display a high sequence similarity to nAChR subunits. 4 alpha subunits, 1 beta subunit were confirmed by RACE and PCR sequencing. Phylogenetic analysis by amino sequence revealed that one alpha 4(Paj-α4), one beta 1(Paj-β1) and three divergent (Paj-α10~12) subunits are classified. Compare with insects, all subunits were much conserved. And Paj-α4 has three variants. This variants site was located between TM3 and TM4. More study is needed on this site. Attempts to express functional native nAChR consisting of Paj-α4, β1, α10~12 in Xenopus laevis oocytes were not expressed. Only Paj-β1 was heterologously expressed with Rα4 (Rattus norvegicus α-4 subunit). We report for the first time a heterologous functional nAChR consisting with invertebrate beta subunit.

P2.105 KIMMITT, A.A.*; REICHARD, D.G.; WELKLIN, J.W.; KETTERSON, E.D. ; Univ. of Mary Washington, Indiana Univ., Bloomington; *aakimmitt@gmail.com*

Differential courtship effort by mated and unmated males in a free-living songbird

Courtship displays that encompass multiple signaling modalities are utilized by males of many species to attract a potential mate. Females often prefer males that court using particular signals or intensities, yet males vary in their courtship characteristics and effort despite these preferences. In this study, we investigated whether mated males differed from unmated males in their courtship behavior or circulating hormone levels. We studied a songbird, the dark-eyed junco (*Junco hyemalis*), and presented free-living, males with a live, caged female conspecific. We stimulated the male to approach and court the female with playback of a female pre-copulatory trill, and we recorded each male's acoustic and visual courtship response. Immediately following the trial, we captured the male to take measurements and collect plasma to measure testosterone (T) and corticosterone (CORT). We also restrained males for 15 min and bled them again to measure restraint-induced CORT levels. Mated males were found to approach the female more closely, be more active, sing less long-range song, and display visually at maximum levels for longer than unmated males. While mated males were also significantly larger than unmated males, age and multiple morphological measures did not significantly correlate with any courtship behaviors. Mated and unmated males may adjust their behavior according to context exhibiting differences in courtship dynamics used when establishing a pair bond (unmated males) as compared to when seeking an extra-pair copulation (mated males). Results of hormone assays are still pending. Collectively, our results suggest that of the characters we measured, mating status is the best predictor of male courtship effort in juncos.

147.4 KINGSBURY, M A*; GATESY, S; GOLDMAN, D I; Georgia Institute of Technology, Brown University; *mkingsbury3@gatech.edu*

Sensitivity of foot intrusion kinematics during walking on granular media

Many long-legged organisms walk across granular media (GM), substrates whose properties depend on compaction state and disturbance history. Previous studies of a short-legged hexapedal robot [Li et al, PNAS, 2009], revealed that mobility was sensitive to timing of limb kinematics. However, limbs were short, feet were not biologically realistic (compliant c-shapes) and spatial kinematics were fixed. To begin to understand the role of foot kinematics on locomotion performance of long-legged locomotors, and to simplify analysis, we study walking in a bipedal robot (39 cm tall, 1.6 kg) moving on a GM of poppy seeds. Each leg is composed of 4 motors connected by segments which mimic avian limb morphology. Its feet are flat disks (diameter 9.2 cm), and toe tip trajectories and foot angle can be varied. The robot uses an alternating striding gait in which toe tips trace rectangular trajectories in the body frame. The robot is constrained by bearings that allow horizontal and vertical motion, but do not allow body rotation. We used an air fluidized bed to create loosely packed GM with volume fraction (the ratio of solid to occupied volume) $\varphi=0.58$, and closely packed GM with $\varphi=0.63$. We examined the role of the foot angle θ (defined as the angle of the foot relative to horizontal throughout its gait) in a range of $-8<\theta<15°$, with positive defined as the toe tip protruding from the GM. Despite its long limbs and large feet, robot performance was remarkably sensitive to θ and φ: forward speed in $\varphi=0.58$ was low (1.2 cm/sec) for $\theta<8°$ and increased by a factor of 2 as θ increased to 15°. For $\varphi=0.63$ speed was as low for $\theta<0$, but increased by a factor of 3 as θ increased to 0°, after which speed was insensitive to θ.

24.3 KINGSOLVER, J.G.*; DIAMOND, S.E.; Univ of North Carolina, Chapel Hill, North Carolina State Univ; *jgking@bio.unc.edu*

Thermal stress and the fitness consequences of climate change for ectotherms

Recent models of the ecological effects of global warming on insects and other ectotherms predict that mean fitness will decrease in tropical species but increase in temperate species. This occurs because temperate species have larger 'thermal safety margins' (the difference between optimal temperature and mean environmental temperature) than tropical species. These models do not account for mortality due to extreme high temperatures in fluctuating environments: such intermittent heat stresses could reduce the mean fitness of a population to zero. Here, we develop a series of models and an alternative definition of the safety margin that incorporate the effects of heat stress. We parameterize these models for insect species at multiple sites along a latitudinal gradient of environmental temperature. At both tropical and many temperate sites, climate change is predicted to increase the frequency with which species experience extreme summer temperatures above their upper thermal limits. Our simulations suggest that because of increasing heat stress, the negative fitness consequences of climate change may not be limited to tropical ectotherms. The consequences of heat stress will be magnified if climate change increases both mean and seasonal variability in environmental temperatures, especially at higher latitudes.

48.6 KINGSTON, A*; HANLON, RT; CRONIN, TW; University of Maryland, Baltimore County, Marine Biological Laboratory, Woods Hole, MA; *anahm1@umbc.edu*

Immunolabeling and diverse expression of opsin in the skin of the squid, Doryteuthis pealeii

Cephalopods, including squid, cuttlefish and octopus, have extraocular photoreceptors located in a variety of different tissues. Cephalopods have photoreceptors in the light organ, stellate ganglion and parolfactory vesicles, all of which operate using opsin. Here, we show that opsin is present in many skin regions of the squid, *Doryteuthis pealeii* (formerly *Loligo pealeii*), and propose a putative distributed photoreceptive system. RT-PCR revealed opsin transcripts in the retina, ventral mantle, ventral fin, arms 1-4, tentacle, and fin muscle tissue. All opsin transcripts are identical, based on predicted amino acid sequences. Further supporting a putative photoreceptive system, RT-PCR revealed the presence of retinochrome, a photoisomerase involved in chromophore recycling in the retina. Retinochrome was found in all tissue regions where opsin was located, and all retinochrome transcripts are identical, based on predicted amino acid sequences. Immunohistochemical staining shows that opsin protein is present in the outer segments of the retina, and in skin from the ventral mantle, dorsal mantle, and dorsal fin. These results lead us to hypothesize that the skin of *D. pealeii* may function as a distributed photoreceptive system. Future work will include immunohistochemistry for opsin and retinochrome on all untested regions of skin.

P3.204 KINSEY, M.J.*; PLACE, S.P.; University of South Carolina, Marine Science, University of South Carolina, Biological Sciences and Environment and Sustainability Program; *kinsey@email.sc.edu*

Localizing the cellular stress response in a simple body plan

Intertidal organisms are often subjected to high levels cellular stress stemming from multiple abiotic factors such as desiccation and temperature extremes that can result in the activation of a nearly ubiquitous organismal response, known as the cellular stress response (CSR). Although highly important for survival during an extreme stress event, this response is also energetically costly. Therefore, the temporal and spatial nature of the response is likely an important factor determining the overall energetic costs. As such, integrating the molecular signals controlling the stress response across multiple tissues and body regions may be an effective strategy in localizing the response and energy expenditure. The sea star, *Pisaster ochraceous*, is a keystone species that inhabits the lower rocky intertidal zone of marine ecosystems where the local environment determines its body temperature. During aerial exposure, body temperatures of *P. ochraceous* often reach 8-10°C above ambient seawater, a level known to induce Hsp70, a hallmark of the CSR. Considering sea stars have a simple body plan with respect to their biological organization, it is possible that *P. ochraceous* is unable to integrate the mechanisms controlling the CSR and localize the synthesis of Hsp70. To gain better insight into the regulation of the CSR in *P. ochraceous*, we first characterized the plasticity of the heat shock response by measuring Hsp70 protein levels in stars acclimated to three different ecologically relevant temperatures. Additionally, we tested the ability of *P. ochraceous* to localize Hsp production using laboratory manipulations to thermally stress individual sea star arms. Overall, we hope to gain a better understanding of the potential energetic impacts a warming climate may have on this important intertidal species.

55.6 KINSEY, S.T.; University of North Carolina Wilmington; *kinseys@uncw.edu*

Why are muscle fibers so large? Solving diffusion problems to attain maximal cell size

Muscle fibers are among the largest cell types, but while diffusion appears to limit maximal fiber size, the selective pressures that control minimal size are unclear. During animal growth, muscle fibers generally increase in diameter and this size increase is associated with a number of structural and metabolic changes to the cells. Many of these changes compensate for the increasing diffusion distances associated with hypertrophic fiber growth. Experimental measurement of metabolic rates, diffusion distances and diffusion coefficients, coupled with mathematical reaction-diffusion models have revealed that many fibers grow to sizes that put them on the brink of extreme diffusion limitation in the adult. This suggests that fibers become as large as possible and structural alterations allow fibers to attain larger sizes than would otherwise be possible. These results are consistent with the 'optimal fiber size hypothesis' proposed by Ian Johnston and colleagues to explain the very large fibers in cold water fishes. This hypothesis posits that the reduced surface area to volume (SA:V) in larger fibers is favored because it reduces the cost of maintaining the membrane potential. To test this hypothesis, the fiber size dependence of Na^+-K^+-ATPase cost and activity were measured in white muscle that grows hypertrophically from juveniles and adults of 16 species of crustaceans and fishes that vary dramatically in body mass and fiber size. Changes in Na^+-K^+-ATPase cost and activity during hypertrophic growth were proportional to changes in SA:V, providing evidence that large fiber size is under positive selection. Ironically, since SA:V is more sensitive to fiber size in smaller fibers, this rule of fiber design may be more relevant to smaller fibers than to the very large fibers for which it was originally proposed.

66.4 KIROUAC, LE; NAIMIE, AA; BIXBY, KA; BOROSKI, CJ; LAWLOR, KE; RAMSEYER, TF; WATSON, III, WH; NEWCOMB, JM*; New England College, University of New Hampshire, University of New Hampshire; *jnewcomb@nec.edu*

A circadian clock regulates both crawling and swimming in the nudibranch Melibe leonina

Many animals exhibit circadian (~24 hours) rhythms of activity in natural light/dark (LD) conditions. If these rhythms persist in constant darkness (DD), this is indicative of an internal circadian clock. The purpose of this study was to determine if the nudibranch mollusc *Melibe leonina* expresses a circadian rhythm of locomotion, specifically crawling and swimming, in DD. Animals were videotaped for three days in LD, followed by at least five days of DD. Videos were quantified visually (n = 30), to determine how often animals swam, or using Ethovision software (n = 8), to measure distance crawled. These data were then visualized as actograms and analyzed using the program ClockLab to determine the periodicity of locomotor patterns. For crawling, 7 of 8 animals exhibited a circadian pattern of locomotion in DD (tau = 22.8 ± 1.3 hours). Swimming does not occur as often and only 11 of 30 animals regularly swam for the duration of the study. Of these 11 animals, 45% expressed a circadian rhythm of swimming in DD (tau = 23.5 ± 0.7 hrs). Regardless of the mode of locomotion, animals were typically most active just after sunset, or the time when sunset would have occurred in DD. These data indicate the presence of a circadian clock that influences both crawling and swimming behaviors in *Melibe*. Considering that the neural circuit underlying swimming in *Melibe* has been previously determined, these data suggest that *Melibe* may be a good model system for investigating how circadian clocks influence the daily expression of certain behaviors.

S6-1.4 KITAYSKY, AS; University of Alaska Fairbanks; *askitaysky@alaska.edu*

Mechanistic links between climate variability, stress, and population processes in seabirds

Climate change is likely to affect food web dynamics in marine ecosystems and thus availability of food to breeding seabirds. Consequences of food shortages for population dynamics of long-lived seabirds are not well understood. I will present the results of our long-term studies of the effects of climate variability on plankton- and fish-eating seabirds breeding in the continental shelf regions of sub-Arctic. I will also discuss our recent advances in studying the consequences of nutritional stress for the quality, sexual maturation, and senescence of individuals, which contribute to the greater goal of understanding how populations of upper-trophic-level predators breeding in the North Pacific may respond to climate warming.

P3.223 KLAIMAN, J.M.*; PYLE, W.G.; GILLIS, T.E; University of Guelph; *jklaiman@uoguelph.ca*

Functional and morphological changes in the trout heart during thermal acclimation

Rainbow trout remain active in waters that seasonally change between 4°C and 20°C. We have previously shown that when male trout are thermally acclimated to the extremes of this temperature range two distinctive cardiac phenotypes emerge. Cardiac hypertrophy is observed in the cold (4°C) acclimated fish with a concurrent increase in connective tissue and a decrease in the thickness of the compact myocardium. Conversely, warm acclimation (17°C), causes a decrease in the amount of connective tissue and an increase in the thickness of the compact myocardium. The opposing effects of cold and warm acclimation suggest that male trout can reversibly remodel the morphology and cellular composition of the heart. This makes the myocardium extremely plastic to changes in environmental temperature. However, how such changes influence the compliance and performance of the trout heart is not yet understood. Here we use a Langendorff preparation to measure how thermal acclimation and the subsequent cardiac remodeling affects the contractility of the isolated trout heart. Briefly, an isolated trout heart is perfused with a modified Krebs-Henseleit buffer using a peristaltic pump. A fluid filled balloon, connected to a pressure transducer, is implanted into the ventricle of the heart via the bulbous. Using this method we are able to measure maximum systolic and end diastolic pressure. By characterizing the passive and active properties of hearts from thermally acclimated trout this study is providing novel perspective into the ability of the vertebrate heart to remodel in response to a physiological stressor.

S8-1.5 KLAUTAU, M.*; AZEVEDO, F.; CóNDOR LUJáN, B.; RUSSO, C.A.M.; COLLINS, A.; Universidade Federal do Rio de Janeiro, Smithsonian National Museum of Natural History; *mklautau@biologia.ufrj.br*

Calcarea evolution: morphology and molecules

One great challenge for taxonomists is how to integrate morphological and molecular data, especially for groups with few morphological characters and virtually no fossil record. One example is the class Calcarea. Whilst the silicious sponges may present hundreds of spicule types, calcareans have only four main types of calcium carbonate spicules, which are used for phylogenetic affiliation, but it remains to be tested whether those characters have a phylogenetic signature. Calcarean subclasses Calcinea and Calcaronea are clearly monophyletic by a wide variety of characters and molecular data have consistently agreed with this split. For other taxonomic levels, however, monophyly was not found. Recent analysis of the paraphyletic genus *Clathrina* showed the presence of phylogenetic signal in the skeleton, so it remains to be seen if those results apply to other calcinean groups. In this study, we have analysed 5.8S, 18S, 28S and the ITS1 and ITS2. Interestingly, many other *Clathrina* species included here have reinforced conclusions that *Clathrina* is not a monophyletic genus and that spicule composition has a strong phylogenetic signal. True members of *Clathrina* are clathroid, with a skeleton without tetractines. A new genus is characterised by the presence of a well-defined clathroid body with triactines, tripods and tetractines with spines. Moreover, clathrinas with tetractines as the main spicule group should be classified as *Ascandra*. *Leucetta* groups with *Pericharax*, *Leucaltis* and *Leucettusa*. Species of these genera have a cortex with large spicules and also very small triactines and/or tetractines in the atrium and choanosome. Our results reinforce that the skeleton in calcareous sponges may show a very strong phylogenetic signal and suggest that calcarean phylogenetics is best addressed using large numbers of species of few genera.

98.5 KLINE, L.W.*; KARPINSKI, E.; University of Alberta, Edmonton; *lkline@ualberta.ca*

A comparison of the effects of estrogen and progesterone on cholecystokinin and KCl-induced tension in female guinea pig gallbladder strips

Estrogen has an inhibitory effect on the contractility of gastrointestinal smooth muscle, including the gallbladder. This study investigated the effect of 17 &beta-estradiol (E2), progesterone (P), 17-hydroxyprogesterone (17-P), and a P metabolite, 20 &alpha-hydroxyprogesterone (20-P) on contraction in female guinea pig gallbladder strips. P, 17-P, 20-P, and E2 each relaxed cholecystokinin octapeptide (CCK) induced tension; the relaxation was concentration-dependent. E2 and P had a similar effect on KCl-induced tension. When the response to E2 was compared between young female guinea pigs and guinea pigs in late pregnancy, no significant difference in the response to either 50 or 100 &microM E2 was seen; however, 10 &microM E2 caused a significant increase ($p<0.05$) in the relaxation in strips from pregnant guinea pigs. Treatment of the strips from young guinea pigs with PKA inhibitor 14-22 amide myristolated had no significant effect on the E2-induced relaxation. Treatment of the strips with 2-APB produced a significant ($p<0.001$) increase in the amount of E2-induced relaxation when either CCK or KCl were used. Neither KT5823 nor L-NMMA had a significant effect on the E2-induced relaxation. Bisindolymaleimide IV and chelerythrine Cl^- were used in combination with no significant effect on the amount of CCK-induced tension, but significantly ($p<0.01$) increased the amount of E2-induced relaxation. When either E2 or P were added to the chambers 3 min prior to either CCK or KCl, a significant decrease ($p<0.001$) in the amount of tension generated was observed. The inhibition of extracellular Ca^{2+} entry mediates both P- and E2-induced relaxation of CCK- and KCl-induced tension in female guinea pig gallbladder strips.

P2.203 KLINGER, J.M.*; BARRILE, G.M.; BOWER, C.D.; DOWNS, L.K.; HRANITZ, J.M.; Bloomsburg University, Bloomsburg; *jmk62794@huskies.bloomu.edu*

Evaluation of cross-species Microsatellite Loci to investigate population genetics underlying a case of Island Dwarfism in Fowlers Toad

Microsatellites are an extremely versatile and powerful tool for studying population genetics. Microsatellite primers for ecological studies can be created at low prices and can yield great genetic insight (e.g., bottleneck effects, founder events, population size, migration). For this reason, 12 microsatellite loci primers originating from the cane toad *Rhinella* (formerly *Bufo*) *marinus* were tested for cross-species amplification in *Anaxyrus fowleri*. Tissues of *Anaxyrus fowleri* were collected from six populations on the Eastern Shore of Virginia. Screening of the microsatellites for cross-specie amplification was carried out by PCR reactions followed by gel electrophoresis. We compared the GC composition of the primers to investigate effects on primers effectiveness. We also downloaded sequences for three mtDNA loci sequenced for several species of toad and calculated genetic distances were also calculated because primers originating from a more closely related species will have better chances for cross-species amplification. Only two of 12 primers amplified cross-species PCR products. Primers composed of 50 percent GC or more appear to be species specific and result in low levels of cross-species amplification. Genetic distances for 16S ribosomal RNA, and cytochrome oxidase subunit I (COI), and the control region confirmed that cane toad primers would not be expected to amplify microsatellite loci in *A. fowleri*. Genetic distance, moreover than GC content, explained the low levels of cross-species amplification witnessed in this experiment, and predicts that primers originating from the more closely related species *Anaxyrus americanus* should be explored for cross-species amplification.

S9-1.2 KLOK, CJ*; HARRISON, JF; Arizona State University; *cjklok@asu.edu*

Interactions between temperature and oxygen and the evolution of body size in invertebrates

Temperature is a key factor that affects the rates of growth and development in animals, which ultimately determine body size. While not universal, a widely documented and poorly understood pattern is the inverse relationship between temperature and body size. Among ectotherms, higher temperatures exponentially increase the rate of oxygen consumption over some ranges, while having minimal effects on gas diffusion. This effect forms one basis to the MASROS hypothesis (maintain aerobic scope – regulate oxygen supply – Atkinson et al. '06) which states that growth and/or development rates will be altered to maintain maximal aerobic scope. The MASROS hypothesis remains one of the prominent explanations for the smaller body size of ectotherms reared at higher temperatures. To test the MASROS hypothesis, we utilize meta-analysis approaches to examine whether the response of an ecothermic species to temperature is associated with sensitivity to oxygen, phylogeny, gas exchange system, flight, or habitat, and how that interacts with other selection regimes that influence body size, eg. sexual selection or anti-predator selection. This research was partially supported by NSF IOS 1122157 to JFH and CJK.

S3-2.2 KNUESEL, Jeremie*; KARAKASILIOTIS, Konstantinos; CRESPI, Alessandro; RYCZKO, Dimitri; CABELGUEN, Jean-Marie; IJSPEERT, Auke Jan; École Polytechnique Fédérale de Lausanne, Switzerland, Groupe de Recherche sur le Système Nerveux Central, Département de physiologie, Université de Montréal, Montréal, Canada, INSERM U862 - Neurocentre Magendie, Bordeaux, France; *jeremie.knuesel@epfl.ch*

Gait transitions between swimming and walking in salamander: lessons from numerical modeling and robotics

The ability to efficiently move in complex environments is a fundamental property both for animals and for robots, and the problem of locomotion control is an area in which neuroscience and robotics can fruitfully interact. Animal locomotion control is in a large part based on central pattern generators (CPGs), which are neural networks capable of producing complex rhythmic patterns while being activated and modulated by relatively simple control signals. These networks are located in the spinal cord for vertebrate animals. In this talk, we will present how we model CPGs of lower vertebrates (lamprey and salamander) using systems of coupled oscillators, and how we test the CPG models on board of amphibious robots, in particular a salamander-like robot capable of swimming and walking. We will show how a CPG model designed for a stereotypical behavior (e.g. swimming lamprey) can be extended to support a diversity of locomotor behaviors observed in the salamander (e.g. swimming, forward and backward stepping and underwater stepping). Additionally, a new salamander-like robot able to replicate the three dimensional movements of the salamander's skeleton will be demonstrated. This robot will enable tests of more complex models owing to its multi-segmented limbs and its 25 degrees of freedom in total (compared to 12 used in our previous robots).

120.2 KNUTSON, VL*; GOSLINER, T; San Francisco State University, California, California Academy of Sciences, San Francisco; *vknutson@gmail.com*

New species, same damn color: Benefits of using molecular data to identify diversity in a poorly studied group of sea slugs

Gymnodoris is a genus of sea slugs that contains approximately 35 described species distributed throughout the Indo-West Pacific. The group displays a variety of feeding habits including cannibalism and parasitism, which offers an opportunity to study the evolution of feeding specialization. However, the relationships between species have not been assessed, and much of the diversity remains undescribed. Many of the species descriptions are poor and lack sufficient details, making it difficult to match existing names to specimens. Preliminary sampling indicates that *Gymnodoris* is a diverse, previously taxonomically neglected group, with tens of undescribed species. Two major difficulties with this group are the similarity of color patterns between different species, and a lack of distinctive external morphological characters. These issues make molecular markers particularly useful for identifying and delineating species. Using molecular markers, we were able to detect the presence of 7 different species of *Gymnodoris* living at one collection site, when in the field we could only detect 4 morphospecies. In addition, based on the molecular mitochondrial markers 16S, cytochrome oxidase subunit I (COI) and the nuclear marker histone 3 (H3), we present evidence for cryptic diversity within some well known, widely distributed taxa. Ultimately, a phylogeny of *Gymnodoris* will bring more attention to this previously neglected genus of nudibranchs and serve to help us understand the evolution of the specialization of feeding in this group.

P3.205 KOBEY, R.L.*; GASSERT, R.; MONTOOTH, K.L.; Indiana University; *rkobey@indiana.edu*

Genetic mechanisms of cold tolerance through increased desiccation resistance in Drosophila melanogaster

We have previously identified complex patterns of cold survival in *Drosophila melanogaster* across genotypes and temperatures that suggest distinct physiological causes for cold mortality across low temperatures. Supporting this interpretation, we found that desiccation contributes to mortality for milder cold exposures (6ºC) but not at lower temperatures (-4ºC). Flies were dehydrated following potentially lethal exposures at 6ºC but were not dehydrated following -4ºC exposures. Additionally, survival increased with humidity at 6ºC but not at -4ºC. We have begun to investigate candidate genes that may mediate differences in cold tolerance through differences in desiccation resistance. In many insects, exposure to either cold or desiccation induces expression of heat shock proteins such as Hsp70. This suggests that Hsp70 expression may increase cold survival by increasing desiccation resistance. To test this hypothesis, we are measuring survival and Hsp70 expression of mutants with differing Hsp70 copy number at low humidity and at cold temperatures. We have found that genotypes with more copies of Hsp70 tend to have higher desiccation resistance than genotypes with fewer copies of Hsp70. However, the pattern appears to be different for survival at 6ºC. Understanding the reason for this difference will further our investigation of the physiological-genetic mechanisms that mediate differences in cold tolerance among populations of *D. melanogaster*.

25.5 KOCH, RE*; HILL, GE; Auburn University; *rebeccabethkoch@gmail.com*

Searching for evidence of a runaway process in art and literature

Although sexual selection is universally accepted as an explanation for ornamental traits in animals, the specific mechanisms that produce extreme elaboration of display traits remain unresolved. The runaway sexual selection model proposes that arbitrary female preference can escalate to drive a male display to a novel and sometimes extreme form in a short period of time. The actual speed of such trait change has never been stated specifically, but it is always presented as much faster than that of traits evolving through natural selection. Many changes in morphological traits have been documented in wild animals on a time scale of decades; we can therefore expect a runaway process to produce novel ornamental traits at least that rapidly. Though the runaway model has been validated by mathematical simulation, no empirical study to date has shown clear evidence of the process in action. Because runaway sexual selection is quick-acting by nature, we should expect to find indications of rapid change in ornamental traits documented in literature or reflected in art as the same species of animal is illustrated across centuries. We searched for evidence of such changes by examining lifelike bird art from the past 100-5000 years and comparing the visual traits of these birds to those of their modern counterparts. We also searched the literature and interviewed experienced ornithologists for examples of such change. To date we have found no cases of rapid change in sexually selected traits in any species of bird.

81.1 KOEHL, M.A.R.; Univ. of California, Berkeley; *cnidaria@berkeley.edu*

Behavior and adhesion of settling marine larvae in turbulent pulses of water flow

Many benthic marine animals produce microscopic larvae that are dispersed by ocean currents. These larvae can only recruit into new habitats on which they have landed if they can resist being washed away by ambient water flow. The adhesive strengths of microscopic organisms such as larvae are typically measured by exposing them to steady flows of different velocities to determine the boundary shear stress at which they are dislodged from a surface. However, our field and flume measurements of water velocities at the scale of larvae on surfaces in different microhabitats within rugose benthic communities (coral reefs, fouling communities) revealed that larvae are exposed to brief pulses of rapid flow as turbulent eddies and waves sweep across the substratum. I used a picospritzer to subject settling larvae of byrozoans, tube worms, and sea slugs to realistic pulses of moving water to measure their adhesive strength under more natural flow conditions, and to determine how such fluctuating flow affected their behavior. I found that the response of a larva to a pulse of flow depended on larval behavior at the time the pulse hit, and on the larva's recent history of exposure to flow pulses. Crawling larvae were more likely to be blown away than stationary larvae, and larval adhesive strength usually increased with duration of attachment to a surface. Larval "glues" that acted like viscous fluids when larvae were sheared off surfaces in steady flow behaved like elastic bungee cords when larvae were exposed to brief pulses of rapid flow. Therefore, to determine how ambient water motion affects the ability of settling larvae to recruit into benthic communities, we must measure larval responses to flow that varies on the rapid temporal scales encountered by the larvae in natural habitats.

11.3 KOENIG, KM*; MEYER, E; GROSS, JM; Univ. of Texas, Austin, Oregon State University; *kmkoenig@utexas.edu*

RNA-seq as a Tool to Understand the Evolution and Development of the Single-Chambered Eye: Transcriptomics of the Long-finned Squid, Doryteuthis (Loligo) pealeii

Cephalopods (Octopus, Squid, Cuttlefish and Nautilus) are a group of highly successful mollusks with advanced cognitive capacity and complex body plans. As the field of evolution and development broadens, these organisms provide an ideal system to examine questions of parallel and convergent evolution of specific organ systems. Our interest in the squid *Loligo pealeii* is to further understand the evolution and development of complex image-forming eyes across the Metazoa. The subclass Coleoidea, which includes squid, octopus and cuttlefish, share a single-chambered image-forming eye, resembling the vertebrate eye. To begin to dissect the molecular and morphogenetic events that underpin the development of this complex organ and to facilitate molecular and functional analyses, we sequenced the embryonic transcriptome of *L. pealeii*. These data enabled us to analyze evolutionarily conserved eye-specific transcriptional cascades and provide a reference for RNA-seq experiments in the absence of a sequenced genome. We performed RNA-seq studies of isolated eye and optic lobe tissues from the developing embryo, quantifying changes in gene expression throughout distinct stages of eye morphogenesis. This work builds the foundation of a model to better understand developmental constraint as well as examine how convergent and parallel evolutionary processes impact the formation of complex organs such as the eye.

P3.161 KOEPPL, H.B.*; OSBORNE, J.P.B.; DRUZINSKY, R.E.; Univ. of Illinois, Chicago; *druzinsk@uic.edu*
Comparative Anatomy of the Digastric Muscle: a Preliminary Study
Of all the mammalian muscles of mastication, the digastric is one of the most interesting. In most mammals it is formed by merging two muscles, the anterior and posterior digastrics, innervated by the trigeminal and facial nerves, respectively. But the architecture and bony attachments vary widely across the Mammalia. To understand this variation we have begun to survey the anatomy of the digastrics using the published literature and through new examinations via traditional gross dissection of formaldehyde-fixed heads and sections of polymer-embedded specimens. To date, we have studied mice, *Mus musculus*, prairie voles, *Microtus ochrogaster*, and opossums *Didelphis virginiana*. With this survey we are developing a new system for encoding variation in the digastric muscle, which will allow us to generate parsimonious phylogenetic reconstructions of these morphological variations with analytical software such as Mesquite (Maddison and Maddison, 2010).

P1.205 KOHANNIM, S; IWASAKI, T*; UCLA; *tiwasaki@ucla.edu*
Resonance in fish swimming to minimize muscle tension
This research provides analytical support for the hypothesis that swimming fish exploit resonance, using a simple body/hydrodynamic interaction model and optimal gait analysis. Carangiform locomotion of fast-swimming saithe is modeled using three rigid bodies with two rotational joints, representing a large head and undulating pre-caudal and caudal regions, subject to resistive and reactive fluid forces. An optimal periodic body movement (gait) is defined through the minimization of muscle tension, or bending moment, subject to a constraint on average locomotion velocity. Results prove that the gait is optimized when the undulation frequency coincides with the resonance frequency that maximizes the ratio of the tail-tip velocity to bending moment. Numerical results of the optimal gait quantitatively match data gathered from observed swimming, illustrating that live fish are exploiting resonance to minimize muscle tension. Optimal locomotion of fish with active anterior muscles and passive tail muscles explains the tendency of live fish to increase flexural stiffness and undulation frequency with increased speed, while maintaining a constant tail-beat amplitude and Strouhal number. If both anterior and posterior muscles are activated, and there is no body flexibility, resonance still exists purely from body-fluid interactions. This result agrees with previous studies suggesting the existence of hydrodynamic wake resonance. Additional analysis demonstrates a direct relationship between steady-state swimming speed and tail-tip velocity for carangiform swimmers. With this relationship, the Strouhal number can be determined based only on the drag coefficient and the ratio of wetted to tail area.

113.4 KOHL, K.D.*; WEISS, R.B.; DALE, C.; DEARING, M.D.; Univ of Utah, Univ. of Utah; *kkohl78@gmail.com*
Gut microbes facilitate consumption of toxic diets by herbivores
For decades, ecologists have hypothesized that herbivorous mammals might host beneficial microbes that facilitate the ingestion of diets containing toxic plant secondary compounds (PSCs). However, this idea has never been sufficiently tested in wild herbivores. We studied a small herbivorous rodent, the desert woodrat (*Neotoma lepida*) that naturally feeds on a toxic shrub, creosote bush (*Larrea tridentata*). Creosote leaves produce large quantities of a phenolic-rich resin that is lethal to lab mice in the doses consumed by woodrats. Woodrats were fed either a control diet of rabbit chow or rabbit chow plus 2% extracted creosote resin. Animals were dissected and we conducted metagenomic sequencing of the contents of the woodrat foregut. Additionally, a subset of animals were given a broad-spectrum antibiotic (neomycin); food intake and body mass were monitored. When feeding on creosote resin, the woodrat foregut metagenome was notably enriched in genes associated with the metabolism of aromatic compounds, stress responses, protein metabolism, carbohydrate metabolism, and membrane transport. Woodrats given antibiotics consumed less food and lost more weight compared to woodrats not given antibiotics, but only when the diet contained PSCs. Metagenomic results revealed that dietary toxins strongly alter the functional profile of woodrat gut microbes, which may have impacts on host homeostasis. The antibiotic study represents the first experimental evidence that microbes enhance the consumption of PSCs in wild herbivores. These results suggest that beneficial microbes play a large role in enhancing dietary niche breadth in herbivores by allowing them to consume toxic plants. This may have implications for wild and domesticated herbivores facing rapid changes in plant communities due to changes in global climate or land-use practices.

P3.31 KOHLENBERG, K.L.*; STANISHEVSKY, A.V.; WATTS, S.A.; University of Alabama at Birmingham, UAB; *katekohl@uab.edu*
Vertical transfer and growth effects of zebrafish consuming Rotifera exposed to copper-loaded carbonaceous particulates
Nano-sized particles have gained attention due to their highly reactive chemical and physical properties and applications to many industrial processes. Little is known about the potential environmental impacts of these nano-sized particulates if released into aquatic environments. Previous studies have evaluated nano-metals, such as copper, lead, and titanium oxides, many of which are toxic. Highly reactive carbonaceous particulates are also widely used in industry, and little is known about the potential environmental impacts of these particulates or related conjugates. These carbonaceous particles are likely to undergo secondary reactions with metals or other compounds and pose a new threat to aquatic ecosystems. There is potential for these carbonaceous particulates to interrupt food web dynamics. Previously, we determined that carbonaceous compounds are consumed by ciliated zooplankton and larvae. In this study we investigated the impacts of copper-loaded carbonaceous particulates (CuLCP) at two different tropic levels (primary and secondary consumers) and evaluated their short-term effects in model organisms. CuLCP were synthesized in a chemical reduction of copper sulfate with sodium borohydride and dextrose. The rotifer *Brachionus plicatilus* were exposed to varying concentrations of CuLCP. These particulates accumulated in the gut within minutes and a 24-hour LC50 was determined at 0.01mg/mL. To investigate vertical transfer, newly-hatched zebrafish (*Danio rerio*) larvae (5 dpf) were fed three times daily to satiation a diet of rotifers exposed previously to CuLCP (0.01mg/mL) for one hour. Larval zebrafish fed treated rotifers showed significant growth limitation after 72 hours. These data indicate that carbonaceous particulates can be consumed by zooplankton (with direct effects) and transferred through the food web to higher order consumers.

71.6 KOHN, A.B.*; MOROZ, L.L.; University of Florida, Whitney lab; *abkohn@msn.com*
Single-cell RNA-seq and cell-specific DNA methylation profiling for comparative and integrative biology: Toward genomic portraits of individual blastomeres and identified neurons
Considering the enormous heterogeneity of cell populations, methodology for single-cell RNA-seq (transcriptome) and unbiased epigenomic analysis of individual cells is essential for biology in general, and for development and neuroscience in particular. Here we present novel approaches that allow fast and cost-efficient transcriptome sequencing from ultra-small amounts of tissue or even from individual cells across phyla. Specifically, the developed protocols not only can perform single-cell transcriptome profiling but also capture nascent RNAs (nRNAs) following a developmental program or experience-dependent plasticity (e.g. following learning and memory consolidation). We implemented and validated these protocols using identified molluscan neurons (*Aplysia californica*) and developmental stages down to the 1 cell stage of the ctenophore *Pleurobrachia bachei*. As a result of initial mapping to the reference genomes, we estimated that the majority of the genome is expressed in a given cell, generating on the order of 100,000 unique transcripts (including large and small non-coding RNAs) supporting unique cell phenotypes. Furthermore, these RNAseq protocols can be integrated with DNA methylation from *the very same cell* and miRNA profiling. Because homologous cells and cell populations can be recognized across classes and phyla, both in early development and in nervous systems, it is now possible to follow dynamic reorganization of the specific cellular genomes in evolution to reveal the molecular bases underlying origins of complex phenotypes and novelties. Integrating this type of resolution to comparative biology has enormous evolutionary implications to deciphering the logic of gene regulation and the full scale integrative activity of genomes across phyla.

120.1 KOHN, AJ; Univ. of Washington; *kohn@uw.edu*
Morphology, molecules, molluscs, and modern monographs: A revisionary systematics case study
Taxonomy, classification and phylogenetic interpretation of shelled marine molluscs have traditionally relied primarily on shell characters, the most durable and often the only ones available for study. However, recent advances in molecular genetics have drastically altered this tradition. In the hyperdiverse neogastropod genus *Conus* of &gt,700 extant species, DNA sequences provided the first species-level phylogenetic hypotheses in1999. Inconsistencies between molecular data and shell morphology-based taxonomy soon became apparent both in Conus and elsewhere in the superfamily Conoidea. Concurrently, increasing attention to other morphological characters, particularly of the hypodermic needle-like radular teeth, indicates greater congruence with molecular data than the latter have with shell characters. Here I report on a systematic revision of the extant species of western Atlantic *Conus* north of Brazil, applying shell, radular, and molecular characters as far as possible to the 263 nominal species described from 1758 to 2011. For the 53 species whose validity the results support, the study estimates infraspecific variation and differentiates each species as clearly as possible from its most similar congeners. It describes shell and radular tooth characters quantitatively and analyzes key mitochondrial genes both as taxonomic characters and to evaluate phylogenetic relatedness among species. I summarize the current species-level phylogeny of western Atlantic Conus, but molecular genetic information is presently limited to small sample sizes and fewer than half the species. Molecular data have revealed the existence of cryptic species with indistinguishable shell morphologies in other regions, and future work will most likely increase the number of known valid western Atlantic species.

72.6 KOHUT, N. K.*; ZARROUK, D.; PULLIN, A. O.; HALDANE , D. W.; FEARING, R. S.; University of California, Berkeley; *kohut@berkeley.edu*
Rapid Terrestrial Turning in Robots Using Tails Inspired from Lizards
Rapid Terrestrial Turning in Robots Using Tails Inspired from Lizards. KOHUT, N.*; ZARROUK, D.; PULLIN, A. O.; HALDANE. D.W.; FEARING, R.S. Univ. of California Berkeley kohut@berkeley.edu Rapid turning in animals is an essential behavior for both predators and prey. For maximum maneuverability, terrestrial robots need effective turning as well. Previous efforts at turning in legged robots primarily have used leg impulses and have not been biologically inspired. We have developed a 45 gram legged robot, similar in scale to a small lizard we call TAYLRoACH - TAYL for Tail Actuated Yaw Locomotion. Our tailed robot was able to make rapid, precise turns using only the actuation of a tail appendage. By rapidly rotating the tail as the robot runs forward, the robot was able to make 90° turns at 400 ° sec $^{-1}$ with almost no change in its running speed of 32 cm sec^{-1}. We have also modeled the dynamics of this phenomenon, allowing us to examine what features, such as tail length, mass, and location, affect the amount and rate of turning possible. To our knowledge, this approach has produced turns that are more rapid than any method previously demonstrated in legged robots and, along with the developed model, could give insight into how animals turn quickly and precisely, and further inform biomechanists why certain morphologies may be advantageous.

P1.199 KOLPAS, A; FISH, F E*; MEADE, A; DUDAS, M A; MOORED, K W; West Chester Univ., Pennsylvania, Dudas'Diving Duds, Pennsylvania, Princeton Univ. New Jersey; *ffish@wcupa.edu*
Mathematical analysis of three-dimensional open water maneuverability by mantas (Manta birostris)
For aquatic animals, turning maneuvers represent a locomotor activity that may not be confined to a single coordinate plane, making analysis difficult particularly in the field. To measure turning performance in a three-dimensional space for the manta ray, a large open-water swimmer, scaled stereo video recordings (30 fr/s) were collected around Yap, Micronesia. Two video cameras in underwater housings were mounted on tripods and positioned on the bottom at a depth of 24 m around a cleaning station frequented by mantas. The cameras were synchronized by periodic discharges of an electronic strobe. Movements of the cephalic lobes, eye and tail base were tracked to obtain three-dimensional coordinates. A mathematical analysis was performed on the coordinate data to calculate the turning rate and curvature (1/turning radius) as a function of time by numerically estimating the derivative of manta trajectories through three-dimensional space. Tikhonov regularization was used for numerical differentiation that involves the minimization of a cost function with a parameter controlling the balance between data fidelity and regularity of the derivative. The approach gives a much more accurate estimate of the derivative than conventional finite-difference schemes which can amplify noise leading to erroneous results. Data for 30 sequences of rays performing slow, steady turns showed a median turning rate of 46.48 deg/s with a median turning radius of 0.39 body lengths. Such turning maneuvers fall within the range of performance exhibited by swimmers with rigid bodies.

118.2 KOMAN, J*; WOOTTON, T.J.; TOMANEK, L.; Cal Poly San Luis Obispo; *jkoman@calpoly.edu*

Proteomic analysis of naturally occurring heat stress in field-acclimatized Mytilus californianus

Temperature sets the vertical distribution limits of intertidal marine invertebrates such as the California mussel *Mytilus californianus*. While previous studies into the heat tolerance of the mussel genus *Mytilus* have been useful in elucidating the pathways involved in the heat stress response, no study to date has characterized the proteomic changes in field-acclimatized specimens under natural conditions. Unstressed individuals of *M. californianus* collected from Tatoosh Island, Washington, were placed for two days at four microhabitats on a coastal rocky shelf of a thermally stressful site along the Strait of Juan de Fuca, WA: subtidal, shaded and unshaded intertidal, and an unshaded pool just above the splash zone. Temperatures at all four microhabitats, measured using data loggers, registered warmer temperatures in the intertidal and unshaded treatments (with the unshaded intertidal warmer than the unshaded pool), and cooler overall on the second day of treatments. Gill collected on both days from each treatment was immediately frozen in the field. Tissue was homogenized and proteins were precipitated before separation with 2D GE to quantify protein abundances. Using a two-way permutation ANOVA ($p \leq 0.01$), we determined over 16% of the detected proteins significantly changed abundance due to the location, day, or interaction effect, with most exhibiting major abundance changes in the more stressful unshaded conditions. Analysis of these proteins with MALDI TOF-TOF tandem MS identified these proteins to be involved in multiple cellular functions, including the cellular stress response (heat shock proteins), energy metabolism, proteolysis, the cytoskeleton, and regulation of oxidative stress, indicating that field-acclimatized specimens undergo complex cellular adjustments in response to emersion.

8.3 KOMOROSKE, LM*; HASENBEIN, M; LINDBERG, J; CONNON, RE; FANGUE, NA; UC Davis; *lmkomoroske@ucdavis.edu*

Understanding climate change impacts on Delta Smelt

The delta smelt (*Hypomesus transpacificus*) is an endemic fish in the San Francisco Bay–Delta and is an important ecological indicator species. Delta smelt have been rapidly declining in the past 30 years due to a variety of physiological and ecological stressors, and climate change is expected to further impact this species by altering regional temperatures and salinities. Some thermal and salinity studies have investigated whole organism tolerance in adults, but little is known about how tolerance thresholds vary across life stages, sublethal stress thresholds, or their mechanistic drivers. We sought to understand climate change impacts on delta smelt by conducting Critical Thermal Maximum (CTmax) and acute thermal exposure-recovery gene expression experiments in all life stages. Similarly, we assessed salinity tolerance and sublethal stress responses by exposing fish to environmentally relevant salinity increases (mimicking tidal cycles). We found that CTmax differed between life stages (15-16°C acclimation, CTmax larval=29.9°C+/- 0.35; adult=26.3°C+/- 1.8). For salinity, percent mortality was similar for all treatments at short time periods (0-6hrs), but increased at high salinity levels over longer time periods (at 48 hours: 18ppt =92% vs. 0ppt=47%), suggesting that while fish may be able to cope with short periods of increased salinity, they may not subsist in the long-term. We also linked these tolerance data to gene expression profiles. Climate change may result in temperature and salinity levels under which delta smelt cannot effectively persist physiologically, causing large-scale habitat reduction or loss. Quantifying tolerance and sublethal stress thresholds helps to understand these physiological limits and better predict habitat suitability for delta smelt under various management plans in the Bay-Delta.

P2.166 KOMPELLI, A.R.*; DEAROLF, J.L.; RICHMOND, J.P.; Hendrix College, Conway, AR, Univ. of North Florida, Jacksonville, FL; *kompelliar@hendrix.edu*

The effect of betamethasone on the citrate synthase activity in fetal guinea pig rectus abdominus

Currently, glucocorticoids are used to promote the survival of premature infants by accelerating their lung development. However, very little is known presently about how these steroids affect breathing muscle development. Work in our laboratory has shown that one of these steroids, betamethasone, increases the concentration of NADH, an oxidative enzyme, in the scalenus, an accessory inspiratory muscle in fetal guinea pigs. These results suggest prenatal glucocorticoids accelerate the acquisition of mitochondria by fetal muscle. Thus, we propose that glucocorticoids will increase the activity of citrate synthase (CS), a mitochondrial oxidative enzyme, in the rectus abdominis (RA), an expiratory muscle of guinea pigs. This hypothesis was tested by quantifying CS activity in RA muscles of steroid-treated and control fetal guinea pigs. Pregnant guinea pigs were given 2 injections, 24-hours apart, of betamethasone (0.5 mg/kg) or sterile water (control) at 65%, 75% and 85% gestation. Twenty-four hours after the last injection, females were euthanized and fetal RA was collected and homogenized. Kinetic assays were performed, and the CS enzyme activities (µmol/min*g) of the fetal muscles were calculated from the rate of change of the absorbance at the maximum linear slope. To determine whether CS activity is higher in treated muscles, an ANOVA was used to compare the average CS activities between treated and control muscles. If the activity of CS is higher in the treated muscles, they may be better able to resist fatigue in comparison to control muscles. Thus, neonates exposed to prenatal steroids will be better able to respond to ventilatory challenges.

10.4 KONCZAL, M.*; KOTEJA, P.; RADWAN, J.; STUGLIK, M.; BABIK, W.; Jagiellonian University in Krakow; *mateusz.konczal@uj.edu.pl*

Accuracy of pooled RNA-seq

For non-model organisms without reference genome, genome-wide information focusing on functionally relevant variation may be obtained through RNA-seq with *de novo* assembled reference transcriptome. Sequencing itself has become relatively cheap, but library preparation for many samples remains prohibitively expensive. In such cases pooling appears an attractive, but nontrivial approach. Inter-individual and inter-locus variation in expression level could cause inaccuracy in allele frequency (AF) estimation, the problem which does not affect pooled genome resequencing. To estimate the accuracy of pooled RNA-seq in predicting AF we analyzed liver transcriptomes of 10 bank voles (*Myodes glareolus*). Each sample was sequenced both as an individually barcoded library and as a part of a pool. The pool consisted of equal amount of total RNA from each vole, combined prior to mRNA selection and library construction. On average 16.8 million reads (100bp PE) were obtained per individual. Reads were mapped on the *de novo* assembled reference transcriptome. For 33 000 SNPs high quality genotype was available for each vole. These genotypes allowed us to calculate true AF in the sample. AFs estimated from the pool were compared to the true values. High correlation between true frequencies and those estimated from the pool (R^2=0,89) was observed. Mean estimation error reached 21% of true value and was independent of expression level, which indicates that accuracy of AF estimation from pooled samples is relatively robust to variation in expression between individuals. However, we observed highly negative correlation between minor AF and calculated error, the problem affecting also genome studies. Our results indicate that the efficiency of pooled RNA-seq may be comparable to pooled genome resequencing.

28.5 KONOW, N*; VON BUSSE, R; CHENEY, JA; BREUER, KS; SWARTZ, SM; Brown University; *nkonow@brown.edu*

What is the relationship between pectoralis muscle recruitment intensity and air speed velocity in an un-laden bat?

Aerodynamics theory predicts a U-shaped relationship between flight power and speed: The cost of transport should be lower at intermediate than at low and high speeds, due to constraints imposed by lift and drag. A similar relationship between muscle recruitment intensity and in some cases actual power production, with respect to flight speed has been found in some birds and insects, but not in others. This relationship remains unknown for bats, the only other extant group that has evolved powered flight. We measured recruitment intensity in two regions of the pectoralis muscle in five Seba's short-tailed bats (*Carollia perspicillata*) flying at 1-7 m/s air speeds in a wind tunnel. The relationship between muscle recruitment intensity (integrated area under the rectified electromyogram) and flight speed was U-shaped in one individual, □-shaped in two individuals and invariant in two individuals. Several factors may combine to produce this inconsistent relationship: Compared with birds and insects, bats can modulate their wingbeat kinematics more extensively, in part due to their numerous wing joints. These joints are crossed by muscles that may contribute to the down-stroke, so the bat pectoralis is not necessarily the only source of flight power. Bats also have muscles in their wing membrane that may modulate camber and thus alter aerodynamic power production differentially with speed. Like other flapping flyers, bats have diversified across a vast range of foraging strategies, and use flight modes that range from hovering to fast hawking. Kinematics differences between these diverse flight modes may constrain power production across speeds as well as individuals and species. Funded by AFOSR.

129.4 KORNEV, KG*; LEHNERT , M; MONAENKOVA, D; ANDRUKH, T; BEARD , E; ADLER, P; Clemson University, Kent State University, Geogia Institute of Technology; *kkornev@clemson.edu*

Wetting and fluid acquisition by butterfly proboscis

We used the butterfly proboscis to elucidate the structural and chemical adaptations necessary for fluid acquisition with a primarily hydrophobic natural device. Using a capillary-rise technique and high speed flow visualization, we studied the proboscis wettability and mechanisms of fluid uptake. We experimentally discovered and theoretically explained the essential role of morphological structure in partitioning of feeding devices into wetting/nonwetting regions. It appears that the complex hierarchical morphology of the proboscis can be put within a physical theory of the wetting of rough surfaces. This classification allows one to explain the fluid partitioning on liquid bridges in the food canal observed with the X-Ray phase contrast imaging. The principle of compartmentalized wettability of the butterfly proboscis has a far-reaching impact on the evolution of insect mouthparts and can be applied to the production of microfluidic devices with tunable wettability.

P2.93 KORYU, K.*; LYNCH, V.J.; WAGNER, G.P.; Yale University, Department of Ecology and Evolutionary Biology; *koryu.kin@yale.edu*

On the evolutionary origin of endometrial stromal cells

Endometrial stromal cell (ESC) is a fibroblast like cell type from the uterine lining of eutherian mammals. ESCs are essential for establishing novel reproductive traits of eutherian mammals such as prolonged internal gestation and invasive placentation. Whether non-eutherian animals possess a cell type homologous to ESC, and if so what biological roles it has is still unknown. In order to elucidate the evolutionary origin of ESC, we first looked for a homologous cell type in the model marsupial *Monodelphis domestica*, which belong to the sister group of eutherian mammals. The uteri at different reproductive stages of Monodelphis domestica were obtained and stained for molecular markers which are known to be crucial for the identity of ESCs. The results show that there are cells in the nonpregnant marsupial endometrial stroma which co-express some important markers for ESCs such as HoxA11 and PR. In the pregnant uterus, the number of stromal cells significantly decreases and the distribution of them becomes much narrower, suggesting that their roles in pregnancy are different from those of eutherian ESCs. Secondly, we compared transcriptomes of human mesenchymal cells in an attempt to find the sister cell type of ESC and to elucidate the developmental context in which ESC evolved. Specifically, we collected and compared the mRNA-seq data of various human cell types including chondrocytes, myometrial cells, myofibroblasts, follicular dendritic cells, undifferentiated and differentiated endometrial stromal cells. We found that, among the cell types compared, follicular dendritic cells, which help B-cell maturation in lymph nodes are the closest to ESCs in terms of gene expression. Based on these results we propose a hypothetical model for the evolutionary origin of ESCs.

P3.137 KOVACEVIC, A*; BIDDULPH, T; WATERS, J/S; HARRISON, J/F; Arizona State University; *sandrakovacevic2010@gmail.com*

Effects of the larval oxygen environment on the three-dimensional branching structure of insect flight muscle tracheae

While it is well-known that insects exhibit compensatory changes in their tracheal structure in response to rearing oxygen levels within the embryonic and larval stages, it is unclear how larval oxygen conditions affect the morphology of the adult tracheal system. We reared *Drosophila melanogaster* from egg to adult in 10, 21 or 40% oxygen, and used confocal microscopy and synchrotron x-ray phase contrast micro tomography (SR-µCT) to examine the three-dimensional structure of adult flight muscle tracheae. The flight muscles are enveloped within a dense network of tracheoles branching off from large air sacs and sac-like tracheae which open to the thoracic spiracles. We focused on one major tracheal branch that supplies about 25% of three of the longitudinal flight muscle fibers. This major branch subdivides into three main levels of tracheae, each penetrating laterally between the fibers, and so separated by approximately 45µm. Rearing oxygen level did not affect the average number of these tracheae, but there was an effect of branch location. Branches farther from the spiracle had more tracheae. The ratio of the number of branches at the level furthest away from the spiracle to the number of branches at the level closest to the spiracle was inversely proportional to rearing oxygen concentration. These findings suggest that the tracheal networks supplying the adult flight muscle are subject to developmental plasticity in tracheal organization induced by larval or pupal oxygen level. This research was partially supported by NSF 0938047 to J. Socha and J.F.H. and NSF IOS 1122157 to JFH.

12.6 KRAATZ, BP*; BUMACOD, N; WEDEL, M; AZEVEDO, B; Western University of Health Sciences; *bkraatz@westernu.edu*

Evolution, Ecology, and Modularity of the Lagomorph Skull

The lagomorph (rabbits, hares, and pikas) skull exhibits a unique set of characteristics that distinguish it from most other mammals. Hares and rabbits hop, and some species show a level of cursoriality that is unmatched for animals of their size. Previous workers have suggested that hare skull morphology is related to locomotion, but this hypothesis has not been thoroughly tested. We explored the relationship between skull shape and ecology using an 2D morphometric data set that included 144 skulls from 17 living leporids (rabbits and hares). Our analyses showed strong correlation of skull shape and burrowing behavior. We also found that the tilt of the facial skeleton relative to the basicranium correlated with locomotion, with generalized scampering taxa having flatter skulls and hoppers having more facial tilt. This led us to investigate possible modularity within leporid skulls. Our 2D data showed that diastema length was more strongly correlated with overall skull length than was basioccipital length. To explore this further we utilized the RV coefficient to analyze a subset of skulls using 3D geometric morphometric data taken from surface renders from CT scans. These analyses suggest a distinct pattern of modularity between the facial and basioccipital regions in the lagomorph skull. The most recent ancestors of lagomorphs, the mimotonids (ca 55Ma), exhibit a facial region that is remarkably similar to that of living lagomorphs, but a relatively primitive basicranium.. It wasn't until tens of millions of years later that the basicranium of fossil lagomorphs showed features that were consistent with those of the highly tilted skulls of living lagomorphs.

P2.168 KRAJNIAK, K.G.*; KERSTEIN, K.W.; Southern Illinois Univ. Edwardsville; *kkrajni@siue.edu*

Effects of APKQYVRFamide and FMRFamide on the Earthworm Body Wall

Recently our laboratory identified APKQYVRFamide, the first earthworm FMRFamide related peptide. Since FMRFamide modulates the contractions of the isolated body wall of *Lumbricus terrestris* we decided to determine the effects of APKQYVRFamide. A 10 segment section of dorsal body wall anterior to the clitellum was removed, attached to a Grass force transducer, and suspended in a tissue bath. Mechanical contractions of the longitudinal muscles were recorded on a computer using Iworx Labscribe 2. The body wall was challenged with increasing concentrations of peptide and the resulting changes in contraction amplitude and rate were used to construct log-concentration response curves. APKQYVRFamide caused a large increase in frequency at 10^{-9} M. Between 10^{-8} and 10^{-6} M it caused a decrease in rate and at 10^{-5} M it caused an increase. For all concentrations of APKQYVRFamide the changes in amplitude remained in the negative range. At 10^{-8} M the peptide caused an increase in amplitude. FMRFamide caused a complex response with a large increase in frequency between 10^{-9} and 10^{-8} M. Between 10^{-7} and 10^{-5} M it caused a decrease in rate. FMRFamide caused a slight inhibition of amplitude between 10^{-9} and 10^{-7} M. Between 10^{-7} and 10^{-6} M there was a substantial increase in amplitude followed by an equally large decrease between10^{-6} and 10^{-5} M. Thus it appears that APKQYVRFamide, which is more potent than FMRFamide, may be involved in controlling body wall movements of the earthworm.

P2.195 KRAKAUER, A.H.*; BLUNDELL, M.; SCANLAN, T.; WECHSLER, M.; MCCLOSKEY, E.; YU, J.; PATRICELLI, G.L.; Univ. of California, Davis; *ahkrakauer@ucdavis.edu*

Successful Sage-grouse Show Greater Laterality in Social Behaviors

Lateral biases in behaviors are common across animals. Greater lateralization may be beneficial (e.g., if it allows for more efficient neural processing), yet few studies have considered the possible importance of inter-individual variation in lateral biases in wild animals, particularly for social behaviors. We examined lateral biases in lekking male greater sage-grouse (*Centrocercus urophasianus*), a species with obviously lateral orientations during aggressive and courtship interactions and in which male mating success can readily be measured. In both agonistic "facing-past events" and courtship "strut" displays, successful males showed greater bias. The greater resolution of angular orientation in our courtship data revealed that bias depended on the region of the visual field being used; struts were left biased in the frontal hemifield and right-biased in the lateral hemifield. Our results suggest that more successful males were more lateralized, although variation in social context and portion of the visual field being used are also important to consider.

31.4 KRASNOV, B.R.*; KHOKHLOVA, I.S.; Ben-Gurion University of the Negev; *krasnov@bgu.ac.il*

Patterns, mechanisms, consequences of gender-biased parasitism in small mammals

We will review patterns, causes and consequences of gender-biased infestation of small mammalian hosts by macroparasites. We start with a description of gender biases in parasite infestation and discuss variation in these patterns among host and parasite taxa. We will also look at temporal and spatial variations in gender-biased parasitism and demonstrate that they can vary seasonally and be mediated by environmental conditions. Then, we will present main hypotheses that examine mechanisms of gender-biased parasitism. One group of these hypotheses focuses on differences between male and female hosts in their probability to be attacked by parasites, while another group links gender-biased parasitism with differences in parasite performance in male versus female hosts. Finally, we discuss possible consequences of male-biased parasitism for individual parasites, their populations and communities.

145.4 KRAUSE, A/J*; SERB, J/M; Iowa State University; *ajkrause@iastate.edu*

Functional divergence? Comparing opsin expression in extra-ocular tissues and eyes of the scallop (Pectinidae).

Photosensitivity plays a role in vision, entrainment of the circadian clock, and phototaxis, ultimately affecting the life history and fitness of many species. While we often think of the eye as the primary light perceiving organ, extra-ocular photosensitivity (EOP) is common in animals and many species maintain photosensitivity despite their eyeless condition. Presumably, the key photoreceptive protein in animals in both ocular and EOP structures is a member of the opsin family, a group of seven transmembrane G-protein coupled receptors, but the relationship between opsins used in these specific photo-sensing systems is largely unexplored. Recently, we isolated two copies of Gq-opsin from eyes of the common bay scallop, *Argopecten irradians* (Pectinidae). One of the copies has been previously reported in scallops, while the second copy differs by 45% in amino acid sequence. Surprisingly, both copies contain a lysine residue required for chromophore binding and photosensitivity suggesting both proteins are functional. To test the hypothesis that a gene duplication event resulted in tissue-specific functional divergence of scallop opsins, we determined the evolutionary relationship and examined spatial expression patterns of the two *A. irradians* Gq-opsin copies. Using *in situ* hybridization techniques, we determined both copies are expressed in the nerves of mantle tissue as well as ocular tissues. Our results suggest a scallop's mirror-type eyes and the EOP in surrounding mantle tissue may be sensitive to similar spectrums of light.

P1.40 KRAUSE, JS*; PEREZ , JH; SWEET, SK; ASMUS, A; RICH, ME; SCHAS, J; WORD, KR; GOUGH, L; WINGFIELD, JC; BOELMAN, NT; University of California, Davis, Columbia University, University of Texas, Arlington , University of Texas, Arlington , Columbia University; *jskrause@ucdavis.edu*

Impacts of Changing Seasonality and the Potential for Trophic Mismatches in the Arctic

Every year, songbirds migrate from their wintering grounds to breeding territories at higher latitudes to take advantage of abundant resources to successfully raise offspring. Global climate change has caused increased average air temperatures throughout the breeding season. This may result in earlier spring and later autumn due to earlier snowmelt and later snowfall dates. These changes in temperature have been accompanied by an altered landscape as deciduous woody shrubs have become dominant in open tundra habitat. While shifts in seasonality may lead to earlier plant phenology and arthropod emergence, the timing of migration is constrained because most migrants are cued by an increase in photoperiod. Based on previous studies on a similar system in Europe, we may expect to see trophic mismatches between the tundra arthropod community and the songbirds that depend on them to feed their young, ultimately leading to changes in songbird communities and species richness. Here we present data on reproductive success for two long distant migrants, Lapland Longspurs (Calcarius lapponicus) and White-crowned Sparrows (Zonotrichia leucophyrs gambelli). Our data thus far demonstrates that timing of breeding events in arctic Alaska coincides with plant phenology as well as arthropod abundance, suggesting that there is a trophic match between resource availability and feeding of young.

124.3 KRAUSZER, M.; LEIKEN, A.; ELLIOTT, J.K.*; Univ. of Puget Sound, Tacoma; *jkelliott@ups.edu*

Ontogenetic color variation in the sea star Pisaster ochraceus as an adaptation to avoid predation by gulls

Early life history stages of many species are often camouflaged to reduce detection by visual predators because they are more vulnerable than older/larger individuals. We have studied a variety of ontogenetic stages of the sea star *Pisaster ochraceus* in Puget Sound, WA. Juveniles are grey/ brown, and at a size of approximate 5 cm arm length they change to their characteristic adult color of purple, brown, or orange. Small sea stars (< 7 cm arm length) of *P. ochraceus* are most abundant in habitats with high structural complexity (e.g. cobble), and are found under rocks or in crevices at low tide. In contrast, large sea stars are often observed out in the open during low tide. We observed gulls foraging under rocks at low tide and feeding on small sea stars, and we hypothesized that the grey/brown coloration of juveniles was an adaptation to reduce detection by foraging gulls. To test this hypothesis we placed different colored clay models (grey, brown, purple, orange) and live sea stars (grey, brown, orange) in the intertidal to determine whether gulls would preferentially prey on certain colors. We also used reflectance spectrometry to compare the brightness of each color morph in relation to their background as a measure of conspicuousness. Orange sea stars were most conspicuous, and they experienced the highest predation rates. Grey and brown sea stars were the least conspicuous and had the lowest predation rates. Selective predation by gulls on small brightly colored orange sea stars may be a factor causing the purple color morph to be predominant in Puget Sound, whereas low predation rates by gulls in more exposed coastal locations may allow orange color morphs to occur at higher frequencies.

66.6 KRIENGWATANA, B*; AITKEN, SDT; GARCIA, L; FARRELL, TM; MACDOUGALL-SHACKLETON, SA; University of Western Ontario, Unveirsity of Western Ontario; *bkrieng@uwo.ca*

Decline in conditions during the juvenile period impair behavioral flexibility, while consistently poor developmental conditions impair spatial memory of zebra finches

Developmental environments can have long-term effects on learning and cognition. Multiple aspects of cognition may be affected by poor conditions during development if underlying systems are maturing simultaneously. The present study investigates the effect of nutritional stress at different stages of development on behavioral flexibility, spatial memory, and neophobia. Zebra finches were raised in consistently high (HH) or low (LL) food conditions until 65 days post-hatch (DPH), or were switched from high to low conditions (HL) or vice versa (LH) at 35 DPH. Subjects were then tested as adults. An attentional set-shifting task that required subjects to inhibit responding to a previously rewarding cue and shift attention to a previously non-rewarding cue was used to quantify behavioral flexibility. A hippocampus-dependent spatial memory task (Bailey et al. 2009) was used to quantify spatial memory, and willingness to approach a novel object was used to quantify neophobia. Results indicate that HL conditions impaired subjects' ability to shift attention and inhibit previously correct responses, while LL conditions impaired subjects' performance on the spatial memory task. Although there was no main effect of treatment conditions on neophobia, birds that were more neophobic tended to be more flexible, especially females. These findings provide insight into the differences in windows of vulnerability for development of attentional and hippocampal-dependent processes, as well as the possibility that a decline in environmental quality during the juvenile period may permanently affect dopaminergic systems responsible for attention and inhibitory control.

17.9 KRISHNAN, A.*; SANE, S.P.; National Centre for Biological Sciences, TIFR, Bangalore; *anandk@ncbs.res.in*

Antennal positioning in flying hawk moths

Insects of diverse orders display forward positioning of the antennae at the onset of flight. Because antennal mechanosensory feedback is important for flight control, proper positioning of the antennae may be of critical importance for the acquisition of these inputs during flight. We investigated the neural mechanisms of antennal positioning in the hawk moth *Daphnis nerii*. Our results indicate that the mechanosensory Bohm's bristles on the antennal scape and pedicel are the primary mediators of positioning of the ipsilateral antenna. Ablation of these mechanosensors results in mis-positioning of the antennae and frequent collisions between the antennae and wings. The antennal motor neurons respond to stimulation of the Bohm's bristles at very rapid latencies, suggesting that the underlying sensorimotor connections are probably monosynaptic. Moreover, we found that the antennal muscles of hawk moths also received visual inputs from both ipsilateral and contralateral eyes. However, the response latencies to visual stimuli were longer than those to stimulation of the Bohm's bristles. Our results thus suggest that antennal positioning behaviour constitutes a multimodal reflex arc, with the Bohm's bristles providing rapid feedback to set the ipsilateral antennal position whereas the visual system functions in slower context-dependent modulation of positions of both antennae. Integration of these multi-sensory inputs may be critical in ensuring that the antennae are properly positioned during rapid flight maneuvers.

84.5 KROCHMAL, A.R.*; BAKKEN, G.S.; Washington College, Indiana State University; *akrochmal2@washcoll.edu*

Temperatures of Trekking Turtles: Estimates by Water-filled Models and Hollow Te Thermometers

Aquatic turtles take to land during oviposition or when seeking out new aquatic habitats. Though such overland treks are central to the biology of aquatic turtles, the physiological strain placed on turtles during such treks remains largely uninvestigated. During treks, turtles encounter environments that are thermally more extreme, more variable, and potentially more stressful than are their aquatic habitats. We tested 3 methods for predicting body temperature (Tb) during treks that might prove useful in management or climate change models. We exploited treks forced by annual drainage of artificial ponds for management purposes in our Maryland study area. Turtles at our site use habitual overland routes, allowing accurate pre-positioning of thermal sensors and thus accurate comparison between the Tb of free-ranging animals and Tb as estimated by an array of temperature sensors. We used and compared several proposed methods – (1) anatomically correct, water-filled, electroformed copper turtle models to estimate Tb directly, (2) hollow electroformed copper models and (3) approximate models consisting of sized-matched aluminum baking pans, both of which were used to compute Tb. Additionally, we used both (4) plain and (5) solar-absorptance matched Thermochrons to record temperature at sensor locations. Models were painted to approximate the solar absorptance of turtle shells and were calibrated against both turtle shells and live turtles. Model accuracy and precision will be discussed, and models will be evaluated for their suitability for use in management and climate change modeling.

15.2 KRUG, P.J.*; VENDETTI, J.E.; TROWBRIDGE, C.D.; California State University, Los Angeles, Oregon Institute of Marine Biology; *pkrug@calstatela.edu*

Do shifts in host use or larval development drive speciation in the sea? A comparative study of herbivorous sea slugs.

Marine biodiversity presents a challenge to current theory of allopatric speciation, given the lack of physical barriers to gene flow and the high dispersal potential of many organisms, either as pelagic adults or as planktonic larvae. Recent studies of invertebrates, fish and marine mammals suggest ecological speciation can proceed in sympatry, but this remains controversial. For specialized consumers or epibionts, disruptive selection on host or habitat choice may drive speciation. Alternatively, life-history shifts from dispersive larvae to short-lived, non-feeding larvae may reduce gene flow among populations, and shrink the scale at which populations diverge in allopatry. Non-dispersive life histories could also act synergistically with selection, together increasing local adaptation to newly colonized niches. Sea slugs in clade Sacoglossa, the most host-specialized marine herbivores, are an excellent system with which to explore how shifts in host or life history alter patterns and rates of speciation. We present a comparative analysis of this group, using a molecular phylogenetic framework of 200 taxa to identify traits that influence the geographic and temporal mode of speciation. Bayesian and maximum likelihood methods of ancestral character state reconstruction and correlated trait evolution will be used to test the evidence for sympatric speciation by host shift, and determine whether clades with frequent host shifts have accelerated rates of evolution or speciation. We will also test the hypothesis that larval type influences rates of (a) molecular evolution, (b) speciation, and (c) gene flow estimated from population genetic data.

39.2 KRUYT, J.W.*; QUICAZAN-RUBIO, E.M.; VAN HEIJST, G.J.F.; ALTSHULER, D.L.; LENTINK, D.; Stanford University; Wageningen University, University of California, Riverside, Technical University of Eindhoven, University of British Columbia; *kruyt@stanford.edu*

Small aspect ratio differences impact hover efficacy among 12 hummingbird species

Hovering is a key behavior of hummingbirds that allows them to time-effectively extract nectar from flowers and catch arthropod prey, which is critical to their high-energy lifestyle. The aerodynamic power demands are high during hovering but how these demands compare among different species is not fully understood. Here we compare the quasi-steady aerodynamic performance of wings from 12 species of hummingbirds to determine how wing morphology mediates hovering performance. We attained lift and drag over a range of angles of attack for Reynolds numbers representative for every species. Whereas other spinner experiments recorded negative drag at low angles of attack, our spinner measured drag accurately across the full range of wing angles. The force measurements allow us to compare hover efficacy among different wings through the power factor, which captures the efficacy of hummingbird wings to lift a unit weight with a minimum of aerodynamic power. We found a strong effect of aspect ratio on quasi-steady aerodynamic performance at angles of attack that are relevant to hovering flight in hummingbirds. To quantify the effect of wing morphology on the airflow we performed particle image velocimetry and visualized the leading edge vortex (LEV) for the up and down stroke configuration of the wing. Our findings show that small differences in aspect ratio affect the hover efficacy of spinning hummingbird wings while having only small effect on quasi-steady flow structure. This result shows the value of precise drag force measurements on wings that produce leading edge vortices.

134.4 KUBLI, SP; MACDOUGALL-SHACKLETON, EA*; Western University; *emacdoug@uwo.ca*

Delusions of immunocompetence: song complexity, song consistency and immune trade-offs in song sparrows

In short-lived, migratory songbirds, constitutive innate immunity is an important component of fitness. Females cannot directly assess immune function of potential mates, but condition-dependent ornaments or displays may provide information about the signaler's past or current condition. We investigated the degree to which song complexity and song consistency, thought to reflect condition over different developmental timescales, predict multiple aspects of constitutive innate immunity in 38 male song sparrows. We also investigated correlations among immune measures. Principal components analysis revealed an overall pattern of opposite loading between protective protein (haptoglobin, lysozyme, natural antibody) versus cellular (microbicidal, phagocytosis) components of immunity. Song complexity, a static trait that does not change during adulthood in this species, was associated with relative investment in protective proteins versus cellular activity: males with large repertoires had higher protective protein titres but lower leukocyte activity relative to males with small repertoires. Song consistency, a dynamic trait that varies throughout the life of the individual, did not predict relative investment in proteins versus cellular defences. Song complexity may reflect individual variation in self-maintenance strategies, rather than overall immune functioning per se. Perhaps most important, these findings illustrate the importance of assessing multiple aspects of immunity rather than attempting to infer "immunocompetence" from a single metric.

97.5 KUNDANATI, L; GUNDIAH, N*; Indian Institute of Science, Bangalore; *namrata@mecheng.iisc.ernet.in*

Biomechanics of Substrate Boring by Fig Wasps: Role of Zinc in Insect Cuticle

There are many biomechanical challenges that a female insect must meet to successfully oviposit and ensure her evolutionary success. These begin with selection of a suitable substrate through which the ovipositor must penetrate without itself buckling or fracturing. The second phase corresponds to steering and manipulating the ovipositor to deliver eggs at desired locations. Finally, the insect must retract her ovipositor fast to avoid possible predation and repeat this process multiple times during her lifetime. From a materials perspective, insect oviposition is a fascinating problem and poses many questions. Specifically, are there diverse mechanisms that insects use to drill through hard substrates without itself buckling or fracturing? What are the structure-property relationships in the ovipositor material? These are some of the questions we address with a model system consisting of a parasitoid fig wasp - fig substrate system. To characterize the structure of ovipositors, we use scanning electron microscopy with a detector to quantify the presence of transition elements. Our results show that parasitoid ovipositors have teeth like structures on their tips and contain high amounts of zinc as compared to remote regions. Sensillae are present along the ovipositor to aid detection of chemical species and mechanical deformations. To quantify the material properties of parasitoid ovipositors, we use an atomic force microscope and show that tip regions have higher modulus as compared to remote regions. Finally, we use videography to show that ovipositors buckle during oviposition and estimate the forces needed to cause substrate boring based on Euler buckling analysis. Such methods may be useful for the design of functionally graded surgical tools.

P1.147 KUO, C-Y*; IRSCHICK, DJ; Univ. of Massachusetts Amherst; *chiyun@bio.umass.edu*

A costly antipredator behavior in a gradient of predation pressure: tail autotomy in the side blotched lizard Uta stansburiana

The ability to survive predation is one of the most important aspects of organismal fitness. To that end, animals have evolved a diverse array of antipredator traits and strategies that costly to express or maintain. Studies that examined the variation of antipredator traits among populations have shown that the degree to which a costly antipredator trait is expressed is often fine-tuned with the intensity of predation. Autotomy, the voluntary shedding of appendages, is a widespread and extremely costly antipredator behavior that allows an animal to escape even when it is already captured by a predator. The occurrence of autotomy involves two processes. The first is a decision making process where an animal determines whether to autotomize based on the level of physical stimulus on the appendage from predators; the second is the breakage of skeletal structures when the appendage is being separated from the body. No study to date has fully examined whether the ability to autotomize varies among populations across a gradient of predation pressure. In this study, we hypothesize that the facility at which autotomy occurs correlates with predation intensity across conspecific populations. Specifically, we test the following two predictions with a lizard species that has a wide geographical distribution and commonly autotomizes the tails. We predict that individuals experiencing higher predation pressure might (1) autotomize at a lower threshold stimulus, and (2) have to overcome a weaker structural resistance posed by the skeletal elements during the breakage process. Our results will provide insight into whether the facility of autotomy is a product of evolution fine-tuned to the degree of predation intensity.

84.1 KURNATH, P.*; DEARING, M.D.; Univ. of Utah, Salt Lake City; *patrice.kurnath@utah.edu*

Turning up the Heat: Investigating the Physiological Effects of Climate Change on Mammalian Herbivores

Climate change is causing range shifts and population declines in many animal populations, particularly mammalian herbivores. One hypothesis to explain these changes in mammalian herbivores is that plant secondary compounds may be perceived as more toxic due to decreased liver metabolism at warmer ambient temperatures compared to cooler temperatures. The phenomenon of temperature-dependent toxicity (TDT) has been documented in pharmacological studies in laboratory rodents, but has not been extensively explored in wild mammalian herbivores. To test for TDT, we investigated how ambient temperature impacts liver metabolism in the desert woodrat, *Neotoma lepida*, by using hypnotic state assays. In a cross-over design, wild caught *N. lepida* (N=26) were housed at two ambient temperatures (warm=29°C, cool=21°C) for either 30 days or 3 hours to capture ecologically relevant situations in the wild (i.e., within season or access to microclimates). After each temperature exposure, animals were given a hypnotic agent (hexobarbital via intraperitoneal injections 100mg/kg), which was used as a proxy for liver function with longer sleep times indicating decreased liver function. The average sleep time of woodrats acclimated to warm temperatures for 30 days was almost 50% longer than cool-acclimated woodrats and almost 30% longer after the 3 hour exposure to warm versus cool temperatures (paired t-tests, $p<0.01$). These results demonstrate that warmer ambient temperatures adversely affect liver function, even within a short period of time, and may provide a physiological mechanism through which climate change acts on herbivorous mammals.

_102.2_ KURTH, J.A.*; KIER, W.M.; University of North Carolina, Chapel Hill; *jkurth@live.unc.edu*

Scaling of the Hydrostatic Skeleton in the Earthworm, Lumbricus terrestris

The structural and functional consequences of changes in size or scale have been well studied in animals with rigid skeletons, but relatively little is known about scale effects in animals with hydrostatic skeletons. We used microscopy and histology to examine the scaling of mechanically important morphological features using an ontogenetic size range of the earthworm *Lumbricus terrestris* from 0.03g-12.89g. Each worm was anesthetized and laid out under a dissecting microscope, and measurements were taken of its elongated body length as well as diameter. The worms were then sacrificed and several segments were removed and embedded in glycol methacrylate plastic. Our results indicate that several functionally important morphological features do not maintain geometric similarity with ontogeny. We found that the cross-sectional area of the longitudinal muscles (which are used to radially expand the worm) scaled as body mass to the ~0.6 power across segments, which is significantly lower than the 0.66 power predicted by isometry. However, the cross-sectional area of the circular muscles (used to axially elongate the worm) scaled as body mass to the ~0.8 power across segments, which is significantly higher what is predicted by isometry. These data suggest that as worms increase in body size, they may produce relatively greater forces during axial elongation but relatively weaker forces during radial expansion than what is expected by scaling with geometric similarity.

_136.3_ KUWAHARA, A*; MEYER, C; COLLINS, A; Humboldt State University, Smithsonian Institution, NOAA/NMFS Smithsonian Institution; *aak23@humboldt.edu*

Assessing Autonomous Reef Monitoring Structures (ARMS) as Biodiversity Monitors

Assessing Autonomous Reef Monitoring Structures (ARMS) as Biodiversity Monitors Akela Kuwahara[1,2], Allen Collins[2] and Chris Meyer[2] [1]Humbolt State University [2]NMNH-IZ, Smithsonian Institution, USA Due to the complexity of coral reef ecosystems and the multitude of cryptic species, accurate estimates coral reef biodiversity are difficult. To better understand coral reef biodiversity and how it varies, Autonomous Reef Monitoring Structures (ARMS) were developed to collect comparable samples of reef cryptobiont communities. These units create standardized, habitable structure for both sessile and motile reef organisms, thus allowing statistically rigorous examination of a consistent, diverse subset of cryptobiota across a variety of reef habitats, locales and time. Over 300 ARMS have been deployed at over 40 sites worldwide, but no tests have been performed to measure the variance in community composition within and/or between sites for the sessile biota. In order to test the sensitivity of ARMS to detect change, we measured percent cover of major sessile groups using high-resolution photographs of the ARMS plates after one-year deployments on reefs in the Coral Triangle and French Polynesia. These data were used to test the following: 1. How much variation in major functional groups exists within regions on local scales (i.e. 2m versus 100m)? 2. Can ARMS detect differences in community composition across regional scales (Indonesia versus French Polynesia)? 3. Are communities established on reconditioned ARMS different from those on new ARMS? These tests are critical to determine the potential of ARMS data as a rigorous biodiversity metric. Our results argue for the use of ARMS as standardized monitoring structures and provide insight into the cryptic community on coral reefs. This morphological data can also be compared with metagenomic data derived from the ARMS, allowing us to assess the accuracy of these emerging molecular methods in measuring biodiversity.

_P1.197_ KWONG, A.*; DOONG, J.; EVANGELISTA, D.; Univ. of California, Berkeley, Stanford University; *devangel77b@gmail.com*

Methods for quantifying disturbance force and sensitivity of simple shapes to turbulent incident air velocities

Airborne objects (animals, plants, and vehicles) flying in real environments may feel disturbances from turbulence in the air they are flying through. The shape of an object and its size relative to turbulent eddies affects the magnitudes and frequencies of the disturbances felt, in other words, the sensitivity to turbulence. As part of a larger study of stability, control, and the evolution of aerial maneuvering, we quantified the sensitivity of simple two- and three-dimensional models to turbulent incident air velocity using simultaneous measurements of forces and torques and air velocities in a wind tunnel. Preliminary results compare well with theoretical predictions of the disturbances an airborne organism of a given shape might experience in a particular environment. We also found good general agreement between simplified geometric shapes and 2D animal planforms of equivalent aspect ratio. Elongated shapes with low aspect ratio are better "filters" of turbulent noise, while high aspect ratio shapes "feel" more of the turbulence. This may have important consequences for maneuvering and noise pickup from a turbulent environment as body plans evolve.

_27.4_ LABONTE, D*; FEDERLE, W; University of Cambridge; *dl416@cam.ac.uk*

Division of labour between adhesion and friction pads in stick insects (Carausius morosus)

Stick insect legs bear two types of attachment pads, tarsal “heel” pads (euplantulae) and a pre-tarsal “toe” pad (arolium). In order to investigate whether these pads are specialised for different functions, we measured friction and adhesion of single pads under varying normal and shear force loads, using a custom-built 2D force transducer. Euplantulae were found to generate negligible adhesion (peak values below 15% body weight), but large friction forces exceeding the insect's body weight. In contrast, peak adhesion of arolia amounted to up to 80% body weight. Adhesive forces significantly increased with the applied shear force, and were independent of the normal pre-load over nearly one order of magnitude. These results suggest that stick insects use their tarsal euplantulae for generating friction forces when no adhesive force is needed (e.g. when walking upright or for legs below the centre of gravity during vertical climbing), and thereby minimize costs associated with detachment of the pads. The distal arolia, in turn, are likely used as “true” adhesive pads that maintain surface contact during vertical climbing or inverted walking. The shear stress (friction per apparent contact area) of euplantulae (but not of arolia) was dependent on normal load. This dependency may be explained by the specific surface topography of the euplantulae, which are covered by tapered microtrichia. High-magnification light microscopy and reflected-light contrast recordings of the euplantula contact area during force measurements confirmed that their real contact area increased both with normal and shear force via a larger number of microtrichia contacting the surface and/or side contact of individual microtrichia.

P1.182 LAFLEUR, K.*; ROTIBI, M.; CATAPANE, E.J.; CARROLL, M.A.; Medgar Evers College; *catapane@mec.cuny.edu*

Effects of Antioxidants and Anti-inflammatory Agents on Neurotoxic Effects of Manganese on Dopaminergic Innervation of Gill of the Bivalve Mollusc Crassostrea virginica

Lateral cilia of the gill of *Crassostrea virginica* are controlled by a serotonergic-dopaminergic innervation. Dopamine acts as an excitatory neurotransmitter within the ganglia, but an inhibitory neurotransmitter at gill, causing cilio-inhibition. The mechanism of action of manganese toxicity is not fully understood, but may be due to oxidative damage. We found several chelators, including p-aminosalicylic acid (PAS) prevented neurotoxic effects of Mn in *C. virginica*. The therapeutic actions of PAS are thought to be due to chelation, but PAS is also anti-inflammatory. We sought to determine if anti-inflammatory agents and/or antioxidants are effective in preventing neurotoxic actions of Mn in gill of *C. virginica*. Indomethacin (IM), an anti-inflammatory agent with antioxidant abilities, and ascorbic acid (AA), an antioxidant with possible anti-inflammation abilities were tested. We examined acute and short term (3 - 5 days) treatment of IM and AA on Mn toxicity on dopaminergic innervation. Beating rates of lateral cilia in gill epithelial cells were measured by stroboscopic microscopy. Acute or short-term treatments of IM or AA (25 - 100 µM) and had no effect on the cilio-inhibitory effects of dopamine (10^{-6} - 10^{-3} M). When acute or short-term Mn treated animals (25 - 100 µM) were pretreated with IM or AA (25 - 100 µM), both drugs effectively prevented the neurotoxic effects of Mn, with AA being more effective than IM. The study demonstrates antioxidants and anti-inflammatory agents can block the neurotoxic actions of Mn and may be possible therapeutic agents in the treatment of Manganism.

134.5 LAHMAN, SE*; MOORE, PA; Bowling Green State Univ.; *slahman@bgsu.edu*

Spatial information in chemical signals: the interaction between odor source and hydrodynamics.

Within an aquatic ecosystem, many organisms rely on chemical signals in order to perform a range of ecological decisions. Understanding the role of chemical signals in the ecology of aquatic organisms requires a thorough understanding of the spatial and temporal distribution of sensory stimuli. For chemoreception, chemical signal dispersion is intimately tied to fluid mechanics. Alterations in the hydrodynamics of a habitat or in the way that chemical signals are introduced to habitats can have profound effects on sensory information which can subsequently alter the behavior or ecology of organisms using chemical signals. As organisms have a defined threshold for the induction of chemically driven behaviors, variations in the information received will elicit alternate behavioral responses. This study examines the influence of point versus non-point introduction of chemical signals into a simulated flowing freshwater habitat. The fine scale spatio-temporal distribution of chemical signals was measured in situ using an electrochemical detector. Molecule concentration at varying distance and height from the source was quantified using the chemical tracer dopamine coupled with an electrochemical detection system (Epsilon, Bioanalytical Systems). The fine-scale distribution of chemical signals from point and non-point sources showed significant differences in the types of information that are available to organisms. This quantification of chemical signal dispersion patterns and the types of information that are available allows a greater understanding of chemoreception. Based on these results, organisms should be able adjust their search strategy to differences in information received.

115.4 LAILVAUX, SP*; WILSON, R; KASUMOVIC, MM; University of New Orleans, University of Queensland, University of New South Wales; *slailvaux@gmail.com*

Sex-specific aging of performance in male and female professional basketball players

The expression of phenotypic traits is often influenced by dynamic resource allocation trade-offs which, when occurring over the course of individual lifespans, may be manifest as trait aging. Although aging has been studied for a variety of traits that are closely tied to reproduction or reproductive effort, the aging of multiple traits related to fitness in other ways are less well understood. We took advantage of almost 30 years of data on human whole-organism performance in the National Basketball Association to examine trends of aging in performance traits related to speed, endurance and accuracy. Given that patterns of aging are known to differ between sexes in other animal species, we also analysed a smaller dataset on players in the Women's National Basketball Association to test for potential sex differences in the aging of comparable traits. Finally, we tested the hypothesis that different aspects of performance trade-off as individuals age. These data suggest that the aging of performance traits used in basketball is generally characterised by senescence in males, whereas females show evidence of terminal investment in performance.

88.5 LAMMERS, A.R.*; DORSEY, E.J.; Cleveland State University, Ohio; *a.Lammers13@csuohio.edu*

Kinetics of locomotion on arboreal and terrestrial substrates in Siberian chipmunks (Tamias sibiricus)

Traveling on tree branches and twigs is common among mammals, but until recently most studies concentrated on primates. With work carried out on gray short-tailed opossums, rats, and red squirrels (Schmidt & Fischer 2010; Schmidt 2011), it is possible to begin generalizing about differences in arboreal locomotor biomechanics between primates and other mammals. We trained five Siberian chipmunks to run on 2 m long trackways – one with a flat surface to simulate a terrestrial surface, and the other cylindrical (2 cm diameter) to simulate an arboreal substrate. We instrumented a portion of each trackway to measure substrate reaction force from the limbs on the animals' right side. The force pole was split so that the right side of the cylinder measured force while the left side was un-instrumented. Peak vertical force and vertical impulse were higher in forelimbs than hindlimbs. Peak vertical force was reduced on the arboreal track. These patterns are consistent with other non-primate mammals traveling on arboreal substrates. Furthermore, the reduction in peak vertical force on arboreal supports is consistent across mammals. If reducing branch oscillation is the reason for this behavior, then the adaptation probably occurred early in the mammalian radiation. Forelimbs were net braking and hindlimbs net propulsive; there were no differences in net fore-aft impulses between arboreal and terrestrial trackways. Laterally-directed substrate reaction impulse was higher on the arboreal supports. On the narrow arboreal cylinder, the chipmunks squeeze the branch between right and left hands or feet, providing a stable grip. This is consistent with the other non-primate mammals from which mediolateral forces were measured from individual limbs.

6.5 LANDBERG, T*; WARKENTIN, K; WILINK, B; MOUNT, K; CLOUSE, E; WHITEMAN, H; Murray State University, Boston University, University of Costa Rica; *tobias.landberg@gmail.com*

Larval density affects jumping performance development during metamorphosis in two arboreal frogs

Metamorphosis is the rapid shift of an organism between niches. In amphibians, the transition between phenotypes adapted for aquatic larval and terrestrial adult environments is awkward and dangerous. Metamorphs are not well-adapted to life either in water or on land and therefore vulnerable to predation. In two separate outdoor mesocosm experiments in Panama and Kentucky we raised larval Red-Eyed treefrogs (RE; *Agalychnis callidryas*; n=344) and Cope's Grey tree frogs (CG; *Hyla chrysocelis*; n=176) under high, medium and low density conditions. To measure the carry-over effects of the larval stage on the development of jumping performance, each individual was placed at the center of a jumping arena marked with concentric circles (1.25cm and 1cm apart for RE and CG respectively) and stimulated to jump by applying gentle manual pressure to their rear ends. We analyzed the average of three jumps per individual and also measured snout-vent, limb (tibiafibula), and tail lengths, mass, and stage of metamophosis (Gosner stages). When analyzed separately using ANCOVA, both species showed similarly strong positive effects of snout-vent length and limb length on jumping performance and strong negative effects of tail length. Both species also showed snout-vent length by mass interactions and effects of density that interacted with morphological traits such as tail and limb length. Clear species effects are also apparent. While limited in scope, this simple two-species comparison reveals that during metamorphosis there is a highly dynamic relationship between body size metrics and jumping performance that is modified by the larval environment.

P1.97 LANDRIGAN, J*; SPRAYBERRY, JDH; Muhlenberg College; *jl242050@muhlenberg.edu*

Effects of Wind Speed on Floral Motion Characteristics

Plant-pollinator relationships are classical systems for examining coevolution. In hovering pollinators, the biomechanical structure of flowers may impact fitness. Previous work has found that *Manduca sexta* not only feed-from and track horizontally-moving flowers better than looming flowers, they actively prefer to feed from horizontally-moving flowers. This naïve preference implies a potential selective force on hawkmoth-pollinated flowers. A preliminary motion analysis showed that these flowers exhibit more motion in the horizontal rather than the looming axis. A more thorough investigation of this system requires a deeper understanding of floral motions. The characteristics of floral motion (frequency, amplitude and direction) are influenced by morphological features (stem structure, physical organization of inflorescences, inflorescence shape, etc.). Although engineering theory predicts that frequency of floral motions will be dominated by stem properties (such as length and stiffness) rather than wind speed, the effects of floral structure may be more complex. This project examined the effect of wind speed on floral motions by filming flowers in a wind tunnel at 1, 5, & 10 m/s. Flower videos were digitized and resultant position traces were filtered, perspective corrected, then subjected to an FFT to produce their amplitude spectra. Results were variable across species, but indicated that frequency of flower motion is not necessarily constant across wind speeds. This variability implies that floral morphology (beyond stem length and stiffness) impacts floral motion characteristics. These data will allow for a better understanding and analysis of companion data on natural floral motions, as environmental wind conditions are difficult to characterize.

P1.145 LANG, S.A.*; COLE, M.C.; KRISTAN, D.M.; California State University San Marcos; *lang014@cougars.csusm.edu*

Short-term Re-feeding After Calorie Restriction Partially Restores Resistance to Parasite Infection

Laboratory mice (*Mus musculus*) given long-term calorie restriction (CR) have greater susceptibility to infection with the intestinal nematode *Heligmosomoides bakeri*, despite an adequate immune response. However, it is not known if short-term changes in food intake might influence susceptibility to infection. The goals of our study were to determine (1) if short-term re-feeding (RF) would ameliorate the expected increase in worm numbers seen with CR, (2) if parasite growth and reproduction would be altered after host re-feeding, and (3) if RF mice would have altered immunoglobulin (Ig) production compared to CR mice. MaleC57BL/6 mice were given 40% CR for six months, after which half of the mice were provided ad libitum (AL) food for seven days prior to infection; control mice were fed AL throughout the entire study. All mice were infected for 21d. As expected, CR mice harbored more worms than AL mice; RF mice had an intermediate number of parasites that did not differ significantly from either AL or CR mice. RF mice had intermediate body mass compared to CR and AL mice. There were no differences in parasite size, sex ratio or egg production, and both total circulating IgG1 and parasite-specific IgG1 were similar among mouse treatment groups. Longer infection durations should be assessed to determine if RF mice are able to clear infections at a similar rate as AL mice. Enumeration of CD4+ T cells and associated cytokines related to parasite expulsion, namely interleukin (IL)-4 and IL-13, may help explain observed differences in parasite susceptibility.

68.7 LANGKILDE, T*; FREIDENFELDS, N.A.; THAWLEY, C.J.; ROBBINS, T.R.; GRAHAM, S.P.; Pennsylvania State University; *tll30@psu.edu*

Are invasive species stressful?

Invasive species represent a substantial threat to native species worldwide. Previous research has focused on population-level impacts on invasive species; however, the sub-lethal effects of invasive species on wild living vertebrates are relatively unknown. We conducted a series of laboratory and field surveys and manipulations to assess the impact of invasive red imported fire ants (*Solenopsis invicta*) on physiological stress levels (coticosterone, CORT) of native fence lizards (*Sceloporus undulatus*). Field surveys revealed that lizards from sites that had been invaded by fire ants had higher levels of CORT than did those from uninvaded sites. Direct encounters with fire ants caused increased levels of CORT in lizards, suggesting that fire ants may be directly driving the pattern observed in the field. Longer-term exposure to fire ants in field enclosures resulted in lower baseline levels of CORT as compared to controls, however. This may be due to the stress associated with enclosures, in combination with fire ant exposure, pushing lizards into chronic stress and resulting in a breakdown in negative feedback controls of the stress response. These results underscore the challenges of assigning causation to studies of anthropogenically-induced stress, and the importance of considering the length, frequency, and magnitude of exposure to the stressor when examining its consequences.

P3.215 LANGLAND, K.M.*; POWERS, D.R.; WETHINGTON, S.M.; Biology Department, George Fox University, Newberg, OR, The Hummingbird Monitoring Network, Patagonia, AZ ; *langlandkm@gmail.com*

Use of Infrared Thermography to Measure Body-Surface Heat Dissipation in Free-Living Hummingbirds

Hummingbirds are tiny endotherms that struggle to maintain a constant body temperature (T_b) because of their high surface-to-volume ratios. Species that live in hot climates will be particularly challenged because hummingbird T_b is only a few degrees below lethal temperature so they must have effective physiological and behavioral mechanisms that will allow them to dissipate heat rapidly when operative temperatures (T_e) are high. Respiratory evaporation plays a major role in heat dissipation, but heat dissipation across external body surfaces will also be important. In this study we used infrared thermography to examine heat dissipation from external body surfaces of perching broad-tailed hummingbirds (*Selasphorus platycerus*; ~3.4 g), a high-elevation species in SE Arizona. We measured surface temperature (T_s) over Te ranging from 23-35 °C. Of particular interest was the area surrounding the eye which was >5 °C above mean body T_s at all T_es. Total area of the eye region (ER) "hotspot" and its mean T_s increased linearly at T_e >29 °C. At T_e=35 °C mean ER T_s=35.5 °C which might suggest increased blood flow to these surfaces to maintain a thermal gradient for heat dissipation. The area of the ER "hotspot" increased ~3X at T_e=35 °C also suggesting an increase in heat dissipation. Interestingly the eye itself remained cool indicating thermal protection from surrounding tissues. We estimate that the ER "hotspot" accounts for dissipation ~5% of metabolic heat production in perching Broad-taileds. Supported by NASA (10-BIOCLIM10-0094), Holman Endowment for the Sciences (George Fox University), and FLIR Systems, Inc.

102.5 LARGHI, N.P.*; DEBAN, S.M.; Univ. of South Florida, Tampa; *nlarghi@gmail.com*

Effects of scaling on bite force and suction index in the Eastern Hellbender (Cryptobranchus alleganiensis)

In 1950, AV Hill developed a series of predictions on how animal movements should scale with body size. Since this pivotal paper, many studies have been published regarding animal locomotion and scaling, but few have focused on feeding mechanisms and scaling. The hellbender *(Cryptobranchus alleganiensis)*, is a salamander that grows over a large range of body sizes (18-74 cm TL) making it an ideal organism for examining scaling effects. Morphology can be expected to change as an organism grows larger, and because morphology and performance are closely linked, this morphological change can result in a change in feeding ability. *C. alleganiensis* are primarily aquatic salamanders and utilize both suction feeding and biting behaviors while feeding. We hypothesized that bite force would increase with positive allometry due a to a possible dietary shift in diet during ontogeny in which larger *Cryptobranchus* favor crayfish, which are hard shelled and aggressive when confronted by a predator. Suction potential is hypothesized to scale with negative allometry because it would be advantageous for smaller animals to rely on suction due to consumption of smaller prey items and a lower absolute bite force. Preserved specimens (11.9-34.5 cm SVL) were used to investigate the effects of scaling on suction potential and bite force. Bite force was calculated by use of a 3D static equilibrium model and suction potential was calculated as suction index. Bite force scaled with positive allometry allowing the animals to bite relatively harder with increasing body size, yet suction index showed no effect of body size.

P3.73 LARSEN, C.*; REYES, J.A.; IWANSKI, E.; PATEL, R.; KELLEY, K.M.; CSU Long Beach, Pacific Coast Environmental Conservancy; *larsen.cody@gmail.com*

Elevated Estradiol in Male Fish" Environmental Differences and Underlying Molecular Mechanisms

In select locations offshore of urban southern California, males of the fish *Pleuronichthys verticalis* (hornyhead turbot) have been found to have elevated plasma concentrations of the female steroid, 17β-estradiol (E2). Over years of study, it has been observed that males sampled within Santa Monica Bay (SMB) (offshore of Los Angeles) typically exhibit as much as 10-fold higher E2 levels than males sampled from down-coast locations (e.g., offshore of Orange County). Since estrogens are often at undetectable levels in the environment, even near regional wastewater treatment plant outfalls, it was of interest to determine whether testicular expression of steroidogenic enzymes involved in estrogen production may be altered (by a putative environmental endocrine disruptor?) and linked to endogenous E2 production. Results indicate that gonadal mRNA expression of some steroidogenic genes are relatively higher in testis of fish from SMB, and this is significantly correlated with plasma E2 levels. Furthermore, rearing of high-E2 males in aquaria with clean seawater for 4 and 8 weeks resulted in subsidence of the high estrogen phenotype and testicular expression of steroidogenic genes, down to levels seen in turbot and other flatfish males from outside of the region. New studies are using proteomics to screen for protein expression differences in testis from "high" vs. "control" E2 males, to identify candidate mechanisms underlying the environment-related high E2 phenotype. Additional screening of hepatic protein expression is aimed at identifying potential biomarkers associated with these environments and the high E2 phenotype. (Supported by NOAA/USC Sea Grant Program)

121.2 LARSON, P.G.*; DALY, M.; The Ohio State University; *larson.309@osu.edu*

Evolution of parental care in Endomyarian sea anemones

In benthic, primarily sessile animals like sea anemones (Cnidaria: Actiniaria), the retention of developing offspring (brooding) can significantly impact the potential for dispersal and speciation when compared with a strategy of producing free-swimming larvae. Brooding internally is a pan-latitudinal phenomenon among anemones, but external brooding is restricted to cold-temperate and polar regions. The genus *Epiactis* contains twelve species that brood, nine of which do so externally and include representatives from the arctic and Antarctic. The life history and reproductive details of brooding species in *Epiactis* are highly variable: for example, the arctic *E. marsupialis* is dioecious and broods offspring within pits in the surface of the column while in Antarctica, *E. georgiana* is hermaphroditic with offspring exposed, attaching directly to the surface of their parent via their pedal disk. *E. fernaldi* and *E. thompsoni* are internally brooding species that can be found in the northern and southern hemispheres, respectively. The close relationships implied by the current classification of these diverse species are tested by mitochondrial and nuclear DNA sequences. The results inform our understanding of the evolution of brooding strategies within Endomyarian sea anemones.

P2.60 LASALA, J.A.*; HARRISON, J.S.; FRICK, M.; WILLIAMS, K.; ROSTAL, D.C.; Florida Atlantic University, Georgia Southern University, Caretta Research Project, Caretta Research Project; *jlasala1@fau.edu*

New microsatellite analyses may confound current population models for loggerhead sea turtles (Caretta caretta)

Mating systems play an important role in shaping life history evolution and population dynamics of a species and should be considered when planning conservation efforts. Polyandry, a single female mating with multiple males, may result in the multiple paternity of progeny arrays. Recent studies have suggested that multiple paternity occurs in most species of reptiles but within the Testudines there is a high degree of variation. Previous studies on the loggerhead sea turtle (*Caretta caretta*) have shown that within large rookeries in Florida, Australia and Greece the occurrence of multiple paternity within nests ranges from 30% (Florida) to 95% (Greece). Our study is the first to study nests from the smaller and more threatened Northern Management Unit for the presence of multiple paternal contributions. On a small beach on Wassaw Island, GA, nesting mothers and up to 20 offspring were sampled from 90 nests (19.5% of nests laid) over three nesting seasons (2008 – 2010). Our study determined that 75% of nests sampled had multiple fathers with an average of 2.65 fathers contributing to each nest; the number of fathers per nest did not change over the three year loggerhead nesting cycle. There was a positive relationship between the number of fathers per nest and female size (SCL), but there was no relationship between number of fathers and hatching success. Finally, 195 individual paternal genotypes were identified over the three years, but each individual male never contributed to more than one nest throughout the three year nesting cycle. We discuss the implications of our findings with current population models.

P2.73 LASH, J/L*; SHERMAN, R/L; Nova Southeastern University, Dania Beach, Nova Southeastern University, Fort Lauderdale; *lash@nova.edu*

A Preliminary Comparative Study of Vascular Corrosion Casts of the Spiral Intestine of Select Acipenseriformes and Elasmobranchs

In members of Families Urotrygonidae (sub-Class Elasmobranchii) and Acipenseriformes, the body cavity encloses an extensive reproductive system and large liver, constraining the available space for the alimentary canal. The digestive system of these organisms have evolved a spiral intestine to compensate for the limited space. Whether it has evolved secondarily or is a conserved trait is unknown, and the evolutionary relationship between these species is still debated (Hymann, 1992). Current phylogenetic placement argues for two hypotheses regarding the relationship of Actinopterygii and Chondryichthyes 1) Actinopterygii and Sarcopterygii are sister taxa, and both share a common ancestor to Chondryicthyes, or 2) Actinopterygii and Chondryicthyes are sister taxa (Martin, 2001). This preliminary study uses vascular corrosion casting techniques to compare the spiral intestine vasculature of the Siberian sturgeon (Acipensiformes, *Acipenser baerii*), North American Paddlefish (Acipensiformes, *Polydon spathula*) and yellow stingray (Elasmobranchii, *Urobatis jamaicensis*). Future studies using vascular corrosion casting and SEM analysis will focus on branching and arteriole and venule patterns and capillary bed characterizations throughout the mucosa, submucosa, muscularis, and serosa, while histology studies will examine the vasculature through various tissue types, connective, epithelial and muscular, and gross dissection will examine the variation of valvular folds between species. Results from this research will offer a greater understanding of the functional morphology and phylogenetic connections between these two diverse groups of fishes.

7.3 LASKER, HR*; PARIS, CB; KOUGH, A; CHERUBIN, LM; University at Buffalo, University of Miami; *hlasker@buffalo.edu*

Reproductive Timing and Connectivity in the Octocoral Pseudopterogorgia elisabethae

Reproductive synchrony is essential for species that cast gametes into the water column. While synchrony is necessary the basis for the day and time of day in which spawning occurs is less clear. Proximal mechanisms based on the intensity and spectral quality of light and endogenous clocks have been identified in some systems and the predictability of those cues may be the basis of selection for that timing. However, discussions of the timing of reproduction most commonly focus on factors such as production of gametes, successful fertilization, and dispersal and survival of the resultant larvae. The Caribbean octocoral *Pseudopterogorgia elisabethae* is a surface brooder which in The Bahamas spawns on a weak lunar cycle centered around the new moon in November and December. The larvae are negatively buoyant. A coupled bio-physical model, the Connectivity Modeling System, was used to simulate patterns of dispersal and larval retention during spawning months in The Bahamas from 2005-2008. The model was used to compare the hypothetical patterns of recruitment and dispersal that would occur with spawning across the entire lunar month. The timing of release across the lunar month affected neither overall settlement nor dispersal. Gonochoric species must exhibit some degree of synchrony in their spawning, but the basis for the timing of those events is not apparent. Bio-physical models provide a valuable tool in exploring the consequences of that timing on successful recruitment.

122.4 LASLO, M*; ANGELINI, DR; American University, Colby College; *mlaslo09@gmail.com*

Gene interactions in the sex differentiation pathway of Oncopeltus fasciatus (Heteroptera)

The regulation and development of sex is a classic subject in developmental biology. The biological importance of sex suggests that sex determination mechanisms could be conserved among sexually reproducing species; however, developmental and genetic studies have revealed great diversity in the ways animals determine sex. Although insects are a diverse and numerous group of animals, sex determination mechanisms have only been examined in Holometabola. True bugs (Heteroptera), such as the milkweed bug, *Oncopeltus fasciatus*, are a diverse and species-rich order that diverged from Holometabola more than 300 million years ago. A conservative null model predicts that genes involved in sex determination in *Drosophila melanogaster* might also be involved in sexual development in the milkweed bug *O. fasciatus*. A model of sex determination in a hemimetabolous insect will offer a better understanding of the evolution of this process in insects. RNA interference is feasible and efficient during juvenile development in *O. fasciatus*, and knockdown of gene activity can be confirmed with quantitative RT-PCR. *doublesex* and *transformer-2*, two highly conserved genes, appear to have no role in *O. fasciatus* sexual development, although *transformer-2* is varies throughout development and is dimorphically expressed in adults. *fruitless*, an early regulator of mating behavior in *Drosophila* and *Blatella germanica*, appears to play a role in *O. fasciatus* genital development. *intersex*, a downstream regulator of sexual development in *Drosophila*, is involved in development of internal reproductive structures and external genitalia. Expression of *intersex* is reduced in a *fruitless* RNAi background, suggesting that *fruitless* normally acts to promote *intersex* expression. These data expand our understanding of insect developmental diversity and suggest ancestral functions of some sex determination genes within Holometabola.

73.6 LATTANZIO, M*; MILES, D; Ohio University;
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Functional and phenotypic responses of lizards to disturbance
Anthropogenic disturbance has been implicated as a factor in many examples of ecological divergence. The changes in resource availability as a consequence of disturbance, mediated by trophic interactions, in part guide how species respond. At the heart of this response is the individual stress response to the disturbance itself: to disperse, adapt, or die. However, plasticity is usually the first response to variation in trophic (functional) relationships. Here we use path analysis to address hypotheses regarding the functional responses of polymorphic tree lizards (*Urosaurus ornatus*) to disturbance (prescribed burning) over a three-year period. Changes to the environment incurred by burning mimic those predicted by recent models of climate change; yet the functional consequences of this reorganization of dominant vegetation types remain unknown. We model trophic links using stable isotope analysis of carbon and nitrogen in tissues from multiple trophic levels (i.e., primary producers, arthropod consumers, and lizards). As predicted, our study sites differ in resource distributions, with grass cover greatest in burned regions. Isotopic data suggest that arthropods integrate vegetation and other prey types consistently across years and sites irrespective of availability. Lizards instead appear to exhibit diet variation specific to burn history: inter-morph diet differences were only significant in the more-frequently burned region. These results are concomitant with other phenotypic data, supporting a potential for ecological divergence. We will extend this analysis to predict the consequences of additional shifts in climatic and prey availability for this (and potentially other) species. Overall we will provide a synergistic model that supports a link between trophic variation and ecological divergence as a viable response to anthropogenic disturbance.

65.4 LATTIN, C. R.*; ROMERO, L. M.; Tufts University;
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Seasonal variation in intracellular glucocorticoid receptor binding in the immune tissues of a wild bird
Glucocorticoids such as corticosterone (CORT) help wild animals regulate their metabolism and cope with environmental stressors, but they can also have immunosuppressive effects. Nelson and others have proposed that animals should have evolved mechanisms to increase immune function to counteract seasonally-recurrent stressors that might otherwise compromise immunocompetence. We hypothesized that this could occur in part by seasonally downregulating immune tissue sensitivity to CORT by reducing concentrations of CORT receptors. We captured wild house sparrows (*Passer domesticus*) in Massachusetts during 6 different life history stages: molt, early and late winter, pre-egg-laying, breeding and late breeding (n = 12 for each period). Mineralocorticoid receptors (MR) and glucocorticoid receptors (GR) were quantified in spleen and skin using radioligand binding assays, and spleen mass was also assessed. Spleen mass was greater in the late breeding period compared to both winter periods. MR binding in spleen was lower in late breeding compared to pre-laying. There were no seasonal patterns in GR binding in spleen, although overall, female sparrows showed greater GR binding than males. The spleen's increased size and decreased sensitivity to CORT during the late breeding period could be related to the large influx of fledgling birds carrying potential pathogens into the house sparrow population at this time of year, or some other predictable life history event. There were no seasonal changes in MR or GR binding in back or belly skin. There is evidence of local production of glucocorticoids in mammalian skin, so skin receptors could be regulated locally. In any case, these results show that glucocorticoid receptors may be seasonally regulated in a tissue-specific manner.

2.2 LAUDER, G.V.*; XIONG, G.; Harvard Univ.;
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Quantifying center of mass motion in swimming fishes
Movement of the center of mass (COM) during locomotion is a key parameter that is crucial for understanding the dynamics of movement in animals. Many studies of terrestrial locomotion have focused on motion of the COM during walking and running, but to our knowledge there is little information on how the COM moves during fish swimming, and no data on whether different patterns of body bending produce differences in COM motion. In this study we present an analysis of COM oscillations in steadily swimming fishes. Using the particle image velocimetry (PIV) method commonly used for flow visualization to instead track patterns on the body, we estimated COM movement of three fish species and swimming types: carangiform and labriform (sunfish, *Lepomis macrochirus*), anguilliform (eels, *Anguilla rostrata*), and gymnotiform (knifefish, *Notopterus chitala*). We estimated COM motion in three dimensions (x: surge, y: sway, z: heave) and at three swimming speeds (0.5, 1.0, and 1.5 L/sec). Surge and sway COM oscillation magnitudes (peak to peak) were in the range of 0.4 to 1.5 mm (for fish of about 20 cm total length). Sway COM increased as swimming speed increased for bluegill and knifefish, but not for eels. Surge COM did not change with swimming speed and was largest for bluegill and smaller for both eels and knifefish. The COM was found to oscillate with twice the tail beat frequency. A log-log plot of COM oscillation cubed versus body mass for different animals shows positive allometry with a slope of 1.4, and fish COM oscillations fall significantly below this line indicating that fish have lower COM oscillations than terrestrial animals. Locomotion using body bending may reduce COM oscillation magnitudes compared to limbed terrestrial locomotion using inverted pendulum or mass-spring mechanisms.

P2.208 LAUMER, CE*; GIRIBET, G; CURINI-GALLETTI, M; Harvard University, Università degli Studi di Sassari;
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A new lithophoran proseriate with inverted genital pores from the New England coast
Although the phylogenetic relationships of the diverse flatworm clade Proseriata have been the subject of recent attention, the frequent discovery of new proseriate species and higher taxa continues to evince unfamiliar characters and character combinations, with potentially meaningful systematic implications. Here, we present the unusual morphology of a new proseriate from coastal waters of New England. The large worms resemble members of the lithophoran families Coelogynoporidae and Calviiridae in many respects, e.g. the presence of paracnida, the vertical collar-shaped pharynx, the short common female duct, and the presence of distinct male and female gonopores. However, the inverted topology of their genital system is unique within Proseriata, presenting an anterior female pore shortly behind the mouth and a male pore opening nearly at the caudal terminus, permitting inclusion into neither family on morphological grounds. To discern the species' systematic position relative to other Proseriata for which molecular data were available, we undertook analyses of its 18S and 28S rRNA sequences under diverse alignment conditions and optimality criteria. However, the phylogenetic position of the taxon proved remarkably unstable, particularly with respect to the method of alignment: analyses using a structural alignment place it as sister to the remaining Lithophora (with complete support), whereas a similarity-based alignment suggests inclusion within Coelogynoporidae (with poor support), while direct optimization yields a position sister to Calviriidae (with poor support). Given its unique morphology, as well as the limited (and conflicting) evidence for its inclusion within any family as currently defined, these worms may be best accommodated in a new, monogeneric family, the exact phylogenetic position of which must be the subject of further inquiry.

S8-2.2 LAVROV, Dennis; Iowa State University; *dlavrov@iastate.edu*
The origin of freshwater sponges: when, where, and why?
All animal phyla originated in the sea but only a few of them have colonized freshwater. The transition to limnic ecosystems required multiple adaptations to cope with highly variable temperatures, salinities, oxygen concentrations, and other parameters that make freshwater environments hostile to animal life. Consequently, freshwater animals typically represent only a few lineages within each phylum that made the transition from marine waters. Freshwater sponges are globally distributed and common members of limnic biotas. They are currently classified in the suborder Spongillina within the class Demospongiae. However their phylogenetic relationship to marine species and the time of their transition to freshwater environments remain controversial. The earliest freshwater sponge spicules are found from two disjoint time periods: from Permo-Carboniferous deposits of Europe and from Jurassic deposits of Europe and North America. It is unclear, however, whether the observed gap in the fossil record is a paleontological artefact or a reflection of two independent transitions to fresh water. Similarly, although freshwater sponges have been traditionally grouped with marine haplosclerids, several recent molecular phylogenetic studies reject this relationship. Here I use complete mitochondrial genome sequences from key representatives of demosponges to explore the phylogenetic position of freshwater sponges and to compare molecular and paleontological estimates for the time of their origin.

P2.112 LAW, CJ*; DORGAN, KM; ROUSE, GW; Scripps Institution of Oceanography, UCSD; *cjlaw9@gmail.com*
Differences in polychaete musculature lead to distinct burrowing behaviors
Divergent morphologies between closely related species can give rise to distinct behaviors and habitat uses. Considerable morphological and behavioral differences are found between the two clades within the polychaete family Opheliidae; *Thoracophelia mucronata* burrows by peristalsis whereas *Armandia brevis* exhibits undulatory burrowing. We investigate the anatomical differences that allow for diverse burrowing behaviors within Opheliidae as well as broader phylogenetic (DNA-based) and morphological analyses of Opheliidae, Scalibregmatidae, and Polygordiidae, which share morphological characteristics including the presence of a ventral groove. Phylogenetic analyses reveal that the three families are monophyletic but further study is needed to resolve the relationships among them and taxonomic problems within Opheliidae. 3D histology (Amira 5.4) of *A. brevis* reveals bilateral longitudinal muscle bands acting as the salient musculature of the body. Circular muscles required for peristalsis are absent; instead thick bands of oblique muscle work antagonistically with longitudinal muscles for undulatory burrowing. Circular muscles are present, however, in the anterior of *T. mucronata*, extending away from the body wall to form oblique muscle bands and transitioning in the posterior to musculature similar to *A. brevis*. Whereas *A. brevis* has an open body cavity, a septum separates the anterior of *T. mucronata* and gives rise to the injector organ needed for the inflation of the head region while burrowing. These morphological differences between opheliids *A. brevis* and *T. mucronata* led to disparate forms of burrowing behavior. Linking differences in morphologies between related taxa to their behaviors and habitats will give us greater context to the evolution and function of burrowing animals.

135.3 LE PABIC, P*; NG, CL; SCHILLING, TF; Univ. of California, Irvine; *plepabic@uci.edu*
Planar polarity controls cartilage morphogenesis during vertebrate jaw development
Little is known about the mechanisms of cell-cell communication necessary to assemble skeletal elements of appropriate size and shape. Skeletal progenitors may behave as coherent units by communicating via the planar cell polarity (PCP) pathway – a signaling system best known for its role in propagating consistent hair orientation across mammalian skin and insect cuticle. We find that cartilage of the jaw and in fact all pharyngeal cartilages in larval teleosts are polarized and that this polarity is conserved across vertebrate taxa. In Drosophila, two sets of factors control PCP independently: the Fat and the non-canonical Wnt signaling systems. While a requirement for components of the non-canonical Wnt system has been recently demonstrated in regulating the oriented divisions and intercalations of chondrocytes in the growth plates of long bones, a role for the Fat system in skeletal development has not been reported. We find that loss of several Fat-pathway orthologues in zebrafish disrupts chondrocyte polarity and stacking – two PCP-regulated behaviors in other contexts such as gastrulation. Furthermore, Fat signaling appears to link polarity with the onset of sox9 and col2 expression necessary for cartilage differentiation. Consistent with a role for Fat in cartilage PCP, mosaic studies demonstrate that requirements for Fat are non-cell autonomous. These results provide genetic evidence that skeletal morphogenesis and differentiation are controlled through a conserved Fat signaling pathway, and suggest that this mechanism of cell-cell communication is important for determining skeletal element size and shape.

P3.91 LEARY, B; KAVANAGH, KD*; Univ. of Massachusetts Dartmouth; *kkavanagh@umassd.edu*
Pedal Digit IV Proportions Reveal Body-Size Associated Constraint on Dinosaur Foot Morphology
The proportions of the pedal phalanges of tetrapods have been found to correlate with foot function. Plotting the phalangeal proportions of birds in morphospace not only allows us to discriminate functional groups, but also reveals a restricted range of variation in which many potential morphologies are unrepresented. Additionally, we observe some striking examples of convergent evolution. We observed that digit IV is effective in discriminating functional groups in birds. We applied this knowledge to the pedal phalanges of 30 non-avian theropods and bipedal ornithischians to identify functional groups and explore the range of variation in the ancestors of modern birds. Analyses revealed that (1) the phalanges proportions of all dinosaurs sampled fall within a subset of the range of variation observed in birds, (2) ornithischian dinosaurs fall exclusively within the range of terrestrial, non-perching birds (e.g. running, walking, swimming); exhibiting in most cases, extreme proximodistal gradient patterning, (3) non-avian theropods fall within a range spanning from terrestrial birds to highly arboreal taxa, but extreme raptorial morphologies are conspicuously absent (PCA) and (4) the phalanx proportions of non-avian theropods are strongly correlated with body length. We conclude that (1) the emergence of modern birds may have been preceded by a shift in pedal morphology to accommodate arboreal lifestyles, (2) the range of variation available to modern birds was also available to non-avian theropods, (3) non-avian theropods can be grouped into 2 distinct functional groups: terrestrial and arboreal, (4) while the ability to develop elongate distal phalanges exists in non-avian theropods, phalanx proportions may be constrained by larger body sizes.

P3.86 LEATHERMAN, L.S.T.*; NOWELL, C.; SCHILLER, A.M.; FRITSCH, P.W.; Oberlin College, San Francisco State Univ. and California Academy of Sciences, Evergreen State College, California Academy of Sciences; *lleather@oberlin.edu*

Taxonomic and adaptive significance of morphological variation in North American Cercis

In North America, *Cercis* traditionally comprises the eastern species *C. canadensis*, composed of three vaguely-defined varieties, and the western species *C. occidentalis*. Although the two species are separated by nearly 1000 km, *C. occidentalis* is often difficult to distinguish morphologically from many populations of *C. canadensis*, and on this basis, alternative classifications recognizing from one to six species have been proposed for the group. This study employed morphometric methods to provide a comprehensive analysis of morphological variation in *Cercis* throughout North America. The data set is based on leaf and fruit characters of 882 herbarium specimens (including 281 used in a prior study limited to Texas and Mexico) sampled from throughout the range of North American *Cercis*. Analyses revealed continuous variation for most characters, with no two or more characters exhibiting overlapping gaps in variation, and with most characters more or less clinal. Thus, distinct taxa appear not to be warranted on morphological grounds. Leaf characters thought to be adaptive to mesic versus xeric climates were strongly and significantly associated with mean annual precipitation and temperature gradients—larger leaves with a more acute apex and shallower sinus occur in cooler, wetter areas of the eastern United States and southern Mexican cloud forests, whereas smaller leaves with a more rounded apex and deeper sinus occur in warmer, drier areas in the western United States, south-central United States, and northern Mexico. These correlations may prove useful in estimating climatic conditions for fossil flora where *Cercis* leaves occur.

94.2 LEDON-RETTIG, CC*; INFANTE, C; HANKEN, J; NASCONE-YODER, NM; North Carolina State Univ., Harvard Univ.; *ccledonr@ncsu.edu*

Altering retinoic acid and thyroid hormone signaling produces integrated modifications in gut morphology and physiology

Novel traits are fascinating because they diverge from their ancestral forms yet, at the same time, become integrated with a preexisting developmental and physiological milieu. How this integration occurs is poorly understood. In this study, we investigated whether molecules that promote the development of evolutionarily derived morphologies also promote the development of derived physiologies. Specifically, we focus on evolutionary derived gut phenotypes that have arisen among anuran larvae.

Unlike typical anuran larvae that have a morphologically and enzymatically simple gut, *Lepidobatrachus* larvae develop a fully formed adult stomach that produces digestive enzymes appropriate for their carnivorous diet (e.g., pepsinogen). Previous studies in our lab revealed key pathways whose modification may have promoted the morphological appearance of this novel trait, specifically, the retinoic acid and thyroid hormone signaling pathways. In the present study, we determined whether differential regulation of these pathways is also responsible for interspecific variation in digestive enzymes, such as pepsinogen. Treating *Lepidobatrachus* with compounds that alter their morphogenesis such that they produce an ancestral-type, omnivore gut morphology (similar to *Xenopus*) also results in the loss of pepsinogen expression. These results suggest that simple alterations to key developmental pathways can simultaneously transform morphology and physiology. Such transformations could provide novel, integrated phenotypes on which selection could act to produce evolutionary change.

S2-1.1 LEDON-RETTIG, CC; North Caorlina State University; *ccledonr@ncsu.edu*

Ecological epigenetics: An introduction to the symposium

Phenotypic variation arises from interactions between environmental and genetic variation, and the emergence of such variation is, in part, mediated by epigenetic mechanisms: factors that modify gene expression but do not change the gene sequence, *per se*. Environmentally generated epigenetic variation has gained increasing attention over the last decade as a potentially important source of phenotypic variation in fueling evolutionary change. Yet, the role of epigenetic variation and inheritance (i.e., when epigenetic variants are passed between generations) in natural populations remains poorly understood. This may be due, in part, to the difficult nature of characterizing epigenetics in genetically heterogeneous populations and across variable environments. Further, while important advances have been made, independently, in disparate fields, the lack of dialogue and synergism among these fields has hampered a synthetic understanding of epigenetic variation in the real world. The budding field of *Ecological Epigenetics* seeks to extend our knowledge of epigenetic mechanisms and processes to natural populations, and recent conceptual and technical advances have made progress towards this goal more feasible. Given both the recent challenges and breakthroughs in ecological epigenetics, the overarching goal of our symposium is to bridge the diverse fields that inform and are informed by ecological epigenetics, and to promote transformative research in this field. In order to accomplish this, our symposium will (i) identify the critical questions that can be answered by research in ecological epigenetics, (ii) feature effective empirical and theoretical approaches to studying epigenetics in the field and (iii) highlight scientists who have been most successful at merging the diverse fields that comprise ecological epigenetics.

P3.110 LEE, H.R.*; SPAULDING, J.D.; COHEN, C.S.; Swarthmore College, Romberg Tiburon Center, San Francisco State University, Romberg Tiburon Center, San Francisco State University ; *hlee3@swarthmore.edu*

Effects of flow on growth of juvenile colonial ascidians, Botrylloides violceus and Botryllus schlosseri

The flow environment is critical to the growth and survival of sessile marine filter feeders. Juvenile colonial ascidians may face particular challenges in filter feeding due to their narrow siphons. Growth rates and zooid increase of newly settled *Botryllus schlosseri* and *Botrylloides violaceus* were measured under different flow rates in both the field and the lab. In the lab, juvenile ascidians were raised from oozooids in a flume, while in the field new recruits were collected on settling plates. Contrary to expectation, there was no correlation between flow rates and growth rates of *B. violaceus* in the field, possibly due to the small range of variation among flow rates tested in this study. In the lab, *B. schlosseri* juveniles had higher relative growth rates than *B. violaceus*. Under low flow, *B. violaceus* grew faster in terms of overall size while *B. schlosseri* grew faster in terms of number of buds. *B. violaceus* had low growth rates and high mortality rates under high flow rates. It is possible *B. schlosseri* has a unique niche in high flow environments where *B. violaceus* does not succeed. A census of colonial ascidians in marinas with varying flow environments may provide more insight into the interspecies dynamics between *B. schlosseri* and *B. violaceus*. Measuring growth rates in the lab under flow rates between 3 cm/sec and 9 cm/sec would help with understanding flow rates that promote maximal growth, although this may also vary with food concentration. These findings may be applied to tunicate lab rearing experiments as well as towards a more basic understanding of the conditions favoring the survival and growth of juvenile sessile invertebrates with internal filter-feeding mechanisms.

13.1 LEE, J.W.*; APPLEBAUM, S.L.; MANAHAN, D.T.; Univ. Southern California, Los Angeles; *jimmylee@usc.edu*

Differential energy allocation for protein synthesis is genetically determined during marine larval development

Many studies have demonstrated that physiological processes change in response to environmental perturbations. Less is known, however, about the genetic bases that might establish physiological potentials for adaptation. Genetically-determined variation in metabolic efficiency will likely impact the energetic scope for stress responses. The energetic requirement of protein synthesis is a major component of metabolism and has been reported to have a fixed cost in specific stages of animal development. We measured the cost of protein synthesis in larvae of a bivalve (*Crassostrea gigas*). Phenotypic contrasts in metabolic allocation to protein synthesis were studied at different temperatures and for different genotypes using crosses of pedigreed families. In wild-type "control" larvae, approximately 60% of available metabolic energy was allocated to protein synthesis. This metabolic allocation varied in contrasting phenotypes. In slower-growing larvae, up to 80% of metabolic rate was allocated to protein synthesis. In faster-growing larvae, this value was 2-fold lower, decreasing to ~40% of metabolic rate. The effect of environmental variation on metabolic allocation to protein synthesis was studied. Variation in temperature differentially changed rates (Q_{10}) of respiration relative to protein synthesis. This differential response resulted in a lower percent of metabolic rate being accounted for by protein synthesis at lower temperatures. The capacity to respond to environmental stress is likely related to metabolic efficiency. Defining the genetic bases of metabolic allocation has implications for understanding the role of genotype-dependent responses to changing environmental conditions.

43.4 LEE, SSM*; BIEWENER, AA; DE BOEF MIARA, M; ARNOLD, AS; WAKELING, JM; Simon Fraser University, Harvard University; *lee.sabrina.sm@gmail.com*

A two-element Hill-type model to predict muscle forces

Muscle models are commonly used to quantify and interpret musculoskeletal function. However, most previous models have assumed homogenous fibre type distribution within the muscle with only a single contractile element, and validation of these models has been limited to in situ experiments that do not represent the muscle's dynamic behavior in vivo. The purposes of this study were to develop and test a two-element Hill-type muscle model with independently activated slow and fast fibre contractile elements. The model was evaluated under in situ and in vivo conditions by comparing the predicted forces to directly measured forces. We recorded electromyography (EMG), tendon force, and sonomicrometry (fascicle length) data in the lateral and medial gastrocnemii of six goats during 1) in situ nerve stimulation experiments (active and passive force length curves and tetanic contractions with different stimulation patterns) and 2) in vivo experiments (goats walked, trotted, and galloped on a treadmill). Activation states of different motor units were quantified via wavelet analysis of the EMG data and tuned transfer functions. By comparing the coefficients of determination between the predicted and measured forces, we found that the two-element model predicted muscle forces with up to 7.6% and 8.2% greater accuracy than several commonly used, one-element models for the in situ and in vivo conditions, respectively. Root mean square errors were up to 21% lower for the two-element model than for the one-element models tested. This study offers a novel Hill-type muscle model, validated against in vivo forces, that can independently activate slow and fast contractile elements. This model has the potential to improve studies of locomotor tasks where recruitment patterns of different motor unit types differ.(NIH R01AR055648)

P3.71 LEE, E*; REYES, J; FORSGREN, K; WAGGONER, C.M.; KELLEY, K.M.; California State University, Long Beach, Pacific Coast Environmental Conservancy, California, California State University, Fullerton, Institute for Integrative Research on Materials, Environment and Society, California, Long Beach; *bob71488@gmail.com*

Thyroid Endocrine Disruption in Coastal California Fish

In urban coastal southern California and in San Francisco Bay, several fish species have been found to exhibit significant location-related alterations in plasma concentrations of thyroxine (T4) and triidothyronine (T3), suggestive of endocrine disruption in the thyroid axis. Reduced T4 is commonly seen when fish are sampled from contaminated locations, and our studies indicate that this is significantly correlated with fish exposures to certain chemical classes including polychlorinated biphenyls (PCBs; mostly non-coplanar, lower-chlorinated congeners). Alterations in T3 levels and in T3/T4 ratio suggest that 5'-monodeiodinase activity may play a role in the thyroid hormone disturbances; assays of hepatic deiodinase activity support this as one underlying mechanism. In addition, it was found that the thyroid gland itself may also be impacted, since treatment of impacted fish with pituitary thyroid-stimulating hormone (TSH) failed to normally activate T4 production. Additional studies are characterizing thyroid tissue histophysiology and protein expression, in addition to screening for changes in hepatic proteins, as part of a project aimed at characterizing the thyroid disrupted condition in these wild fish. [support by NOAA-USC Sea Grant Program and Pacific Coast Environmental Conservancy]

S4-1.2 LEE, HN; HSU, TY; BREM, RB*; University of California, Berkeley; *rbrem@berkeley.edu*

Evolution of an iron response regulon in a wild population of Saccharomyces cerevisiae.

Comparative genomic analyses have revealed widespread variation in levels of gene expression within and between species. In the vast majority of cases, the selective forces that underlie regulatory change remain unknown. We have investigated regulatory evolution in a population of S. cerevisiae isolated from bertam palm flowers in West Malaysia. These yeast, when cultured in standard laboratory medium and compared to vineyard and European yeast strains, exhibited dramatic upregulation of a set of genes involved in the response to iron toxicity. A second set of iron metabolism genes, those required for sequestration in vacuoles, harbored rare coding polymorphisms in the Malaysian strains. When cultured in medium containing excess iron, Malaysian isolates exhibited compromised growth, which could be attributed to loss of function in the latter set of iron storage genes. Taken together, our results support a model in which the function of machinery for vacuolar iron storage has eroded in Malaysian yeast owing to a history of relaxed purifying selection; in these strains, the iron concentration of standard laboratory medium is sufficient to overload the cell's iron-storage capacity and drive activation of the iron-toxicity response. Our findings underscore power of integrating expression- and sequence-based tests of natural selection in the study of evolutionary forces that underlie regulatory change.

115.5 LEE, D/V*; COMANESCU, T/N; BERTRAM, J/EA; University of Nevada Las Vegas, University of Calgary; *david.lee@unlv.edu*

Collision-based analysis of human walking versus running with and without additional vertical loading

Collision-based analysis quantifies geometrically and energetically the interaction between the center of mass (CoM) and the environment. This approach is applied here for the first time to bipedal locomotion. The force-velocity angle is the deviation from perpendicular of the angle between the instantaneous velocity and force vectors. If these vectors were to remain perpendicular throughout a cycle of locomotion, the force-velocity angle would be zero and the mechanical cost of transport would also be zero. Furthermore the 'actual collision' given by the instantaneous force-velocity angle can be expressed as a fraction of the 'potential collision' given by the sum of instantaneous force and instantaneous velocity angles. This collision fraction would be zero in the previous idealized example, whereas a compliant spring-like inverted pendulum (SLIP) would produce a collision fraction of unity. During walking, the force-velocity angle was 0.08 radians on average throughout the stride. Collision fraction was 0.50 during walking, hence the dynamics of walking afforded on average a 50% reduction of the potential mechanical cost. During running, the force-velocity angle was 0.29 radians - 260% greater than that of walking. Consequently, collision fraction was 0.83 during running compared with 0.50 during walking and the dynamics of running reduced the potential mechanical cost by only 17%. We also simulated hyper-gravity by applying a constant downward vertical force equal to 35% body weight through a climbing harness. Despite a significant reduction in force angle due to this manipulation, the force-velocity angle and mechanical cost of transport remained statistically similar Collision fractions show striking similarities between bipedal and quadrupedal walking as well as bipedal running and quadrupedal trotting.

P3.162 LEHMKUHL, A M*; WILLIAMSON, B J ; JAYNE, B C ; University of Cincinnati; *lehmkuaw@mail.uc.edu*

Branch structure affects perch preference and the performance and behaviors of gap-bridging by the snake, Boiga irregularis

Branch size, shape and orientation have well documented effects on locomotion, such as larger diameter increasing the speed of limbed vertebrates but decreasing the crawling speed of snakes. Despite this detrimental effect, a previous study found that rat snakes prefer larger diameter perches when crossing a gap. Although the maximal distance of gaps that snakes can span has been studied, the effects of perch attributes on gap bridging are unknown. Reaching a larger target requires less precise motor control, leading us to expect that wider destinations may enhance either the speed or distance of crossing a gap. Thus, for the gap bridging of a highly arboreal species of snake (*Boiga irregularis*), we tested whether different destinations affected perch preference, gap-bridging ability and behavior. *B. irregularis* usually preferred wider destinations. The snakes readily crawled and gripped our control perch (4.9 cm diameter cylinder with two rows of pegs 10 cm long). Five treatments varied the cylinder diameter, presence of pegs and orientation of destination perch while using the control perch as the supporting perch, and three treatments used the control perch as the destination with three different supporting perches. Differences in the supporting perches did not significantly affect gap bridging performance. However, wider destinations significantly increased both the maximum gap bridging distance and the proportion of snakes using a high speed lunge. Lunging avoided the large torques experienced when snakes crawl slowly and hold their posture the instant before contacting the perch. Thus, wider destinations (which were preferred) elicited a behavior which circumvented a mechanical constraint and in turn improved performance.

10.3 LEHNERT, EM*; MOUCHKA, ME; BURRIESCI, MS; SCHWARZ, J; PRINGLE, JR; Department of Genetics, Stanford University School of Medicine, Stanford, CA 94025, Department of Ecology and Evolutionary Biology, Cornell University, Ithaca, NY 14817 , Biology Department, Vassar College, Poughkeepsie, NY 12604; *elehnert@stanford.edu*

RNA-Seq uncovers extensive differential expression of metabolic genes in symbiotic versus aposymbiotic cnidarians

Aiptasia pallida, a small sea anemone that hosts dinoflagellates similar or identical to those found in reef-building corals, is being developed as a model system for study of the underlying molecular and cell biology of cnidarian-dinoflagellate symbiosis. As a step to that end, we have sequenced and assembled the transcriptome of both aposymbiotic (dinoflagellate-free) and symbiotic *Aiptasia* using the Illumina sequencing platform. We have also developed a support vector machine learning algorithm to identify the organism of origin for each transcript, which was 97% accuracy on our test sets. A comparison of transcript levels revealed extensive differences between aposymbiotic and symbiotic animals, with many changes in the levels of transcripts encoding transporters and metabolic enzymes. We identified 38 classes of transporters that are differentially regulated, as well as transcripts from pathways involved fatty acid metabolism, sulfur-containing amino acid synthesis, and carbon-nitrogen metabolism.

S4-1.3 LEHR, Nina; SIKHAKOLLI, Usha; WANG, Zheng; LOPEZ-GIRALDEZ, Francesc; LI, Ning; TRAIL, Frances; TOWNSEND, Jeffrey P*; Yale University, Michigan State University; *Jeffrey.Townsend@Yale.edu*

Comparative phylogeny, ecology, and transcriptomics of fungal fruiting body development.

Studies linking the evolution of gene expression and the evolution of development are challenging in complex organisms. Of animal, plant, and fungal multicellular development, the genomic basis of fungal development is arguably the most different and the least well understood, but also has tremendous potential for illumination of evolutionary principles. Fungi can provide ideal systems for these studies. In many cases, multiple species can thrive in a single simple heterotrophic environment. We undertook to reveal elements of the underlying program of fruiting body development by transcriptomic sequencing of genome-wide gene expression in a set of five closely-related fungi with differing morphological development. These developmental processes are fundamental to sexual reproduction, recombination, and to the adaptive dynamics of pathogens and hosts. Because we maintained a strictly common medium across experiments, our transcriptomic data revealed solely evolved differences in the transcriptional basis of morphological changes. We assayed the transcriptome of two plant pathogenic Fusarium species and three species of Neurospora during fruit body development. We estimated the ancestral evolutionary transitions that resulted in the shifts in morphology of these two genera, knocking out genes with evolved function and assaying phenotype. Our transcriptional studies and candidate gene knockouts reveal regulatory circuits that control development and clearly identify many relevant genes without prior annotation. These results provide a model for how transcriptional shifts drive the evolution of morphological variation.

20.5 LENTINK, D; Stanford University; Wageningen University; Harvard University; *dlentink@stanford.edu*

Direct aerodynamic force measurements in avian flight support active upstroke hypothesis

Birds dynamically change the shape of their wing during the stroke, resulting in dramatic differences in wing shape between the up- and down-stroke. The wing is partially folded during the upstroke, which suggests that the upstroke of birds might not actively contribute to aerodynamic force production. This hypothesis is supported by the significant mass difference between the large pectoralis muscle that powers the down-stroke and the much smaller supracoracoideus that drives the upstroke. Previous workers used indirect or incomplete techniques to measure the total force generated by bird wings ranging from muscle force, airflow, wing surface pressure, to detailed kinematics measurements coupled with bird mass-distribution models to derive net force through second derivatives. I will present a new validated and verified technique that measures aerodynamic force directly time-resolved. It does not require exposing animals to laser light, surgery or sacrificing animals to obtain mass distribution - and is more precisely verified and validated compared to previously published methods. Results obtained for 5 slowly flying lovebirds (Agapornis roseicollis) show that the upstroke of birds is surprisingly active during slow hovering flight. The method is scalable and can be applied to all flying animals from birds and bats to insects. Other potential applications could include swimming.

91.2 LENTINK, D*; FIAZ, A.W.; Stanford University; Wageningen University, Wageningen University; *dlentink@stanford.edu*

Flight Artists: An outreach project that enables the general public to film natural flight using the worlds most advanced high-speed camera.

In 2010-2011 we developed a world-unique outreach project “Flight Artists” with a large team of scientist, students, and support staff at Wageningen University. The goal was to enable the general public to use the world’s most advanced high-speed camera , the Phantom v710, to experience the magic of natural flight in their backyard in super slow motion. After we announced the project on national TV and radio we got 800 online-applications. This idea won the Dutch Academic year prize 2010 for the best outreach idea that translates high-impact research to the general public. The award and additional university funding and sponsoring, totaling 260k+, enabled us to purchase the Phantom v710 that can film up to 7500 fps in full color, to modify it into an unique field high-speed camera, buy an additional 30 (Casio EX-F1) consumer high-speed cameras, and build-up the infrastructure to deploy our outreach project nation-wide. We developed specific course materials and weekend courses to educate 460 Dutch members of the general public how to film flying wildlife in their backyard using our high-speed cameras. After they completed the course they used our cameras to pursue their own 2-day film projects focused on their specific interest in natural flight - ranging from flying birds and bats to insects. The outreach project was highly successful resulting in overwhelming positive responses from participants, several national TV programs and world-wide media attention. The project resulted in a large open-access high-speed video library: www.flightartists.com to inspire and facilitate research and teaching in animal flight world-wide. The project is currently continued at Wageningen University and Stanford University.

P3.58 LENZ, E.A.*; EDMUNDS, P.J.; California State University, Northridge; *ealenz@gmail.com*

Evidence that octocorals are increasing in population density in the Caribbean

Coral reefs have long been valued as the most diverse marine ecosystem in the world, but their persistence is now threatened by multiple disturbances. In contrast to the high sensitivity of scleractinians to many of the agents of the recent changes on coral reefs – notably high temperatures, storms, and perhaps rising pCO_2 - octocorals show signs of resistance to the same disturbances. Such signs come in the form of a flexible body plan that resists hydrodynamic stress, potentially a strong utilization of heterotrophic resources, and an internal support system isolated from the effects of seawater chemistry. In this study, we asked whether there were signs that octocorals are now unusually abundant on coral reefs in St. John, U.S. Virgin Islands. Population densities and colony sizes were measured for a suite of octocoral genera on shallow reef (7-10m) along the south shore of St. John, and the results contextualized by historic data from photoquadrats in the same location, together with published studies from other locations. Surveys conducted in 2012 in St. John revealed mean octocoral densities of 9.5 ± 0.4 colonies m^{-2}, with colonies distributed among the common genera *Plexuara* (21% of colonies), *Eunicea* (20%), *Gorgonia* (15%), *Pseudopterogoria* (15%) and *Pseudoplexaura* (15%); overall, 40% of colonies were juveniles (<10 cm tall), suggesting the populations were growing. Preliminary analysis of photoquadrats taken in 1992 from the similar locations suggests population densities have increased in St. John, and relative to historic records from Carrie Bow Cay (Belize) and the Yucatán – where octocoral densities were 5.5 colonies m^{-2} in 1982 and 7.6 colonies m^{-2} in 1987, respectively – the present octocoral densities in St. John are high. Our preliminary analyses are consistent with the hypothesis that octocorals are becoming more abundant on Caribbean reefs.

S11-1.1 LEONARD, J.L.; Univ, of California-Santa Cruz; *jlleonar@ucsc.edu*

Williams's Paradox and the role of phenotypic plasticity in sexual systems

As George Williams pointed out in 1975, although evolutionary explanations, based on selection acting on individuals, have been developed for the advantages of simultaneous hermaphroditism, sequential hermaphroditism and gonochorism, none of these evolutionary explanations adequately explains the current distribution of these sexual systems in the Metazoa (Williams’s Paradox). As Williams further pointed out, the current distribution of sexual systems is explained largely by phylogeny. Since 1975 we have made a great dealof empirical and theoretical progress in understanding sexual systems. However we still lack a theory that explains the current distribution of sexual systems in animals nor do we understand the evolutionary transitions between hermaphroditism and gonochorism.Empirical data collected over the last 40 years, demonstrate that gender may have more phenotypic plasticity than was previously realized. We know that not only sequential but also simultaneous hermaphrodites use phenotypic plasticity to vary their sex allocation in response to social and environmental conditions. A focus on phenotypic plasticity suggests that one sees a continuum in animals between genetically determined gonochorism on the one hand and simultaneous hermaphroditism on the other, with various types of sequential hermaphroditism and environmental sex determination as points along the spectrum. Here I suggest that perhaps we have been unable to resolve Williams’s Paradox because the problem was not correctly framed. Perhaps the question we need to ask is what selective forces favor increased vs. reduced phenotypic plasticity in gender expression. With this symposium we hope to begin to look at the question of sexual system as one of understanding the timing and degree of phenotypic plasticity in gender expression in the life history in terms of selection acting on a continuum, rather than a set of discrete sexual systems.

S1-1.4 LEONARDO, A; Janelia Farm / HHMI;
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Guidance laws underlying prey capture in the dragonfly

Dragonflies are aerial predators that intercept small flying insects. Classic studies from Olberg, using single high speed camera recordings of dragonflies foraging outdoors, have suggested that the basic mechanism underlying these interception flights is the active stabilization of prey on the dragonfly eye. However, to date there are no in-flight measurements of 3D head position, nor are there any quantitative descriptions of how prey position is converted into wing steering signals. We have begun to study the dynamics of dragonfly prey capture using a custom built camera array that allows us to measure the three-dimensional position and rotational state (Euler angles) of the head and wings of the dragonfly at high temporal resolution, as well as the center-of-mass of the dragonfly and its prey. These data are collected in an indoor flight arena, where we can track interception flights over a large spatial volume in reproducible environmental conditions, allowing us to studying the dynamics of foraging flights with complex maneuvering. Many of characteristics of the prey capture flight, such as the interception angle and position of the prey, are based on a short timescale prediction of the prey's flight statistics ~100ms before takeoff. Once the interception flight has begun, a simple closed-loop guidance law, in which lateral acceleration is proportional to the angular velocity of the target and the dragonfly's speed, is used as an estimator of future target location. Preliminary head kinematics data show prey stabilization begins with a saccadic head movement immediately prior to takeoff, and this "foveation" of the prey is maintained actively during flight through continual head rotation. During flight, prey position varies 5-10x less in head-centered coordinates than body centered coordinates. I will discuss the dynamics of each of these components of the interception flight, and their relation to the underlying neural control system.

105.3 LESSIOS, N*; RUTOWSKI, RL; COHEN, JH; Arizona State University, University of Delaware;
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Visual ecology of two ephemeral pool crustaceans: phototaxis and light-orientation behavior of Triops (Branchiopoda: Notostraca) and Streptocephalus (Branchiopoda: Anostraca)

Triops and *Streptocephalus* are branchiopod crustaceans that are often found within the same ephemeral freshwater pools. *Triops* are mainly benthic foragers but also swim to the air-surface boundary in hypoxic conditions. They have two sessile compound eyes, as well as four median ocelli (naupliar eyes). *Streptocephalus* swim within the water column and are mainly suspension feeders. They have two stalked compound eyes and three median ocelli. Both lay desiccation-resistant eggs that also require light to resume development. This study aimed to characterize the light environment, phototactic response and dorsal light-orientation of *Triops* and *Streptocephalus* from the same pools (filled by monsoon rains in SE Arizona, USA). Irradiance measurements were taken over a depth gradient, and over time. Phototactic responses were observed within an acrylic chamber in the horizontal plane using a 500W Tungsten projector with interference filters to limit stimulus light to narrow bandwidths. Action spectra and phototaxis thresholds were obtained from ovisac-bearing adults for species of each genus, taken from the field and lab-reared. A distinct dorsal light reflex was observed by testing orientation in an acrylic chamber that simulates natural angular light distribution near the surface of an ephemeral pool. Statocysts have not been reported in branchiopod crustaceans, suggesting that light is a primary means of vertical orientation. Irradiance measurements were red-shifted with increasing depth, suggesting that vertical orientation could have a wavelength-specific component. Understanding the adaptive significance of eyes in *Triops*, *Streptocephalus* and other non-malacostracan crustaceans will help to infer transitions in eye evolution, and will illustrate the diversity of extant insect-crustacean sensory systems.

P1.163 LEUNG, N.L.*; TAKETA, D.A.; TORRES, E.; OAKLEY, T.H.; UCSB, California State Univ. Los Angeles;
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Origin of luciferase genes in cypridinid ostracods (Crustacea)

How new features originate is a central question in evolutionary biology, but the molecular changes that lead to evolutionary novelty are difficult to surmise. Our goal is to identify the molecular changes that gave rise to bioluminescence in cypridinid ostracods. Bioluminescence is a convenient system for understanding the molecular basis of origins because biochemical assays of protein function are tractable. Cypridinid bioluminescence occurs when light-reaction catalyzing enzymes (luciferases) are secreted from the upper lip, a glandular structure above the mouth also involved in digestion. To date, only two luciferases are described in cypridinid ostracods, even though bioluminescence is present in approximately 100 species in the family. Here, we obtain sequences similar to known luciferases from 454 transcriptomes of a luminescent and a non-luminescent cypridinid species. We confirm luciferase function of a gene from the luminescent species *Vargula tsujii* by expressing the protein in cell culture and performing a light reaction assay. Amino acid sequence comparisons of *Vargula tsujii* luciferase indicate only 47% sequence identity to known luciferases from *V. hilgendorfii* and *Cypridina noticula*. We confirm that all three cypridinid luciferases contain two von Willebrand Factor type D (vWF-D) domains. We next analyzed a 454 transcriptome of non-bioluminescent cypridinid *Skogsbergia lerneri* and found several genes with single vWF-D domains. We hypothesize that cypridinid luciferase originated by duplication of vWF-D containing digestive proteins secreted from the upper lip of non-luminescent ostracods. We also hypothesize that subsequent duplication of the vWF-D domains itself increased efficiency of the light reaction. Future research will localize expression of vWF-D genes in the non-luminescent species, and test efficiency of their light reaction in *in vitro* assays.

13.7 LEVESQUE, D.L.*; LOVEGROVE, B.G.; University of KwaZulu-Natal; *danielle.l.levesque@gmail.com*

Reproduction and the evolution of endothermy-Increased homeothermy in reproductively active female Greater hedgehog tenrecs (Setifer setosus)

There is increasing evidence that the level of homeothermy observed in most modern endotherms was derived from an ancestral heterothermic state. One of the hypotheses for why this occurred is that homeothermy allows for greater energetic output during reproduction (gestation and lactation) which has direct benefits to fitness. We tested this hypothesis by recording free-ranging body temperatures as well as resting metabolic rate over a range of ambient temperatures in both reproductive and non-reproductive Greater hedgehog tenrecs (*Setifer setosus*, Tenrecidae), a physiologically primitive mammal from Madagascar. During pregnancy and lactation there was an increase in metabolic rate and body temperature, accompanied by a decrease in body temperature variability. This indicates that homeothermy accompanies reproduction, and that benefits to parental care may have contributed to the evolution of endothermy in mammals.

45.4 LEVY, O*; BUCKLEY, L. B.; KEITT, T. H.; ANGILLETTA, M. J.; Arizona State University, Tempe, University of North Carolina at Chapel Hill, Chapel Hill, The University of Texas at Austin, Austin; *levyofi@gmail.com*

Modeling the costs of thermoregulation in lizards: the interplay between competition, climate and vegetation cover in Sceloporus undulatus

Models of population dynamics have been used to infer the impacts of climate change on the distributions of species. The predictions of these models depend greatly on parameters that characterize the phenotype and the environment. Throughout the range of *S. undulatus*, behavioral thermoregulation buffers environmental extremes that would otherwise decrease performance. Under climate change, the frequency and magnitude of these extremes may increase while vegetation that provides shade may decrease. Moreover, competition during thermoregulation may entail costs that will reduce energy gain. When competing for space, individuals may be excluded from preferred thermal patches. By contrast, when competing for food, individuals may obtain less energy in preferred thermal patches. We used an individual-based model to study the outcomes of competition for shade and food in current and project climates. We also studied how changes in vegetation would affect the life-history and geographic range of *S. undulatus*. In the model, juveniles competed for food while adults competed for food and space. Introducing costs of competition while reducing vegetation enhances a lizard's vulnerability to environmental extremes. Improving the realism behind individual-based thermoregulation models may increase our understanding of the complex interactions between climate, animals and vegetation cover.

100.2 LEVY, M/G; NIRODY, J/A*; NEU, J/C; HENDRICKS, J/R; SLATKIN, M; OSTER, G/R; =EQUAL CONTRIBUTION, ; Univ. of California, Berkeley, Duke University, San Jose State Univeristy; *jnirody@berkeley.edu*

A neural-field model for the evolution of Conus shell patterns

Conus shell patterns are thought to be generated via a neurosecretory process. Gong et al. (2012) have shown that the parameters used to model this process can be used to infer phylogenetic histories. We construct a new formalism for this model and use it to examine intraspecific variation in *Conus spurius*, a species with a good 5 million year fossil record. We use UV imaging to reconstruct these fossil patterns and examine how morphospace may have changed over time. We propose that evolutionary trajectories within this parameter space correspond to an evolutionary history of the mantle neurosecretory network itself.

P3.144 LEWALLEN, MA*; BURGGREN, WW; Univ. of North Texas; *melissalewallen@my.unt.edu*

Chronic Hypoxia and Hyperoxia Modifies Morphology and VEGF Expression of the Lungs of the Developing Chicken

Congruous developmental mechanisms occur in the parabronchial bird lung and the brochoalveoloar mammal lung. Vascular endothelial growth factor (VEGF) is critical to development of mammalian lungs by inducing angiogenesis and vasculogenesis. The chicken embryo (*Gallus domesticus*) offers an animal model of lung development not dependent upon maternal interaction and easily manipulated by ambient oxygen. This study determines effects of oxygen levels on the morphology and VEGF expression of developing chicken lungs. Eggs were chronically incubated in normoxia (21% O_2), hypoxia (15% O_2) or hyperoxia (30% O_2), until developmental days 16 or 18. Lung morphology was assessed using light microscopy, while VEGF expression was determined with ELISA. The proportion of parabronchial tissue to total lung tissue (measured as cross-sectional surface area) in the hypoxic group showed a significant increase from day 16 (61±2%) to day 18 (68±2%). Non-parabronchial tissue was significantly higher in the hypoxic group than in the hyperoxic group on day 16 (26±3% vs. 20±1%). However, by day 18, there were no significant differences between the groups. VEGF expression was significantly higher in the hypoxic group over the hyperoxic group on day 16 (736±91 vs. 492±31 pg/ml). By day 18, VEGF expression was significantly higher in the hyperoxic group over the normoxic group (673±76 vs. 381±37 pg/ml), while the hypoxic group remained elevated with a significant difference over the normoxic group (631±58 pg/ml). VEGF thus appears to facilitate the morphological changes to parabronchial lungs exposed to chronic hypoxia and hyperoxia.

94.3 LEWIS, Z*; KERNEY, R; DORANTES, J; HANKEN, J; Harvard Univ., Cambridge, MA, Gettysburg College, Gettysburg, PA; *zlewis@oeb.harvard.edu*

Genetic and morphological vestiges of lost lungs in plethodontid salamanders

Vestigial structures and rudiments provide windows into the evolutionary history of animals. Common examples are the transient limb buds or atavistic pelvic girdles found in tetrapods that have undergone limb loss. Vestiges of internal organs have received far less attention, and they have the potential to reveal how organ loss can occur in highly pleiotropic genetic networks and within tightly integrated organ systems. One example of organ loss is the loss of lungs in plethodontid salamanders (Caudata: Plethodontidae). We have discovered several atavistic features of lungless salamanders during both organogenesis and adulthood. Plethodontid embryos form a transient lung rudiment and express lung-specific and functionally significant genes, including surfactant protein C. Surprisingly, adult plethodontids display novel pharyngeal expression of lung-specific transcripts in the absence of lungs. From one perspective, presence of the transient rudiment in embryos suggests conservation of inductive interactions that govern lung formation. In contrast, unanticipated expression patterns of lung-specific transcripts in lungless adults may be an example of evolutionary novelty. In light of our results, we reexamine the idea, proposed first in 1900, that the pharynx may play a significant respiratory role in lungless salamanders. By studying atavistic features of internal organs we have uncovered unexpected conservation of lung developmental-genetic programs following lung loss, as well as a novel expression pattern of a gene that may play important functional roles.

136.1 LEWIS AMES, C*; YANAGIHARA, AA; KEIL, D; LAWLEY, JW; VAN BLERK, J; GILLAN, B; BENTLAGE, B; BELY, A; COLLINS, AG; University of Maryland, College Park/Smithsonian NMNH, Pacific Biosciences Research Center, HI, University of Maryland, College Park, Universidade Federal de Santa Catarina, Brazil, Bonaire, The Netherlands, Boynton Beach Community High School, Fl, University of Maryland, College Park, NMFS, NSL, Smithsonian NMNH; *clames1@umd.edu*

Establishing the neotype of the enigmatic oceanic box jellyfish Alatina alata (Reynaud 1830) (Cnidaria: Cubozoa).

The "winged box jellyfish" *Alatina alata* has had a troubled taxonomic past. It was first discovered in the Atlantic Ocean and described as *Carybdea alata* Reynaud 1930, but no holotype was established, rendering the original description and accompanying line drawing as the only definitive reference for the species for more than 182 years. More than a century went by until *C. alata* was reported again in the Atlantic Ocean, despite various accounts in tropical Indo-Pacific waters. Notorious for causing the debilitating Irukandji-like syndrome, *Alatina* populations are relevant to the tourism industry, as they form monthly massive reproductive swarms 8-10 days after the full moon in some locations. Paradoxically, *Alatina* medusae have also been collected in the open ocean at great depths, an atypical habitat for cubomedusae, which usually occupy shallow coastal waters. Recently, nine nominal species formerly synonymized under the name *C. alata* were restored as different species within the new genus *Alatina*, leaving the epithet *Alatina alata* as the new combination for the only Atlantic species in the genus. Our recent discovery of a thriving Caribbean *Alatina* population in Bonaire (The Netherlands) allowed us to examine live medusae from the Atlantic, and to monitor monthly spawning events. Herein, we redescribe *A. alata* and establish a neotype for the species. Furthermore, we present results of molecular analyses of three geographical populations that support the hypothesis of a single widespread, variable species called *A. alata* (Reynaud 1830) by nomenclatural precedence.

147.6 LI, C*; HSIEH, S.T.; UMBANHOWAR, P.B.; GOLDMAN, D.I.; UC Berkeley, Temple Univ., Northwestern Univ., Georgia Tech; *chen.li@berkeley.edu*

Rapid locomotion of a small lizard on sand requires fluid-like ground reaction forces

The desert-dwelling generalist zebra-tailed lizard (*Callisaurus draconoides*, ~10 cm, ~10 g) uses its large, elongate hind feet to rapidly run (~10 body length/s) on a diversity of substrates ranging from solid rocks to loose sand. In a previous study (Li et al., 2012, *J. Exp. Biol.*), visible light high speed video showed that during each step on granular media (sand), the lizard's hind feet slapped on the surface at touchdown and penetrated into the substrate during stance. To explain the observed center-of-mass dynamics, the ground reaction force was assumed to be dominated by speed-independent frictional drag, and it was hypothesized that during stance the hind feet rotate subsurface in the vertical plane to generate lift. Here we use x-ray high speed video to obtain the lizard's subsurface foot kinematics during running on granular media and confirm the hypothesized foot rotation. However, using granular impact force measurements, a recently developed terradynamics of granular media, and the observed foot kinematics, we find that the combined impact force during initial foot touchdown and speed-independent frictional drag force during foot rotation only account for part of the required lift to support locomotion. This suggests that the rapid foot rotation further allows the lizard to utilize inertial forces from the local acceleration of the substrate (particles), analogous to the basilisk lizard which runs on the surface of water using hydrodynamic forces. Further evidence of inertial-force-dominated propulsion has been found in small lizard-sized robots (~10 cm, ~20 g) running on granular media (Qian et al., 2012, *Robotics: Science & Systems*).

P1.71 LIAO, J.C.*; BALLO, A.W.; AKANYETI, O.; The Whitney Lab for Marine Bioscience, University of Florida Gainesville; *jliao@whitney.ufl.edu*

Signal transmission properties of the zebrafish larval lateral line in response to neuromast deflections

Fishes use their lateral line system to detect flow-related information using sensory units called neuromasts. Previous studies have elucidated the frequency response of neuromasts in adult fishes, but we still understand very little about how well afferent neurons can convey this information to the hindbrain. We set out to characterize the transmission capabilities of afferent neurons in response to neuromasts deflections for zebrafish larvae. We recorded afferent spike activity using intracellular sharp electrodes while deflecting neuromasts with a piezoelectric stimulator driven by a pulse train of 1-100 Hz. We calculated the vector strength, a measure of response fidelity to a stimulus, in addition to the average spike rate. At low pulse rates (<10 Hz), afferent neurons spiked in response to each pulse (i.e. phase-locked) but also retained spontaneous activity. The overall spike rate was 13.59±1.93 Hz (mean ± standard error) and the vector strength was 0.33±0.08, where a vector strength of 1 indicates that all spikes have the same phase to a pulse stimulus. 10-30 Hz stimulation revealed a vector strength of 0.99±0.01, during which spontaneous activity disappeared. The spike rate varied from the pulse rate within ± 2%. 30-60 Hz stimulation elicited a vector strength of 0.97±0.02 and spike rate was 20% less than the pulse rate. Above 60 Hz, there was no correlation between the stimulus and spike activity. Our results indicate that the optimum pulse rate that can be transmitted without information loss is between 10-30 Hz, while pulse rates up to 60 Hz can occur with only moderate information loss.

37.5 LIAO, J.C.*; CHAMBERS, L. M.; AKANYETI, O.; The Whitney Lab for Marine Bioscience, University of Florida Gainesville, Robotics Laboratory, University of Bristol, UK; *jliao@whitney.ufl.edu*

Pressure across the head of a freely-swimming rainbow trout (Onchorynchus mykiss) in uniform flow

The mathematician Sir James Lighthill indicated that in order to reduce drag swimming fish should move in a manner that reduces the pressure difference across the head. According to his theory, this pressure difference is equal to $C_1A - C_2U\Omega$, where the coefficients C_1 and C_2 are defined by the head morphology, U is the swimming speed of the animal and A and Ω are the lateral acceleration and the angular velocity of the head, respectively. The maximum drag reduction is predicted to occur when A and $U\Omega$ are in-phase and their ratio is C_2/C_1. Passive undulating body does not naturally achieve this indicating that active head control is likely required. In this study, we provide the first direct pressure measurements on a free swimming trout and use these measurements to experimentally validate Lighthill's equation. We swam four rainbow trout of total body length (L) 18.5±1.0 cm (mean ± standard deviation) at 3, 4 and 5 L/s. We simultaneously measured the swimming kinematics and pressure along the head using a high speed camera and miniature pressure catheters. Pressure measurements from all speeds closely matched values estimated by Lighthill; the Pearson's linear correlation coefficient was 0.89±0.04 ($p<0.05$). In contrast, the ratio (0.64±0.09) and the phase difference (43.8±6.4°) between A and $U\Omega$ differed significantly from the theoretical optimums (0.95±0.08 and 0°, respectively), resulting in an average pressure difference 17.0±7.2 Pa. However, this value is still 49% less than the expected pressure difference for a head rotating passively, indicating that active head control is correlated to the reduced pressure difference.

138.6 LIBBY, T*; GUDENUS, V; HARRINGTON, P; FULL, R.J.; Univ. of California, Berkeley; *tlibby@berkeley.edu*
Coordination between inertial and impulsive mechanisms during rapid turns in lizards.
Animals induce aerial reorientation by swinging appendages or bending torsos. Inertial torques also play a role during terrestrial locomotion, but ground reaction impulses can change angular momentum. To examine the role of back bending and tail swinging during rapid terrestrial turns in lizards (*Agama agama*), we developed a six-link, planar, rigid-body dynamics model. Informed by the morphometrics of lizards, our model enabled estimation of total angular momentum about the animal's center of mass (COM) from high-speed video kinematics. We derived the model to represent the expression for angular momentum about the COM of a chain of rigid bodies for an arbitrary number of segments. By writing angular momentum in terms of shape coordinates, we decomposed body velocity into two components revealing the extent to which shape change and impulsive force each contribute towards turning the body. During escape responses, lizards started from a standstill, executed a rapid turn and then ran away from the stimulus. Escape turns typically began with curling and pivoting about the hind legs, followed by an acceleration through the second stride in a maneuver analogous to a C-start in fish. Turns averaged 112°. 86% of the turn was completed within the first stride. Our model predicts that 57% of the rotation during the first stride can be attributed to inertial torques due to curling. Systematically reducing the number of segments in the zero angular momentum model revealed that over 70% of the shape change induced rotation was due to the tail, with the remaining fraction due to back bending. During the second stride, angular velocity from impulsive ground contact countered the tendency towards backwards rotation when the tail uncurled as the animal transitioned to steady running.

S2-2.3 LIEBL, AL*; SCHREY, AW; RICHARDS, CR; MARTIN, LB; Univ S. Florida, Armstrong Atlantic State Univ; *aliebl@mail.usf.edu*
Epigenetic variation: a mechanism to overcome reduced diversity in novel environments?
Many introduced populations experience reduced genetic diversity in their new areas, and house sparrows (*Passer domesticus*) in Kenya (one of the most recent vertebrate introductions) are no exception. Microsatellite data indicate that Kenyan house sparrows are less genetically diverse than other house sparrow populations, with higher relatedness and lower heterozygocity than expected by chance; further, data also suggest that the pattern of spread within Kenya has resulted in little to no admixture in some areas, while others are considerably admixed. Despite reduced genetic diversity, other research from our lab shows that behavioral, physiological, and immune differences exist among Kenyan house sparrows dependent on time since colonization. Epigenetic mechanisms, such as methylation, sometimes inherited across generations, can control gene expression; epigenetic changes can be stable (determined either through inheritance or during early life) or labile within an individual's lifetime permitting enhanced responsiveness to the environment. We propose that in a novel or changing environment, more labile epigenetic marks might provide the variation necessary to facilitate short term adaptation in populations constrained by low genetic diversity. Here, we document high epigenetic variation (measured using MS-AFLP techniques) among Kenyan house sparrows- even in cities with little or no genetic admixture. Our results suggest that DNA methylation might allow an enhanced response to new environments when genetic variation is limited, allowing individuals to rapidly adjust to novel habitats as their range expands.

P2.197 LIEBL, AL*; TROTTER, JH; KELLOGG, SL; FIORELLI, T; MARTIN, LB; Univ S. Florida; *aliebl@mail.usf.edu*
Variation in Hippocampal-Dependent Behaviors and Neurogenesis during a Range Expansion
Individuals in novel habitats are typically more innovative, more exploratory, and less fearful of novelty than individuals in familiar habitats; however, the mechanisms underlying these patterns have not been revealed, particularly in a species undergoing range expansion. The ability to form memories often influences behavior and in unfamiliar habitats, where the necessity to form memories of novel surroundings and resources is vital to survival, it may be a particularly strong predictor of observed behavioral differences among populations undergoing range expansion. Vertebrates typically form new memories through two mechanisms: morphological plasticity of existing neurons and the generation of new ones. Here, we compared house sparrows (*Passer domesticus*), differing in time of colonization (birds from areas that were colonized 60, 30, <10 years ago). Using behavioral tests as well as Golgi staining (to determine dendrite density and shape) and immune-histo-chemistry (to identify newly formed cells), we compared the relationship among range expansion, neurogenesis, and behavior (innovation and learning). We hypothesized that individuals at the edge of a range expansion (<10 years old) would be better innovators and have a greater capacity to form memories; we further predicted these differences were due to greater synaptic density and hippocampal neurogenesis. Sample analysis is ongoing, however this study is one of the first to evaluate the effects of a changing environment on neurogenesis and its associated behaviors.

1.10 LIGHTON, J*; BROWNELL, P; Sable Systems International, Oregon State University; *Lighton@sablesys.com*
Extrasomatic energy storage in scorpions
Why do scorpions have low metabolic rates - if in fact they do? We undertook a rigorous study of scorpion metabolic rates, and found that their metabolic rates are in fact much lower than those of conventional arthropods such as insects and spiders. By analysis of covariance we found that their metabolic rates were only 25% of the expected values. The logical question to ask is why? If we consider that a scorpion, relative to other arthropods, requires only one quarter of the energy needed for basic metabolism, it follows that the remaining energy available to it can be channeled into somatic growth. It is our contention that this explains another widely debated area of scorpion biology: cannibalism. Because of their high trophic efficiency, scorpions can convert food into biomass extremely efficiently. Consequently their unusually high population densities result in high interaction rates. This leads in turn to cannibalism. it is additionally our contention that in effect, adult scorpions are using their young as extrasomatic energy storage reservoirs, further facilitated by the likelihood that juvenile scorpions occupy a predator niche distinct from that of adults. This is all a grotesque (to humans) side effect of their extreme metabolic efficiency. Ken Nagy has data on scorpion field metabolic rates, as yet unpublished, that I hope to analyze to add further light on this deliciously Gothic phenomenon.

24.6 LIGHTON, JRB*; FOERSTER, TD; KAIYALA, KJ; WISSE, B; Sable Systems International, University of Washington, University of Washington; *lighton@sablesys.com*
Problem and solution: Multiplexing distorts metabolic data
When measuring the metabolic rates of multiple animals, it is common practice to sample excurrent air from each cage or chamber, and direct these air samples to a single gas analyzer chain. These samples are analyzed in succession (or "multiplexed"), interleaved with periodic analysis of incurrent air composition in order to compensate for analyzer drift and fluctuations in incurrent gas concentrations. Each such analysis takes a finite time, and must be completed before the next sample is analyzed. Thus an appreciable time – the "cycle time" of the system – will elapse between successive measurements of a given animal. The actual metabolic signal from each animal is therefore composed of a series "metabolic snapshots" which are separated by the cycle time of the system. This approach has the advantage of requiring only a single gas analyzer chain, and thus lowering costs. However, it suffers from two major disadvantages. First, rapidly changing metabolic signals may be missed, or, even worse, distorted by aliasing effects. Second, the nature of the sampled data depends critically on the moment at which the sampling cycle is initiated. Because the effect of starting time cannot be predicted because its effects lie along the future path of time's arrow, the results of any multiplexing system include a strong stochastic component, especially where the metabolic data are variable. As a result, resting energy expenditure (REE) is generally overestimated and activity EE (AEE) is underestimated. Using a Promethion multiple-animal, continuous (non-multiplexed) metabolic phenotyping system, we model a variety of multiplexed systems using continuous data from 16 mice, demonstrating and quantifying the serious errors that result from multiplexing.

4.2 LILLIE, MA*; PISCITELLI , MA; GOSLINE, JM; SHADWICK, RE; University of British Columbia; *lillie@zoology.ubc.ca*
Structure and Mechanics of Fin Whale Arteries
The mechanical properties of mammalian arteries are linked to their function and generally reflect the loads they experience in vivo. Fin whales have a collagen rich and unusually incompliant thoracic aorta. We hypothesized that it might represent a mechanism to deal with changing transmural arterial pressures, which may vary if thoracic pressure differs from ambient. To test this hypothesis we examined the morphology and the in vitro mechanical properties of a range of fin whale arteries exposed to both positive and negative transmural pressures. Arteries were tested under inflation for the pressure-stretch response and under deflation to determine the negative pressure required to cause buckling and collapse. We found abundant adventitial and perivascular collagen in all arteries. With the exception of the subclavian artery, the collagen became taut at very low pressures, stiffening the arteries circumferentially, allowing little compliance at low strains and stretches of only 10% at physiological pressures. Circumferential stiffness increased non-linearly with stretch. Under a negative transmural pressure some arteries collapsed readily while others did not, depending on their wall-thickness-to-radius ratio and on the stretch-dependent modulus. Wall bending was resisted by adventitial collagen, indicating a possible advantage of its recruitment at low stretches. However, adaptations to resist collapse under negative pressures and render diameter independent of pressure are of value only in a system where transmural arterial pressures vary. Whether these arterial properties provide evidence that transmural pressures do vary has yet to be established.

148.3 LIN, Y.F.*; LU, T.W.; DUMONT, E.R.; LEE, L.L.; University of Massachusetts, Amherst, National Taiwan University; *yifen@bio.umass.edu*
Sticking necks out: A novel sesamoid bone in crocidurine shrews
Sesamoid bones develop in tendons or other connective tissues that are subject to stress and are thought to function to diminish friction, distribute loads and alter muscle force vectors. However, the effect of sesamoid bones on performance is rarely tested experimentally. In this study, we combined anatomical, behavioral and biomechanical analysis to examine the function of a newly-found sesamoid bone in axial skeleton of shrews. This novel sesamoid bone is embedded in the nuchal ligament over the 2nd thoracic vertebra (T2) in *Crocidura shantungensis*, *C. tanakae*, *C. rapax*, *Suncus murinus*, *Scutisorex somereni* (subfamily Crocidurinae) but not in *Episoriculus fumidus*, *Chodsigoa sodalis*, *Anourosorex yamashinai*, and *Blarina brevicauda* (subfamily Soricinae). The T2 sesamoid bone supports the origin of splenius muscle, which attaches to the skull and controls head movement. Postural and behavioral analysis demonstrated that the necks of *C. shantungensis* and *C. tanakae* are significantly more flexible ($p = 0.015$), and they stick necks out more frequently (55 times/hour) during routine activities than does *E. fumidus* (16 times/hour). We modeled the mechanical advantage of splenius during postures used by the three species, and found that mechanical advantage was more than twice as high in *Crocidura* spp.. We also modeled the mechanical advantage of splenius in Crocidura *with* and *without* the sesamoid bone, and found that the presence of the sesamoid bone greatly enhances mechanical advantage ($p < 0.001$). To our knowledge, this is the first sesamoid bone reported from the axial skeleton and we have demonstrated its function in neck extension among crocidurine shrews.

107.1 LINDBERG, D.R.*; ERLANDSON, J.M.; GRAHAM, M.; BYRNES, J.; Univ. of California, Berkeley, University of Oregon, Moss Landing Marine Laboratories, University of Massachusetts, Boston; *drl@berkeley.edu*
Assembly and Anthropogenic Alterations in Kelp Forest Ecosystems: Historical Perspectives from Deep Time
We examine the assembly and anthropogenic alterations in 20 kelp forest ecosystems – comprised of 15 kelps, and 18 key predators and 22 key herbivores. Our analyses found age and assembly differences between kelp forests in the northern and southern hemispheres. In the northern hemisphere predators are oldest in the lower latitudes. Herbivores are the youngest lineages typically originating after the kelp in the northern hemisphere. The sea otter is the youngest component in North Pacific kelp forests. In the southern hemisphere most herbivores and predators are substantially older than the kelp; the herbivores are the oldest lineages and have low latitude ancestry. Kelp forests in the North Atlantic show patterns similar to the North Pacific; most likely due to the role of recent migration of numerous kelp forest taxa from the North Pacific into the Atlantic. In addition to assembly differences, humans have differentially affected kelp forests. Some of the earliest evidence for intensive marine harvesting by humans is in kelp forest ecosystems, and human impacts on shellfish, apex predators, and other marine fauna affects trophic cascades as well as size class structure of key interacting taxa. These data and analyses from paleontological, geological, archaeological, and historical sources all demonstrate that coastal ecosystems are highly dynamic, and understanding the modern structure of these ecosystems requires deep paleontological and biogeographic perspectives that shed light on their assembly, as well as the long human history of interference and alteration of these systems.

93.2 LINQUIST, AG*; BURNETT, JB; HATLE, JD; University of North Florida; *alicia@linquist.net*

The effects of inhibited reproduction by ovariectomy or vitellogenin-RNAi on the longevity of grasshoppers (Romalea microptera).

Reduced reproduction has been shown to increase lifespan in many animals, yet the mechanisms behind this trade-off are mostly unknown. A previous study has shown that in the lubber grasshopper, *Romalea microptera*, ovariectomized (OVX) individuals have a 30% increase in lifespan relative to controls (Sham). In a separate study, an increase in fat body mass and a halting of ovarian growth were seen upon reduction of vitellogenin transcript via RNAi (VgRNAi). The protein vitellogenin is a precursor to vitellin, which constitutes 90% of egg protein. These data suggest that VgRNAi may increase lifespan through the trade-off between reproduction and longevity. We used two injection control groups for the VgRNAi treatment, namely buffer injection or injection with RNAi against a 90kDa hexamerin storage protein (Hex90RNAi). In this study we have combined these manipulations to test lifespans upon: OVX & VgRNAi, OVX & Hex90RNAi, OVX & Buffer, Sham & VgRNAi, Sham & Hex90RNAi, and Sham & Buffer. By combining these treatments we wish to determine if they use separate mechanisms in lifespan extension. To date, 40 of the 151 individuals have died; OVX & Buffer, and OVX & VgRNAi individuals are currently showing the highest survival rates at 77% and 84% respectively, while OVX & Hex90RNAi and Sham &Hex90RNAi individuals exhibit the lowest survival rates at 68% and 56%. Consistent with previous data, OVX groups are showing a reduction in feeding rates (all $P < 0.03$). However, all other treatment groups show no differences among feeding rates. Survivorship and feeding rates will be discussed in terms of whether or not reduced feeding is consistently associated with life-extension via reduced reproduction. Funding provided by NIH 2R15AG028512-02A1 to JDH.

50.1 LINS, L.S.F.*; HO, S.Y.W.; WILSON, G.D.F.; LO, N.; University of Sydney/Australian Museum, University of Sydney, Australian Museum; *luana.lins@sydney.edu.au*

Evidence for Permo-Triassic colonization of the deep sea by isopods

The deep sea is one of the largest ecosystems on Earth and is home to a highly diverse fauna, with polychaetes, molluscs, and peracarid crustaceans as dominant groups. A number of studies have proposed that this fauna did not survive the anoxic events that occurred during the Mesozoic Era. Accordingly, the modern fauna is thought to be relatively young, perhaps having colonized the deep sea after the Eocene/Oligocene boundary. To test this hypothesis, we performed phylogenetic analyses of nuclear ribosomal *18S* and *28S* and mitochondrial *COI* and *16S* sequences from isopod crustaceans. Using a molecular clock calibrated with multiple isopod fossils, we estimated the timing of deep-sea colonization events by isopods. Our results show that some groups have an ancient origin in the deep sea, with the earliest estimated dates spanning 232-314 Myr ago. Therefore, anoxic events at the Permian–Triassic boundary and during the Mesozoic did not cause the extinction of all the deep-sea fauna; some species may have gone extinct while others survived and proliferated. The monophyly of the "munnopsid radiation" within the isopods suggests that the ancestors of this group evolved in the deep sea and did not move to shallow-water refugia during anoxic events.

S7-1.3 LIWANG, A.*; CHANG, Y.-G.; TSENG, R. D.; University of California, Merced; *aliwang@ucmerced.edu*

Rhythmic Ring-Ring Stacking Drives the Circadian Oscillator Clockwise

The oscillator of the circadian clock of cyanobacteria is composed of three proteins, KaiA, KaiB, and KaiC, which together generate a self-sustained circadian rhythm of phosphorylation of KaiC. The mechanism driving this oscillator, however, has remained elusive. We show that stacking interactions between the CI and CII rings of KaiC drive transitions from the phosphorylation-specific KaiC-KaiA interaction to the dephosphorylation-specific KaiC-KaiB interaction. We have identified the KaiB-binding site, which is on the CI domain. This site is hidden when CI domains are associated as a hexameric ring. However, stacking of the CI and CII rings exposes the KaiB-binding site. Since the clock-output protein SasA also binds to CI and competes with KaiB for binding, ring stacking probably regulates clock output. We demonstrate that ADP can expose the KaiB-binding site in the absence of ring stacking, providing an explanation for how it can reset the clock.

8.6 LOCKWOOD, B.L.*; BYRD, N.; MONTOOTH, K.L.; Indiana University; *bllockwo@indiana.edu*

Coping with stress: the cellular maintenance of embryonic development

It is widely known that thermally variable environments adversely affect the physiologies of ectothermic organisms. However, it is a widely held tenet in the field of developmental biology that embryos are 'canalized' to develop normally despite environmental perturbation. Are embryos actually vulnerable to thermal stress, and what structures and developmental processes are most vulnerable? Here we investigate the effects of heat stress on embryos of *Drosophila melanogaster* by measuring whole-organism survival, the cellular structures that mediate this stress, and the mechanisms that may buffer this stress during development. We find that exposure of early stage embryos to temperatures as low as 28°C causes a significant decrease in survival to adulthood. We also find that some genotypes are more tolerant to heat stress than others, suggesting that heat tolerance in embryos has a genetic basis. We discuss our progress using confocal fluorescence microscopy to assess the effects of heat stress on cellular structures that coordinate early development.

25.3 LOGAN, ML; Dartmouth College;
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Fine-scale variation in thermal ecology suggests resilience to climate change among tropical lizards

Recent studies have predicted widespread extinctions among tropical ectotherms driven by anthropogenic climate change. Tropical forest lizards, in particular, are thought to be vulnerable due to an assumed homogeneity of forest thermal environments and the risk posed by increased competition from heat-adapted open-habitat species. Many of these predictions, however, are based on environmental temperature data measured at a maximum resolution of 1 km^2, whereas individuals of most species experience thermal variation on a much finer scale. Here, I combine thermal performance curves for three species of *Anolis* lizards from the Bay Islands archipelago of Honduras with high-resolution temperature distributions generated from species-specific physical models. I use these data to model the potential for open-habitat species to invade forest habitat and drive forest species to extinction, and to compare the vulnerabilities of closely related forest species occurring on different islands. My analyses suggest that the open-habitat species I studied will not invade forest habitat and may actually benefit from predicted warming for many decades. Conversely, by the year 2100, one of the forest species should experience reduced activity time as a result of warming, while the other is unlikely to experience a significant loss in performance. Our results suggest that global-scale predictions generated using low-resolution temperature data may overestimate the vulnerability of some tropical ectotherms to climate change.

P1.127 LOHMAN, BK*; SIROTKIN, HI; BELL, MA; University of Texas at Austin, Stony Brook University; *lohman@utexas.edu*

A Whole-Mount Method for Trypsin Clearing and Collagen Type II Antibody Staining

Although cartilage and bone are often stained to study development in fishes, collagen forms before either of these tissues during skeletal ontogeny. We describe a new method that combines conventional trypsin clearing of whole-mount specimens with staining of Collagen Type II using antibodies. Specimens were fixed briefly in paraformaldehyde, digested in a trypsin solution, bleached with hydrogen peroxide, permeabilized with Proteinase K, antigen labeled with primary and secondary antibodies, and stored in glycerol. This method makes both cellular and acellular collagen visible under ultraviolet light with limited background staining. Specimens showed no signs of damage from any of the solutions used for staining, but the length of time for fixation appears to be important. This method permits visualization of collagen condensation prior to cartilage formation in endochondral bone and can be used to study evolution of skeletal ontogeny and to develop new skeletal characters for phylogenetic analysis.

55.3 LONDRAVILLE, RL*; LIU, Q; DALMAN, MR; BAGATTO, B; Univ. of Akron; *londraville@uakron.edu*

Leptin Function in Zebrafish.

One of the most striking anatomical features of both cold adapted and cold acclimated fishes is their extreme adiposity, with lipid comprising up to 60% of the dry mass of Antarctic fishes. We are investigating the hormone leptin as an approach to understanding both the 'how' and 'why' of lipid accumulation in fish from cold environments. In mammals, leptin influences appetite, metabolic rate, lipid deposition, lipid metabolism, and many other systems, including bone growth and immune function. Because leptin has not been cloned in polar fishes, we used a genome-enabled model fish (zebrafish, *D. rerio*) to manipulate leptin expression in developing embryos. Reduced leptin expression (via morpholino oligonucleotides) results in poor yolk absorption, reduced sensory structures (eyes and ears), reduced otoliths, impaired cardiac function, and significantly reduced metabolic rate. A majority of these effects can be rescued with recombinant zebrafish leptin. Identical or similar effects were seen when we reduced expression of the leptin receptor (also with morpholino oligonucleotides). Leptin's effects on metabolic rate are similar between mammals and zebrafish, and its effects on sensory structure development may be a clue to hearing loss common in diabetic humans. Reduced leptin signaling was also associated with reduced otolith size. We hypothesize that leptin signaling is disrupted in Antarctic fishes, leading to both lipid accumulation and reduced skeleton mineralization. Supported by NIH 1R15DK079282-01A1 to RLL, QL, and BB.

116.2 LOPEZ, JV*; CUVELIER, M; GILBERT, JA; LARSEN, P; WILLOUGHBY, D; WU, Y; BLACKWELDER, P; MCCARTHY, PJ; SMITH, E; VEGA THURBER, R; Ocean Center -Nova Southeastern University, Florida International University, University of Chicago, Argonne National Laboratory, Ocean Ridge Biosciences, Harbor Branch Oceanographic Institute at Florida Atlantic University, Florida International University/Oregon State University; *joslo@nova.edu*

Synergistic Effects of Crude Oil and Corexit Dispersant on a Sponge Holobiont System

Following the worst oil spill in US history, Macondo crude oil from the Deepwater Horizon spill and Corexit 9500 dispersant were applied in experimental dosing of the common reef sponge, *Cinachyrella alloclada*, found in both the GOM and many Caribbean reefs. Physiological monitoring included baseline descriptions of a) tissue ultrastructure by electron microscopy, b) profiling the sponge "microbiome" and c) preliminary RNA-sequencing of the host transcriptome. SEM revealed novel (embryo-like) structures. Under closed aquaculture conditions, *C. alloclada* individuals (n > 75) were dosed with sublethal amounts of oil or 10:1 oil/Corexit mixtures for 1, 24 and 48 hours. Unexpectedly, microbial communities of the same sponge host diverge into two distinct 16S rRNA clades after PCA analysis. Additionally, over 8000 sponge transcriptome sequences were identified; with oil and/or Corexit dosed samples having increased expression of protein transport and breakdown, cytochrome P450, and DNA repair responses. Predicted metabolite turnover demonstrated differential metabolism of sulfur-containing and phenolic compounds.

P2.104 LOPEZ, S.R.*; BOYD, C.; KRISTAN, D.M.; California State University San Marcos; *lopez266@cougars.csusm.edu*

A method to identify sex of post-infective third stage nematode larvae: a stepping stone to understanding parasite life history

Studies of parasite life history have revealed much about the complexities of host-parasite associations. However, for dioecious parasite species, sex specific survival is not well documented for every stage of the life cycle. Many Trichostrongyloidea nematodes have a free-living third larval stage (L3) prior to host infection and worms can remain in the L3 stage for 3-4d post-infection. Importantly, sex of L3 in Trichostrongyloidea nematodes has been shown to be chromosomally determined for all species studied to date and, therefore, does not change from free-living to post-infective stages. Although male and female L3 occur, it has been difficult to study sex specific life history characteristics of this stage in the life cycle because of a lack of sex-specific external morphology. As L3 develop into the fourth larval stage (L4), their gondal primordium (a group of cells that will become sex organs) will change size and position in the worm. We verified and expanded upon previous studies to develop a reliable method to determine sex of L3 from the nematode *Heligmosomoides bakeri*. We infected male laboratory mice (*Mus musculus*) with 200 L3 and then removed worms at 48h, 60h, 72h, and 84h post-infection and preserved worms in 10% phosphate buffered formalin. Using Nomarski optics and an ocular micrometer, the length of the gonadal primordium and its position in the worm were measured at each of these times post-infection and for free-living L3 that had been similarly preserved. We found that position of the gonadal primordium was a reliable indicator of sex at 72h post-infection. By knowing the sex ratio of L3 worms, we can now develop a better understanding of sex specific life history traits in every stage of the life cycle for this parasite.

P3.128 LOPEZ-CATIVA, L*; MOLINA-MARINO, L; GONTERO-FOURCADE, M; CAVIEDES-VIDAL, E; Univ Nac de San Luis, Univ Nac de San Luis - Consejo Nac de Inv Científicas y Técnicas; *enrique.caviedes@gmail.com*

SHORT TERM FASTING AND IMMUNE SYSTEM FUNCTION IN THE BROAD SNOUTED CAIMAN, Caiman latirostris

Caimans experience different environmental pressures during their life, such as decreased availability of food resources. Since a reduction of energy intake at early ages may result in a trade-off between growth and immune function, we studied immune, metabolic and stress parameters of young caimans subjected to short term fasting. Fifteen 8-month old caimans were divided in 2 gropus: A) with food ad lib (F+, N=8) B) fasted (F-, N=7) for 60 days. Blood was collected to perform the following assays: whole blood for hematocrit and heterophil/lymphocyte (H/L) index; plasma for biochemical parameters, total IgG (humoral immunity) and complement hemolytic activity (CHA) (innate immunity); blood cells for Heat Shock Protein 60, 70 and 90 (HSPs) (stress biomarkers) assessment. After fasting, the F- group lost 12% of their initial body-mass versus a 5% loss of the F+ group. Hematocrit and H/L index were not different between treatments. The four biochemical parameters showed significant differences between groups. No differences were apparent for the IgG index, though CHA exhibited a decreasing trend in fasted caimans. None HSPs analyzed showed differences in their expression levels. These results show that even after a significant period of fasting that alters their metabolic status, young growing-caimans can endure an energy shortage without altering their immune parameters. This is a key fact for survival considering they must face highly pathogenic environments and food scarcity in nature. Funded by PICT97-01320 to EC-V.

141.6 LOPEZ-MARTINEZ, G.*; HIGHT, S. D.; CARPENTER, J. E.; HAHN, D. A.; University of Florida, USDA-ARS, Tallahassee, FL, USDA-ARS, Tifton, GA; *gc.lopez@ufl.edu*

Physiological conditioning hormesis improves post-irradiation organismal and sexual performance

Oxidative stress can be a strong mediator of organismal life history because oxidative stress damage extends from merely affecting survival and longevity into mating and reproduction. The organism must carefully balance their oxidative status with reproduction and performance in order to properly allocate limited resources. We previously showed that physiological conditioning hormesis can lower oxidative damage and improve organismal performance in fruit flies. When a hormetic treatment was applied to these flies early in life, it led to improved longevity and sexual performance later in life. Here we investigated whether these hormetic effects were present in a moth species, *Cactoblastis cactorum*, which already has a short adult lifespan. These cactus moths must carefully allocate their resources between defense and reproduction as they do not have functional mouthparts as adults and therefore are unable to replenish spent nutrients. We hypothesized that an hour of anoxic conditioning will reduce post-irradiation oxidative damage and lead to an improvement in organismal performance. We found improvements in several metrics of organismal performance including longevity and flight. Male mating was also improved as the anoxia-irradiated males mated with unirradiated females more frequently in subsequent days than their normoxia-irradiated counterparts. The effects of anoxic conditioning hormesis on longevity were restricted to males; however irradiation extended female longevity due to sterility. Currently we are conducting field trials to monitor hormesis-based moth performance in a release-recapture experiment in our field cite in central Florida.

S11-1.3 LORENZI, M.C.*; SELLA, G.; Univ. of Turin, Italy; *cristina.lorenzi@unito.it*

Gonochorists or hermaphrodites? Gonochoric worms with flexible sex allocation

Related species share genetic and developmental backgrounds. Therefore, hidden genetic variation for sex determination may allow separate sex species - that share recent common ancestors with hermaphroditic species - to express flexible sex allocation and sex lability as a function of environmental factors. Worms of the polichaete species *Ophryotrocha labronica* have separate sexes whereas their congeneric species are hermaphroditic. *O. labronica* worms have a worldwide distribution and different populations may be subject to different selective pressures on sexual traits. Therefore, we exposed newly-mature *O. labronica* worms from three geographically-distant populations to different social conditions where worms had different levels of mating opportunities. Worms were either isolated (i.e., had no mating opportunities), or kept in pairs (intermediate mating opportunities), or in promiscuous groups (high mating opportunities). After three weeks, we measured the sexual phenotype of the worms checking whether they had sperm, oocytes and nurse cells in their coeloms. The analyses showed that 55-95 % of the worms (depending on the population) had allocated to both sex functions after the experimental period. However, the sex allocation of the worms was influenced by mating opportunities in different ways depending on the population. These results 1) confirm the hypothesis that separate sex species that share recent common ancestors with hermaphroditic species adjust their sex allocation to current mating opportunities; 2) indicate that worms from different populations exhibit different levels of sex allocation plasticity and 3) suggest that intermediate steps exist along the evolutionary trajectories between hermphroditism and gonochorism.

S7-2.1 LOUDON, FK; SPENCER, R-J*; University of Western Sydney, Australia; *r.spencer@uws.edu.au*

Egging each other on: embryonic communication in a nest maintains circadian rhythms of heart rate in turtles?

Amniotic eggs provide model organisms to explore the embryonic development of endogenous physiological circadian rhythms without the influence of maternal biorhythms. Recent studies have demonstrated that embryonic turtles within the nest respond to the developmental status of siblings by increasing both heart and metabolic rates, independent of temperature. A first step to understanding the physiological mechanisms underpinning this form of communication within a nest of ectothermic organisms is to develop profiles of embryonic heart rates at different temperatures throughout incubation. We developed daily embryonic heart rate profiles of embryonic freshwater turtles in different group sizes, under constant temperature and lighting conditions to determine if circadian rhythms exist and at what stage of embryogenesis they become established. Murray River turtle eggs were incubated in darkness at constant temperatures (26C and 30C) in groups of six or individually and heart rates were monitored at 6hr intervals over 24-48 hrs every seven days throughout incubation. Circadian heart rate rhythms were detected at week four of incubation and were maintained until hatching in on species. Heart rates throughout the day varied by up to 20% at constant temperatures over a 24h period and were not related to time of day. Circadian rhythms of heart rate were not as developed sympatric species that do not hatch synchronously. This study established that endogenous circadian rhythms of heart rate are established early during embryogenesis and suggests biotic cues from siblings within a nest (eg. changes in heart rate) may be as important as external environmental cues (eg. temperature) for establishing developmental rates and coordinating hatching and emergence from the nest.

56.2 LOVE, O.P.*; BOURGEON, S.; MADLIGER, C.L.; HARRIS, C.; WILLIAMS, T.D.; University of Windsor, ON, Norwegian Polar Institute, Tromsø, Simon Fraser University, BC; *olove@uwindsor.ca*

Feather corticosterone predicts offspring performance in a context-dependent manner

The use of feather Corticosterone (CORT) as a measure of integrated HPA activity is rapidly increasing in integrative studies of environmental "stressors" in numerous avian species. However, we currently know very little about how biologically-relevant stressors relate to feather CORT levels and even less about whether these levels can predict meaningful metrics of fitness. We examined whether a biologically-relevant manipulation of post-natal developmental stress translated into measurable and meaningful changes in feather CORT for a sexually size-dimorphic passerine, the European starling (*Sturnus vulgaris*). Lower growth rates during the linear phase of growth and higher catch-up growth rates during the asymptotic phase predicted higher feather CORT in the larger, faster-growing males, but there was no such relationship in females. However, higher feather CORT predicted lower predator escape performance in both sexes, independent of treatment. Taken together, these results suggest that feather CORT can indeed capture variation in relevant environmental stressors, but that the context within which this stress is integrated must be well understood to appreciate what feather CORT levels mean for individual performance.

91.1 LOWERY, M.S.*; KAUFMANN, R.; GRAY, S.; BOUDRIAS, M.; TALLEY, D.; University of San Diego; *slowery@sandiego.edu*

Sailing for Science: Authentic Oceanographic Field Experience as the Core of Multiple Science Courses

For over a decade, students at the University of San Diego have participated in a 24 hour oceanographic cruise aboard the R/V Robert Gordon Sproul, a research vessel of the Scripps Institution of Oceanography. Using professional marine sampling gear, students collect data at sea and engage in a long-term multidisciplinary study of nearshore sites through inquiry-based learning. Multi-week analysis of hydrographic parameters including CTD depth profiles and water chemistry, sediments collected with grabs and multicorers, and plankton tows continues throughout the semester and is integrated into biological and geological oceanography courses. Students write several reports in the format appropriate for submission to a scientific journal or a poster presentation at a conference. Major studies among these courses include the following: variability in mineralogy, grain size distributions, and organic matter content; variation in the living (stained) and sub-fossil benthic foraminifera community; variation in plankton with distance from shore, hydrographic parameters, and time of day; variation in benthic macrofauna with sediment characteristics, oxygen concentration, and overlying plankton communities. Increasingly, students from additional courses such as analytical chemistry participate in the cruise, enhancing the scope of the project and underscoring the importance of collaboration in modern science. In fact, many students participate in the cruise in multiple years, gaining deeper insight from a different analytical focus on samples from the same sites. Emphasis on integration of physical and biological parameters provides a unique opportunity for students to make connections among disciplines and gain experience in executing field studies.

P1.201 LUCAS, K.N.*; JOHNSON, N.; COSTELLO, J.H.; COLIN, S.P.; Roger Williams Univ., Texas A and M Univ., Providence College; *klucas830@g.rwu.edu*

Convergent inflexion patterns of flexible margins of oscillating animal propulsors during swimming and flight

Propulsion of swimming and flying animals in relatively high Reynolds number fluids is dependent on kinetic energy transfer via vortices, and as such, these animals cruise with vortex kinematics tuned for high hydrodynamic or aerodynamic efficiency. Recently, flexible margins of oscillating propulsors have been shown to significantly enhance thrust during propulsion. This suggests that flexible margins should demonstrate selection for morphologies that optimize thrust and efficiency. We examined if patterns existed across swimming and flying animals in how their propulsors inflexed during propulsion. Inflexion angles and ratios were measured using video of multiple animal species representing several divergent evolutionary lineages during steady state swimming and flying. Aggregate groupings of these measurements fell within strict ranges: ˜10°-40° for inflexion angles and ˜0.6-0.7 for inflexion ratios. These patterns suggest an optimization of propulsors which is likely related thrust generation.

116.10 LUDEMAN, DA*; REIDENBACH, MA; LEYS, SP; University of Alberta, University of Virginia; *sleys@ualberta.ca*

Testing passive flow and oxygen consumption in three temperate demosponges

Sponges are suspension feeders that process up to 900x their body volume in water daily, and extract bacteria with up to 98% efficiency. Because of their small incurrent openings and larger excurrent vents, sponges have long been considered to take advantage of passive flow to reduce the cost of pumping for filtration. But it is unclear whether all sponges a) need to use passive flow, and b) are able to use passive flow. Deep-water glass sponges live in nutrient-poor waters, and are found mainly in areas of constant high ambient flow. The cost of pumping (resistance through their filtration system) for glass sponges has been found to be nearly 30% of their metabolism, and the expense of pumping is reduced by taking advantage of current induced flow. Demosponges have much finer canal systems which should provide higher resistance than in glass sponges. We predict that passive flow does not occur in these sponges, but instead their food-rich temperate waters provide enough energy to sustain maintenance and growth despite the high cost of pumping. To determine this we studied excurrent filtration rates and oxygen consumption during ambient flows of 0-18cm/s in three temperate demosponges using particle imaging velocimetry, profiling acoustic Doppler velocimeters, and an oxygen optode. We found that excurrent velocities varied among the three demosponges, but none increased with increasing ambient flow. Oxygen drawdown was similar for all three sponges (0.1-0.4 mg/mL) and also did not increase with increased ambient flow, meaning no additional energy was expended to pump during increased ambient flow. Morphometric analysis of the aquiferous system will be used to model whether increased ambient currents can induce excurrent flows.

P3.177 LUTTERSCHMIDT, DI; Portland State University, Oregon; *d.lutterschmidt@pdx.edu*

Corticosterone regulates the transition from courtship to feeding behavior in male red-sided garter snakes (Thamnophis sirtalis).

Seasonal modulation of glucocorticoids plays an important role in supporting critical life-history events such as reproduction and migration. In a well-studied population of red-sided garter snakes (*Thamnophis sirtalis parietalis*), glucocorticoids are elevated during the brief mating season. Glucocorticoids likely facilitate energetically expensive courtship behavior, as snakes do not eat during the mating season and must migrate up to 17 km to forage at feeding grounds. Our previous data demonstrated that dispersing male red-sided garter snakes have significantly lower baseline corticosterone than courting males, suggesting that elevated corticosterone is necessary to support reproductive behavior. To test this hypothesis, I collected 40 courting male snakes and randomly assigned them to one of two implant treatments: control or 5 mg metyrapone, a corticosterone synthesis inhibitor. Snakes were housed in outdoor arenas and blood samples were collected 0, 2, 4, and 7 days post- treatment. Males were then tested on a y-maze and allowed to choose between a female or worm trail (i.e., a courtship or feeding cue). As expected, plasma corticosterone decreased significantly during the mating season ($P < 0.001$). A significant interaction between treatment and sampling time occurred ($P = 0.024$), indicating that the seasonal decline in corticosterone depended on treatment condition. Significantly more snakes receiving metyrapone (16 of 20) chose worm trails than snakes receiving the control implant (6 of 20; $P = 0.004$). These results indicate that a decrease in plasma corticosterone induces the behavioral switch from reproduction to foraging during the spring mating season. Future studies are needed to understand the mechanisms by which corticosterone regulates this seasonal transition in behavior.

P3.149 LUTZ, E.K.*; RIFFELL, J; University of Washington; *lutze@uw.edu*

Visual and Olfactory Learning in Anopheles stephensi and Aedes aegypti mosquitoes.

The host seeking behavior of disease-vector mosquitoes may be impacted by olfactory and visual learning. By enabling mosquitoes to better find prey, this behavior may allow mosquitoes to remain longer in the environment, transmitting diseases to more organisms. Recent work has shown that mosquitoes respond to Pavlovian conditioning that pairs visual and olfactory cues with an unconditioned stimulus. However, the relative importance of each sensory system has not yet been explored. In addition, there is little research that compares the learning abilities of two different mosquito species. We investigated both subjects using *Aedes aegypti* and *Anopheles stephensi*. Firstly, the Riffell lab conducted appetitive conditioning experiments on *Anopheles stephensi*. We found that *Anopheles* learned well when both visual and olfactory cues accompanied a reward, but were unable to learn with only olfactory cues. Similar behavior was seen in *Aedes aegypti*: The animals learned successfully when both visual and olfactory cues were present, but responded poorly when given only an olfactory stimulus. These data suggest that olfactory cues are insufficient to induce conditioned behavior. However, a combination of olfactory and visual cues is sufficient for learning. Interestingly, *Aedes aegypti* also demonstrated an ability to associate a location with an appetitive reward. This behavior was only observable in experiments that used an innately attractive odor (nonanol) as the predictor of a reward. *Aedes* demonstrated a strong preference for the conditioned location over the conditioned olfactory stimulus. This suggests that mosquito learning may be more multifaceted than previously proposed. Further research will provide valuable information that may be useful in ameliorating the spread of mosquito hosts of virulent diseases.

86.5 LYONS, S.M.*; BEAULIEU, M.; SOCKMAN, K.W.; University of North Carolina, Chapel Hill; *lyonssm@live.unc.edu*

Recent song experience alters the threshold for female mate choice

The costs of mate choice can be high, and therefore females should adjust their threshold for choice according to the prevalence of high-quality males. In many songbird species, vocal signals advertise male quality. Because of a constraint of frequency bandwidth on syllable-production rate, trill performance (the capacity to produce high-bandwidth syllables at a rapid rate) is thought to provide females with information about male quality. Using Lincoln's sparrows (*Melospiza lincolnii*), we manipulated the perceived availability of high-quality mates by exposing one group of females to songs with experimentally reduced trill performance and another to the same songs but with experimentally elevated trill performance. Initially, females in the high-performance group spent more time next to playback speakers than females in the low-performance group, demonstrating a preference based on trill performance previously shown for this species. This difference between groups disappeared by day six of song exposure as females habituated. We then exposed all females to a novel song with trills of intermediate performance. Females accustomed to low-performance trills spent more time near the playback speaker than females accustomed to high-performance trills. In a second round, we switched the females' treatment assignments and consequently reversed individual females' preferences for a new novel song of intermediate trill performance. These findings indicate that females have highly flexible song-choice criteria and adjust their standards for choosing a novel song based on the quality of songs they have most recently experienced. This would seem adaptive in species in which the prevalence of high-quality males fluctuates.

63.5 M.N., M; Univ. of the Ryukyus; *masaru@lab.u-ryukyu.ac.jp*
Differentiation and development of steroid-producing cells during ovarian differentiation in tilapia
Sex hormones produced from steroid-producing cells (SPCs) play important role in sexual phenomena such as sex differentiation, gonadal development, maturation, sexual behaviour etc. Differentiation and development of SPCs and folliculogenesis during ovarian differentiation in Nile tilapia *Oreochromis niloticus* were ultrastructurally and immunohistochemically. SPCs with ultrastructural features were first observed in the area near the blood vessels in the gonads of fish at 20-25 day after hatching (dah) around the time of ovarian differentiation. Ultrastructural results showed that differentiation and development of SPCs from undifferentiated to maturation occurred in the area near blood vessels, indicating that it would be the original site of SPCs. The process of folliculogenesis was ultrastructurally observed. SPCs enclosed by fibroblastic cells invaded the interstitial areas among oocytes and some reached the surfaces of oocytes. The upper portions of these elongations opened and began to enclose the outer surfaces of developed oocytes to become thecal layer. Later, newly migrated SPCs reach the thecal layer to become thecal cells. These results indicate that steroid-producing thecal cells originate from the SPCs in the area near blood vessels. After thecal layer formation, an immunopositive reaction against P450arom AB, but not against P450scc or 3β-HSD ABs, appeared first in the granulosa cells enclosing the vitellogenic oocytes at 100 dah. At this time, estrogen production in serum levels rapidly increased. At 70–80 dah, IPC clusters invaded the interstices among oocytes at the perinucleolar stage from the area near the blood vessels. IPCs increased in number in the interstices among the previtellogenic oocytes, and some clusters began to enclose the outer thecal layer of the previtellogenic oocytes at 90 dahThus, folliculogen- esis could be essential for active production of estrogen in the ovary.

P2.118 MAAYAN, I.*; RITZMAN, T.B.; HUTCHINS, E.D.; STAPLEY, J.; LASKU, E.; ECKALBAR, W.L.; WILSON-RAWLS, J.; HUENTELMAN, M.J.; BERMINGHAM, E.; HSIEH, S.T.; FISHER, R.E.; KUSUMI, K.; Arizona State Univ., Smithsonian Tropical Res. Inst., Translational Genomics Res. Inst., Temple Univ., Univ. Arizona College Med.-Phoenix; *kenro.kusumi@asu.edu*
Comparative appendicular osteology and evolutionary genetics of Panamanian anoles with divergent locomotor strategies
Across the Neotropics, anole lizards have repeatedly diversified and evolved to fill open niche spaces, as evidenced by their abundance and variety. Recurrent convergence upon a set of relatively conserved body plans among anole radiations in the Greater Antilles suggests a significant correlation between habitat and morphology. Specifically, species with smaller fore-to-hindlimb length ratio will use jumping more frequently, whereas those that predominantly run will exhibit a larger fore-to-hindlimb length ratio. To test for similar patterns in mainland species, we analyzed the predator avoidance strategies and appendicular osteology of *Anolis apletophallus*, *A. auratus* and *A. poecilopus*, three Panamanian anole species occupying different microhabitats. We also collected measurements of body size and limb lengths to investigate whether features of appendicular morphology are associated with locomotor patterns observed in the field. These findings were compared with the limb osteology of the green anole, *A. carolinensis*, and with that of the invasive brown anole, *A. sagrei*, two well-studied island species from separate phylogenetic radiations. With genome sequencing near completion for *A. apletophallus*, comparisons with *A. carolinensis* can be made for genes regulating limb patterning, including *pitx1*, *tbx4*, and *tbx5*. This study will help to define the divergent morphological and locomotor features of the mainland anoles and the evolutionary genetic basis of changes in appendicular development.

P2.49 MACDONALD, I.A.*; GIBB, A.C.; Northern Arizona University; *iam26@nau.edu*
Cranial movements of the Pacific Sandfish are coupled with descent into the substrate: Are fish fluidizing sand using the opercular pump?
Many fish use burial as a method of avoiding predation and remaining cryptic in order to ambush prey. The Pacific sandfish, *Trichodon trichodon*, however, exhibits an unusual mode of burial when compared to many other sand burying fishes because it descends abdomen first into the sand while producing body bending in the lateral-medial plane and in the dorso-ventral plane. Based on our initial observations of the burial cycle, we hypothesized that dorso-ventral movements of the cranium assist the sandfish in burrowing into the sand. To quantify both cranial and body movements during burying, we used high-speed videography to extract kinematic variables. Sandfish took ~8 seconds to complete their burying behavior; during this time they and underwent ~30 cycles of cranial rotation, where the average dorsal neurocranial rotation was 5° and the magnitude of the rotation increased over time . Periods of cranial rotation occurred just before intervals in which the body descended into the sand and maximum gape consistently occurred at the same time as peak neurocranial rotation. In addition, the operculae were maximally abducted as the cranium rotated upward, and were adducted as the cranium rotated back downward . The tight coupling of cranial rotation, gape and opercular movements with descent of the body into the sand suggests that movements of the head play a key role in the sandfish burial cycle. Although it is still unclear how the body and paired fins contribute to the burying behavior, our preliminary analysis suggests that sandfish may be forcing water out of the opercular cavity into the substrate, thereby fluidizing the sand and enhancing their ability to penetrate it quickly.

P3.84 MACEDO, D.C.*; JOHNSON, J.B.; ROSENTHAL, G.G.; Texas A&M University; *dani.macedo429@gmail.com*
The impact of hybridization on morphological variation in Xiphophorus fish
Natural hybrid systems allow for the study of sexual and natural section as they may be responsible for populations that are free to evolve in novel directions. The hybrid system of *Xiphophorus* fish has been shown to be replicated in seven streams along an elevation gradient. The two parental species, *Xiphophorus birchmanni* and *X. malinche*, are found in different habitats, a factor that may explain the significant differences in morphology between the two species. To determine if these replicated hybrid zones have unique divergence, morphometric data of the parental species and hybrids was collected. Morphometric measurements were taken from digitized landmarks using R. This data was also used to elucidate the relationship between sexual and non-sexual traits and whether they diverge in alternate directions relative to each other. We expect hybrids to display greater morphological variation than parentals, in addition to greater among population variance relative to parentals. Given that the hybridization events occurred seven independent times, each hybrid zone is likely to have independent patterns of phenotypic variation.

128.2 MACIAS, N/A*; COLON-GAUD, C/; Georgia Southern University; *nm01510@georgiasouthern.edu*

Population differentation of an invasive crayfish Cherax quadricarinatus on the island of Puerto Rico

Cherax quadricarinatus is a tropical freshwater crayfish endemic to Northern Australia and Southern Papau New Guinea and was introduced to the island of Puerto Rico for experimental purposes in aquaculture. Species introductions can have multiple effects on the population genetic structure of cultured populations. Population variation may decrease due to bottlenecks and strong selection; or diversity may increase as a result of multiple introductions from diverse native populations. Cultured taxa show high adaptability for available niche space due to breeding for traits such as rapid growth, large size potential, disease resistance and tolerance of stressful environmental conditions. During June-August 2012, populations of C. quadricarinatus were sampled from Puerto Rican reservoirs (e.g. Carraizo, Carite, Cidra, Guajataca, Dos Bocas, Guineo) as well as an aquaculture farm located in the Southwestern town of Lajas. A total of 158 crayfish were caught with a 75:69 reproductive female to reproductive male sex ratio. Catch-Per-Unit-Effort (CPUE= the number of individuals per trapnight) was calculated as an estimate of relative abundance for Cidra, Carite, and Guajataca reservoirs with a CPUE of 2.20, 0.361, 1.033, respectively. Sample sites represent the three main physiographic regions of Puerto Rico (mountainous interior, coastal lowlands, and karst area) from five major watersheds (Eastern, Southern, Interior, Cibuco-Guajataca, and Culebrinas-Guanajibo). Tissue samples were taken from all individuals and brought back to Georgia Southern University to estimate population differentiation. We predict that populations come from the same broad stock and any differentiation of these populations would be a result of genetic drift due to little interaction amongst populations.

P1.167 MACIAS, A*; YUAN, F; MONTEIRO, A; BRISCOE, A; University of California, Irvine, Yale University; *amaciasm@uci.edu*

Visual transcriptomics of seasonal forms of the butterfly Bicyclus anynana

Males and females allocate resources differently to avoid high energy costs. Vision is an example of a high-cost trait in which sophistication should decrease as the need for the trait decreases. The butterfly species *Bicyclus anynana* has two seasonal forms that are produced in response to different rearing temperatures. The sex that displays the brightest wing patterns and who performs most of the courtship displays changes with rearing temperature. In butterflies reared at high temperatures, mimicking the wet season, males court females and females are choosy, whereas when rearing temperatures are low females court males and males are choosy. We expect choosy individuals to have more complex visual functions and thus to vary in gene expression from that of its non-choosy same-sex form. We extracted RNA from the eyes of dry season and wet season males and females. We then created RNA sequencing libraries using Illumina technology and did de novo assemblies to explore the genes that are being expressed. We focus our study by looking at differences in phototransduction gene expressions across sexes and seasonal forms. These results will show how males and females differ in their visual systems and will also test whether visual function decreases from choosy to non-choosy individuals with changes in rearing temperature.

P2.69 MACIEL, J; PINON, M; ZARAGOZA, D; CORDERO, G; NEUMAN-LEE, L; STRICKLAND, J; THOL, S; WARNER, D; MITCHELL, T; REEDY, A; JANZEN, F*; Iowa State Univ., Kelly High School, Chicago, Utah State Univ., U.S. Fish & Wildlife Service, Univ. Alabama, Birmingham, Kelly High School, Chicago; *fjanzen@iastate.edu*

Planting a TREE: designing a program to facilitate ecological research, outreach, education, and mentoring for underrepresented students

There is a serious dearth of female and minority representation in the sciences. To help remedy this problem in the field of ecology, we carefully developed a program called TREE (Turtle Camp Research and Education in Ecology). We seeded the program primarily with an economically and racially diverse group of high school students from rural Iowa and Illinois, as well as Des Moines and Chicago, along with undergraduate and graduate student mentors from five different institutions across the country. Participants converged at a field site known as “Turtle Camp” in June of 2007-2012 (totaling 33 high school students, 15 undergraduate students, 11 graduate students, and 2 post-doctorates over the six years). All individuals worked toward four main goals at Turtle Camp: research experience, local outreach, education, and mentoring. The program utilized the extensive local diversity in reptiles to allow students to receive hands-on experience with research and related activities. Overall, TREE provides an excellent environment for advancing interest in, and knowledge of, science and for positively influencing career plans of the participants, the vast majority of whom were female and/or minorities. We hope that this program can serve as a model to help other organizations develop programs to expose students from diverse background to the benefits of ecological research, outreach, education, and mentoring.

100.5 MACKEY, T.L.*; JAYNE, B.C.; University of Cincinnati, Ohio; *mackey.93@gmail.com*

Meal size affects the speed and modes of arboreal locomotion of the brown tree snake, Boiga irregularis

Snakes commonly consume large prey and move in diverse environments including trees. Unlike many terrestrial environments, animals in trees commonly need to move on variable slopes and to balance on narrow, cylindrically shaped branches. Hence, we expected the arboreal locomotor performance of snakes to decrease substantially after consuming large meals that increased their weight and altered their distribution of mass. To test for this likely cost of consuming a large meal, we determined the maximal speed and mode of locomotion for 15 individuals of a highly arboreal snake species, *Boiga irregularis*, when they were unfed and within 48 hours of eating one or two mice, each of which averaged ~12% of the snake’s mass. The snakes crawled on cylindrical surfaces 24 mm in diameter, with and without pegs and with the long axis oriented horizontally or inclined 45 degrees. On all surfaces with pegs the snakes performed lateral undulation, and their maximum speed decreased significantly with increased meal size. When moving up the inclined cylinders without pegs, all snakes used concertina locomotion, and the maximum speeds after eating two mice were significantly slower than those of the other two treatments. On the horizontal cylinders without pegs, 87% of the unfed snakes had continuous sliding contact while performing lateral undulation, whereas after eating two mice 80% of the snakes periodically stopped and gripped the cylinder while performing concertina locomotion at speeds that were not significantly different from those of the unfed snakes. Thus, although large meals were often detrimental to speed, the behavioral response of switching the mode of locomotion (concertina) prevented slipping and long-axis rolling which commonly occur on smooth cylindrical surfaces.

123.4 MACLEAN, H J*; HIGGINS, J K; KINGSOLVER, J G ; BUCKLEY, L B; University of North Carolina Chapel Hill; *heidi.maclean@gmail.com*

Responses to climate change: morphology and behavior, in Rocky Mountain Colias species

Colias butterflies have long been a model system for understanding thermoregulatory behavior and local adaptation to climate. What are the behavioral, ecological and evolutionary responses of *Colias* to recent climate changes in the Rocky Mountains? *Colias* use behavioral postures to maintain body temperatures required for flight (30-40˚C) and to avoid overheating, and adapt to local climate conditions via differences in melanin on the ventral hind wings and the thickness of thoracic setae ('fur'). Our recent reciprocal transplants with high-elevation *Colias meadii* and lower-elevation *Colias eriphyle* show that butterflies from higher elevations with darker wings and thicker setae tend to initiate morning flight sooner regardless of location. Moreover, the high-elevation phenotype experiences more frequent overheating and consequences thereof.

P2.85 MACNEIL, K/E A*; BISHOP, C/D; St. Francis Xaviery University, Antigonish NS; *x2007tev@stfx.ca*

The curious shapes of sea urchin larvae: A comparative investigation into a putative olfactory structure

Sea urchin planktotrophic larvae have evolved highly elaborate body shapes to increase the surface area of the body and thus the length of the ciliary band, their feeding and locomotory organ. One such elaborated structure is the adoral lobe (ADL), a newly described putative olfactory structure on the ventral surface of Lytechinus variegatus larvae. The ADL is composed of ciliary band and the associated epithelium, which are folded into a "U "shape. At the base of the "U" shape NOS-defined neurons (NDNs) differentiate and project axons to the pre-oral neuropile around the time of juvenile rudiment formation. I am interested in the relationship between the number and distribution of neurons and the morphology of the surrounding epithelium. Are there functional reasons for this intriguing structural arrangement? There is considerable interspecific variation in the presence (some feeding larvae do not have one) and shape of this structure among sea urchin larvae, the significance of which remains untested. Therefore my near term goal is to establish a method to conduct a comparative morphologic analysis of the ADL. Thereafter, I will test for the presence and distribution of neurons in this region of selected larvae. Using the comparative method, I will test my hypothesis that there is a function reason for the specific placement of NDNs within the ADL that predicts covariance between the presence of NDNs and an ADL.

122.5 MACNEIL, K.E.A.*; PATEL, D; TAYLOR, V; BISHOP, C.D.; BURKE, R.D.; St. Francis-Xavier Univ., Antigonish, Nova Scotia, Univ. of Victoria, Victoria, B.C.; *cbishop@stfx.ca*

The canonical echinoid apical organ evolved from within the euechinoids: evidence from the cidaroid Eucidaris tribuloides

Descriptions of the structure and development of larval nervous systems of all five classes of echinoderms have recently been reported. Among these taxa, several differences in neural development and neuroanatomy support the hypothesis that echinoid larvae are the most derived. The cidaroids, a major clade of echinoids, are considered to have several primitive features that more closely represent the common ancestor to all extant echinoids. To test whether cidaroid larvae also present features that are ancestral to the euechinoids, and to clarify the timing and nature of changes from a dipleurula-like condition to the echinopluteus condition we have investigated the development and anatomy of the larval nervous system of *Eucidaris tribuloides*. Using markers for neurons (SynB, serotonin), ciliary band (Hnf6), oral ectoderm (Chd) and anterior ectoderm (Nk2.1), we describe the development and organization of the larval nervous system. In most respects the larval nervous system of *E. tribuloides* more closely resembles that of non-echinoid larvae. We also used LiCl and 1-azakenpaullone (GSK-3β inhibitors) and ZnSO4 (an animalizing agent) to test for the presence of known echinoid anterior-posterior axial signaling mechanisms. Collectively these neuroanatomical and experimental data have allowed us to conclude that the evolution of the canonical sea urchin apical organ was derived within the euechinoids about 250 million years ago.

P3.186 MADDEN, A.A.*; LATTIN, C.R.; ROMERO, L.M; FIERER, N.; STARKS, P.T.; Tufts University, Medford, MA, Univ. of Colorado, Boulder; *madden.anne@gmail.com*

The effect of chronic stress on the avian gut microbial community

Acute host stress causes a shift in the vertebrate gut microbial community, independent of the immune system. This can lead to the increase shedding of microbes, an up-regulation of microbial pathogenicity factors, and a decreased ability of the host to gain energy from food. Chronic stress, the maladaptive response to prolonged stress, has many negative effects on vertebrate host performance and fitness. Despite this understanding, it is not established if chronic stress leads to a continued microbial gut dysbiosis, and continued increase in microbial shedding. To assess the effect of chronic stress on the abundance and diversity of gastrointestinal bacteria within a wild-caught host system, we investigated the microbiota of house sparrows, *Passer domesticus*. Following acclimation to captivity, a portion of forty-six captured birds underwent a standardized chronic stress protocol—featuring rotating stressors—while the rest remained as captivity controls. Throughout four weeks, the cloaca of each bird was swabbed once. The experimental treatment was validated by measuring host blood corticosterone levels in response to stress. Changes in the cloaca bacterial community within these samples were measured using the culture-dependent methods of selective plating with subsequent bacterial colony enumeration, and high-throughput 16S rDNA sequencing. We provide a characterization of the house sparrow microbiome, and contribute to the body of knowledge on how chronic stress holistically affects vertebrate hosts.

P2.224 MADDEN, A.A.*; SORIANO, J.N.; ELLIS, N.; GRASSETTI, A.; FIERER, N.; STARKS, P.T.; Tufts University, Medford, MA, Univ. of Colorado, Boulder; *madden.anne@gmail.com*

Fungal patterns across space and species: Comparative studies of the mycobiomes of sympatric paper wasp species

Recent investigations of ant-associated microbial communities have revealed diverse assemblages of commensal microbes. Some of these microbes have been shown to affect host insect nutrition, nest hygiene, and colony health. However, microbial communities associated with other hymenoptera remain understudied. Paper wasps are globally distributed, social hymenoptera that construct nests annually out of macerated plant material and saliva. Disparate studies have suggested that paper wasp nests contain culturable fungi, including a previously uncharacterized fungal species. However, the full diversity of these communities remains unexplored. We extend these preliminary studies by investigating the fungal diversity of the bodies and nests of congeneric, sympatric paper wasps in Massachusetts—*Polistes dominulus* and *P. fuscatus*. We measured the fungal abundance and diversity associated with these wasps across multiple nesting locations to investigate how location and species correlate with fungal community patterns. Fungal communities were assessed qualitatively and quantitatively using culture-dependent methods to investigate specific isolates and their viability, as well as culture-independent methods, such as microscopy and high-throughput sequencing of ITS rDNA. Contrary to the general understanding that these nest habitats are constructed solely out of macerated paper and saliva, our results indicate that paper wasp nests and bodies contain an abundance of diverse, viable fungi.

45.6 MADLIGER, C.L.*; LOVE, O.P.; University of Windsor, Ontario; *madlige@uwindsor.ca*

Fitness consequences of individual variation in stress hormone levels: why repeatability and plasticity of physiological traits matter

Physiological measures can provide insight into how organisms respond mechanistically to changes in their environment. Baseline stress hormones (glucocorticoids – GCs) have garnered considerable attention due to their essential role in the maintenance of energetic balance. However, to understand the evolutionary implications of individual variation in GCs and interpret concentrations as population-level indicators of environmental change, GCs must display two characteristics: i) high repeatability (consistency); ii) a predictable relationship with fitness. Results pertaining to both have been markedly mixed and investigations often lack a consideration of ecological or demographic contexts. We investigated the repeatability of baseline GCs in a free-living population of tree swallows (*Tachycineta bicolor*) within and across breeding seasons. In addition, we incorporated a feather-clipping manipulation to examine the influence of changing energetic cost (i.e., environmental quality). We find high repeatability within, but not across, years. However, our results indicate that this high within-season repeatability is dependent on age and energetic constraints, providing evidence for individually-specific plasticity in the response to environmental fluctuations. We further investigate whether plasticity in GCs represents a better predictor of fitness than static measures of the trait. Our results call to attention the importance of considering the contexts of environmental quality and age when examining repeatability, caution the interpretation of individual baseline GC levels as population-level indicators of environmental disturbance, and indicate that an investigation of plasticity can provide insight into the evolutionary consequences of variation in physiological traits.

121.4 MAH, C.*; FOLTZ, D.; Dept. of Invertebrate Zoology, NMNH, Washington DC, Dept. of Biological Science, Louisiana State University; *mahch@si.edu*

Biogeographic Insights from Molecular Phylogenetics of Pacific Northwest Sea Stars

Recently molecular phylogenetic analyses of the Asteroidea have produced comprehensive and well-resolved trees for the Forcipulatacea and the Valvatacea, two of the most taxonomically diverse and ecologically important groups of asteroids. Although our work is broadly concerned with higher level phylogeny, we have focused on projects across a diversity of scales and herein we present highlights from our work that emphasize interests relevant to asteroid taxa on the west coast of North America. Analysis of the Asteriidae shows it is composed of multiple clades corresponding to specific geographic/climatic regions. The boreal clade suggests endemism for asteriids occurring on the west coast of N. America and adjoining regions, including familiar genera such as *Pisaster* and *Leptasterias*. *Pycnopodia* and the deep-sea *Rathbunaster* were supported as sister taxa which presents at least 2 different hypotheses of relationship. The goniasterid *Hippasteria* includes 15 nominal species and is widely distributed in cold-water settings throughout the Atlantic, Pacific and southern Indian Ocean. In order to assess relationships and genetic structure, we sampled populations from throughout the world. Partial sequences for a mitochondrial gene (COI) and a nuclear gene (ATPS) were obtained for approximately 150 specimens. Our results showed little ongoing genetic exchange between trans-Arctic populations. Only 1 of 31 COI haplotypes and 4 of 16 ATPS haplotypes were shared among two or more ocean regions (N. Pacific, S. Pacific and N. Atlantic) despite sampling between 50-100 sequences per region. The widespread *H. phrygiana* identified from Atlantic, New Zealand, and Kerguelen Island populations and *H. spinosa* from the N. Pacific were all supported as one widely distributed global lineage, which has recently diversified.

43.6 MAHALINGAM, S; WELCH, KC*; University of Toronto, University of Toronto Scarborough; *kwelch@utsc.utoronto.ca*

Neuromuscular modulation of kinematic performance in hovering hummingbirds

While producing the highest power output of any vertebrate hummingbirds must also precisely modulate muscle activity to vary wingbeat kinematics and modulate lift production. However, wingbeat kinematics can vary in different ways depending on whether increased lift requirements are the result of lifting greater mass or hovering in lower density air mixtures. It is possible that differences in drag on wings due to variation in air density and viscosity may affect wingbeat kinematics that result from given muscle activation profiles. We evaluated whether wingbeat kinematics varied in response to increased lift requirements differently in hypodense heliox gas mixtures compared to when birds were hovering while lifting small weights and whether any differences were solely a function of muscle activation patterning. To do this, we simultaneously recorded wingbeat kinematics and electromyograms (EMGs) from the pectoralis and supracoracoideus (responsible for the downstroke and upstroke, respectively) in ruby-throated hummingbirds (*Archilochus colubris*). As expected, increased lift was achieved through increases in stroke amplitude during both treatments. However, wingbeat frequency increased only during air density reduction trials. Overall relative EMG intensity was the best predictor of wingbeat frequency, stroke amplitude, and power output, while the relationship of kinematic features to spike number and EMG amplitude was less consistent. The relationship between EMG intensity and kinematics was quite similar between treatment types, suggesting wingbeat frequency did not change solely as a result of decreased drag on the wings. Despite the relative symmetry of the hovering downstroke and upstroke, the timing of activation and number of spikes per EMG burst were consistently different in the supracoracoideus compared to the pectoralis, likely reflecting differences in muscle morphology.

67.5 MAHLER, D. L.*; INGRAM, T.; REVELL, L. J.; LOSOS, J. B.; Univ. of California, Davis, Harvard Univ., U. Mass., Boston; *lmahler@ucdavis.edu*

Testing for exceptional among-island convergence in Greater Antillean Anolis: introduction and application of a novel comparative method

Replicated adaptive radiations suggest that diversification may be strongly deterministic, even over macroevolutionary timescales. However, species-rich clades are expected to produce many convergent species by chance alone, such that the convergence we observe among selected species pairs in “replicated radiations” may be nothing more than a by-product of extensive diversification. To date, there have been few studies of clade-wide convergence, and these have tended to examine only those species that are most obviously similar. It thus remains to be determined whether the similarity of these clades is due to deterministic adaptive convergence. To test this hypothesis, we investigated patterns of trait evolution in Greater Antillean *Anolis* lizards, a group famous for among-island convergence. We developed an Ornstein-Uhlenbeck method for detecting convergence of lineages to the same peaks on a shared macroevolutionary landscape, without requiring prior hypotheses about which lineages may have converged. This allows us to test for convergence in faunas with some non-convergent species, which must be ignored by alternative methods. Applying this method to island anoles, we found exceptional clade-wide convergence among islands, supporting the hypothesis that evolutionary radiation has deterministically produced similar outcomes in *Anolis*. Although not every species of Greater Antillean anole has a phenotypic match from another island, most do, and among-island convergence greatly exceeds expectations from evolutionary null models. Our results demonstrate that historical contingencies are insufficient to preclude the emergence of deterministic macroevolutionary patterns during diversification.

74.6 MAIA, A.*; COUTO, A.; ADRIAENS, D.; Ghent University, Belgium; *anabelamaia@gmail.com*

How seahorses hang on to their life

Tail prehension is a common, although poorly studied behavior among seahorses. We investigate this behavior in the potbellied seahorse, *Hippocampus abdominalis*, and the longsnout seahorse, *H. reidi*. *Hippocampus abdominalis* has a slender tail and significantly higher number of tail segments (45-48) than *H. reidi* (33-37). We hypothesize that the tail of *H. abdominalis* would be more flexible than the shorter tail of *H. reidi*. We compared 3D grasping kinematics on a 1cm horizontal perch. In *H. reidi* the whole tail is involved in grasping with an increased range of motion towards the tip. In contrast, in *H. abdominalis* the most proximal third of the tail is not involved in grasping. Still, other kinematic variables are similar for the two species. In addition, both species show lateral bending during tail curling, an unexpected finding that might be important for modulation of grasping in substrates with different orientations, such as corals and seagrasses. Different artificial holdfasts were also tested in a preference study in *H. abdominalis*. Seahorses selected for vertical oriented, cylindrical and smooth holdfasts. However, color (sand vs. green) and holdfast diameter (1 and 1.5cm) were neutrally selected for. Preference for vertical holdfasts is likely a result of the relative abundance of similarly oriented substrates in the wild, and thus selection for lateral bending may have played a role in prehensile tail evolution in seahorses. Pot-bellied seahorses also selected negatively for rough and blade like structures, which is likely explained by increased contact area in smooth, cylindrical surfaces which should facilitate attachment. Negative selection for rough structures seems to indicate that friction mechanisms are not predominant, while selection for higher contact area suggests reliance on wet adhesion and muscular grasping.

P1.81 MAIE, T.*; SCHOENFUSS, H.L.; BLOB, R.W.; Clemson Univ., St. Cloud State Univ.; *maie045@gmail.com*

Musculoskeletal determinants of pelvic sucker function in Hawaiian gobiid fishes: interspecific comparisons, allometry, and many-to-one mapping

Gobiid fishes possess a distinctive ventral sucker, formed from fusion of the pelvic fins, which can be used to adhere to a wide range of substrates including the vertical cliffs of waterfalls during upstream migrations in some species. Previous studies of waterfall-climbing species have found that pressure differentials and adhesive forces generated by the sucker increase with positive allometry as fish grow in size, despite isometry or negative allometry of sucker area. To produce such scaling patterns for pressure differential and adhesive force, waterfall-climbing gobies might exhibit allometry for other muscular or skeletal components of the pelvic sucker that contribute to its adhesive function. Using anatomical modeling, we evaluated the potential for allometric growth in the cross-sectional area, mechanical advantage, and force generating capacity of major protractor and retractor muscles of the pelvic sucker that help to expand the sealed volume of the sucker,,producing pressure differentials and adhesive force. We compared patterns for three Hawaiian gobiid species including a non-climber, a poor climber, and a proficient climber. Scaling patterns were similar for all species, typically exhibiting isometric or negatively allometric scaling for the muscles and lever systems examined. Although these scaling patterns do not help to explain the positive allometry of pressure differentials and adhesive force as climbing gobies grow, the best climber among the species we compared, *Sicyopterus stimpsoni*, does exhibit the highest mechanical advantage, muscular input force, and output force for pelvic sucker retraction at any body size, potentially facilitating its adhesive ability. NSF-IOS 0817911, 0817794.

P2.193 MAINE, AR*; POWERS, SD; LUTTERSCHMIDT, DI; Portland State University, Oregon; *Amaine@pdx.edu*

Seasonal changes in neurogenesis in red-sided garter snakes: Neurons or glial cells?

Seasonal rhythms in physiology and behavior may be regulated by neuroplasticity, including the generation of new cells. In the current study, we investigated whether seasonal variation in neurogenesis (i.e., cell proliferation, migration, differentiation) occurs in the highly seasonal red-sided garter snake (*Thamnophis sirtalis parietalis*). We collected male snakes from the den site during the spring mating season or fall pre-hibernation period and treated them with bromodeoxyuridine (BrdU), a thymidine analog that is incorporated into newly synthesized DNA. Snakes were euthanized at 1, 5, or 10 days post-BrdU treatment and the brains were processed for BrdU immunohistochemistry to visualize newly proliferated cells. Fall-collected snakes had significantly more BrdU-labeled cells in the dorsal cortex ($F= 5.276$; $p= 0.032$), nucleus sphericus ($F= 12.275$; $p= 0.003$), and septal nucleus ($F= 5.357$; $p= 0.033$) than those collected in the spring. Within the nucleus sphericus, significantly more BrdU-labeled cells migrated into the parenchymal layer during the fall ($F= 13.464$; $p= 0.002$). Days post-BrdU treatment did not significantly affect the number of BrdU cells in any brain region. These results suggest that increased neurogenesis during the fall may play a role in preparing for winter dormancy (e.g., neuroprotection). Furthermore, we show that cell migration increases during the fall in the nucleus sphericus, a structure important for processing information from the vomeronasal system. Using double-label immunohistochemistry for BrdU and neuron-specific nuclear protein (NeuN), we are examining whether these newly generated brain cells differentiate into neurons or glial cells. Collectively, these data will provide insight into the functional significance of neurogenesis in a seasonal breeder.

P1.26 MALDONADO, K.*; LÓPEZ-MORGADO, N.; PÍRIZ, G.; ANGUITA, S.; REYES, C.; CHAURA, R.; SABAT, P.; UNIVERSIDAD DE CHILE, SANTIAGO, CHILE, UNIVERSIDAD DE LA SERENA, LA SERENA, CHILE, UNIVERSIDAD AUSTRAL DE CHILE, VALDIVIA, CHILE; *kmaldonado@ificc.cl*

Testing the temporal consistency of dietary individual specialization in Rufous collared-sparrows from different ecological environments: the role of environmental variability

There is increasing evidence that ecological generalist populations, which use a wide diversity of resources, are in fact the sum of specialized individuals. This phenomenon, called individual specialization (IE), promotes frequency-dependent interactions, which may drive evolutionary diversification, and influence population dynamics and ecological interactions. Nevertheless, despite the temporal consistency of IE is crucial to understand these ecological and evolutionary consequences, further research on this topic is clearly required. We investigated the timescales at which dietary IE occurs in bird populations (*Zonotrichia capensis*) that experience different levels of environmental variability –from Desert, Mediterranean and cold-temperate climates. In order to determine the birds' diet at different times, we used stable isotope signatures ($\delta^{15}N$) from tissues characterized by different turnover rates. We found differences in the level of IE among populations; individuals from the cold-temperate site, in contrast to birds from the Mediterranean site, showed a high temporal consistency in their dietary habits. Interestingly, dietary IE did not appear to be maintained over long-term timescales. We suggest that these individual dietary shifts are influenced by seasonal changes in food diversity and intraspecific competition. Funded by Fondecyt 3120229 to K.M and Fondecyt 1120276 to P.S.

17.11 MALEC, A.M.; WILLIS, M.A.*; Case Western Reserve University; *maw27@case.edu*

Overlap between the fore and hind wings in the moth Manduca sexta is different associated with sex and weight in free flight.

Moths and butterflies have four-wings, but most flight studies focus on their forewings and treat them as functionally two-winged fliers. In fact, previous studies showed that a variety of moths and butterflies can fly with their hind wings removed, but are less maneuverable. How the fore and hindwings work together to affect this increased maneuverability is unknown. It is known that the fore and hindwings in male and female moths are linked in anatomically different ways. By studying this natural anatomical difference in fore-hindwing interaction we might reveal how the wings interact in flight. In the moth *Manduca sexta*, females are larger and heavier, on average, than males so comparing the two sexes may provide important clues about how the wings, and the whole moth, operate together to generate the maneuvers we observe. To test the effects of weight, sex, and wind speed on fore-hindwing overlap, we marked male and female moths on the thorax, fore, and hindwings. By measuring the change in angle between the fore and hindwings as moths flew through either 75 cm/s or 150 cm/s winds, we were able to quantify the changes in wing overlap and thus wing area. Regression analyses revealed a significant relationship between wing area and body weight and analyses of covariance showed that this relationship was different in males and females. Further analyses and experiments are ongoing to determine if the observed changes in overlap are actively controlled by the moths or a passive property of the mechanics of the flight system. We thank Jennifer Avondet for her assistance in managing the insect colony and help with all aspects of this project. A.M.M. was supported by the Howard Hughes Medical Institute funded Summer Program in Undergraduate Research. M.A.W. was supported by an Air Force Office of Scientific Research grant FA9550-07-0149.

51.4 MALISKA, ME*; LOWE, E; WEBER, C; PIERCE, T; BROWN, CT; SWALLA, BJ; University of Washington, Michigan State University; *mem24@uw.edu*

Molgulid Ascidians have a Radical Heterochronic Shift in the Metamorphic Gene Network

Transcriptome and genome data offer an exciting new approach to examine the origin and evolution of the chordate body plan. Chordate body plan evolution can be studied with two tunicate species with radically different larval body plans—the tailed ascidian *Molgula oculata* and the tailless *M. occulta*. Tailed *M. oculata* embryo have 40 notochord cells that are converged and extended, tail muscle cells flanking the notochord, and the otolith, a gravity sensory organ located in the head. The tailless *M. occulta* does not form a tail in their larval stage, and have only 20 notochord cells that do not converge and extend during larval development. We show by transcriptome analyses that the ascidian metamorphosis program begins earlier in molgulid ascidians. This radical heterochronic shift has been documented in another tailless ascidian, *Molgula tectiformis*, and is now reported for both the tailed, *Molgula oculata* and tailless *Molgula occulta*. Further functional data is necessary to determine if this pronounced heterochrony is the necessary preadaptation for tailless tadpole to evolve in molgulid ascidians. However, we forecast that these studies will facilitate the elucidation of the metamorphic signal in ascidian tadpole larvae, which is still currently unknown.

P3.109 MALLETTE, S/D*; PABST, D/A; MCLELLAN, W/A; BARCO, S/G; University of North Carolina Wilmington, Virginia Aquarium and Marine Science Center; *sarahmallette@yahoo.com*

Investigation of growth in a coastal apex predator, the bottlenose dolphin (Tursiops truncatus)

The bottlenose dolphin (*Tursiops truncatus*) is a long-lived apex predator that is considered a sentinel of coastal ecosystem health (Reddy *et al.* 2001; Wells *et al.* 2004). The goal of this study is to describe patterns of growth of *Tursiops* utilizing two complimentary methods, ontogenetic allometry and body composition. Ontogenetic allometry describes the rate of growth of a given body component, whereas the body composition technique offers a snapshot of how developmental rates are manifested in the distribution of body mass over time (McLellan *et al.* 2002). The dataset consists of 175 stranded individuals and specimens incidentally killed in fishing operations, collected along the coasts of NC and VA, from 1990 to the present. All specimens have undergone a systematic mass dissection protocol, which separates of the body into discrete anatomical components, including: integument and blubber, functional muscle groups, viscera, and skeleton. To determine how the body conditions of the specimens in this sample compare to those of wild, free swimming *Tursiops*, a body mass index, (total body mass/total body length^2 * 1000) (Schwacke *et al.* 2011) will be used to compare the stranded sample to analogous data collected from wild individuals during health assessments in Beaufort, NC and Sarasota Bay, FL. This study will contribute a comprehensive analysis of growth in *Tursiops* and provide a quantitative baseline reference for the distribution of body mass to its components in a sentinel species of ecosystem health.

85.3 MANAHAN, D.T.*; HEDGECOCK, D.; Univ. Southern California; *manahan@usc.edu*

Developmental physiology: Predicting "Winners and Losers" to environmental change

Physiological variance is clearly evident in the biological responses of conspecifics to changing environmental conditions. This variance cannot fully be attributed to experimental error - some of the variance likely represents underlying, genetically-determined variation in physiology and therefore a potential basis for an evolutionary adaptive response to environmental change. Understanding how developmental stages function under various scenarios of environmental change will require a merging of physiological (phenotypic), genetic, and environmental information - i.e., Phenotype = Genotype + Environment + Genotype-by-Environment Interaction. Variance in components on the right hand side of this equation could give rise to adaptive phenotypes of "Winners" regarding tolerance to environmental change. Of particular importance is the genotype-by-environment component, which heretofore has received less attention in marine larval biology but bridges genetics and physiology to provide new insights into adaptive mechanisms. We have studied genotype-by-environment interactions in larval stages of the Pacific oyster *Crassostrea gigas*. This species has genetic and genomic resources that are unparalleled for most marine animals and permit cross-generational experiments because of the availability of purebred lines. Contrasting larval phenotypes have been used to study the physiological, biochemical, and global gene-expression bases of potential "Winners and Losers." Such experimental approaches offer the potential of improving predictions through a mechanistic understanding of the physiological and genetic bases of biological adaptation to changing environmental conditions.

P1.79 MANDECKI, J.L.; The University of Chicago; *jmandecki@uchicago.edu*

Retinal topography in pectoral fin swimmers

Most vertebrates engage in a repertoire of eye movement behaviors that includes spontaneous rapid eye shifts called saccades. In foveated animals, saccades function to target objects by placing a desired image on the retinal area most densely packed with photoreceptors. Though few fishes have a true foveal pit, fish retinas do often contain one or more regions of high photoreceptor or ganglion cell density, which are typically associated with habitat and behavior. In fishes with limited retinal specialization, the role of saccades is thought to shift to scanning the environment. I have previously found that saccades in surfperches (Teleostei: Embiotocidae) tend to be timed to abduction of the pectoral fins during steady swimming and that the strength of this behavioral coordination lies on a spectrum that is loosely related to feeding strategy. Because retinal topography has not been studied in surfperches, here I investigate whether eye-fin coordination behavior is associated with a particular topographic pattern in the retina. Staining for ganglion cells reveals that coordination behavior may be linked to the presence of specific high-cell-density regions, and further work will strive to untangle these associations. Studies of retinal topography are important for understanding both an organism's visual capabilities and how the organism may be perceiving its environment. This material is based upon work supported by the National Science Foundation under Grant Nos. DGE-0903637 and DEB-0844745.

P1.175 MANGIAMELE, L.A.*; KEENEY, A.D.T.; D'AGOSTINO, E.N.; THOMPSON, R.R.; Bowdoin College, Brunswick, ME; *lmangiam@bowdoin.edu*

Pheromone exposure influences preoptic arginine vasotocin gene expression and inhibits social approach behavior in response to rivals, but not potential mates

The nonapeptide arginine vasotocin (AVT) mediates a variety of social behaviors in non-mammalian vertebrates. In fish, AVT stimulates the aggressive and courtship responses typical of dominant males in several species, although it can also inhibit social interactions in some cases. Such differential effects may depend upon AVT influences within brain circuits that differ among species or between males that adopt alternative reproductive phenotypes and/or upon the differential activation of those circuits in different social contexts. However, to date, very little is known about how social stimuli that provoke alternative behavioral responses influence AVT circuits within the brain. To address this issue, we exposed adult male goldfish to androstenedione (AD), a pheromonal signal that is released by both males and females in the context of reproduction, and measured social approach responses of males towards same- and other-sex individuals before and after AD exposure. In a second experiment, we also measured AD-induced AVT gene expression using *in situ* hybridization. We found that brief exposure to AD induces social withdrawal in response to rival males, but does not affect the level of sociality exhibited in response to sexually receptive females. Exposure to AD also increases AVT gene expression in the preoptic area of male goldfish, particularly in the parvocellular population of the preoptic nucleus. Together, these data suggest that AD is part of a social signaling system that induces social withdrawal specifically during male-male interactions by activating the parvocellular AVT circuit.

47.5 MANN, W*; BURGE, C; MYDLARZ, L; The University of Texas at Arlington, Cornell University; *wtmann@uta.edu*

The Effects of Climate Change on the Immunocompetence of the Caribbean Sea Fan Coral

Effects of climate change have been shown to negatively affect a multitude of organisms causing increases in disease prevalence, mortality, and ultimately changes to the biodiversity and structure of ecosystems. This is especially true for coral reefs. We hypothesize that the effects of climate change, such as elevated sea surface temperatures are compromising the immunity of corals leading to disease outbreaks. In this study, we examined the immunocompetence of the Caribbean sea fan coral, *Gorgonia ventalina* under natural and experimental temperature stress. Naturally stressed sea fans were collected during an abnormally warm year (2010) where temperatures remained elevated (>29°C) for 12 weeks or longer. To examine short term thermal stress, sea fans were also exposed to elevated temperatures in the lab for a period of 18 days. Immune responses were quantified using a suite of biochemical assays examining antioxidant, antimicrobial, protease inhibitor and melanization activity of crude protein extracts. Both experiments exhibited significant decreases in the various measures of immunity with the natural temperature stress having the most dramatic effect. Considering the increase in disease prevalence of corals, the data suggest that elevated sea surface temperatures are affecting the immunocompetence in corals that may lead to disease susceptibility. With the current trends of climate change, where temperatures are expected to continue increasing, incidences of coral disease and mortality rates are likely to continue increasing. It is imperative to continue to look at effects of climate change on corals in order to develop mitigation and management tools for coral reef conservation.

P1.75 MANSFIELD, S*; EVANGELISTA, D; Univ. of California, Berkeley; *devangel77b@gmail.com*

Design of a phased array acoustic tracking system for flight biomechanics tracking studies

We are developing a phased array acoustic tracking system intended for use in several types of biological study: 1) biomechanical studies of flying animals in which the trajectory and data about wingbeat frequency and movement is needed; 2) ecological studies of acoustic communication or behavioural ecology; 3) surveys to count and locate species based on audible calls. Other uses are also possible. A phased array uses the phase or time difference of arrival of sound at multiple microphones to estimate position of a sound source, such as a wingbeat, chirp, whistle or other acoustic signal. The prototype system consists of multiple microphone and amplifier boards connected via an analog-to-digital converter to a computer that performs the phased array signal processing. The end goal is a low cost system, portable and field-deployable by a single researcher, and an open source, modular design able to be modified or scaled up or down or combined according to the needs of individual researchers and the constraints of particular projects. The current design, remaining design challenges, and preliminary performance in tracking of flying animals will be discussed.

138.5 MANTILLA, D.C.*; HOYOS, J.M.; Florida International University, Miami, Pontificia Universidad Javeriana, Bogota, Colombia; *dmant010@fiu.edu*

Myolgy of the Foot-Leg Mechanical Unit of Anolis antonii (Boulenger, 1908) (Squamata, Polychrotidae)

Understanding the morphological characteristics of an organism opens the possibility of making future morphofunctional and systematic studies. The aim of the present study is to define the general myology of the foot-leg mechanical unit of the lizard *Anolis antonii* (Boulenger, 1908). This was done by the observation of the leg and foot muscles with a stereoscope, their description by dissecting them, their identification, and their comparison with the available literature. We identify foot and leg muscles as well as the ones belonging to the foot-leg mechanical unit, and describe two new muscles which we name: *m. extensor digitorum brevis profundus IV* and *m. extensor digitorum brevis profundus IV-V*. Our observations and comparisons indicate several differences between the descriptions of the literature and the ones suggested in the present paper. This new information may have great potential systematic value, since it can be considered as characters for future cladistic studies to assess whether they are synapomorphies or autapomorphies, and may serve as a starting point in biomechanic studies.

P2.82 MANZO, W.J.*; GARDNER, E.; MENON, J.; William Paterson University; *menonj@wpunj.edu*

Programmed cell death by reactive oxygen species in tail of tadpoles, Xenopus laevis

During metamorphosis, anuran tadpoles undergo morphological, biochemical and physiological changes in order to adapt to a different habitat. The process involves reorganization of the body plan and regression of the tail which are controlled by several pathways of apoptosis including autophagy. Autophagy induces cell death in regressing tail in response to reactive oxygen species (ROS). Several antioxidant systems regulate the presence of oxidant species such as superoxide dismutase (SOD), glutathione, ascorbic acid, catalase etc. Nitric oxide synthase(s) (NOS) leads to production of nitric oxide (NO), a free radical, important in cellular signaling. We performed a cellular, biochemical and molecular analysis of SOD, catalase, NOS, *in situ* staining for NO and mitochondria in the tail of tadpoles *Xenopus laevis*. NO also has profound effect on the mitochondrial function as mitochondria possess their own NOS enzyme. Spatiotemporal distribution of SOD and catalase showed significant co-localization (overlap coefficient of 95%) during earlier stages of metamorphosis. However, during climax (just before the tail regression begins), there was a significant decrease in activity of these enzymes as well as reduction in overlap coefficient (49%) which suggests an elevated ROS accumulation. Expression for nNOS and iNOS was found to be stage specific and both enzymes co-localized in epidermis and muscle tissue of tail, their expression being controlled by thyroxin as evidenced by RT-PCR studies. Additionally, NO and mitochondrial staining also shows co-localization suggesting that NO is derived from mitochondria. These findings are discussed in terms of putative functional importance of ROS and mitochondria derived NO in programmed cell death in tail tissue.

138.2 MARA, K.R.*; HSIEH, S.T.; Temple University; *kylemara@temple.edu*

Differentiating slip perturbation recoveries from falls in bipedally-running lizards.

In nature, animals often encounter unsteady or unpredictable surfaces that they must counteract to maintain locomotor stability. Yet, the recovery mechanisms aiding restabilization remain under studied. The goal of this study was to describe the recovery kinematics that lead to successful slip recoveries compared to falls in the bipedally-running frilled lizard (*Chlamydosaurus kingii*). Lizards were run along a 2.5 m trackway and filmed with a six-camera auto tracking system (Motion Analysis Corp). Each lizard was run on a full-traction surface, as well as one in which we embedded an obscured low-friction surface. Trials were divided into three groups for analysis: steady-state unperturbed, successful recoveries, and falls. When lizards successfully recovered from a slip, perturbation compensation occurred rapidly and locomotor kinematics returned to unperturbed, steady-state values within one stride. Successful recoveries differ from falls by the proportion of ground contact time (duty factor), absolute slip surface contact time, and total displacement of the perturbed foot. In all perturbed trials, stride frequency increased relative to steady-state running, independent of the outcome. When lizards fell, the duty factor of the unperturbed foot (0.50 ± 0.058 SD) was significantly greater than that during steady-state (0.43 ± 0.10) or recovery (0.34 ± 0.19) trials. However, the duty factor of the perturbed foot was greater during falls (0.41 ± 0.12) than recoveries (0.32 ± 0.07) but no different than steady-state trials. Total translation distance of the perturbed foot appears to be an important factor determining perturbation outcome as falls coincided with the perturbed foot slipping significantly further (56.89 ± 4.82 mm) and for longer (0.067 ± 0.026 s) than in recovery trials(38.55 ± 16.48 mm; 0.053 ± 0.010 s).

P3.97 MARCROFT, TA*; MODLIN, J; SLATER, G; VAN WASSENBERGH, S; SANTINI, F; ALFARO, ME; Univ. of California, Los Angeles, Smithsonian Institution, University of Antwerp, University of Torino; *tmarcroft@ucla.edu*

Functional consequences of carapace shape diversity in boxfishes

The carapace is a hard structure, similar to that of a turtle, which encases boxfishes and comes in a variety of shapes. Boxfish are composed of two families: the aracanids, which primarily consist of disk and tube-like shapes, and the ostraciids, which consist of prism, box, and bell-like shapes. This diversity in shape might be explained by its multiple functions, i.e. its hydrodynamic abilities and its ability to distribute stress. The carapace's many keels are implicated in creating stabilizing forces via vortices shed posteriorly. We suggest that the boxfish carapace may have initially served as a defensive structure, but recently its function was altered for hydrodynamic stability and/or maneuverability, reflected in the aracanid-ostraciid split. We hypothesized that these two functions trade-off, i.e. stabilizing well means being less able to distribute stress and vice versa. We actually found that the association between the two functions and their morphologies is more complex. We found strong correlation between lift, lift/drag and morphology, suggesting maneuverability rather than stability explains some of the variation. While we did find a trade-off in function between two major carapace shapes, we also found that some shapes minimize performance in multiple orientations, but not as strongly as in extreme cases.

P2.111 MARELLI, C.A.*; SIMONS, E.L.R.; Midwestern Univ., Midwestern Univ. ; *cmarelli64@midwestern.edu*

Microstructure and cross-sectional shape of limb bones in Great Horned Owls and Red-tailed Hawks: how do these features relate to differences in flight and hindlimb usage?

The Red-tailed Hawk (RTH) and Great Horned Owl (GHO) are two species of raptor that are similar in body size, have generalized diets, and often occur sympatrically. The RTH is active during the day and the GHO is nocturnal. They also differ in primary flight style; the RTH uses static soaring and the GHO uses flap-gliding. Both species use their hindlimbs to catch prey, but the RTH uses rapid leg movements, whereas the GHO uses high force grip. The objectives of this study were to characterize the microstructure and cross-sectional shape of limb bones of these species and examine the relationship with flight and hunting behaviors. The mid-shaft of four limb bones (humerus, ulna, femur, tibiotarsus) from 6 individuals of each species was sampled and prepared histologically. The laminarity (proportion of circular primary vascular canals) and cross-sectional parameters (measure of the amount and distribution of cortical bone: cortical area, second and polar moments of area) were calculated. As predicted, the forelimb elements and femur in both species exhibit higher laminarity than the tibiotarsus. The humerus and femur also exhibit higher polar moment of area, suggesting a higher resistance to torsional loading. The tibiotarsus has a larger relative cortical area than other bones, suggesting better resistance to compressional loads. Between species, the laminarity of the RTH femur is higher than that of the GHO. The femur of the RTH is more circular and the tibiotarsus is more elliptical than that of the GHO. Although the species use different flight modes, the microstructure and shape of forelimb bones is quite similar. Differences among hindlimb elements may reflect different methods of capturing prey.

P3.53 MARION, ZH*; PAULY, GB; FORDYCE, JA; Univ. of Tennessee, Knoxville, Nat. Hist. Mus. of Los Angeles; *zmarion@utk.edu*

Quantifying the variation in antipredator chemotypes among populations of western toads (Bufo boreas)

The majority of chemical research on antipredator adaptations has concentrated on the effects that individual chemical compounds have on ecological and evolutionary interactions. Yet many, if not most, chemical defenses consist of complex blends of multiple interacting compounds that vary qualitatively (i.e, molecular structure) and quantitatively (i.e., concentrations or total amounts) in effectiveness. Unfortunately, the multivariate nature of complex integrated phenotypes are often ignored, especially within the chemical defense literature. In this study, we collected parotid secretions from individuals from multiple populations of western toads in the *Bufo boreas* species complex across their range and analyzed their defensive chemotypes via HPLC. We then applied multivariate statistical methods traditionally used in the analysis of ecological community composition and species diversity to document the variation and diversity of defensive chemicals within and among toad populations. We show that substantial variation exists both in the total quantitative amount of cardiac steroids (bufadienolides) in toads but also in terms of chemical diversity, especially among calling and non-calling populations.

23.6 MARK, MM*; RUBENSTEIN, DR; Columbia University; *mark.melissa@gmail.com*

Interspecific brood parasitism prolongs parental care and increases the stress response in a tropical songbird

Interspecific brood parasitism in birds negatively affects parental fitness by reducing current reproductive success, but its impact on future reproduction has been rarely tested. Glucocorticoid stress hormones often mediate the trade-off between current and future reproduction by mobilizing resources towards parental care or self-maintenance. To determine if brood parasitism alters the trade-off between current and future reproduction, we measured parental care behavior and glucocorticoid levels in nestlings in the Neotropical host-parasite system of the striped cuckoo (Tapera naevia excellens) and the rufous and white wren (Thryophilus rufalbus) during three reproductive stages: incubation, nestling, and fledgling. We found that foster parents of cuckoo chicks had significantly higher levels of stress-induced, but not baseline, corticosterone during the post-fledging stage. Higher maximal levels of stress-induced corticosterone were associated with an increase in parental care. Foster parents delayed re-nesting due to prolonged care of a cuckoo chick and were less likely to return to nest the year following a parasitism event. Together, these results suggest that foster parents express higher parental investment in cuckoo chicks than their own chicks, mediated by corticosterone, and that parasitism reduces opportunity for future reproduction.

92.3 MARKER, N.*; AYERS, A.; University of Hawaii at Manoa; *nmarker@hawaii.edu*

Evaluation of the Undergraduate Research and Mentoring in the Biological Sciences (URM) program in Hawaii

In 2008, the Pacific Biosciences Research Center at the University of Hawaiʻi at Mānoa was awarded a five-year grant to administer the Undergraduate Research and Mentoring in the Biological Sciences (URM) program from the National Science Foundation (NSF). The goal of the URM program is to increase the number and diversity of individuals pursuing graduate studies in all areas of biological research. The Hawaiʻi URM faces the challenge of teaching science and research to students from diverse cultural backgrounds, and seeks to help students develop skills and knowledge to prepare for a graduate education that could address pressing environmental issues across the Pacific. The Social Science Research Institute (SSRI) at UH-Mānoa was contracted to conduct a formative and summative evaluation of the URM program. Evaluators developed a protocol designed to gauge changes in the program and in student progress over time. Data were collected through pre- and post-tests, case study interviews, and observations. The evaluation looks at student academic success, and the students' and mentors' attitudes, beliefs and perceptions of the program. Summary findings from four years of evaluation of this undergraduate mentoring program for minority students in the environmental sciences will be presented. The wider implications of these findings, with respect to the relative strengths and weaknesses of mentoring approaches to teaching science, will also be discussed.

P3.160 MARRANZINO, AN*; FRANK, MM; LINDEMANN, SD; GUIFFRIDA, BA; SIPPER, K; WEBB, JF; MENSINGER, AF; Regis Univ., Denver, CO, St. Olaf Coll., Northfield, MN, Univ. of Minnesota, Duluth, Wareham Middle School, MA, Northern Michigan Univ., Marquette, Univ. of Rhode Island, Kingston, Univ. of Minnesota, Duluth; *marra938@regis.edu*

Functional morphology of cephalic protuberances in the oyster toadfish, Opsanus tau

The oyster toadfish, *Opsanus tau*, is an important model organism for muscle and sensory physiology. However, the roles of two prominent anatomical features on the head of the fish remain unknown. These include multilobed protuberances, or cirri, that project primarily from the lower jaw and simpler, paired projections termed papillae that surround superficial neuromasts. Scanning electron microscopy (SEM) and light microscopy (LM) were used to investigate the morphology and potential functional significance of these structures. It has been proposed that the cirri serve a mechanosensory function, but both SEM and LM failed to reveal neuromasts. However, domed structures with apical microvilli seen with SEM, were determined to be bulbiformous organs using LM. These organs were similar to type II taste buds, suggesting a putative gustatory role for the cirri. *O. tau* has a reduced number of anterior canal neuromasts (which detect water acceleration). However, numerous superficial neuromasts (which serve as velocity detectors) are present, and flanked by linguiform protuberances. It has been proposed that these papillae protect the neuromasts from the loose sediment that characterizes the fish's benthic habitat. The papillae may also channel water over the neuromasts, possibly allowing them to function as canal neuromasts. SEM revealed that hair cell orientation in these superficial neuromasts was parallel to the channel formed by the papillae, supporting this hypothesis. Supported by NSF REU 1005378 (AFM), and the Coll. Environment & Life Sciences, URI (JFW).

P2.126 MARSHALL, C.D.*; ROSEN, D.A.S.; TRITES, A.W.; MARSH, A.; Texas A and M University, University of British Columbia; *marshalc@tamug.edu*

Feeding and Suction Performance in Two Basal Otariid Pinnipeds

Feeding performance studies can address questions relevant to foraging ecology and evolution among vertebrates. Trials were conducted to characterize the feeding kinematics and suction performance of Steller sea lions (SSL) and northern fur seals (NFS). We collected behavioral, kinematic and physiological data to test the hypothesis that both species use suction as their primary feeding mode. Food items were presented to the subjects using a platform designed to capture simultaneous frontal and lateral views of feeding events via an underwater video system. Footage was analyzed field-by-field, and suction was measured using a pressure transducer connected to a portable electrophysiological recording system. SSL used suction as their primary feeding method, but also used a bite behavior. In contrast, NFS used a snapping bite in combination with a head strike as their primary feeding mode. Pressure recordings did not detect any measureable subambient pressure forces during NFS feeding events. NFS exhibited a greater gape, a greater gape angle, and a shorter depression of the hyolingual apparatus compared to SSL. The evolution of these divergent prey capture tactics likely constrains the type and size of prey that can be captured, as well as foraging success. The use of head strikes and biting by NFS is likely an adaptation for capturing more elusive prey found in open-ocean mesopelagic habitats. The greater feeding repertoire of SSL likely enables them to feed on a greater variety of prey and prey sizes, in more diverse habitats. Suction feeding behavior by SSL likely increases the capture success of more cryptic, benthic and dermersal fishes.

13.11 MARSHALL, H.M.*; BRILL, R.; BUSHNELL, P.; SKOMAL, G.; BERNAL, D.; University of Massachusetts Dartmouth, Virginia Institute of Marine Science/NOAA, Indiana University South Bend, Massachusetts Division of Marine Fisheries; *hmarshall@umassd.edu*

Comparison of fishing-induced stress response and post-release mortality between sandbar (Carcharhinus plumbeus) and dusky (Carcharhinus obscurus) sharks

In recent years, exploitation of many shark species has incited management organizations to revise commercial fisheries management plans (FMPs) with the hopes of conserving shark populations. Specifically in the western Atlantic, amendments to the Consolidated Highly Migratory Species FMP demand the post-capture release of several coastal species, including the sandbar (*Carcharhinus plumbeus*) and dusky (*C. obscurus*) sharks (Family Carcharhinidae). Although these FMPs are designed to conserve populations, they result in an increased number of sandbar and dusky sharks being released after capture. Research on fishing-related stress indicates that the survival of released fish after capture is not well understood. This study investigates stress response in sandbar and dusky sharks after longline capture, and subsequent post-release mortality. Pop-up Satellite Archival Tags were used to determine post-release survival of sharks after capture on longline gear, and blood stress parameters (electrolytes and metabolites) were collected from each fish. Post-release mortality appears to occur more often, after shorter capture times, in the dusky versus the sandbar shark. In addition, at-vessel mortality occurs after ~3 hours on the longline in the dusky shark. Regression analysis reveals a significant ($p<0.05$) correlation of increasing levels of sodium, potassium, glucose, and lactate with soak time in the dusky shark, whereas the sandbar shark did not show any correlation. Physiology of the dusky shark seems greatly affected by capture, relative to sandbar sharks, resulting in higher rates of at-vessel and post-release mortality.

104.4 MARSHALL, K.E.*; THOMAS, R.H.; ROXIN, A.; CHEN, E.K.Y.; BROWN, J.C.L.; GILLIES, E.R.; SINCLAIR, B.J.; University of Western Ontario, University of Toronto; *kmarsh32@uwo.ca*

The goldenrod gall fly's liquid little secret: 3-acetyl-1,2-diacyl-sn-glycerols are associated with natural survival of intracellular freezing in Eurosta solidaginis

The fat body cells of the goldenrod gall fly *Eurosta solidaginis* have the unusual ability to naturally withstand intracellular ice formation (IIF). To date, no unique compounds associated with natural IIF survival have been identified for any animal. Here we show that *E. solidaginis* seasonally synthesizes an unusual class of neutral lipid, 3-acetyl-1,2-diacyl-*sn*-glycerols (acTAGs). acTAGs are accumulated in preparation for winter and at their peak concentration comprise over 36% of the insect's neutral lipid pool while long-chain TAGs (lcTAGs) comprise only 17% percent (by molarity). The acTAGs have a low melting point (-17 °C), and are therefore expected to remain liquid at temperatures where the cells freeze. These acTAGs are not found in other cold tolerant insects, and are not present in the *Solidago* spp. host or other members of the gall community. In addition, the amount of acTAGs increases when repeatedly frozen, and when added to saline, acTAGs lower the melting point of the resulting emulsion. We suggest these properties are consistent with a role as a candidate molecule for IIF survival.

P1.6 MARSON, K.M.*; ANDERSON, C.; KLEIN, A.; COOK, M.; EARLEY, R.L.; University of Alabama, Tuscaloosa; *krismars02@yahoo.com*

Female Ornaments and Male Mate Choice in Convict Cichlids

Females of the monogamous, pair bonding convict cichlid (Amatitliania siquia) possess carotenoid-based coloration on their ventral integument, which has been hypothesized to serve functions in intrasexual and intersexual signaling. We hypothesized that variation in female orange patch size might reflect variation in female quality and that males would prefer to pair bond with more highly ornamented females. We established triads of two size-matched females with one male that was at least twenty percent larger than the females. Females were either matched or mismatched for orange patch size. The male and females interacted freely under one of two light conditions - full spectrum lighting with either a clear filter (full transmittance) or a green filter (prevented transmission of orange wavelengths). Behavior was quantified for 15-minute increments at 0815 and 1515 daily for 10 days. Courtship and aggressive behaviors, as well as the identities of the interacting fish, were recorded. Pair bonds were said to have occurred if the male and one female spent the majority of their time together with very little aggression for three consecutive days. Once a pair bond occurred, the non-pair bonded female was removed and after 10 days the reproductive success of the pair was determined by counting the number of eggs or fry. We predicted that males would choose the female with the largest orange patch and that latency to pair bond formation would be shortest in full-spectrum light with mismatched orange patch size. We also predicted offspring number would be highest in pair bonds involving females with large orange patches. If female traits relate to male mate choice in this reversed sexually dimorphic species, we stand to gain a deeper understanding about the dynamics pair bond formation.

S3-1.5 MARTIN, K.L.*; MORAVEK, C.L.; CARTER, A.L.; Pepperdine Univ., Pepperdine Univ. , Charleston Southern Univ.; *kmartin@pepperdine.edu*

Brave New Propagules: Terrestrial Embryos of Aquatic Fish

Species within many lineages of teleost fishes reproduce terrestrially, despite lacking the key evolutionary innovation of the amniotic egg. In contrast with shelled eggs of reptiles and birds, the anamniotic eggs that contains an embryo of a fish or amphibian is typically much smaller and enclosed in relatively simple membranes. Anamniotic embryo incubation duration is usually brief and hatchlings arrive as larvae rather than juveniles. Advantages of terrestrial incubation include the increased availability of warmer temperatures and higher oxygen levels that may speed development, while disadvantages include desiccation, exposure to novel predators and pathogens, and the risk of hatching into a hostile habitat. In most species of teleosts that nest terrestrially or semi-terrestrially, adults are fully aquatic, and resultant hatchlings often require the return to an aquatic habitat. However, some amphibious teleost fishes not only incubate eggs in air but also emerge out of water as adults and may be active terrestrially. Providing the appropriate incubation conditions and maternal investment for a fish embryo in a terrestrial environment is challenging, and most teleost examples occur in the marine intertidal zone, with its predictable ebbing and flooding of seawater. Examples of terrestrially breeding freshwater teleosts and their habitats will be provided for contrast and comparison with examples of terrestrial incubation among amphibian taxa. The selection pressures leading to successful nesting and early development out of water for fish and amphibians may provide numerous alternate routes to vertebrate land invasion, even if only for the early portion of the life cycle.

1.6 MARTIN, K.L.; Pepperdine Univ.; *kmartin@pepperdine.edu*

Seas of Sand, From Desert to Beach: Sand as a Nesting Habitat for Fish, Turtles, and Tortoises

Deserts and beaches are both characterized by sandy substrates, abundant sunshine, minimal fresh water, and desiccating terrestrial conditions. Surface substrates in these highly variable habitats experience rapid diurnal changes in temperatures, a propensity for wind transport, and a dearth of attached plants. In spite of the harsh physical conditions, beaches and deserts both support diverse forms of vertebrate life at all stages of growth and development. In these highly variable ecosystems, nesting within or beneath the surface of the substrate of beach or desert sand may provide the embryos with protection, thermal stability, and other potentially beneficial conditions. However, survival is constrained by temperature-driven sex determination, and threats such as vulnerability to predators, desiccation, pathogens, and the potential for flooding and oxygen deficit. Some ecological advantages and consequences of egg burial in beaches and desert sand will be compared for example species of marine fish, sea turtles, and desert tortoises.

P3.134 MARTIN, GG*; VALK, J; Occidental College, Los Angeles; *gmartin@oxy.edu*

The Peritrophic Membrane of the Giant Keyhole Limpet

Peritrophic membranes are acellular wrappers secreted by the gut epithelium around ingested materials and persisting to package fecal pellets. They may serve to protect the gut from abrasive items such as sand grains, protect against pathogen penetration, and may bind enzymes related to digestion. Peritrophic membranes are most common and most thoroughly studied in insects and to a lesser degree in crustaceans. They are barely mentioned in mollusks aside from basic descriptions by Peters (1992). We have observed transparent peritrophic membranes up to 7cm long extending from the dorsal shell hole in the giant keyhole limpet *Megathura crenulata*. A limpet will produce 1-2 membranes per week whether fed or not. They are composed of chitin based on 1) their insolubility in concentrated KOH, 2) staining with PAS and the lectin WGA which is specific for n-acetyl-glucosamine, the monomer of chitin, 3) digestion in chitinase but not protease, cellulose or cellulase. They are secreted by the distal third of the intestine although these epithelial cells do not show morphological features distinct from adjacent cells in anterior regions of the gut. Electron microscopy reveals a fibrillar network which seem to block penetration of materials larger than 0.5 um. Clean peritrophic membranes from starved animals were incubated with calcofluor, SDS, guanidine HCl, urea, and Congo red dye, agents shown to detach associated protein from membranes in insects. We will present preliminary attempts to identify these proteins by SDS-PAGE and Western blot analysis and compare them to proteins associated with membranes produced in other taxa.

P3.47 MARTIN, G.G.*; KELLY, T.J.; SAFRAN, R.; Occidental College, Los Angeles; *gmartin@oxy.edu*

Response of the Giant Keyhole Limpet to Major Blood Loss

Stellar Biotechnologies Inc. routinely bleeds limpets *Megathura crenulata* in order to extract and purify keyhole limpet hemocyanin (KLH), the respiratory pigment of the limpet. KLH is a molecule used in studies in vertebrate immunology, specifically in the treatment of cancers and allergies. One half of the limpet's body weight is blood and approximately 50% of that may be withdrawn as a non-lethal bleed. This sets up an unusual situation for an animal that uses blood as its hydrostatic skeleton. Before and after a bleed the osmolarity of the blood and the concentration of hemocytes and KLH remain constant the total volume of blood is decreased. This prompts the question: when will body weight and blood volume return to pre-bleed levels? In our closed aquaria, this is a slow process. Weight increases slowly over several weeks presumably through an influx of seawater. This dilution of the blood should trigger production of hemocytes and KLH. We determined that there was an increase in hemocyte cell division 48 hours post bleeding followed by a return to pre-bleed level by the end of the first week. KLH levels showed no change. However, without a significant increase in body weight should there be a trigger to stimulate KLH synthesis? With the loss of so much oxygen carrying capacity, does the limpet need to resort to anaerobic metabolism? We are testing for indicators of this shift, such as succinate. We have also developed a procedure to bleed a limpet and then replace the lost volume with culture medium. This drops the THC and KLH levels to half their initial concentrations, yet maintains the pre-bleed hemolymph osmolarity. In preliminary trials, limpets have survived and were able to maintain their pre-bleed body weights. We will report on the response of hemocyte division and KLH synthesis to this novel transfusion.

14.5 MARTIN, CH*; WAINWRIGHT, PC; University of California, Davis; *chmartin@ucdavis.edu*

Multiple fitness peaks on the adaptive landscape drive the evolution of novel ecological niches within a recent sympatric adaptive radiation of Cyprinodon pupfishes

Multiple fitness peaks corresponding to ecological opportunities are thought to be the major force driving niche diversification during adaptive radiation. Here we measured a large portion of the adaptive landscape within a 10,000-year-old radiation of *Cyprinodon* pupfishes endemic to San Salvador Island, Bahamas from the growth and survival of 1,865 F2 hybrids placed in field enclosures in two lakes. We found that hybrid phenotypes corresponding to the abundant generalist species sit atop an isolated fitness peak separated by a valley from a higher fitness peak corresponding to the hard-shelled prey specialist species. We confirmed experimentally the presence of multiple fitness peaks in sympatry driven by increased competition in high-density field enclosures, strongly supporting the early burst model of adaptive radiation. Furthermore, this striking multi-peak landscape explains both the rarity of trophic specialists across the Caribbean due to stabilizing selection on generalist founding populations and the rapid increase in morphological diversification rates of specialists due to the higher fitness of the specialist peak.

107.4 MARTIN, RA*; LANGERHANS, RB; NIMBioS, North Carolina State Univ.; *ryanandrewmartin@gmail.com*

Piscivorous fish in a fishless environment: dietary and phenotypic differentiation of bigmouth sleepers in Bahamas blue holes

Ecology's role in driving predictable differentiation between populations is a central topic in evolutionary ecology. Based on a priori knowledge of theory and natural history, just how predictable are organism's responses during times of ecological change? Here, we use the model system of inland blue holes in the Bahamas to test the predictability of dietary, demographic, and phenotypic differentiation following the invasion of an otherwise fishless environment by a piscivorous fish, the bigmouth sleeper (*Gobiomorus dormitor*). In its ancestral environment of coastal streams and lakes, the bigmouth sleeper is a benthic, ambush predator, feeding primarily on fish and large invertebrates. On Andros Island, The Bahamas, bigmouth sleepers have colonized numerous land-locked blue holes. These isolated blue holes harbor depauperate fish communities, with bigmouth sleeper often co-occurring with only one other fish species, the small, livebearing Bahamas mosquitofish (*Gambusia hubbsi*). However, bigmouth sleepers inhabit two isolated blue holes in which no other fish species are present. Without any potential fish prey (other than cannibalism), how has their diet diverged? And has this shift in ecological environment driven changes in population and phenotypic characters, such as density, habitat use, size structure, sex ratio, feeding performance, and locomotor and trophic morphology? We first use existing ecological and biomechanical knowledge to build a set of predictions for ecological differentiation, and test them using comparative and experimental approaches. We find that bigmouth sleepers have diverged in many ways between populations with and without potential fish prey, mostly (but not always) in manners consistent with our predictions.

127.2 MARTIN, P; Humboldt University, Berlin; *Peer.Martin@alumni.hu-berlin.de*

The relevance of parthenogenesis to the role of Marmorkrebs as a model organism and potential invader

Animals as model organisms are indispensable tools for life sciences and thus a series of species have been firmly established in research for this purpose. Nevertheless, genetic differences between individuals often bias the results and therefore genetically identical organisms are more and more in demand as laboratory objects. Here, the use of asexual organisms would provide an opportunity. However, parthenogenetic animals are relatively rare, in particular those that combine a high reproduction rate and a complex organization. In addition, not all forms of parthenogenesis lead to genetically identical progeny. In the automictic mode, for example, meiosis occurs and diploidy is then restored by fusion between two of the resulting haploid nuclei. Thus, the genetic composition of automictically produced progeny is not absolutely identical because of recombination by crossing over during the reduction division. In contrast, Marmorkrebs propagate apomictically, i.e. meiosis is completely suppressed. The progeny develop directly from unreduced oocytes and therefore all offspring are true clones of their mother. In addition, Marmorkrebs are very robust and have a high reproductive rate and so they are very suitable as experimental animals for a number of questions. However, the advantages of apomixis for its use as a model organism are counter-balanced by the fact that this reproduction mode also makes Marmorkrebs an effective invader. Due to the parthenogenesis only a single individual is able to found a new population. Furthermore, the apomixes protects the clones from the effects of low population size such as bottlenecks, inbreeding depression and genetic drift and this enables the Marmorkrebs to also conquer areas which provide less favourable living conditions.

P3.17 MARTIN III, A.L.*; BOURCIER, T.; Saginaw Valley State University; *almarti2@svsu.edu*

Effects of Flow on Social Structure

Agonism influences the development of social status amongst animal conspecifics. These interactions structure the social dynamics that develop within a population. A variety of factors influence the outcome of social interactions such as size of conspecifics, sex, resource availability, and environmental dynamics. Environmental factors, including flow and shelter availability, dramatically influence and alter fight interactions between individuals, which will influence population social structure. These external factors influence an animal's decision by modifying signals during communication and an increased resource value may influence competition. Environmental factors influence behavior by altering the agnostic interactions that structure social dynamics. Flow is a very important environmental factor in a lotic environment. Knowing how these factors influence agonism and their impact on structuring social dynamics, we will be able to better understand the importance of environmental factors, such as stream flow, on behavior. Crayfish have been a model organism for quantifying agonistic bouts and social behavior amongst conspecifics. The role that agonism plays in crayfish population dynamics has been understudied. It is poorly understood how a well developed social dynamic influences crayfish position in a lotic environment. In this experiment a 7.569 X 0.991 X 0.175 m3 artificial stream was constructed. Trials consisting of populations with 4 size matched (within 10%) male crayfish, Orconectes propinquus, were analyzed in this study. Video analysis was used to observe these interactions over a 72 hour time period. Time spent up and downstream relative to conspecifics was cataloged and quantified. Preliminary data suggests that flow may influence relative social position of conspecifics in a lotic environment.

P1.116 MARUNDE, M*; SAMARAJEEWA, DA; NGUYEN, M; HAND, SC; MENZE, MA; Eastern Illinois University, Louisiana State University; *mmenze@eiu.edu*

Improved Tolerance to Salt and Water Stress in Drosophila melanogaster Cells Conferred by Late Embryogenesis Abundant Protein

Mechanisms that govern anhydrobiosis ('life without water') involve the accumulation of highly hydrophilic macromolecules, such as late embryogenesis abundant (LEA) proteins. We designed primers based on NCBI sequence ACX81198 (Warner et al., 2009) to amplify cDNA from *Artemia franciscana* and a mitochondrial localized Group 1 LEA protein comprised of 197 amino-acid (LEA1.3) was stably expressed in *Drosophila melanogaster* cells (Kc167). In the presence of mixed substrates, oxygen consumption was statistically identical for permeabilized Kc167 control and Kc167-AfLEA1.3 cells except in the uncoupled state. Acute titrations with NaCl up to 500 mM led to successive drops in oxygen flux, which was significantly ameliorated by 18% in Kc167-AfLEA1.3 cells compared to Kc167 controls. Expression of AfLEA1.3 did not improve the decrease in viability in response to 1h heat shock at 42 °C (35 ± 4.6) of Kc167-AfLEA1.3 cells showed compromised membranes 24h after heat shock vs. 32.4 ± 4.0 of control cells, n = 12; ±SD, p>0.05), but AfLEA1.3 expressing cells survived desiccation by air drying to lower final moisture contents than did control Kc167 cells (0.36 gH_2O/gDW vs.1.02 gH_2O/gDW). Thus, AfLEA1.3 exerts a protective influence on mitochondrial function and increases viability of Kc167 cells during water stress. Notably, in some cases where we observed protection, LEA proteins were no doubt fully-hydrated and intrinsically disordered, because folding into α-helix occurs only during severe desiccation. Consequently, the folded conformation of LEA proteins is not always required to confer protection against water stress (NSF-IOS-0920254, CFR-EIU).

S5-2.2 MARUSKA, K.P.*; FERNALD, R.D.; Louisiana State Univ, Baton Rouge, Stanford Univ, CA; *kmaruska@lsu.edu*

Social regulation of male reproductive plasticity in an African cichlid fish

Social interactions and position in a dominance hierarchy can have profound effects on reproductive behavior and physiology, requiring animals' to constantly integrate environmental information with their internal physiological state. How is salient information from an animal's dynamic social environment transformed into adaptive behavioral, physiological, and molecular-level changes? The African cichlid fish *Astatotilapia burtoni* is an ideally-suited model to examine socially-controlled reproductive plasticity because activity of the male reproductive axis is linked to social status. Males form hierarchies where a small percentage of brightly colored dominant individuals have an active reproductive axis, defend territories, and spawn with females, while the remaining males are subordinate, drably colored, do not hold a territory, and have a suppressed reproductive axis with minimal spawning opportunities. These social phenotypes are plastic and reversible, meaning that individual males may switch between dominant and subordinate status multiple times within a lifetime. Here we review the rapid and remarkable plasticity that occurs along the reproductive axis when males change status, a transition that has important fitness implications. Transformations occur in the brain, pituitary, bloodstream, and testes over short time scales, which are evident in overt behavioral modifications as well as physiological, cellular, and molecular level changes that impact reproductive capacity. These widespread changes triggered by a switch in rank highlight the significance of external social information in shaping internal physiology, and emphasize the importance of the vertebrate reproductive system as a substrate for phenotypic plasticity to promote survival and fitness in a dynamic social and physical environment.

147.3 MARVI, H.*; CHRYSTAL, R.; SHIEH, J.; MENDELSON, J.; HATTON, R.; CHOSET, H.; GOLDMAN, D.; HU, D.; Georgia Institute of Technology, Georgia Institute of Technology and Zoo Atlanta, Oregon State University, Carnegie Mellon University; *hamid.marvi@gatech.edu*

Sidewinding snakes on sand

Desert snakes such as the sidewinder rattlesnake *Crotalus cerastes* propel themselves over sand using sidewinding, a mode of locomotion relying upon traveling waves. While the kinematics of sidewinding on hard ground have previously been studied, movement on more natural substrates such as granular media remain poorly understood. In this experimental study, we collected animals near Yuma, Arizona, and in the laboratory we use 3-D high speed video to characterize the motion of sidewinders (N=4, mass=110 ± 53 grams) as they move on a granular bed composed of natural desert sand. We used a tiltable air-fluidized bed trackway to challenge the animals on different compactions and inclination angles of the granular media. We find that speed decreases with increasing inclination angle while wave frequency remains constant at 0.57 ± 0.01 Hz. Moreover, body speed also increases with increasing body length. We evaluate the ability of an elliptical helix model [Hatton & Choset, 2010] to describe the sidewinders' body configurations.

P2.159 MARX, J.*; HOFFMAN, T.; SCEIA, K.; PATEL, S.; BAILEY, A.; YATSONSKY, D.; BIGGERS, W.J.; Wilkes University; *william.biggers@wilkes.edu*

Oxidative Stress Induces Settlement and Metamorphosis of Larvae of Capitella teleta

Metatrochophore larvae of the marine polychaete annelid *Capitella teleta* normally settle and metamorphose in response to presently uncharacterized chemicals that are present in marine sediments. We have recently found that inducers of oxidative stress, including hydrogen peroxide and exposure to short-wave UV light, are also able to induce settlement and metamorphosis of these larvae. Prolonged exposure to oxidative stressors also resulted in larval mortality, however this mortality was found to be decreased by pre-exposure of the larvae to glutathione-ethyl ester, a cell permeable form of the antioxidant glutathione. We are now further exploring the biochemical mechanisms whereby metamorphosis is induced by oxidative stress, including the involvement of calcium channels and intracellular glutathione.

136.4 MASLAKOVA, SA*; VON DASSOW, G; HIEBERT, LS; HIEBERT, TH; Oregon Institute of Marine Biology, Univ. of Oregon; *svetlana@uoregon.edu*

Biodiversity of nemertean larval forms in NE Pacific

Planktonic larvae of many marine invertebrates look nothing like their benthic adults, and the problem of matching the two life-history stages is as old as the studies of plankton. Nemertean larvae are commonly found in plankton samples. They are diverse and distinct, but at present can only be identified to class or family level at best. This is because the development of most species is unknown. Our efforts over the past four years to match planktonic nemertean larvae from Coos Bay, Oregon to morphologically identifiable adults using DNA sequence data revealed a surprising amount of undescribed species-level diversity in a region where nemertean fauna is thought to be well characterized. We found many species new to science, and detected species previously known only from the other side of the Pacific Ocean. We identified planktonic larvae of several hoplonemerteans, including *Carcinonemertes errans*, an egg predator and parasite of commercially important crab species. Contrary to expectations, these hoplonemerteans appear to have long-lived pelagic larvae that feed and grow in the plankton, which is likely to have consequences for larval dispersal and population connectivity. We solved a long-standing mystery of the identity of an unusual larva called *pilidium recurvatum*, and discovered a new trochophore-like lecithotrophic pilidial larval type; both of these findings have implications for the evolution of larval form. A particularly important emerging insight from this study is that while nemertean larvae often have species-specific morphology, they can also be grouped into morphotypes that characterize clades of closely related species. This means that larval characters may provide unique synapomorphies to help define phylogenetic clades in this morphology-poor phylum.

P2.32 MATOO, O; DICKINSON, G.; IVANINA, A.; BENIASH, E.; SOKOLOVA, I.*; University of North Carolina at Charlotte, University of Pittsburgh; *isokolov@uncc.edu*

Elevated CO_2, temperature and salinity interactively affect biomineralization and shell properties of hard shell clams Mercenaria mercenaria

Ocean acidification (OA) driven by elevated atmospheric CO2 concentrations has been shown to negatively affect survival, growth and shell formation of marine calcifiers. In estuaries, the effects of OA may be modified by other environmental stressors such as fluctuations in salinity or temperature. We tested the interactive effects of elevated CO2 levels (hypercapnia) combined with increased temperature or decreased salinity on biomineralization and shell properties of the hard shell clam, Mercenaria mercenaria. In adult clams, shell formed during exposure to hypercapnia (800 ppm) at an elevated temperature (27 °C) showed significantly reduced hardness compared to the shells formed in normocapnia (400 ppm CO2 at 22 or 27°C) or hypercapnia at 22°C despite higher aragonite saturation in the high temperature treatments. In juvenile clams, increased CO2 levels (800 and 2000 ppm) led to reduced shell hardness, deterioration of the hinge region, and shell erosion. These effects were considerably more pronounced at the reduced salinity (15 PSU) compared to the normal salinity of 30 PSU. This suggests that hyposalinity and elevated temperature stress may exacerbate the negative effects of OA and compromise growth and survival of hard shell clams under future ocean conditions. Supported by NSF award IOS-0951079.

P2.109 MATTERSON, K.M.*; THACKER, R.T.; FREEMAN, C.J.; University of Alabama at Birmingham; *Kenanm@uab.edu*

Reduced Irradiance Alters Cyanobacterial Symbiont Abundance and Growth Rate of three Tropical Sponges

Tropical sponges can host cyanobacterial symbionts that supply essential, photosynthetically fixed nutrients. In such species, symbioses with the sponge-specific cyanobacterium *Synechococcus spongiarium* are of particular interest, especially since this taxon is composed of at least 12 genetically distinct clades that may differ in their benefit to a host sponge. To determine if this genetic diversity translates to variation in host benefit, we coupled manipulative shading experiments with light-dark bottle incubations to determine the effects of reduced irradiance on photosymbiont populations and host sponges. We carried out these experiments using three common Caribbean sponges that each host at least one unique clade of *S. spongiarium*: *Verongula rigida*, *Neopetrosia proxima* and *Ircinia felix*. Photosymbiont abundance and growth rates varied substantially across species. *I. felix* exhibited a 20% reduction in growth under shaded conditions, while *V. rigida* varied little between control and shaded treatments. Interestingly, *N. proxima* had positive growth rates under shade, but these growth rates were significantly less than those of control treatments, suggesting a method of compensation for reduced light. Respiration and productivity (P:R) values from light-dark bottle incubations of sponges used in these shading experiments also varied across species. We observed no significant differences in P:R ratios in *V. rigida* and *N. promixa* between shaded and control treatments. However, *I. felix* exhibited significantly higher oxygen production in controls. Combined, these results support the hypothesis that symbioses between sponge hosts and cyanobacterial symbionts are highly variably across host species, spanning a range of interactions from commensalisms to facultative and obligate mutualisms.

71.4 MATUS, D.Q.*; CHANG, E.; SHERWOOD, D.R.; Duke University; *david.matus@duke.edu*

Patterning of cell cycle arrest during formation of the nematode uterine-vulval connection

During development, transcription factors program the differentiation of discrete cell types. The adoption of a differentiated fate is often accompanied by cell cycle arrest. Many of these differentiated cells are then required to execute morphogenetic behaviors. Data suggests that the complex cell biological behaviors that occur during morphogenesis (e.g., EMT and convergent extension) also require a prolonged cell cycle arrest. We are examining the transcriptional control of cell cycle arrest during nematode larval development. The anchor cell (AC), a specialized gonadal cell, invades through the underlying basement membranes (BM) to connect the developing uterine and vulval tissues. After initiating the breach, the AC is no longer required to expand the BM gap. Instead, the BM breach is widened through BM sliding and is stabilized by the innermost secondary fated vulval precursor cell, vulD. We are dissecting AC invasion and vulval morphogenesis in *C. elegans* and related nematode species as a model to understand how morphogenetic mechanisms evolve. We performed a tissue-specific RNAi screen targeting ~700 *C. elegans* transcription factors, identifying the TLX ortholog NHR-67 as a new regulator of invasion. Strikingly, loss of NHR-67 results in multiple mitotic ACs that fail to invade. Prevention of cell cycle progression in NHR-67-depleted animals rescues the invasion defect, demonstrating that cell cycle arrest is required for invasion. This requirement for cell cycle arrest may also hold true during BM stabilization. Similar to *C. elegans*, in all other nematode species we have examined, the BM appears stabilized over the post-mitotic vulD cell. Together our molecular, cell biological, developmental and evolutionary studies indicate a requirement for the precise transcriptional control of a genetic program that links cell cycle arrest to both BM invasion and stabilization.

10.2 MATZ, MV*; KENKEL, CD; BAY, LK; Univ. of Texas at Austin, Australian Institute of Marine Science; *matz@utexas.edu*

Gene expression signatures of local adaptation in reef-building corals

The role of algal symbionts (*Symbiodinium* sp.) in adaptation of corals to local environmental conditions is well established, but little is known about the complementary mechanisms employed by the coral host. We present two experiments involving RNA-seq profiling of host gene expression in corals originating from different thermal environments. In the first experiment (*Porites astreoides*, Florida Keys), corals from inshore and offshore reefs were kept in common garden conditions involving long-term heat stress for 6 weeks. In the second experiment (*Acropora millepora*, Great Barrier Reef), corals were reciprocally transplanted between their native locations separated by about 1000 kilometers along the length of GBR, for 6 months. Two particularly interesting themes emerge from the functional analysis of hundreds of genes that were differentially regulated with respect to the site of origin or, in the second experiment, the site of outplanting. There is an effect on genes processing carbonate and bicarbonate ions and putatively involved in calcification. In addition, many genes involved in lipid transport and metabolism become regulated. It is tempting to speculate that these two apparently disparate functional modules might be linked through the regulation of proteins converting pyruvate to oxaloacetate, which was a strong signal observed in both experiments. There is, therefore, a possibility that corals might possess a central regulatory mechanism for physiological adaptation or acclimatization, similarly to what has been observed through ecological genomics studies in threespine stickleback fish (*Gasterosteus aculeatus*) and the Glanville fritillary butterfly (*Melitaea cinxia*).

147.1 MAYORGA, O*; YIP, V; MAZOUCHOVA, N; GOLDMAN, DI; SPAGNA, JC; William Paterson University, Georgia Institute of Technology; *spagnaj@wpunj.edu*

Running performance and gait kinematics of a sand-adapted arachnid, Galeodes granti

Solifuges (“camel spiders”; Arachnida: Solifugae) typically live in desert environments and run quickly on sandy substrates. To test the hypothesis that Solifugae are well-adapted to running on sand, we compared the running performance of the solifuge *Galeodes granti*, to three cockroaches: *B. discoidalis* and immature *B. discoidalis*, which are tropical, and *A. investigata*, a desert species. We then analyzed the solifuges’ gait characteristics and compared them to those of spiders and scorpions. The animals were placed on a platform covered with a uniform layer of 0.3 mm diameter glass particles, similar to natural sand, ~1 cm deep. The platform was adjusted to four angles (0, 5, 10, 15, 20 degrees) and locomotion bouts were recorded using a high-speed camera. Comparisons of slopes of speed vs. angle showed that with increases in angle, solifuge performance was maintained, while the other species slowed (ANCOVA, $p < 0.05$). Each solifuge video (n=3 individuals, mean mass 1.7g, 34 total runs) was analyzed to measure periods of ground contact and swing phase for each leg across two step-cycles. These indicated that the solifuges used their 6 rear legs in alternating sets of three, analogous to the insect ‘alternating tripod’ gait. Average speed was 12 cm/sec, stride frequency was approximately 3 strides/sec, duty factor was 0.86. , and tripod synchrony factor was 0.62. Regression analysis revealed a significant relationship ($p < 0.01$) between speed and frequency, but not between speed and duty factor, or speed and stride length. The gait patterns of solifuges are more similar to those of scorpions than to comparably-sized spiders, which may reflect adaptation to their shared sandy habitats.

76.2 MAZOUCHOVA, N*; WILSHIN, S; HSIEH, T; Temple University, Royal Veterinary College; *nicole.mazouchova@temple.edu*

The aquatic-terrestrial transition of freshwater turtles from a dynamical systems perspective

A multitude of complex environments are found on our planet and are inhabited by a variety of animal species exhibiting diverse forms of adaptation. Animals that must locomote across the land-water interface range from mammals, to birds, to reptiles or fish. Studies have focused on movement on unfamiliar terrain but fewer analyze the locomotor requirements when transitioning from one environment to another, such as at the land-water interface. We are interested in a dynamical system analysis of locomotor abilities of freshwater turtles when transitioning from swimming to walking. Freshwater turtles frequently utilize freshwater streams and ponds to hunt for food and emerge onto the shores to bask in the sun. We hypothesize that transitions may be asymmetrical with gaits being specialized for escape and others for prey pursuit. The animals are kept in a freshwater tank outfitted with a dry-land dock and equipped with a high-speed video camera to film their behavior and kinematics during transitions between land and water. A simple dynamical systems model is fitted to the kinematics of the flipper motions during the aquatic/terrestrial transitions to explore patterns of gait changes between these two environments. The model captures the variability in the phase of the flippers and any phase locking of the transition onset. We will examine how the structure of the gait transitions affects performance of the turtles.

76.5 MAZOUCHOVA, N.; UMBANHOWAR, P.B.; GOLDMAN, D.I.*; Temple Univ., Northwestern Univ., Georgia Tech; *daniel.goldman@physics.gatech.edu*

Principles of flipper use during walking on flowing ground

Animals, like lobe-finned fishes, likely first walked on wet sand and mud. In the evolutionary transition from aquatic to terrestrial locomotion, the rheology of limb (fin) interaction changed from slipping through fluid to pushing against materials that can be fluid or solid. Locomotor strategies thus changed as bodies and appendages shifted from generating thrust during swimming to generating both lift (to maintain posture and reduce ground contact) and thrust (to propel the body). However, as little is known of the biomechanics of walking/crawling on soft substrates, detailed hypotheses for how limbs and control strategies adapted to these substrates are lacking. To discover principles of flipper/fin based terrestrial locomotion, we study a sea turtle-inspired robot, FlipperBot (FBot), during quasi-static movement on dry granular media. FBot implements a symmetric gait using two, servo-motor driven front limbs with flat-plate flippers and either freely rotating or fixed wrist joints. For a range of gaits, FBot moves with constant step length. For gaits with sufficiently shallow flipper penetration or sufficiently large stroke, step length decreases with successive steps resulting in failure after a few steps. The biologically inspired free wrist is less prone to failure than the fixed wrist, largely because it does not yield material and can thus maintain FBot's base above the surface. Failure occurs when FBot interacts with ground disturbed during previous steps; measurements reveal that flipper forces decrease as step length decreases. When step length is constant, models provide insight into how disturbed ground leads to locomotor failure. We hypothesize that the evolution of limb morphology (like a flexible wrist) and control strategies in terrestrial locomotors was influenced by flowing substrate rheology.

P2.223 MAZZILLO MAYS, M.*; KEMPF, S. C.; Auburn University; *mazzimj@auburn.edu*

Symbiodinium mucilage and ultrastructural variation

Symbiodinium are unicellular dinoflagellates that reside intracellularly in a variety of invertebrate hosts, including cnidarians. In this symbiosis, the endosymbiotic algae are enclosed in a symbiosome membrane (host and symbiont-derived) and donate photosynthetically fixed carbon to the host in exchange for nutrients. *Symbiodinium* is a diverse genus of 9 clades with multiple strains in each clade. The specificity of the association between symbiont and host varies with some relationships being highly specific and others of a general nature. The symbiont secretes mucilage that lies at the interface with the host and therefore, may be involved in recognition and specificity. Antigenic variation of this mucilage layer demonstrated that differences are present in the mucilage layer that could impact recognition and specificity. An antigen previously created against a clade B alga from *Aiptasia pallida* was found in cultured *Symbiodinium* from clades A and B but not clades C, D, and F. Within clades A and B there was variation in the amount of label present. Ultrastructural examinations using High Pressure Rapid Freezing were then performed on 6 strains (2 each from clades A and B, 1 from clade C, and a free-living *Symbiodinium* strain from clade E) to examine variation amongst these strains that could effect the ability of a particular symbiont to reside within a particular host. Variations in mucilage composition could provide important molecular differences involved in the recognition of a symbiont by the host. Examining the ultrastructure of the symbiont may help to explain where variation between strains may exist, and how this variation may impact both the recognition and establishment of a symbiosis as well as its maintenance.

S7-1.1 MÜLLER, W.E.G. *; WANG, X.H. ; University Medical Center, Mainz, GERMANYz.de), University Medical Center, Mainz, GERMANY; *wmueller@uni-mainz.de*

Metazoan circadian rhythm: an universal "Zeitgeber" existing from sponges to humans

In higher metazoans, the 24 h periodicity in the environment contributed to the evolution of the molecular circadian clock. We studied the circadian clock circuit in the lowest metazoans, the sponges. First, we identified in the demosponge Suberites domuncula the enzyme luciferase which generates photons. Then very likely, the photos generated by luciferase are transmitted via the biosilica glass skeleton of the sponges and are finally harvested by cryptochrome, acting as photosensor. Therefore, we propose that this photoreception/phototransduction circuit functions as a nerve-cell like signal transmitting system. This could be certified by the fact that S. domuncula reacts to different light wavelengths with a differential gene expression of the transcription factor SOX. Recently, we succeeded to demonstrate that the sponges nocturnin is a light/dark controlled clock gene and shows a poly(A) specific 3' exoribonuclease activity. qPCR analyses revealed that primmorphs, 3D cell aggregates, after transferred from light to dark, show a 10-fold increased expression of nocturnin gene. In contrast, the expression level of glycogenin decreases in the dark by 3- to 4-fold. Finally it is concluded that sponges are provided with the molecular circadian clock protein nocturnin which is highly expressed in the dark and controls in the dark the stability of a key metabolic enzyme, glycogenin. References: Müller et al. (2009) Cell Mol Life Sci 66: 537. * Müller et al. (2010) FEBS J 277: 1182. * Wiens et al. (2010) J Cell Biochem 111:1377–1389. * Wang et al. Soft Matter; in press. DOI:10.1039/C2SM25889G

87.2 MCALISTER, J/S*; MORAN, A/L; College of the Holy Cross, Clemson University; *jmcalist@holycross.edu*

Egg size and exogenous food level interact to affect larval growth in tropical Echinometra spp. sea urchins

Planktotrophic larvae of marine invertebrates develop and grow by utilizing energy and materials from a combination of maternally-supplied endogenous egg reserves and exogenous food. Egg size varies considerably among planktotrophic species, and egg size is thought to evolve in the context of food availability; large eggs will be favored if food for larvae is scarce, and small eggs will be favored if food is abundant. Evolutionary changes in egg size can also affect maternal fitness by altering the balance between per-offspring maternal investment and fecundity. To test the hypothesis that egg size alters the effect of food availability on larval growth and development, we reared larvae of three closely related species of *Echinometra* that differ in egg size and egg energetic content at three different food levels. We found that overall, at a given food level, larvae of species with larger eggs developed more rapidly than larvae of species with smaller eggs; larvae reared at higher food levels also grew more rapidly than those fed less. We also found a significant interaction between egg size and food level for larval size and developmental rate: food level had a greater effect on species with smaller eggs than those with larger eggs. These data support the prediction that larger eggs act as a nutritional and energetic buffer against the unpredictability of food in the plankton, and that smaller eggs may enhance maternal fitness in high-food environments.

P1.224 MCAVOY, K.A.*; BENOWITZ-FREDERICKS, Z.M.; Bucknell University, Lewisburg, PA; *kam048@bucknell.edu*

Influence of maternal yolk testosterone on aromatase activity in the pre-optic area of the brain in 3-day-old domestic chickens

Maternal effects are a mother's non-genetic contributions to development, such as the deposition of androgens into avian egg yolks, that alter many phenotypic traits in offspring. For example, elevated yolk testosterone increases male sexual behaviors such as copulations and courtship displays in some species. However, the mechanism connecting *in ovo* testosterone exposure with increased sexual behaviors has yet to be elucidated. While testosterone released by the gonads is important in the activation of avian sexual behaviors, it must undergo conversion to estrogen by the enzyme aromatase in the pre-optic area (POA) of the brain for full expression of sexual activity. We hypothesize that the mechanistic link between yolk testosterone and frequency of sexual behavior lies in changes in aromatase activity in the POA. We investigated the effect of elevated yolk testosterone on aromatase activity in the POA of 3-day-old domestic chickens (*Gallus gallus domesticus*). Unincubated eggs were injected with either 10 ng testosterone in 50 &muL sesame oil ("T chicks") or 50 &muL sesame oil ("C chicks"). At 3 days post-hatch, the aromatase activity in the POA was quantified by measuring production of tritiated water from [1&beta-^{3}H]-androstenedione. We predicted that aromatase activity would be higher in the brains of T chicks, however found no difference between treatments. Though juvenile T production peaks at 3 days post-hatch, it's possible that the POA and its aromatase activity are not fully developed at this time.

P1.211 MCCAFFREY, A*; GARCIA, J; PRIYAMVADA, L; YAO, A; HECKMAN, K; SCHREIBER, A; St. Lawrence University; *aschreiber@stlawu.edu*

Estradiol induces thymus gland apoptosis via both estrogen and glucocorticoid receptor pathways in Xenopus laevis tadpoles

Similar to the suppressive effects of glucocorticoids on the immune system, high levels of endogenously-produced or exogenously-administered estrogen are known to cause the thymus to atrophy in mammals. However, the influence of estrogen and estrogenic compounds on thymus gland development in tadpoles and other aquatic vertebrates remains unknown. Here we show that treatment of young tadpoles (7 days-post fertilization; Nieuwkoop and Faber stage 50) for 6 days with estradiol (10 uM), or dexamethasone (DEX, 2 uM; a glucocorticoid receptor agonist) significantly reduces thymus gland size by 35%, and 67%, respectively. Treatment of tadpoles with estradiol induces maximum active caspase-3 expression (a mediator of programmed cell death) in thymocytes within 48-72 hours, after which levels of thymus cell apoptosis decrease. Compared with tadpoles treated with DEX alone, those treated with DEX + RU-486 (200 nM; a glucocorticoid receptor antagonist) completely rescued tadpoles from reduction in thymus size. In contrast, treatment of tadpoles with estradiol (10 uM) + fulvestrant (25 uM; an estrogen receptor-specific antagonist) only resulted in a partial rescue of the estradiol-induced reduction in thymus size. Interestingly, treatment of tadpoles with estradiol + RU-486 also produced a partial rescue of the estradiol-induced reduction in thymus size. These findings suggest that some of the effects of estradiol and estrogenic compounds (such as bisphenol-A and atrazine) on thymus gland apoptosis may be mediated by a concurrent activation by estrogenic substances of the glucocorticoid stress-response pathway.

P2.57 MCCANN, MJ; Stony Brook University; *mccann@life.bio.sunysb.edu*

Nutrient stoichiometry, species traits, and regime shifts in freshwater ponds

Alternative community regimes can occur in freshwater ponds, which are either dominated by submerged aquatic vegetation (SAV) or by unrooted, free-floating plants (FFP). Shifts between regimes are driven by changes in nutrients (nitrogen and phosphorous). At low nutrient levels, SAV species dominate because they uptake scarce nutrients directly from the sediment via roots. At high nutrient levels, FFP are not nutrient-limited and are the superior competitors because of their primacy for light. In any waterbody, both plant groups are represented by a diversity of species. The species richness of each plant group may affect the likelihood of a regime shift depending on the degree of redundancy or complimentarity in relevant species traits such as growth rate, nutrient uptake rate, shade tolerance, or resistance to herbivory. If there is high trait complimentarity, then greater species richness within a plant group may increase the likelihood that a pond is found in that regime. Through both natural and anthropogenic mechanisms, ponds vary in the dissolved nitrogen (ammonia and nitrate) to phosphorus ratio (N:P). To test the effects of N:P stoichiometry on a FFP growth rate (a key trait), I measured relative growth rates of three species of FFP – *Lemna minor*, *Spirodela polyrhiza*, and *Wolffia borealis* - grown in laboratory monocultures for 17 days in a fully-crossed factorial design of 3 nitrogen levels (0.5, 5.0, and 10 mg N / l, as a 1:1 ammonia: nitrate mix) and 3 phosphate levels (0.083, 0.83, and 1.66 mg P / l) for a total of nine combinations. Also, species-specific uptake rates of nitrate, ammonia, and phosphate were measured after 48 and 96 hrs. Identifying, measuring, and quantifying the complimentarity or redundancy of relevant species traits will help inform the effect of species richness on the likelihood of community regime shifts.

P3.54 MCCLARY, JR., M.*; GARAH, M.; ELIA, S.; Fairleigh Dickinson University, Paramus High School, Passaic County Technical Institute; *mcclary@fdu.edu*

Measurements of various water parameters to explain shell characteristics of barnacles

Previous observations have shown that shells of barnacles, *Balanus improvisus*, from the Hackensack River of New Jersey were brittle compared to shells of *B. improvisus* from Laurence Harbor in Old Bridge, New Jersey. Although previous studies showed that barnacle shells from the Hackensack River contained more calcium than barnacle shells from Laurence Harbor, the calcium concentrations in barnacle shells from the Hackensack River did not increase with barnacle size like they did in the shells of barnacles from Laurence Harbor. To determine if this was due to a higher salinity, water samples were collected from the Hackensack River and from Laurence Harbor to measure and compare salinity, calcium concentration, general hardness, carbonate hardness, nitrite, nitrate, pH, and phosphate concentration. Water from Laurence Harbor contained a higher level of calcium than the water from the Hackensack River. Phosphate concentrations in all water samples were higher than 0.1 mg/l which may explain why the calcium concentrations were lower than they should be. General hardness, carbonate hardness, nitrite, nitrate and pH were similar in all water samples. Future studies may try to determine the calcium uptake rates of barnacles of various sizes and ages to determine if this is the reason for the lack of calcium increase with increase in barnacle size that was found in barnacles from the Hackensack River.

P3.62 MCCLINTOCK,, J.B*; WHITE, BA; AMSLER, CD; MAH, CL; AMSLER, MO; WHITE, S; QUETIN, LB; ROSS, RM; Univ. of Alabama at Birmingham, National Museum of Natural History, Univ. of California, Santa Barbara; *mcclinto@uab.edu*

Abundance and distribution of echninoderms in nearshore hard-bottom habitats near Anvers Island, Antarctic Peninsula

Echinoderms are well represented in nearshore hard-bottom habitats along the Antarctic Peninsula where they are presumably important contributors to benthic productivity, carbon flow, and determinants of community structure. Remarkably, very few quantititive studies exist on their patterns of abundance. The present study assesses the densities of echinoderms at shallow depths (2-15 m) at five sampling sites near Anvers Island on the central western Antarctica Peninsula. Four of five classes of the Echinodermata were present. Mean total echinoderm densities were high (34.9 individuals per meter square) and ranged from 21.9 individuals per meter square for asteroids and 2.7 individuals per meter square for holothuroids. With the exception of a positive relationship between the abundance of the regular sea urchin *Sterechinus neumayeri* and the biomass of the brown alga *Himanthothallus grandifolius*, no significant relationships were found between the abundance of asteroids, ophiuroids, or holothuroids and two species of brown algae or three algal ecotypes. The present study indicates nearshore hard-bottom echinoderms along the Antarctic Peninsula are important in the carbon cycle. Moreover, their inherent vulnerability to ocean acidification and climate warming in a rapidly changing environment makes these baseline data important metrics for future comparison.

63.1 MCCORMICK, S.D.; USGS. Conte Anadromous Fish Res Ctr; *mccormick@umext.umass.edu*

Downstream: the hormonal control of smolt development in salmon.

The parr-smolt transformation is a series of behavioral, morphological and physiological changes that are adaptive for downstream migration and seawater entry. The Bern lab conducted some of the earliest work on the hormonal control of smolting, particularly with regard to the development of seawater tolerance. Growth hormone, insulin-like growth factor I, cortisol and thyroid hormones increase during smolt development, whereas prolactin decreases. There are important interactions among these endocrine axes that control the timing and magnitude of smolt development. The recent identification of salinity-specific isoforms of the ion transporting enzyme Na/K-ATPase has helped identify cellular changes in the gill that promote salt secretory capacity and their hormonal control. Areas of future research include the hypothalamic control of smolting and the identity of mechanisms contributing to interaction of endocrine axes during this "pan-hyperendocrine" developmental event.

117.4 MCCORMICK, G.L.*; LANGKILDE, T.; Pennsylvania State University; *glm173@psu.edu*

Immune costs of the physiological stress response are affected by cross-generational exposure to stress

An organism's ability to respond to stressors is integral to its survival and reproductive fitness, and is increasingly important in light of environmental change. An animal's physiological response to stress is generally adaptive. For example, the production of glucocorticoid hormones, including corticosterone (CORT), can trigger survival-enhancing behavior. However, chronic stress, such as that elicited by frequent encounters with predators, can divert energy from other important processes, such as immune function. Additionally, it is possible that the costs of chronic stress differ between populations that have evolved in high- versus low-stress environments. We investigated the tradeoff between stress and immune function in male Eastern fence lizards (*Sceloporus undulatus*) in both high- and low-stress sites. This difference in field stress (measured as baseline CORT levels) is associated with the long-term presence or absence of predatory invasive fire ants (*Solenopsis invicta*). We experimentally manipulated CORT levels by applying exogenous CORT, or a control vehicle, to lizards daily for 23 days, and then measured two immune parameters (complement bacterial lysis and antibody hemagglutination). Immune function of lizards from low-stress sites appears to be fairly robust to stress. However, lizards from high-stress sites had a stress-sensitive immune response, and the nature of this response varied between the two immune measures. This suggests that cross-generational exposure to stressors can affect tradeoffs between the physiological response to a stressor and other nutrient-demanding processes, such as immune function.

P1.169 MCCOY, R.C.*; BOGGS, C.B.; PETROV, D.A.; Stanford University; *rmccoy@stanford.edu*

Evaluating methods of demographic inference and testing for balancing selection using genomic data from the checkerspot butterfly Euphydryas gillettii

Motivated by recent theoretical work, our study refocuses attention on the relative importance of balancing selection versus other evolutionary forces in maintaining consequential genetic variation in natural populations. As many tests for selection are sensitive to demography, our system is unique in allowing us to explicitly incorporate detailed knowledge of demographic history into our tests. We investigate the interaction of selection and demography in *Euphydryas gillettii*, a univoltine checkerspot butterfly that was intentionally introduced to Gothic, Colorado in 1977. The population established and subsequently experienced severe fluctuations, including extreme bottlenecks of fewer than 25 adult individuals as estimated by annual mark-release-recapture experiments. We prepared and sequenced barcoded cDNA libraries from 8 whole larvae from the introduced Colorado population and 8 whole larvae from its ancestral Wyoming population on the Illumina HiSeq2000 platform. These data were used to assemble the *E. gillettii* transcriptome *de novo* using Trinity and discover expressed SNPs using GATK. After filtering, we obtained a SNP set to which we applied several common methods of demographic inference and allele frequency spectrum-based tests for selection. This isolated population with well known demographic history allows us to compare the ability of methods of demographic inference to estimate the timing and strength of the bottleneck based on genomic data. Deviations from expected neutral patterns of genomic variation given the known demography suggest natural selection. In particular, our data reveal the action of purifying selection in spite of strong drift during recurrent bottlenecks.

36.4 MCCUE, M.D.; St. Mary's Univ; *mmccue1@stmarytx.edu*

Direct measurement of starvation-induced shifts in endogenous fuel oxidation in mice

Fasting animals typically switch from one metabolic substrate to another in the order of carbohydrates, lipids, and then proteins. The timing of these physiological transitions are traditionally estimated using *indirect* measures of substrate oxidation including, changes in respiratory exchange ratios (RER), blood metabolites, or enzyme activity. Here I describe how different nutrient pools in the body can be chronically ^{13}C labeled and how fasting-induced physiological shifts in substrate oxidation can be *directly* quantified using $^{13}CO_2$-breath testing. Weanling mice were raised to adulthood on diets supplemented with one of three artificially enriched isotope tracers (i.e., ^{13}C-1-L-leucine, ^{13}C-1-palmitic acid, or ^{13}C-1-D-glucose). The adult mice were then fasted for 72 hours during which VO_2, VCO_2, $\delta^{13}CO_2$, and blood metabolites (i.e., glucose, ketone bodies, and triacylglycerides) were continually measured. The fasting mice exhibited predicted reductions in body mass, activity, BMR, and RER. Although RERs rapidly decreased between 6h-8h, they remained constant thereafter, precluding meaningful interpretations of changes in fuel oxidation. Breath testing revealed a clear, transient peak in $^{13}CO_2$ production in the ^{13}C-glucose mice occurred between 8h-18h, during the transition of Phase I to Phase II. By 6h endogenous lipid oxidation increased from 6% of the energy budget to over half of the energy used by mice. The amount of energy derived from protein oxidation dropped sharply during the first 10h (i.e. protein sparing) and eventually reached a point where protein oxidation accounted for as little as 9% of the energy expenditure. By the end of the 72-hour experiment protein oxidation accounted for at least 24% of the total energy expenditure. This experiment supports the idea that direct measurements of substrate oxidation complement traditional,indirect approaches to studying fasting physiology.

P2.60A MCCULLOCH, KJ*; BRISCOE, AD; University of California, Irvine; *mccullok@uci.edu*

Sexual dimorphism and species divergence following UV opsin duplication in Heliconius butterflies

Butterflies are known to have some of the most spectrally diverse photoreceptor types in the animal kingdom. The genus *Heliconius* is of particular interest because it represents an adaptive radiation in which many species have formed Müllerian mimicry rings throughout Central and South America. Species of this genus have a duplication of a UV opsin gene typically expressed in short wavelength photoreceptor cells (R1 and R2 cells). However nothing is known about the spatial expression pattern of short wavelength opsin proteins in the compound eyes of species with the duplicated gene. We used immunohistochemistry to fluorescently label cryosections of compound eyes with UV opsin-specific antibodies. The UV1 and UV2 opsins of seven species in the genus *Heliconius* were labeled, representing all major clades in the phylogeny. We reveal strikingly different spatial expression patterns among species in different branches of the *Heliconius* phylogenetic tree. We also observe unexpected sexual dimorphism of opsin expression in a majority of the species we examined. These results suggest the strength of natural and sexual selection shaping the compound eye has varied considerably over the evolutionary history of the genus. Further genetic, molecular, and physiological analysis may inform us how complex traits such as visual systems play a role in the early divergence of species.

P2.169 MCCULLOUGH, K.A.*; KRAJNIAK, K.G.; Southern Illinois University Edwardsville; *kmccull@siue.edu*

The Effects of APKQYVRFamide on the Isolated Intestine of the Earthworm Lumbricus terrestris.

The digestive tract of the earthworm *Lumbricus terrestris* responds to a variety of neurotransmitters including FMRFamide and its related peptides (FaRPs). Recently we identified the first earthworm FaRP, APKQYVRFamide, from the genes of *Lumbricus rubellus*. The goal of this project was to examine the effects of this peptide on the intestine of *L. terrestris*. The intestine was removed and placed into a bath filled with worm saline. All movements of the intestine were recorded with a Grass force transducer and were displayed on a computer using iWorx Labscribe 2 software. Increasing concentrations of peptide were added to the bath and adequate time was allowed for each to take effect. The resulting changes in contractions were used to create log-concentration response curves. APKQYVRFamide caused a concentration dependent increase in contraction rate with a threshold of 10^{-9} M. These results suggest that APKQYVRFamide may play a role in controlling the motility of the earthworm intestine. We are currently examining the effects of other structurally related peptides to characterize the intestinal receptor.

14.4 MCCULLOUGH, E.L.*; TOBALSKE, B.W.; EMLEN, D.J.; University of Montana; *mccullough.e@gmail.com*

Long and strong? Mechanical limits to maximum weapon size in a giant rhinoceros beetle

In the Japanese horned beetle (*Trypoxylus dichotomus*), males have a long, branched head horn that they use to compete for access to females. These horns can reach exaggerated proportions of up to two-thirds the length of the beetle's body. Sexual selection theory predicts male ornaments and weapons will evolve until the fitness costs outweigh the reproductive benefits of further trait exaggeration. Interestingly, the giant horns of *T. dichotomus* do not incur substantial fitness costs, so it is unlikely that weapon size is limited by a cost-benefit equilibrium. However, males often damage and sometimes break their horns during intense male-male combats, suggesting that maximum horn size is set by mechanical constraints on horn strength. We tested this hypothesis by measuring the safety factors of horns across the full range of horn sizes. Horn safety factors were calculated as the ratio between the force required to break a beetle's horn and the force a beetle would have to generate to dislodge a typical size-matched rival. In support of our hypothesis, we found that horn safety factors decreased as horn length increased. Large horns are therefore more likely to break and perform poorly in combat. We suggest that mechanical constraints have played an important role in shaping the evolution of the beetles' elaborate horn morphologies.

74.1 MCELROY, EJ*; BERGMANN, PJ; College of Charleston, Clark University; *mcelroye@cofc.edu*

The evolution of tail size, tail autotomy, and locomotor performance in lizards

The effect of tail autotomy on locomotor performance has been studied in a number of lizard species. These studies show that tail autotomy can have a positive, a negative, or no effect on locomotor performance with a variety of mechanisms proposed to explain these findings. This study will test the hypothesis that tail size is correlated with the magnitude of change in performance after tail autotomy. To test this hypothesis, we compiled published records of the effect of tail autotomy on sprint speed in lizards. Based on these data, we measured relative tail length and volume using museum specimens. There is tremendous variation in relative tail size and the impact of autotomy on performance which inhibits the ability to detect patterns within the data. However, when the outlying species are down-weighted prior to regression analysis, we find a positive relationship between tail size and performance change after autotomy. Lizards with larger tails exhibit a larger change in performance after tail loss. Phylogenetically-informed analyses indicate that relative tail length and volume and the magnitude of change in sprint speed after autotomy have co-evolved. These findings suggest that future studies of tail autotomy and locomotor performance might be most productive if they focus on clades with large variation in tail size. To help identify such clades, we compiled all published records of relative tail length combined with a published lizard supertree, which yielded a final data set of 365 species. We then estimated the rate of relative tail length evolution for each lizard family. The results suggest uneven rates of tail length evolution across lizards, with several sister-families exhibiting very different rates (e.g. Pygopodidae - high rate, Gekkonidae, low rate).

15.1 MCENTEE, JP*; PENALBA, J; BOWIE, RCK; University of California, Berkeley; *jaymcentee@yahoo.com*

Singing out from sky islands: sunbird song evolution across the Eastern Afromontane

Song evolution is thought to be important to the diversification of extant birds, because songs are functionally critical in social interactions such as mate choice and are thought to diverge rapidly among isolated populations. The sky island distribution of the Eastern Double-collared Sunbird (EDCS) species group (*Nectarinia* spp.) allows examination of song divergence among spatially isolated populations at varying degrees of evolutionary relatedness. In this study, we examine the trajectory of song evolution among these populations; phenotypic differences were assessed at levels ranging from within-species to among-species divergences. Previous authors have reasoned that song in song-learning species should be especially subject to rapid divergence in allopatry, regardless of ecological differences or divergence in other traits. Multi-locus molecular phylogenies indicate that six to eight distinct EDCS lineages have evolved, and moreover that several individual EDCS populations have existed in isolation long enough for reciprocal monophyly in mtDNA to develop. Our study indicates that, while major shifts in song phenotype have occurred coincident with molecular divergence, spatial isolation alone does not appear sufficient for substantial song divergence to accrue. Conservatism in learned song phenotypes despite the opportunity for divergence in isolation suggests the possibility that social selection can promote not only directional change but also stasis.

12.1 MCGEE, MD*; BORSTEIN, SR; WAINWRIGHT, PC; University of California Davis, California State University Sacramento; *mcgee@ucdavis.edu*

Origin and loss of cichlid craniofacial diversity

Cichlid fishes are famous for their exceptional diversity, particularly in craniofacial morphology. Despite remarkable phenotypic diversity in locations like the East African Rift Valley, it is not currently known which lineages produced the extremes of cichlid phenotypic diversity, or how extinction events have altered patterns of morphospace occupation in cichlids. We generated a dataset of lateral head images of one species from each of the two hundred and twenty three genera of cichlids. We then digitized a set of ten craniofacial landmarks to generate a cichlid morphospace using geometric morphometrics. We reveal a major axis of craniofacial diversity associated with dorsoventral compression or expansion. Surprisingly, cichlid phenotypes associated with the extremes of the diversity axes were not from the well-known recent lake radiations, but were from older lineages found in fast-flowing river and flooded forest habitats in Africa, Asia, and South America. This suggests that the processes generating extreme phenotypes may not be the same as the processes generating phenotypic diversity over extremely short time scales. We also examined the largest vertebrate extinction event in modern history, which occurred when introduced Nile perch extirpated hundreds of endemic cichlids in Lake Victoria. We generated a craniofacial morphospace of over one hundred Victorian cichlids and recorded whether each species crashed after the Nile perch introduction or was relatively unaffected. Craniofacial morphology was a strong predictor of a species' likelihood of crashing, suggesting that the dynamics of extinction in Victorian cichlids were not simply a result of increased predation in the lake, but were biased towards particular phenotypes.

21.3 MCGINTY, E.S.*; MCMAHON, R.F.; MYDLARZ, L.D.; Univ. of Texas at Arlington; *mcginty@uta.edu*

The effect of temperature on the growth rates and oxygen consumption of 6 cnidarian algal symbionts

Algal symbionts in the genus *Symbiodinium* that form mutualistic relationships with many cnidarians are critical to coral reef maintenance, growth and persistence, but little is known about their physiology, especially in how it relates to genetic diversity that exists within the genus. In particular, gaps surround our understanding of variation among different symbionts, and how that physiology changes during exposure to stressors associated with climate change, such as elevated temperatures. To investigate this, 6 different *Symbiodinium* cultures (types A1, A2, B1, B2, E1 and F2) were exposed to a range of temperatures and the resulting oxygen consumption rates and growth rates were compared. Cultures were acutely exposed to temperatures ranging from 25°C to 37°C (42°C for F2) and dark oxygen consumption rates were measured, allowing determination of maximum oxygen consumption rates and Q10 rates. Differences existed among algal types for the maximum rate, temperature where maximum rates were reached, which ranged from 31°C (B1) to 41°C (F2), and Q10 rates, with the lowest at 2.804 (E1) and the highest at 5.880 (B2). Growth rates at 26°, 30°, and 34°C were also measured and differences among *Symbiodinium* types were again observed. Preliminary analysis suggests that in some *Symbiodinium* types, oxygen consumption continued beyond temperatures where positive growth rates were maintained, indicating that algal cells are still alive at these temperatures but unlikely able to support their own growth. These findings, and the potential implications on the algal-cnidarian symbioses, will be applied to elucidate the physiological responses of *Symbiodinium* to stressors associated with climate change and address their role in coral decline.

50.2 MCGLOTHLIN, J. W.*; FELDMAN, C. R.; BRODIE, JR., E. D.; PFRENDER, M. E. ; BRODIE III, E. D.; Virginia Tech, University of Nevada, Reno, Utah State University, University of Notre Dame, University of Virginia; *joelmcg@vt.edu*

Evolutionary history of tetrodotoxin-resistant sodium channels in snakes

The garter snake *Thamnophis sirtalis* and its prey, the toxic newt *Taricha granulosa*, appear to be engaged in a coevolutionary arms race in western North America, with snakes evolving ever greater resistance to increasing levels of tetrodotoxin (TTX) in newts. On a molecular level, resistance in garter snakes derives from amino acid substitutions in voltage-gated sodium channels (Nav1.x, a family of 9 proteins found in excitable tissue), that prevent TTX from binding and and thus blocking ion flow. Populations of western *Th. sirtalis* that vary in resistance vary in the genotype of skeletal muscle sodium channels (Nav1.4), indicating an ongoing arms-race at that locus. We have recently discovered parallel evolution of signatures of resistance in two other channels, Nav1.6 and Nav1.7, which are found primarily in peripheral nerves. Here, we trace the evolutionary history of these genes in *Thamnophis* snakes and their relatives. Our results suggest that resistant nerves predate resistant muscles, perhaps predisposing garter snakes and their relatives to escalating coevolutionary arms races with toxic prey.

6.4 MCGOWAN, CP*; SHINE, C; University of Idaho; *cpmcgowan@uidaho.edu*

Incline hopping by kangaroo rats: Is there a division of labor?

Muscle-tendon specializations associated with specific modes of locomotion are often linked to trade-offs in function. In wallabies, the short, pinnate muscle fibers and long, thin ankle extensor tendons are well suited for elastic energy and return. However, they have a limited capacity to generate net mechanical work and control joint position. Because of this, there is a division of labor within the hind limb when performing tasks that require work to be done against the environment such hopping up an incline. Kangaroo rats share a similar hind limb morphology with wallabies, expect their ankle extensor tendons are relatively thicker and are thus better suited for generating work and controlling joint position. The goal of this study was to determine if a division of labor between proximal and distal muscles also exists during incline hopping by kangaroos rats, or if relatively thicker tendons enable all joints to contribute equally to raising the body's center of mass. To test this, we collected data from desert kangaroo rats (*D. deserti*) as the hopped up a track inclined to 10, 15, 20 and 25 degrees. High speed video and ground reaction force data were combined in an inverse dynamics analysis to calculate the mechanical power and net work developed at each joint. Our results show that the net mechanical work done by the ankle is largely independent of slope, whereas the work done the hip and knee both increase significantly. At the highest slope, 44% of the positive mechanical work was developed by the hip, compared to 35% but he knee and 20% by the ankle. Therefore, similar to wallabies, muscles acting at the proximal joints are primarily responsible for modulating mechanical power output during incline hopping. However, the ankle extensors do contribute, suggesting that there is not a similar division of labor.

P2.162 MCGRAIL, K.A.*; WALKER, R.A.; DEAROLF, J.L.; RICHMOND, J.P.; Hendrix College, Conway, AR, Univ. of North Florida, Jacksonville, FL; *mcgrailka@hendrix.edu*

Effects of prenatal steroids on the citrate synthase activity of the fetal guinea pig (Cavia porcellus) diaphragm

Glucocorticoids are often given to women in clinical settings who are expected to go into preterm labor. These corticosteroids ensure that the lungs of premature fetuses mature before birth, thereby increasing the chances of survival for these preterm infants. However, the effects of these steroids on the development of ventilatory muscles are not well known. Studies in our laboratory have shown that multi-course prenatal treatment with corticosteroids increases the proportions of highly oxidative fibers in fetal guinea pig breathing muscles. These findings suggest that prenatal glucocorticoids accelerate muscle development. Based on the previous results, we hypothesize that the diaphragm muscles of fetal guinea pigs treated with the steroid will show increased citrate synthase (CS) enzyme activity, an important enzyme for aerobic respiration, than those not treated with the steroid. To test this hypothesis, pregnant guinea pigs were injected with betamethasone (0.5 mg/kg) or sterile water twice a week, 24-hours apart, for three weeks at 65%, 75%, and 85% gestation. Samples of the diaphragms were then prepared, and their CS activities were measured with a microplate reader under the following conditions: 50 mM imidazole, 0.25 mM DNTB, 0.4 mM acetyl CoA, and 0.5 mM oxaloacetate, pH 7.5 at 37°C. The rate of change of the assay absorbance (at 412 nm) at the maximum linear slope (Vmax) was used to calculate the CS activities of the control and treated fetal diaphragms, and the average activities of the muscles were compared. If our hypothesis is supported, prenatal steroids could prepare premature babies for ventilation by increasing fatigue resistance in the diaphragm.

P3.95 MCHORSE, BK*; HOPKINS, SSB; DAVIS, EB; University of Oregon; *bmchorse@uoregon.edu*

Functional morphology in modern horses: natural vs. artificial selection

Functional morphology plays an important role in modern sport horse purchase and breeding decisions. Conformation, or the skeletal proportions of the animal, is considered a reliable indicator of athletic ability and long-term resistance to injury. Despite the influence of conformation assessments on equine breeding and trade, few studies have used analytical methods to establish quantitative relationships between conformation and performance in artificially-selected competition horses, and none have examined the differences between domestic breeds and the feral mustang. Existing work suggests a significant relationship between judgments of quality and conformational variables, especially shoulder and pelvis angle, which influence the reach and timing of stride. We investigated the conformation-performance correlation in eventing, an equestrian discipline that tests the ability of the horse to complete three unique phases. We conducted the same measurements on extant mustangs, which are under natural selective pressures. Results suggest a significant relationship between conformational variables and competition scores; however, the characters that predict performance in eventing are not exactly the same as those that distinguish between the morphology of mustangs and performance horses. Higher performance correlates with a shorter back, longer neck, shorter metapodials, and a sloping pelvis. Mustangs tend to differ from domestic breeds in their generally smaller size and more compact structure, as well as having a narrower range of variation in conformational traits. These results show the need for caution when using domestic horses in evolutionary studies. Mustangs, even if domesticated after ranging as part of a feral herd, may be a more appropriate group to use when exploring the evolutionary history and patterns of horses.

P1.17 MCKEE, A*; VOLTZOW, J; PERNET, B; California State University, Long Beach, University of Scranton, Pennsylvania; *biologymajor8@gmail.com*

Substrate attributes determine gait in a terrestrial gastropod

Some terrestrial gastropods are able to move using two gaits: adhesive crawling, where the entire foot is coupled to the substrate by mucus and the snail leaves a continuous mucus trail, and loping, where regions of the foot arch above the substrate and the snail leaves a discontinuous mucus trail. Some previous researchers have suggested that loping is only used as a means of escaping predators rapidly. We found that in the pulmonate *Cornu aspersum*, gait choice is determined in part by attributes of the substrate: snails moved using adhesive crawling on dry acrylic or glass substrates, but loped on dry concrete or wood. Loping snails did not move more rapidly than snails moving by adhesive crawling. Snails loping on concrete secreted a greater volume of pedal mucus per area of substrate contacted than those moving by adhesive crawling on acrylic. Because loping snails contact a smaller area of substrate per distance travelled than do snails using adhesive crawling, loping may help conserve mucus when moving on porous, absorbent substrates like concrete. Additional studies are needed to understand gait choice by terrestrial gastropods in natural habitats and the effects of factors such as body hydration and atmospheric humidity on locomotory behavior.

P1.152 MCKENNEY, E.*; WU, S.; YODER, A.D.; RODRIGO, A.; Duke University; *eam50@duke.edu*

MMAP: A Pipeline for Metagenomic Analysis of Complex Microbial Populations

Comparative metagenomics is here to stay. Investigators have increasing needs for characterizing microbial communities in unexplored environments and biological systems, and next generation sequencing technologies provide a nearly instantaneous means for describing these communities at the DNA sequence level. While several pipelines exist for the integrated analysis of phylogenetic datasets, to date no program is available to streamline a similar approach to whole genome shotgun sequences (WGS). To meet this challenge, we introduce Microbial Metagenomic Analysis Pipeline (MMAP), a bioinformatic program that integrates software packages to synthesize WGS reads (MetaSim-optional), align reads into contigs (Genovo), identify open reading frames (Glimmer), perform a blast search for gene ontology (GO) terms, and finally compare the resulting profiles between metagenomic libraries (MINE). MMAP inputs WGS to retrieve GO terms, instead of identifying individual genes, to paint a comprehensive picture of community functions. This approach is valuable for the study of microbial populations, which may display considerable convergent evolution despite high biodiversity. In the gastrointestinal tract (GIT), for example, functional redundancy results from a combination of evolutionary pressures unique to that environment and the microbes' ability to transfer genes laterally amongst themselves. Yet, despite the core metagenome exhibited across GIT microbial consortia, genetic profiles can and do change with differences in population composition and host factors. We built MMAP to tease apart these intertwining patterns and to elucidate the relationship between taxonomy and functionality within the GIT microbial community. Our open-source program is written in Python and can be downloaded at https://github.com/YoderLab/MMAP.

P2.172 MCKINNEY, M.L.*; WALKER, R.A.; DEAROLF, J.L.; RICHMOND, J.P.; Hendrix College, Conway, AR, Univ. of North Florida, Jacksonville, FL; *mckinneyml@hendrix.edu*

The scalenus and diaphragm muscles' contributions to inspiration in the bottlenose dolphin (Tursiops truncatus)

Dolphins have a unique ventilatory system that allows them to have an explosive intake of air during their brief rise to the surface. This extremely quick inhalation suggests that the muscles that drive this behavior are composed primarily of fast-twitch fibers. However, previous studies have shown that in bottlenose dolphins, the diaphragm, the main muscle of inspiration in terrestrial mammals, is composed primarily of slow twitch fibers, while the scalenus muscle is composed primarily of fast twitch fibers. These results suggest that the diaphragm and scalenus of bottlenose dolphins do not contract together to drive inspiration, and muscles that do not work together should be found to have different levels of oxidative enzyme activities. Samples of the diaphragm and scalenus muscles of eight bottlenose dolphins were taken and analyzed for their citrate synthase (CS) activity, which can be used as a measure of aerobic capacity. Extracts of the muscles were prepared, and their CS activities (µmol/min*g wet muscle mass) were measured with a Synergy HT microplate reader under the following conditions: 50 mM imidazole buffer (pH 7.5 @ 37°C), 0.25 mM DTNB, 0.4 mM acetyl-CoA, and 0.5 mM oxaloacetate. The scalenus muscle consistently had a higher CS activity (overall average: 15.07 +/- 0.91 µmol/min*g) than the diaphragm muscle (6.10 +/- 0.55 µmol/min*g) from the same bottlenose dolphin, which supports the hypothesis that the scalenus and diaphragm do not work together to power ventilation in bottlenose dolphins. Our results suggest that the diaphragm may not be the main muscle of inspiration in these cetaceans, because it does not have the fiber composition or aerobic capacity to drive this behavior.

P2.30 MCLEAN, K.M.*; TODGHAM, A.E.; San Francisco State University; *kmclean@mail.sfsu.edu*

Effect of food availability on thermal tolerance of juvenile Dungeness crabs in the San Francisco Estuary

Understanding the consequences of anthropogenic environmental change to Dungeness crabs, *Metacarcinus magister*, is crucial for the successful management of this species. By 2100 the San Francisco Estuary (SFE) will experience a 1.5-4.5°C increase in average temperature as well as more frequent extreme thermal events. Within the estuary, 0+ age group juvenile crabs prefer eelgrass beds and oyster beds because they provide refuge from predators and elevated nutrient availability. Little is known about whether this increased nutrient availability enables juvenile Dungeness crabs to better tolerate extreme thermal events by providing them with more energy to grow and allocate to other physiological processes like stress tolerance. We investigated the effect of different food rations on the upper thermal tolerance of juvenile Dungeness crabs. 0+ Dungeness crabs (15-25mm) were collected from the SFE and were held in outdoor tanks for four weeks under two feeding levels: high (300mg squid tissue/48hrs) and low (50mg squid tissue/week). Crabs in the low food group weighed significantly less and had significantly smaller carapace widths than crabs in the high food group. When crabs were separated by whether they recently molted, the weight differences between feeding groups were apparent in both molted and non-molted crabs. Heart rate was then monitored in crabs as temperatures were increased from 12°C (current bay temperature) to 36°C (representing a thermal extreme) over a 4h period. Upper thermal tolerance was determined by a break in heart function. To assess the metabolic response to elevated temperature, crabs were placed in respirometers held at constant temperature (15, 20, 25 and 30°C) and oxygen consumption was measured until oxygen levels decreased to 80% air saturation.

P3.127 MCMICHAEL, J. W. *; FIELD, K. A.; Bucknell University; *jm081@Bucknell.edu*

Cytokine Gene Expression and Lymphocyte Expansion During Graft Rejection in Mice

The strength and type of immune response triggered by an antigen can be quantitatively measured by determining the gene expression profile of cytokines. By comparing the relative expression of certain cytokine genes, we can determine which subset of T cells are mediating the immune response. Using a model of organ rejection known to depend on a Th2-mediated immune response, we will compare the expression of the signature cytokines for Th1 cells (interferon-g), Th2 cells (interleukin-4), Th17 cells (interleukin-17), Treg cells (TGF-b), and the anti-inflammatory cytokine, interleukin-10. We are using skin graft rejection in mice as a model to demonstrate the usefulness of this approach, which then will be extended to non-model species, including bats affected by white-nose syndrome. To cause an immune response, C-57BL/6 mice in a pathogen-free environment received allogeneic MHC II disparate skin grafts from bm12 mice. Graft draining lymph nodes were collected on days 12-14, and the total RNA was isolated for qRT-PCR analysis of gene expression. In addition to analysis of the signature cytokines, a broad spectrum analysis of 80 other cytokines involved in the rejection response will be compared. The resulting total gene expression associated with the T-cell mediated response then can reveal a focused panel of cytokine expression specific to this type of graft rejection. Identifying the relationship between gene expression and lymphocyte cell expansion in laboratory mice during graft rejection can assist in the continued development of research on the immune responses of other diseased mammals. We will be developing a quantitative PCR panel for bat cytokine genes in order to measure the immune responses involved in susceptibility to white-nose syndrome.

98.1 MCWHORTER, TJ*; SCHONDUBE, JE; NICOLSON, SW; PINSHOW, B; FLEMING, PA; MARTíNEZ DEL RIO, C; University of Adelaide, Universidad Nacional Autónoma de México, University of Pretoria, Ben-Gurion University of the Negev, Murdoch University, University of Wyoming; *todd.mcwhorter@adelaide.edu.au*

Convergence in digestive capacity in nectar-feeding birds

Across five continents, nectarivorous birds show striking similarities in their physiological and morphological attributes and foraging strategies. We tested whether different nectar-specialist avian taxa are convergent in characteristics of their digestive physiology and gastrointestinal morphology. Specifically, we compared the digestive traits of eight nectarivorous passerine species from the families Meliphagidae (Australasian honeyeaters) and Nectariniidae (Old World sunbirds) with published data for hummingbirds (Trochilidae) and other passerine species that are considered diet-generalists. We examined the capacity to digest three food substrates: sucrose (via the activity of the enzyme sucrase-isomaltase), maltose (via maltase-glucoamylase activity; an indirect measure of capacity to digest starch) and protein (via aminopeptidase-N activity), and also compared intestinal nominal surface area. Intestinal surface area and maltase activity were similar across species. Aminopeptidase activity was lower in hummingbirds than in passerines. Nectar-specialist passerines had lower capacity to digest sucrose (a common nectar sugar) than hummingbirds, but higher sucrase activity than diet-generalist passerines. Using a chemical reactor model of digestive function we found that the ability of nectar-specialist passerines to assimilate energy from sucrose solutions falls between that of hummingbirds and diet-generalist passerines. The ability of passerines that specialize in feeding on nectar to hydrolyse sucrose therefore appears to be convergent with that of hummingbirds.

36.1 MCWILLIAMS, S.R.*; BAUCHINGER, U.; BOLSER, J.A.; ALAN, R.R.; SMITH, A.D.; SEERAM, N.P.; PIERCE, B.J.; BOYLES, M.; LANGLOIS, L.; GERSON, A.; PRICE, E.; GUGLIELMO, C.; Univ. Rhode Island, Kingston, Sacred Heart Univ., Fairfield, CT, Univ. Western Ontario, London; *srmcwilliams@uri.edu*

The stress of stopping over: oxidative stress associated with long-duration flights and its implications for the ecology of migrants at stopover sites.

Birds during migration use primarily fats to fuel their long-duration flights and this high rate of fat metabolism during exercise substantially increases the bird's oxidative stress. We tested the following series of related hypotheses: (a) free-living birds at migration stopover sites select fruits based on antioxidant content; (b) dietary protein consumption in uricotelic birds is positively related to circulating antioxidant levels; and (c) exercise training such as flight causes upregulation of liver antioxidant enzymes. We report evidence from field and captive studies that support all three hypotheses. Thus, birds actively select antioxidant-rich fruits during autumn migration and upregulate their endogenous antioxidant capacity during migration, and this protects them from the potentially damaging effects of oxidative stress caused by long-distance fasting flight. Supported by NSF (IOS-0748349), USDA (RIAES-538748), and Canadian Foundation for Innovation (AFAR).

P2.171 MEEHAN, ST*; TAYLOR, KR; NISHIKAWA, KC; Northern Arizona University; *stm48@nau.edu*

Breathing with a spring: Exploring the role of titin in respiration

Respiration in mammals requires continuous power output and thus a constant energy supply. For that reason, one would expect a strong selective pressure to reduce the energetic cost of respiration. Therefore, the properties of the diaphragm, including muscle stiffness, are expected to impact respiration. The diaphragm muscle in the muscular dystrophy with myositis (MDM) homozygous mutant is about 2-4 times stiffer than in nonmutant mice when the muscle is stretched passively. Mutant MDM mice have a deletion in the N2A region of titin, an integral elastic muscle protein. Nonmutant and mutant mice were filmed with a high-speed digital camera to allow measurement of changes in abdominal width during resting respiration at room temperature. From these measurements, we calculated the respiration rate. The respiration frequency for both mutant and nonmutant mice conformed to allometric predictions and were not significantly different from one another in absolute terms. In addition, the duration of inspiration was similar between nonmutant (77 ms +/- 13 ms) and mutant (80 ms +/- 26 ms) mice. However, the duration of expiration in nonmutants (165 ms +/- 20 ms) was about double the expiratory duration observed for mutants (86 ms +/- 30 ms), meaning that the mutants expired twice as quickly as the nonmutants. The observed doubling of the speed of exhalation in mutants is not difficult to explain since the mutant diaphragm is more than twice as stiff as the nonmutant diaphragm and therefore would be expected to exhibit faster passive recoil. These results provide in vivo support for the idea that mutant muscles are stiffer during the passive phase. Thus, these data indicate that titin stiffness plays an important role in muscle function on the organismal level.

P1.96 MEHRABANI, H; TSE, K.L.*; RAY, N.A.; EVANGELISTA, D.A.; Univ. of California, Berkeley; *hmehrabani5110@gmail.com*

Development of Bio-Inspired Surfaces to Prevent Ice Formation

Growth of ice on surfaces poses a serious challenge for both organisms and devices that come into contact with liquids below the freezing point. Resistance of some organisms to ice formation and growth, either in subtidal environments, such as Antarctic anchor ice, or in environments with moisture and cold air, such as plants, begs examination of how this is accomplished. To examine the effect of surface texture alone, we tested four candidate surfaces, inspired by hard-shelled marine invertebrates and constructed by three-dimensional printing processes. We developed a new experiment to examine ice formation from surface droplets as encountered in environments with moist, cold air. We compared these to results from adopted assays from previous literature designed to screen for ice formation and accretion in submerged conditions. While most surfaces promoted ice formation relative to a flat control surface, grid patterns, corresponding to the freshwater clam *Mya arenaria*, inhibited the time of ice formation by up to 6%, depending on pattern parameters. Surface texture, rather than surface area, appears important in ice formation. However, this does not explain by itself the large variation in ice formation observed in other studies. This suggests examination of additional factors, such as material properties and coatings, and their interaction with surface patterns.

P3.118 MEHTA, R/S; Univ. of California, Santa Cruz; *rsmehta1123@gmail.com*

Density Estimates, Growth Patterns, and Diet of the California moray, Gymnothorax mordax, Around Catalina Island

Documenting the trophic ecology, density, spatial distributions, and growth rates of top predators is essential to our understanding of community dynamics. Despite the probable importance of morays in structuring kelp forest dynamics no study has attempted to investigate the predatory habits, relative abundance, and growth patterns of the California moray, *Gymnothorax mordax*. Here, I propose to assess the potential importance of the California moray in structuring kelp forest communities by collecting basic biological data that is lacking for this apex predator such as density estimates, growth patterns, and diet. I used modified lobster traps to catch eels at 6 different sites along the west side of Catalina Island. Once captured, 8 morphological measures were recorded on each individual and morays were PIT tagged before release. At the end of August – early September,over 200 moray eels were captured along 1400 meters of rocky kelp forest habitat. Morays ranged from 10g to just over 5kg in mass. Morphological variables such as head length, vertical gape, and body width exhibited negative allometry with standard length. At smaller size ranges (20-60 cm in standard length) morays appear to increase their mass at a much faster rate while mass appears to slow down when individuals reach roughly 80 cm in total length. This slowing of mass with standard length may indicate that morays are reaching their maximum body size. Diet data from field observations suggest that the California moray has a more omnivorous feeding habit compared to other tropical moray species and consumes a variety of crabs and fish that inhabit the temperate kelp forest.

68.6 MEIR, J.U.; University of British Columbia; *meir@zoology.ubc.ca*

Energy expenditure is independent of dive function in a deep diving vertebrate, the northern elephant seal

Although energetics are fundamental to animal ecology, traditional methods of assessing metabolic rate are not both direct and instantaneous. Recently, continuous blood oxygen (O_2) measurements were used to document energy expenditure in diving elephant seals (*Mirounga angustirostris*), demonstrating that an exceptional hypoxemic tolerance and exquisite management of blood O_2 stores underlie their extraordinary diving capability. Despite numerous behavioral and ecological diving studies and a growing body of physiological data, we lack a clear understanding of how diving behavior affects energy expenditure in air-breathing vertebrates. To begin to unravel these relationships, we analyzed dive profiles and classified O_2 utilization according to dive type (overall function of dive: transit, foraging, food processing/rest), linking fine scale behavior with *in vivo* O_2 measurements for the first time in a free-diving animal at sea. In routine dives of elephant seals, the blood O_2 store was significantly depleted to a consistent level for dives of the same duration irrespective of dive function, indicating that all dive types have equal costs. Thus, although elephant seals appear to devote one major task to a given dive, thereby separating dive functions into distinct dive types, each of these bears the same sizeable expense. This strategy may optimize O_2 store utilization and recovery, consequently maximizing time underwater and allowing these animals to take full advantage of their underwater resources. Additional studies integrating dive behavior and physiology will provide a more complete understanding of the ecology and conservation needs of these animals. This may be especially important to species like the elephant seal that operate regularly at considerable cost, particularly in determining their ability to cope with unpredictable environmental perturbations.

P1.181 MEKDARA, PJ*; SHINKAWA, N; MEKDARA, NT; GOTO, JJ; MULLER, UK; California State University, Fresno; *pmekdara@csufresno.edu*
Acute effects of BMAA-induced neurodegeneration in Drosophila
Beta-methylamino-L-alanine (BMAA) is a non-essential amino acid that has been linked to amyotrophic lateral sclerosis (ALS), which is a severe human neurodegenerative disease. In humans, long exposure to BMAA causes Parkinson-like symptoms. The functional properties of BMAA in the nervous system are similar to glutamate, suggesting that BMAA is a glutamate agonist. Since glutamate is a major neurotransmitter in both insects and vertebrates, we used *Drosophila melanogaster* to study the effects of BMAA toxicity. In insects, glutamate functions as the excitatory neurotransmitter at the neuromuscular junctions, and is also a neuromodulator in the central pattern generator, making glutamate an important factor in controlling walking activity. The study (1) quantified the acute effects of BMAA injection on locomotory behavior, (2) compared these effects to the effects of injected glutamate to determine if BMAA has the same effects as glutamate, and (3) found evidence of a sequestering mechanism by observing transient effects of the toxin. Fruit flies injected with BMAA at the concentration of 12.5 mM, 25 mM, and 50 mM showed hyperactivity almost immediately. Flies injected with BMAA and glutamate differed in their walking and flight behaviors. Fruit flies injected with glutamate were able to recover from their initial locomotory deficits within one hour after injection while the symptoms of the BMAA treated flies continued. So the sequestering mechanism for glutamate seems to be less effective for BMAA.

P1.120 MELICHER, D*; TORSON, A; North Dakota State University; *dacotah.melicher@ndsu.edu*
Understanding novel evolutionary changes in morphology using next-generation sequencing technology
Morphological evolution is often the result of changes in the location, level, or duration of the expression of developmental genes. The sepsid fly Themira biloba has a complex, jointed abdominal appendage with no homologous structure outside of the family Sepsidae. This appendage appears to have evolved independently in several Sepsidae specices which implies that the underlying genetic regulatory network responsible for its development was already in place prior to the appearance of the appendage itself. Improvements in next-generation sequencing technologies allow us to compare gene expression in different tissues. By sequencing samples of different tissues we are able to create a transcription profile of the gene transcripts present in each tissue. This allows us to perform a comparative analysis to determine which developmental genes are up-regulated during appendage specification and development. Because the appendage develops from cells located in the 4th larval segment in male flies we have chosen to compare the transcription profile of the 3rd and 4th segments of males as well as the 4th segments of male and female larva to determine the genes involved in specification and patterning of the appendage.

137.4 MEMBRENO, N.A.*; ELSEY, R.M.; OWERKOWICZ, T.; California State University, San Bernardino, Rockefeller Wildlife Refuge, Louisiana Dept of Wildlife and Fisheries, Grand Chenier; *membrenn@coyote.csusb.edu*
Importance of the calcareous eggshell to normal skeletal development in the American alligator
During development, oviparous reptiles rely on both yolk and eggshell calcium stores for skeletal growth of the embryo. By hatching time, squamates and chelonians deplete the yolk almost completely of calcium. In contrast, embryonic archosaurs (crocodilians and birds) sequester calcium from the heavily mineralized eggshell and store it in yolk, so that the yolk sac can serve as a mobile calcium source in hatchlings. We studied the relative importance of eggshell calcium to normal development and growth of the American alligator (*Alligator mississippiensis*). At approximately three weeks after egg laying, the calcareous eggshell layer of the experimental eggs was completely peeled by hand, while clutch-matched control eggs were sham-handled but not altered. All eggs were incubated at 30°C and 100% humidity, and embryos were sampled at regular intervals until hatching. At first, there was no discernible difference in embryo growth. As incubation progressed, however, experimental embryos grew more slowly than sham embryos. At hatching, experimental embryos were 36% smaller than their sham siblings, whereas their yolk sacs were 3-4x larger. Despite being diminutive, experimental hatchlings were active and apparently healthy. Our results suggest that eggshell calcium is important for embryonic growth in alligator, but sufficient calcium reserves are found in the yolk. Shell-less embryos are capable of survival until and after hatching. We posit that evolution of heavily mineralized eggshells of archosaurs may have been driven by factors other than the need for calcium mobilization during embryonic skeletal development.

126.3 MENZEL, L.P.*; BIGGER, C.H.; Florida International University; *lorenzo.menzel@fiu.edu*
Antibacterial peptides from the caribbean octocoral Swiftia exserta.
Endogenous small antimicrobial proteins (and peptides) are important components of the innate immune response of animals. Microbicidal peptides are widespread and have been found in all living organisms studied. Since our understanding of the evolution of innate immunity is not well developed, particularly those immune responses in cnidaria, our lab endeavors to study such immune responses in the octocoral *Swiftia exserta* (an azooxanthellate, ahermatypic anthozoan). Understanding aspects of coral immune responses may lead to ameliorating the precipitous decline of these important marine animals. The survival of sessile marine animals depends heavily on an efficient mechanism to protect themselves against infection/colonization by the multitude of microbes in the surrounding water column.
In order to study the proteinaceous effectors of *Swiftia*'s antimicrobial defense we extracted branches in acidified water. Nuclei and large debris were removed, the clarified extract size fractionated with a 10 kDa cutoff membrane, and the filtrate then partially purified via continuous electrophoresis. Timed fractions were collected, concentrated by centrifugal evaporation, and tested for antibacterial activity with a two-stage radial diffusion assay. Several fractions exhibited potent antibacterial activity against gram-negative (*E. coli, P. aeruginosa*), and gram-positive (*S. aureus, L monocytogenes*) bacteria.
These preliminary results from an anthozoan supplement the 2006 report on Aurelin (from the scyphozoan *Aurelia aurita*) to establish a repertoire of antibacterial peptides in cnidaria. Characterization of the antibacterial proteins (amino acid sequence and structure) found in *Swiftia* (and other cnidaria, animals that diverged before the protostome-deuterostome split) will further our understanding of the evolution of this crucial aspect of innate immunity.

P3.126 MENZEL, L.P.*; BIGGER, C.H.; Florida International University; *lorenzo.menzel@fiu.edu*

Can enzyme histochemistry identify the immune cells of the octocoral Swiftia exserta?

Most animals rely on circulating hemocytes (leukocytes in mammals) as cellular effectors of their immune system. These cells have traditionally been characterized based on morphology, function, and/or cellular contents/products. Morphological descriptions utilize granular sizes, shapes, and abundancy, and cell shapes; functional descriptions rely mainly on phagocytic ability and oxygen transport; while cellular content descriptions include cytochemical features and an array of enzymes.

Some of the key enzymes have become standard identifiers of phagocytic cells in tissues, e.g., hydrolytic enzymes, peroxidase, and, in invertbrates, phenoloxidase. Sudan black, neutral red, and several histological stain combinations (Wright's stain, Ehrlich's trichrome, Mallory's connective tissue) have been used for cytochemical differentiation of hemocytes.

Cnidaria, such as our model animal *Swiftia exserta*, lack a circulatory system making the isolation and characterization of immune effectors cells more challenging. To date a cell type termed the "granular amoebocyte" (clearly a purely morphological description) has been the suggested "immunocyte" (possibly a mixed cell population). In order to identify and characterize the immune effector cells in *S. exserta* we employed several classical enzyme histochemistry techniques for sub-cellular (histological and ultrastructural) localization of phosphatases, peroxidases, phenoloxidase, and mono-amine oxidase. In addition, we utilized several cytochemical methods (periodic acid-Schiff, sudan black, neutral red, and Wright's stain) to characterize these cells. The results with these staining techniques allow us to characterize the putative "immunocytes" in anthozoans.

P1.139 MENZEL, E.J.*; SECOR, S.M.; University of Alabama; *ejmenzel@crimson.ua.edu*

Exploring the phenotypic plasticity of intestinal responses for snakes

The proposed dichotomy in the capacity for phenotypic flexibility of snake intestine is seated in studies on distinctly frequent or infrequent feeding species. However, snake feeding habits lie along a continuum and species do exhibit distinct ontogenetic shifts in feeding habits and/or possess populations that differ in feeding ecology. Snake species that posses large geographic ranges and therefore have populations that vary in feeding habits due to localized diversity and abundance of suitable prey, may exhibit a single established intestinal response or a mosaic of responses that reflect localized feeding habits. This study explores whether population differences in feeding habits are matched in a predicted fashion to their corresponding intestinal response. The species chosen for this study was the cottonmouth, *Agkistrodon piscivorus*. From preserved specimens we analyzed for differences with respect to feeding state microvillus length. We used variation in microvillus length as a proxy of intestinal regulation. Very short microvilli (~0.5 µ m) and much longer microvilli (~ 2 µ m) would indicate that the species widely regulates intestinal performance. The lack of any significant differences in microvillus length (2±0.5 µ m) among museum specimens would suggest that the species modestly regulates intestinal performance. Specimens showed significant statistical difference in microvilli length between those with (1.4±0.02 µ m) and without food items (1.4±0.02 µ m) in the gut ($p<0.01$, $F=103.76$). Although there is a significant difference in microvillus length they are not of the magnitude of difference seen in infrequently feeding pythons and boas. This suggests that there is relatively modest regulation between fasted and fed snakes.

50.3 MERNER, M.J.*; BERENDZEN, P.B.; Univ. of Northern Iowa; *mernerm@uni.edu*

Hox Gene Evolution in North American Suckers (Cypriniformes: Catostomidae), a Tetraploid Family of Fishes

Most eukaryotic organisms are diploid, containing two sets of chromosomes, one from each parent. However, having more than two sets of chromosomes, a condition known as polyploidy, is prominent in some taxa such as vascular plants. Members of Catostomidae, a fifty million-year-old monophyletic family comprising sucker fishes, have four sets of chromosomes. This condition, known as tetraploidy, presents interesting questions in regard to the fate of the duplicated genome. In particular, Hox genes in a diploid organism are normally highly conserved due to their role in orientation and morphology of organisms. The duplication of Hox genes in Catostomidae may lead to a higher rate of mutation. This is due to the presence of the extra copy which would mask a normally detrimental effect. This study tests the hypotheses that 1) fourteen Hox clusters will be present in Catostomidae rather than the seven clusters found in most teleost fishes; 2) some Hox genes within the clusters will not be conserved but silenced through the formation of stop codons; 3) Hox genes that are silenced will show a phylogenetic pattern across the catostomids; and 4) the species of catostomids with more derived traits will have more changes to their Hox genes. To test this, thirteen degenerate primer sets were used to target and isolate specific regions of Hox genes. Subsequent amplification through PCR, cloning of plasmid DNA, and sequencing of the clones were performed on a diversity of species across the catostomid phylogeny. Preliminary results will be presented.

86.2 MERRICKS, J.A.*; GERHARDT, H.C.; Univ. of Missouri, Columbia; *jawfz2@mail.missouri.edu*

Signal plasticity and mate recognition in the pine woods treefrog, Hyla femoralis

Both female preference and male competition shape the evolution of acoustic sexual signals. In the complex acoustic environment of anuran breeding aggregations, signalers are challenged to transmit signals that receivers must recognize and then respond to appropriately. Often signal traits are classified as static or dynamic based on the amount of within-individual variation. Static traits have little variation, while dynamic traits can vary drastically within a single calling bout. For North American hylids, fine-scale temporal patterns are generally static. In several species, females show a strong preference for a narrow range of variation; therefore, the static nature of certain temporal traits is presumed to be crucial for mate choice. The advertisement signal of *Hyla femoralis* is characterized by a highly unusual, irregular series of pulses. Our research is the first to explicitly investigate pulse period irregularity in this group of hylids and may reveal new recognition mechanisms in females of this species, in which females attend to subpulse structure. Our results show that competition among males as well as female preference for fast and regular pulse rates may enhance signal detection in noisy choruses.

P3.185 MERRILL, L.*; NAYLOR, M.F.; WASELIK, M.W.; GRINDSTAFF, J.L.; Oklahoma State University; *loren.merrill@okstate.edu*

Effects of pre- and post-natal exposure to two antigens on adult stress responsiveness in the zebra finch (Taeniopygia guttata)

Pre- and post-natal environments are known to impact the adult phenotype in many ways. In this study we used captive zebra finches (*Taeniopygia guttata*) to examine the effects of pre- and post-natal exposure to two kinds of antigens and a control on hypothalamic-pituitary-adrenal (HPA) axis reactivity in adults. Prior to breeding, we injected a subset of adult female finches with lipopolysaccharide (LPS) which induces a systemic, febrile response, activates the HPA axis and results in elevated levels of corticosterone (CORT). In another subset, we injected keyhole limpet hemocyanin (KLH) which results in a response comprised primarily of anti-KLH antibodies without activation of the HPA axis. Offspring of the three treatments were themselves broken into subsets and exposed to LPS, KLH or control at the age of 5 days. Offspring were then tested at a minimum age of 18 months to determine the impact of treatments on adult stress responsiveness. Birds were blood-sampled at capture, 10 min and 30 min post capture to assess the strength of the stress response via circulating levels of CORT. We documented differences both in the strength and duration of the stress response among treatment groups, indicating that pre- and post-natal exposure to infectious agents can result in permanent changes in HPA axis reactivity.

S7-1.6 MERRITT, DJ*; MAYNARD, AJ; The University of Queensland, Australia; *d.merritt@uq.edu.au*

Synchronization of circadian bioluminescence as a group-foraging strategy in cave glowworms

Flies of the genus *Arachnocampa* are sit-and-lure predators that use bioluminescence to attract flying prey to their silk webs. Some species are most common in rainforest habitat and in others their habitat includes both caves and rainforest. We have studied the circadian regulation of bioluminescence in two species; one found in subtropical rainforest with no known cave populations, the other found in temperate rainforest with large populations in limestone caves. The rainforest species is typical of most nocturnal animals in that individuals are entrained by the light:dark cycle to be active at night: in this case, their propensity to bioluminesce is greatest at night. The dual-habitat species shows the opposite entrainment response; it's bioluminescence propensity rhythm is entrained by L:D exposure to peak during the day. Nevertheless, in L:D environments, individuals don't bioluminesce during the day because ambient light inhibits their bioluminescence (negative masking), pushing bioluminescence into the dark period. This unusual and unexpected phenomenon could be related to their association with caves. Entrainment of the bioluminescence rhythm to the photophase causes colonies of larvae in the dark zone to synchronise to each other, creating a daily sinusoidal rhythm of bioluminescence intensity in the many thousands of individuals making up a colony. This synchronisation could provide a group-foraging advantage, allowing the colony to glow most brightly when the prey are most likely to be active.

S7-2.3 MEUTI, Megan E.*; DENLINGER, David L.; The Ohio State University; *meuti.1@osu.edu*

The Role of Circadian Clock Genes in the Overwintering Diapause of the Northern House Mosquito, Culex pipiens

Diapause is an arrested state of development that allows insects and other arthropods to survive adverse seasonal conditions, such as the limited food availability and lower temperatures that are associated with winter. Temperate insects enter diapause in response to the short day lengths of late summer and early fall. However the molecular mechanisms by which insects measure day length is unknown. Several researchers have hypothesized that the circadian clock, which provides insects with information on the time of day, might also be involved in measuring day length. To determine whether the circadian clock is involved in initiating the overwintering diapause of the Northern House Mosquito, *Culex pipiens*, we used RNA interference to knock down several core circadian clock genes (*period*, *timeless*, *Cryptochrome2* and *Cycle*). We confirmed RNA knock down using qPCR, and assessed the diapause status of RNAi-treated females by measuring the length of their egg follicles (large follicles = non-diapause; small follicles = diapause). We found that knocking down the clock gene *Cycle*, a positive regulator of the circadian clock, had no effect on diapause initiation. However when negative regulators of the circadian clock (*period*, *timeless* and *Cryptochrome2*) were knocked down, female mosquitoes that had been reared under diapause inducing conditions failed to enter diapause. Our results suggest that a functioning circadian clock is essential for initiating the overwintering diapause of these mosquitoes.

P2.131 MICHEL, K.B.; University of Antwerp; *krijn.michel@ua.ac.be*

Kinematics and functional morphology of feeding in the Northern clingfish

The northern clingfish *Gobiesox maeandricus* uses the lower jaw to pry limpets from the substrate. This study investigated the unique morphology and kinematics of the clingfish feeding apparatus and the structural elements involved when feeding on limpets. Through the use of high speed video and micro CT-scan we answered the following questions: (1) What are the primary structures involved in this unique prey capture process? (2) How is the clingfish morphology adapted to perform these movements? (3) How is the force needed to dislodge limpets generated? The feeding apparatus has been adapted to be able to force the teeth as a wedge between the limpet shell and the substrate. The pectoral suctorial organ functions as the pivot from which the anterior wedging force is generated via the post cranial musculature. The epaxial muscles elevate the entire skull, including oral jaws, thereby helping to dislodge the limpet from the substrate. We hypothesize that the pectoral suctorial organ is of crucial importance for clingfish to be able to generate enough force to feed on limpets. By using the pectoral suctorial organ as a fulcrum, the entire skull is protruded and elevated in order to pry a limpet from the substrate.

60.5 MIDDLEBROOKS, ML*; BELL, SS; CURTIS, NE; PIERCE, SK; Univ. of South Florida; *mlmiddle@mail.usf.edu*

Molecular analysis demonstrates that proximity is a poor indicator of food source for a photosynthetic herbivore.

The diet of many herbivore species has been determined, often incorrectly, by their proximity to potential food plants. Many species of herbivorous, sacoglossan sea slugs, can acquire energy through photosynthesis by intracellular chloroplasts sequestered from their algal food. This additional source of energy might allow these slugs to inhabit areas devoid of food sources for as long as they are photosynthetically capable. We tested this hypothesis on *Elysia clarki*, a kleptoplastic sacoglossan endemic to the Florida Keys. *Elysia clarki* can maintain photosynthetic activity for 3 to 4 months without feeding and even synthesizes chlorophyll and other plastid related compounds to sustain the symbiotic chloroplasts. Using a combination of field surveys and DNA sequencing to identify the sequestered chloroplasts, we found that proximity to food sources was a very poor indicator of the diet of *E. clarki*. In fact, in some cases, slugs had been feeding on alga not detected in the field surveys. These findings support the idea that photosynthetic herbivores may be able to survive in areas lacking food sources for prolonged periods of time. (Supported by an anonymous patron).

36.3 MIDDLETON, KM*; COATS, BR; University of Missouri, University of Chicago; *middletonk@missouri.edu*

Energy metabolism of small muscle phenotype mice compared to inbred strains in response to exercise

In recent years, studies of the skeletal system have revealed that it occupies a central role in whole-organism energy regulation via interactions with the autonomic nervous and endocrine systems. Much of this interaction is mediated by the adipocyte-derived hormone leptin, which has broad activity on appetite, energy expenditure, reproduction, and the skeletal system. Although the leptin-bone-insulin pathway has been extensively studied in leptin or leptin receptor knockout models, selection experiments may provide a novel system in which to address similar questions. We compared physiological parameters between an inbred line of high activity mice that exhibit a small muscle mutation and two inbred strains of mice that exhibit high and low bone mass phenotypes. The high activity mice were derived from a long-term selection experiment for high levels of voluntary wheel running. We divided mice from three strains into activity and stationary groups (n = 8 each) and recorded daily wheel activity for 10 weeks. Insulin and fasting glucose levels were assayed post wheel access, while circulating leptin was assayed both before and after wheel access. Insulin was significantly lower in the activity group but did not differ among strains. In contrast, fasting glucose did not differ between strains or treatments. Mini-muscle mice showed significantly higher initial leptin levels than the other strains, and were significantly lower in exercise groups. Leptin levels were more variable in sedentary mice across strains compared to the activity group. We conclude that mice with the small muscle phenotype exhibit a similar response to exercise as has been shown in other strains and that these mice might be an appropriate model for simultaneous studies of exercise, skeletal morphology, and energy physiology.

P1.157 MIER, J.S.*; ZUZOW, M.; TOMANEK, L.; California Polytechnic State University, San Luis Obispo; *jmier@calpoly.edu*

Comparison of the proteomic responses in adductor muscle tissue of Mytilus galloprovincialis and M. trossulus to acute heat shock

Recent anthropogenic influence has caused increases in global temperature. The potential rises in temperature can impose thermal tolerance constraints which can alter marine ecosystems and restructure the extent of communal diversity. Organisms able to acclimate and adapt to thermal stress will be more resilient to the episodic and more extreme disturbances caused by climate change. To assess the biochemical mechanisms imposing thermal limits, we used a discovery based approach by comparing the proteomic responses of two species of the genus *Mytilus* (*M. galloprovincialis* & *M. trossulus*) that differ in thermal tolerance in response to acute heat stress. These mussels were acclimated to 13°C seawater for four weeks and then exposed to acute heat stress (24°C, 28°C, and 32°C respectively, with a 13°C control) for 1 h before being returned to 13°C seawater for a 24-h recovery. Multiple tissues were excised including the gill, adductor and mantle tissues. Gill tissue was then homogenized and proteins were separated using 2D gel electrophoresis followed by protein identification through MALDI TOF/TOF mass spectrometry. Protein expression profiles differed between the more heat-tolerant *Mytilus* (i.e., *M. galloprovincialis*) and the more heat-sensitive congener (i.e., *M. trossulus*), including changes in the abundances of proteins involved in cytoskeleton, molecular chaperoning, oxidative stress, energy metabolism and proteolysis. Currently, we are using the same proteomic approach to characterize the adductor muscle to elucidate whether similar changes are observed in the proteome of other tissues. These implications can provide insight as to the physiological mechanisms that govern the response to acute heat stress.

P3.44 MIKA, T.L.*; REIBER, C.L.; University of Nevada, Las Vegas; *mikat@unlv.nevada.edu*

Cardiac response to temperature in hyperoxia and normoxia in the grass shrimp, Palaemonetes pugio .

Poikilothermic animals experience a mismatch between oxygen supply and demand with increasing temperature. Thermal tolerance may be related to a failure of the cardiorespiratory system to deliver available oxygen. Animals placed in a hyperoxic environment had a higher CT_{max} than animals in a normoxic environment, suggesting a physical limitation in oxygen delivery. Analyses were performed on grass shrimp, *Palaemonetes pugio*, acclimated to 20° C exposed to a range of temperatures (5° – 40° C) in both normoxic and hyperoxic environments to determine response of the oxygen delivery system to this increased demand. Previous work investigated the ventilatory aspect of the delivery system. Current work investigates the cardiovascular aspect of the oxygen delivery system. Pressure-area loops are generated to provide estimates of stroke work, cardiac work, and myocardial oxygen consumption in both normoxic and hyperoxic conditions to determine how the system responds to reduced oxygen availability at extreme temperatures and if that response is altered in a hyperoxic environment.

P1.101 MILBERGUE, M.*; BLIER, P.; VEZINA, F.; Univ. of Quebec in Rimouski; *myriam.milbergue@live.fr*

Do small wintering birds adjust their metabolic performance in response to perceived level of cold?

Small resident bird species wintering at northern latitudes must cope with high daily energy demands, resulting mainly from thermoregulation costs. Birds respond to these conditions by physiological acclimatization where two components of metabolic performance, basal metabolic rate (BMR; maintenance energy costs) and summit metabolic rate (Msum, maximal thermogenic capacity to cold) are typically elevated. However, in most cases, parameters of metabolic performance show high variability between individuals. Although seasonal changes in BMR and Msum have been thoroughly studied for decades, we still know very little of the underlying causes for individual variation in winter metabolic performance. In this study, we investigated whether plumage insulation (measured via thermal conductance), and thus the perception of cold by individuals, was related to metabolic performance in black-capped chickadees (*Poecile atricapillus*) wintering in Quebec, Canada. We predicted that individuals expressing higher body conductance would also show higher levels of BMR and Msum as they would adjust their metabolic machinery to the perceived level of cold. More than 140 measurements were performed on fleshly captured individuals between November 2011 and April 2012. Conductance, BMR and Msum were measured by respirometry on all birds within 24h. Preliminary analyses suggest that individual variation in BMR and Msum are independent from individual thermal conductance. Further analyses will consider intra-seasonal variation in metabolic performance and ambient temperature.

124.2 MILES, D.B; Ohio University; *urosaurus@gmail.com*

Covariation of dorsal pattern, locomotor performance and escape behavior

As temperatures rise and habitats become less favorable, species may shift their distributions, adapt to the new environments, or go extinct. However, phenotypic plasticity is likely to be an immediate response for coping with climate change. We have documented fluctuation in dorsal melanin patterns in the common lizard *Zootoca vivipara* that is consistent with variation in June temperatures. Individuals exhibit two dorsal patterns, reticulated and linear, with the latter morph having higher amounts of melanin. Variation in dorsal melanin should affect thermoregulatory behavior and covary with habitat structure (openness), and local climatic conditions (e.g., elevation), which may affect basking behavior and field active Tb. Variation in Tb has performance consequences and hence affects individual fitness and ultimately population dynamics. Few studies have examined the interaction between habitat structure, dorsal pattern, escape behavior and locomotor performance. We measured locomotor performance and escape behavior for 18 populations of common lizards during 2007 and 2008. The populations occupied habitats at different altitudes and differed in structure. More reticulated females occurred in open habitats at low elevation sites, but linear individuals predominated at high elevation, humid sites with higher vegetation cover. Endurance and maximum velocity was greater in linear than reticulate females, but only during 2008, a cool, wet year. Escape behavior covaried with morphotype and habitat. Reticulated females from open, disturbed habitats tended to reverse and stop more frequently when running than linear females. Linear females from closed habitats reversed more frequently when running on the treadmill, which mimics their escape behavior in the wild. These results suggest that variation in dorsal pattern affects performance differences that correspond with habitat and thermal opportunities.

P2.36 MILLER, N.A.*; PAGANINI, A.W.; STILLMAN, J.H.; San Francisco State University, San Francisco State University and Univ. of California, Berkeley; *namiller@sfsu.edu*

DIFFERENTIAL THERMAL TOLERANCE AND ENERGETIC TRAJECTORIES DURING ONTOGENY IN PORCELAIN CRABS, GENUS PETROLISTHES

Thermal tolerance limits of marine intertidal organisms are elevated compared to subtidal species, but are typically only slightly higher than maximal habitat temperatures. The small thermal safety margins maintained by intertidal organisms suggest high thermal tolerance is associated with a physiological cost. If true, we hypothesize that species that transition between intertidal and planktonic thermal habitats during ontogeny, will adjust their thermal tolerance accordingly, to capitalize upon potential energy savings while in a thermally benign habitat. We tested this hypothesis in two porcelain crab species (genus *Petrolisthes*) that transition between the thermally stressful, intertidal zone as embryos, to the thermally benign pelagic zone as larvae, and back at settlement. We found the more thermally tolerant mid-intertidal species, *Petrolisthes cinctipes*, reduced thermal tolerance as a pelagic larvae, but that this was not associated with a reduced larval metabolic rate. The less thermally tolerant subtidal species, *Petrolisthes manimacilis*, reduced thermal tolerance throughout ontogeny with the lowest thermal limits in juveniles, though reduced thermal tolerance was not reflected in a reduced metabolic rate. While embryos and juveniles of *P. cinctipes* had thermal tolerance limits near habitat thermal maxima (~32.5 °C), all three life-history stages in *P. manimaculis* (especially embryos and larvae) exhibited considerable thermal safety margins. The mechanisms underlying this "excess" thermal tolerance in *P. manimacilis* embryos (~5 °C higher than the adults whose abdomen they are brooded upon) is unknown, but suggests that patterns of thermal tolerance in early life history stages are species specific.

P2.123 MILLER, L.B.*; MEHTA, R.S.; University of California, Santa Cruz; *leithmiller1@gmail.com*

A Descriptive Study of the Cranial Morphology of Opistognathidae: Linking skull characteristics to burrow construction

The skulls of fishes accomplish many critical functions, only one of which is capturing prey. For example, many jawfish species (Opistognathidae) are not only oral brooders but also exemplify a unique behavior that consists of lifting and manipulating large pieces of rubble to construct burrows using their jaws. Previous research of this group has been largely observational, mainly describing the burrow construction behaviors of various jawfish species. However, there has been no investigation on what cranial modifications may allow jawfish to lift large pieces of rubble with their mouths. Here, we investigate the cranial morphology of three species of shallow water rubble-dwelling jawfish: the yellow-barred jawfish, (*Opistognathus sp.*), the galapagos jawfish (*O. galapagensis*) and the giant jawfish (*O. rhomaleus*) to gain insight into what particular features of the skull may contribute to this interesting behavior. We used clearing and staining techniques as well as gross dissections to examine the musculoskeletal elements of the skull. We find that in all three species, jaw length comprises a significant portion of total head length and that there is very little to no jaw protrusion ability, despite the fact that there are many species that have been reported to feed on planktonic prey. We also find that jawfish species have robust lower jaws, relatively large adductor mandibulae muscles, and large oral gape dimensions, adaptations that may assist in lifting pieces of rubble with the jaws.

81.3 MILLER, L. A. ; University of North Carolina, Chapel Hill; *lam9@unc.edu*

Fluid dynamics of forward swimming and turning in jellyfish

Jellyfish propel themselves through the water through periodic contractions of their elastic bells. Some jellyfish, such as the box jellyfish *Tripedalia cystophora* and the upside down jellyfish *Cassiopea xamachana*, can perform turns via asymmetric contractions of the bell and by generating asymmetries in the outflow opening of the bell. The fluid dynamics of jellyfish forward propulsion and turning is explored here using the immersed boundary method. The 2D and 3D Navier-Stokes equations are coupled to the motion of a simplified jellyfish represented by an elastic boundary. An adaptive and parallelized version of the immersed boundary method (IBAMR) is used to resolve the detailed structure of the vortex wake. The asymmetric contraction and structure of the jellyfish generates asymmetries in the starting and stopping vortices. This creates a diagonal jet and net torque acting on the jellyfish. This effect will be explored over a range of Reynolds numbers and contraction kinematics.

P1.136 MINEO, P.M.*; SCHAEFFER, P.J.; Miami University ; *mineopm@muohio.edu*

Thermal acclimation of locomotor performance in the Eastern Newt.

Biochemical acclimation to temperature is evident in some amphibians; for example, previous studies demonstrated biochemical acclimation of oxidative enzymes in muscle of the Eastern Newt (*Notophthalmus viridescens*). However, the degree to which this response is associated with locomotor performance is uncertain. Our goal is to determine how the acclimation of these metabolic enzymes is correlated with the thermal sensitivity of locomotor performance. We measured the burst-swimming speed and the endurance capacity of warm (25°C) and cold (5°C) acclimated newts at 5°C, 10°C, 15°C, 20°C, 25°C and 30°C. The thermal sensitivity of burst swimming speed differed between cold acclimated and warm acclimated newts such that cold acclimated newts swam faster than warm acclimated newts at the lower assay temperatures (5°C-20°C). The thermal sensitivity of endurance capacity was also different between warm and cold acclimated newts. Cold acclimated newts performed better at the lower temperatures (5°C-15°C), whereas the warm acclimated newts performed better at higher temperatures (25°C-30°C). The activities of creatine kinase, lactate dehydrogenase, citrate synthase, and cytochrome c oxidase in muscle extracted from these animals was measured across the same temperature range as the locomotor tests to determine if thermal sensitivity of enzyme function is matched with the thermal sensitivity of burst and endurance locomotion, as well as whether phenotypic flexibility of enzyme function is associated with phenotypic flexibility of locomotor performance.

107.5 MITCHELL, J.S.; The University of Chicago; *mitchelljs@uchicago.edu*

Ecomorphology in Modern and Fossil Birds

The origin of the staggering ecological diversity of modern birds remains unresolved. A major limitation to studying the evolution of avian ecology has been the difficulty of determining the timing and overall rate of key ecological divergences in the avian tree of life. Here, I present results combining a recent molecular phylogeny with an extensive database of ecological characters (habitat, diet, foraging mode) and a very large morphological database (>1100 specimens, representing 451 genera in 138 families). Phylogenetic canonical correlations analysis of ecology and morphology yielded 3 statistically significant axes with Pearson's r of 0.6, 0.48 and 0.4 each. The first axis mainly describes the distinction between large-bodied, ground foraging birds and small-bodied, aerially foraging birds. The second axis describes the distinction between aquatic and terrestrial foragers, and the third the separates leg locomotors (e.g., ostriches and loons) versus wing locomotors (e.g., hummingbirds and penguins). I also examined how disparity was partitioned along the avian tree and found substantial departures from Brownian motion expectations early and near the middle of the tree, with disparity on the higher end of the Brownian prediction for almost every node. This suggests that major breaks in ecomorphological evolution may have happened early in the avian tree, and that many of the major groups have retained ecological distinction from one another for an extended period of time.

25.6 MITCHELL, T.S.*; MACIEL, J.; JANZEN, F.J.; Iowa State University; *timmitch@iastate.edu*

Sex-ratio selection influences nesting behavior in a reptile with environmental sex determination

Evolutionary theory predicts that dioecious species should produce an even primary sex ratio, which will be maintained by frequency-dependent selection. Organisms with environmental sex determination, however, are vulnerable to experiencing sex-ratio skews, because environmental conditions vary through space and time. For reptiles with temperature-dependent sex determination (TSD), nest-site choice is a behavioral maternal effect that may respond to sex-ratio selection, as mothers can adjust offspring sex ratios by choosing nest sites that will have particular thermal properties. This theoretical prediction has generated decades of empirical research, yet researchers have not provided convincing evidence that sex-ratio selection influences nesting behaviors. Here we provide experimental evidence that sex-ratio selection is an important component of nest-site choice in a reptile with TSD. We compare painted turtle (Chrysemys picta) neonates from eggs incubated and hibernated in maternally selected nest sites to those in randomly-selected nest sites and observe no difference in hatching success or overwinter survival, but detect a profound difference in offspring sex ratios. As predicted by theory, our results suggest that sex-ratio selection has shaped maternal nesting behavior in ways likely to enhance maternal fitness by producing a balanced primary sex ratio.

82.4 MITTELMAN , B.*; GLAZER , L.; WEIL, S.; GAFNI, O.; KHALAILA, I.; TOM, M.; DAVIDOV, G.; ZARIVACH, R.; SAGI, A.; Ben Gurion University of the Negev , Israel Oceanographic and Limnological Research, Ben Gurion University of the Negev; *mittbiny@post.bgu.ac.il*

Novel chitin binding proteins with suggested role in organization of a crustacean cuticular chitinous extracellular matrix

Arthropod cuticles are multifunctional structures exhibiting a diverse set of mechanical properties. This diversity is partially attributed to interactions between a chitinous organic matrix and a plethora of proteins. Among these is a protein family containing three Chitin binding type 2 domains (ChtBD2), covering almost their entire length, found in cuticles across the arthropod phylum, and presumed to play a role in the organization of the chitinous matrix. Gastroliths are cuticular structures formed by the crayfish *Cherax quadricarinatus* during premolt, as transient calcium deposits. However, unlike the exoskeleton, gastroliths are relatively homogenous in composition, making them excellent research candidates for cuticular assembly. Two novel, strong chitin-binding proteins containing three ChtBD2 domains, were identified from *C. quadricarinatus* gastroliths. Their transcripts were fully sequenced based on RNA from the gastrolith-forming epithelium, and designated *C. quadricarinatus* gastrolith protein 30 and 35 (Cq-GAP30 and Cq-GAP35, respectively). 454-sequencing of *C. quadricarinatus* cuticular transcripts revealed additional expressed sequences from the same family. Furthermore, we recombinantly expressed both proteins, demonstrated their chitin-binding ability, and used them for production of polyclonal antibodies to examine the protein distribution pattern within the gastrolith matrix. Our study is aimed towards a better understanding of how chitin and proteins interact in arthropod cuticular structures.

112.5 MLOT, N.J.*; MORRISON, J.; LEAMY, M.; TOVEY, C.A.; HU, D.L.; Georgia Tech, Atlanta; *njmlot@gmail.com*

Assembly and disassembly of fire ant bivouacs

Fire ants are capable of linking together to form bivouacs, which serve as temporary shelter when alternatives cannot be found. While the presence of army and fire ant bivouacs has long been known, much remains to be learned about the factors that limit the shape and speed of construction. In this combined experimental, theoretical, and computational study, we use time-lapse video to investigate the construction of fire ant bivouacs that are built against a teflon supporting wall. By roughening the wall, we can control the maximum adhesion and shear force applied by the ant's foot. In turn, we find that the wall properties affect the height and shape of the constructed bivouac. We present a model that rationalizes bivouac shape based on ant adhesion force and the internal distribution of force by the ants. Next, we consider the bivouac disassembly process whereby ants evacuate and disassemble the bivouac and move into a nearby home. We present an agent-based simulation, founded on experimental measurements of ant trajectories, that predicts the rate of disassembly. We pay particular attention to traffic jams and resulting ant clumps that slow the rate of disassembly when ant numbers are sufficiently high.

69.2 MOERLAND, TS*; WHITTINGTON, AC; Kent State Univ., Ohio, Florida State Univ., Tallahassee; *tmoerlan@kent.edu*

Time Travel in the Lab: Exploring Thermal Compensation in Antarctic Fish Parvalbumins

Antarctic notothenioid fishes display a suite of adaptations to their habitat, including proteins that function optimally in the cold. Studies of enzymes have shown that adaptation to temperature is driven by subtle changes in primary structure that lead to changes in conformational flexibility. We have focused on the Ca^{2+} binding protein parvalbumin (PV) to determine if the enzymatic paradigm of thermal adaptation applies also to non-enzymatic proteins. Characterization of PV from white muscle of Antarctic notothenioids and from temperate zone teleosts reveals that the pattern of thermal sensitivity for PV Ca^{2+} dissociation constants (K_d) parallels that of K_m for many enzyme systems: At common measurement temperatures, PVs from Antarctic fish have a higher K_d than temperate counterparts, but at physiological temperatures function is conserved. Attributing this observation to specific amino acid substitutions is a difficult task as notothenioids are highly diverged from most temperate fishes, meaning that accumulated neutral substitutions can confound a simple analysis by sequence alignment. Accordingly, this work employs ancestral sequence reconstruction and three-dimensional modeling to pinpoint residues possibly responsible for functional adaptation. Reconstruction and modeling suggested that just two amino acid substitutions can lead to the current Ca^{2+} binding thermal profile of nothenioid PVs. Expression and characterization of the ancestral Antarctic and temperate PVs supports this hypothesis. Hence, thermal adaptation of PV follows the paradigm established for catalytic proteins: The evolutionary loss of just two hydrogen bonds is sufficient to explain the observed thermal phenotype of Antarctic notothenioid PVs.

P3.125 MOHAIMANY-APONTE, A.*; KRISTAN, D.M.; California State University San Marcos; *mohai001@cougars.csusm.edu*

Environmental enrichment does not increase susceptibility of female mice to intestinal parasites

Laboratory mice (*Mus musculus*) are one of the most frequently used models to study physiology and oversight committees are increasingly interested in enhanced housing conditions. Environmental enrichment (i.e., the addition of “toys”, shelters, etc.) has been shown to influence physiological responses ranging from brain function to production of stress hormones. Relatively little is known about effects of environmental enrichment on immune function and results using infections with intact worms are equivocal. Our study investigated if environmental enrichment affected susceptibility of young, female mice to the intestinal nematode *Heligmosomoides bakeri*. Mice were weaned at 20d old and housed in groups of four in cages that were either enriched or control (only). Enriched cages contained bedding, cotton nesting material, chew toys, climbing structures, and a nesting container. Control cages contained bedding and cotton nesting material only. Preliminary data indicates no effects of environmental enrichment on mouse morphology (body mass, spleen mass, small intestine mass, and small intestine length) or on number of *H. bakeri* worms in the mouse small intestine. However, parasite reproduction when measured *in vitro* was lower for worms taken from enriched than control mice. While enriched housing did not alter the susceptibility of female mice to *H. bakeri* infection, an investigation of changes in host physiology during enrichment that may determine parasite reproduction would be fruitful.

P3.124 MOLINA-MARINO, L*; LOPEZ-CATIVA, L; CAVIEDES-VIDAL, E; Univ Nac de San Luis - Consejo Nac de Inv Científicas y Técnicas, Univ Nac de San Luis; *enrique.caviedes@gmail.com*

IG Y INDEX VARIATION THROUGHOUT A FAST-REFEEDING PERIOD IN COMMON PIGEON (Columba livia)

Humoral immunity, antibody-mediated, is the aspect of the immune system that stands in defense against extracellular pathogens and toxin neutralization among other functions. The most abundant isotype in blood is IgY. One way to characterize the humoral status of an individual is to evaluate the profile of Ig Y under different conditions. In this study we assessed the IgY index of the common pigeon along a fast-refed trial. Pigeons (N =11) received water ad lib and were fasted until a body mass loss of 30-35 % (day F) of the initial day (day 0). Then, birds were refed until they reached their initial body mass (day RF). On days 0, F and RF plasma samples were obtained. We performed an ELISA using different dilutions (1/2500 to 1/20000) of plasma and anti chicken IgY HRP conjugated antibody (1/250). Dilution of plasma gave the same proportional response for each treatment (P=0.91). The effect of nutritional status on the index IgY resulted in a significant difference ($F_{2,84}$=6.99 P<0.002). Ig Y index significantly diminished (28 % P<0.05) between day 0 (when birds fed ad libitum) and day F (when birds lost 30% of their body mass). Following the refed period (day RF), a 20.8 increase in the IgY index was observed, though this difference was not significant from both day0 and day RF birds. It is interesting that birds even after recovering their initial body masses did not recover completely their initial IgY levels, though a clear trend is observed. Dietary restriction reduces circulating IgY, probably as a mechanism for energy conservation due to other vital functions. This marked decrease in immune system component decline the pigeon's immune capacity and would make these birds potentially more susceptible to infection. Funded by PICT97-01320 to EC-V

P3.55 MOMIN, N.*; HIGGINS, A.; MUSOLF, B.E.; Clayton State University; *NuzhatMomin@mail.clayton.edu*

The Use of Chemoreception for Host Selection in Ovipositing Callosobruchus maculatus

The bean beetle, *Callosobruchus maculatus*, parasitizes beans causing a reduction in the nutritive value and quality of seeds in developing countries. If it were known which sensory structure the *C. maculatus* uses to distinguish among different substrates then more specific methods of pest control could be developed. We hypothesized that the antennae are used in distant chemoreception by female *C. maculatus* host selection. We placed mated females with intact and ablated antennae in a maze with four canisters. Each canister held a different substrate choice: glass beads, wooden beads, black-eyed peas, and an empty canister. We recorded the first 12 hours after they were placed in the maze to observe their choice of canister. The females were given 48 hours to lay eggs on the different substrates. We measured the time it took for the beetles to choose a canister and found that the beetles with antennae were faster on average at selecting a canister than those with ablated antennae. More beetles with antennae chose the canister with black-eyed peas. We counted the number of eggs laid on the different substrates. Significantly more beetles with intact antennae chose to oviposit their eggs on black-eyed peas ($p < .01$). These results suggest that the antennae of *C. maculatus* are used for distant chemoreception in host selection for oviposition by female bean beetles.

P1.18 MONAENKOVA, D*; GRAVISH, N; . GOODISMAN, M; GOLDMAN, D; Georgia Institute of Technology; *dmonaen@physics.gatech.edu*

Effect of moisture content on nest construction activity of fire ants

Fire ants (*Solenopsis invicta*) build large underground nests, which provide them with a living space protected from overheating, dehydration and predators. Field studies and laboratory experiments have revealed that one of the important environmental factors affecting nest building activity is soil moisture content. In this work we use x-ray computed tomography to study the growth in 3D of nest networks as a function of soil wetness. Because capillary cohesion in wet soils leads to the competition between tunnel stability and the labor-intensity of the excavation, we expect to find an optimal moisture content, which allows the most effective nest construction. We prepared digging containers (2.8 cm diameter by 11.5 cm deep plastic tubes) with a simulated soil of 240±30 µm glass particles. The prepared moisture content W (defined as the ratio between mass of water in the soil to mass of dry soil) varied from 0 to 0.2. Fifty fire ant workers were placed in the enclosed digging region and allowed to dig for 18 hours. We found that ants constructed tunnels in all moisture levels. However, maximum tunnel depth, H, was significantly affected by W. The minimum H was observed at two saturation extremes: W=0 (H=5.1 ±1.6 cm) and at W=0.2 (H=4.4 ±1.1 mm). The minimum tunnel depth at W=0.1 (H=11.5 cm) was at least two times greater than at either W=0 or W=0.2 for all tested colonies ($p < 0.0001$). The increase in H mirrors the dependence of the soil cohesion on W and we therefore conclude that the tunnel stability is a key factor influencing the digging strategy of fire ants.

17.6 MONGEAU, J.-M.*; SPONBERG, S.N.; FULL, R.J.; Univ. of California, Berkeley; *jmmongeau@berkeley.edu*

Unit responses from antenna in cockroaches generate control input predicted from control-theoretic model of wall following

Connecting neural responses to task-level control during high-bandwidth tasks is critical to understanding the neuromechanics of high-speed locomotion. We studied high-speed wall following in the cockroach *Periplaneta americana* where neural delays impose severe constraints on sensorimotor control. A simple neuromechanical model of wall following developed within a control theoretic framework suggested that proportional (P) and derivative (D) information from antenna bending in response to a wall projection is sufficient for control. Population recordings of mechanoreceptive neurons in the antenna during a simulated turning experiment revealed a neural response with a phasic and tonic component consistent with P & D signaling thus suggesting that a temporally-filtered control input is generated at the level of the antenna. How the population response arises from individual mechanoreceptors remained elusive. Multi-unit extracellular recordings at the base of the antennal nerve revealed that individual units are tuned to both wall position and velocity. We hypothesized that the antenna could act as a delay line by the spatial arrangement of sensors to generate a filtered population response. We determined that afferents have different latencies and direct summation of the variable-latency responses generates a temporally-elongated phasic response supporting predictions from the model and whole-nerve recordings. Variable-latency afferent signals may provide a sufficient and low-delay preconditioned control input to the neuromechanical system of the cockroaches as demonstrated from the correspondence between the time course of the population response and the turning kinematics.

P1.87 MONTUELLE, SJ*; VESSEL, C; WILLIAMS, SH; Ohio University; *montuell@ohio.edu*

In vivo measurement of cranial kinesis in Gekko gecko using XROMM methodology

Kinetic skulls are characterized by moveable joints within the cranium. While cranial kinesis is a variable feature among vertebrates, the skull of gekkotan lizards is a textbook model for studying cranial kinesis. However, most evidence for cranial kinesis is extracted from manipulating skeletal specimens and experimental data quantifying kinetic movements are rare. Because of the lack of *in vivo* evidence, the ecological relevance of cranial kinesis (i.e., biological role) remains poorly understood. We used the X-ray Reconstruction Of Moving Morphology (XROMM) methodology to quantify mesokinesis, or the movements of the snout with respect to the braincase, in *Gekko gecko* during two routine behaviors: mouth-gaping displays and aggressive biting. We chose *G. gecko* because they are territorial animals that use gaping display and biting to protect their territory daily. During biting, we simultaneously recorded bite force using a bite force transducer. Our first hypothesis is that cranial kinesis may enhance maximum gape by rotating the snout dorsally when threatening predators. Our secondary hypothesis is that the snout can also rotate ventrally during biting to puncture the food item or the predator, thus potentially increasing bite force. Preliminary results confirm dorsoflexion of the snout during mouth-gaping display as well as ventroflexion during biting. This reveals that mesokinesis in the gekkotan skull may be a key adaptation for the defensive behaviors associated with territoriality.

P3.169 MONTUELLE, SJ; SIDOTE, J; RETTIG, M; DAVIS, JS; WILLIAMS, SH*; Ohio University; *willias7@ohio.edu*

Sensorimotor integration during feeding: Effects of transection of the lingual nerves on jaw movements during chewing in pigs

While the tongue plays a crucial role in proper positioning of food in the oral cavity, its movements are also coordinated with those of other oral structures, such as the jaws, during feeding. Thus, diminished tongue sensation due to lingual nerve injury may affect the coordination of tongue and jaw movements during chewing. Here, we investigate the functional consequences of lingual nerve transection on jaw movements during chewing in pigs (*Sus scrofa*). Our hypothesis is that lingual nerve injury will result in changes in the kinematics of the jaw movements during intraoral food processing. Radiopaque markers were implanted in the jaw and skull to quantify jaw movements in 3 dimensions from biplanar high speed fluoroscopy movies of pigs feeding on various foods before and after lingual nerve transections. Our results show that loss of sensation from of the anterior part of the tongue affects the movements of the jaw during feeding as well as the overall feeding behavior. While normal jaw movements during feeding in pigs are characterized by significant mediolateral displacement, jaw movements after bilateral nerve transection are primarily dorsoventral with little mediolateral displacement. Moreover, feeding cycles are longer in the treatment animals. Mediolateral movement of the jaw during feeding is important, especially during the power stroke when food is broken down. Without the sensory information from the tongue, we propose that pigs are unable to precisely locate the bolus within the oral cavity and place it on the teeth. Longer gape cycles after sensory deprivation also suggests that pigs may be more careful in their feeding movements to avoid injury.

145.2 MOONEY, T.A.*; LI, S.; KETTEN, D.R.; WANG, K.; WANG, D.; Biology Department, Woods Hole Oceanographic Institution, Hawaii Institute of Marine Biology, University of Hawaii, Institute of Hydrobiology, The Chinese Academy of Sciences ; *amooney@whoi.edu*

Hearing of the Yangtze finless porpoise: Form and function in an 'unrepresentative' species

While it is broadly accepted that odontocetes receive sound through tissues near the lower jaw, there are important species differences in the tissue shapes potentially related to what it hears. This paper addresses the hearing of a divergent cetacean species, the Yangtze finless porpoise (*Neophocaena phocaenoides*). Hearing was measured using auditory evoked potentials. Clicks and low-, mid- and high-frequency (8, 54, 120 kHz) tones were presented through adapted jawphone transducers at nine locations on the body. Thresholds were related to underlying anatomy determined from CT and MR images. Results showed 'acoustic fat' regions coincident with lowest thresholds (best hearing) at locations adjacent to the auditory bullae. Response latencies were shortest from this region, indicating subtle preferential sound pathways. Mean thresholds did not vary significantly along a line from the rostrum to the ear (11.6 dB). This is quite different from the bottlenose dolphin and beluga, in which 30-40 dB threshold differences were found across their heads. Greater stimulus levels produced higher amplitude and faster auditory responses suggesting sound pathways influence hearing in multiple ways. Yet, finless porpoises have relatively less 'shading' of sounds compared to some odontocetes, implying they hear well from many directions. These distinctions indicate sound reception differences among odontocetes which likely influence vital bio-acoustic behaviors of these sound specialists, and supports caution when attempting to generalize from limited auditory data across cetacean species.

P1.221 MOORE, B.C.*; BRINKMAN, E.; BOGGS, A.S.P; MENDOZA, R.; Louisiana Tech University, Ruston LA, Arkansas Game and Fish Commission, Camden AR, Medical University of South Carolina, Charleston SC, Universidad Autónoma de Nuevo León, Mexico; *bmoore@latech.edu*

Assessment of circulating sex steroid hormones and vitellogenin content in male and female breeding spotted gar (Lepisosteus oculatus)

Vitellogenesis, a vital component of fish reproduction, has been extensively studied across teleost fishes. However, this process of yolk deposition in eggs has received less of a research focus in holostean fishes, such as gar. Here we collected male and female spotted gar serum and tissue samples from Felsenthal Reservoir, Arkansas in April 2011 during the beginning of the active spawning period. Gonad histology characterized the reproductive state of ovary and testes. We cross-validated an antibody designed against alligator gar (*Atractosteus spatula*) vitellogenin (VTG) for use with spotted gar samples. Vitellogenin concentrations were measured in serum, liver, and gonad tissues. Using liquid scintillation RIA, we quantified circulating serum concentrations of estradiol and testosterone. Testes were undergoing active spermatogenesis while ovary morphologies included gravid, partially ovulated, and depleted states. Gonad somatic index (GSI) and serum and ovary VTG concentrations were greater in egg-bearing females as compared to females with depleted ovaries and males, while all female liver VTG concentrations were greater than those measured in male livers. Heptosomatic index (HSI) did not vary among fish. Serum testosterone concentrations did not vary among fish and estradiol concentrations were greater in all females as compared to males, regardless of the ovaries egg-bearing state. These results lay a foundation to further characterize spotted gar reproductive physiology and vitellogenesis.

P2.202 MOORE, J. M.*; ROUSE, G. W.; WILSON, N. G.; Scripps Institution of Oceanography, The Australian Museum; *jmoore@ucsd.edu*
Does the Scotia Arc facilitate connectivity between South America and Antarctica? An example from the sea star Porania antarctica
The Antarctic Circumpolar Current is a potentially powerful isolating force separating the faunas of South America and Antarctica. Marine invertebrates exhibiting distributions on the continental shelves of both Antarctica and South America provide evidence for genetic connection via dispersal across the Polar Front, or alternatively, the existence of cryptic species complexes. This study tested the hypothesis that the islands of the Scotia Arc allow dispersal and gene flow of a sea star with planktonic larvae, *Porania antarctica*. We sampled 15-20 individuals from 7 sites spanning the Scotia Arc from Burdwood Bank in the southern Atlantic Ocean to Bransfield Strait, Antarctica, as well as additional sites with fewer than 20 individuals. We built multi-gene phylogenetic trees and haplotype networks to test the presence of cryptic species complexes, and used phi-st to infer patterns of genetic connectivity along the Scotia Arc.

P1.36 MOORE , JT*; BARRILE, GM; BOWER, CD; HRANITZ, JM; Bloomsburg University, Bloomsburg; *jtm18586@huskies.bloomu.edu*
Co-occurrence of Anurans in Freshwater Habitats on a Mid-Atlantic Coast Barrier Island
The small size of barrier islands and the few freshwater habitats available on them, along with the increased sensitivity anurans have to salinity and changes in their environment, result in a depauperate anuran community. The scarcity of suitable habitats should lead to competition due to niche overlap among the different anuran species for suitable breeding habitats. The purpose of this research was to determine what species of anurans are present in Chincoteague National Wildlife Refuge (Virginia) and which of these species potentially compete as indicated by co-occurrence of adults or larvae at breeding sites. Interspecific competition for suitable breeding habitat between different anuran species was assessed by conducting a male-advertisement call survey and a vernal pool anuran larval survey. The male advertisement call survey sampled 13 sites along a transect for 3 minutes at each site between May and July 2012. The species were identified by their advertisement call and relative abundance was estimated by using the Wisconsin frog call index. The anuran larval survey was conducted by sampling larvae from vernal pools. The male advertisement call survey detected three anuran species with different levels of activity on different nights. The number of species present during the summer activity differed among the 13 sites. In contrast, the larval survey found two species, *Anaxyrus fowleri* and *Hyla cinerea*, in eight vernal pools. The distributions of *A. fowleri* and *H. cinerea* larvae overlapped 100%, indicating co-occurrence of these two species in our pilot study. These results suggest island anurans converge upon sources of freshwater, possibly because so few sources of freshwater exist or because there is little distinction between habitats surrounding sources of freshwater.

P2.119 MORAN, C.J.*; LERMA, C; JIMENEZ, J; GIBB, A.C.; Northern Arizona University; *cmoran.mlml@gmail.com*
Can members of the imperiled Gila species-complex be identified as morphologically distinct across life history stages?
Imperiled cyprinid species in the genus *Gila* (Teleostei, Cypriniformes) from the southwestern United States are of critical concern to conservation biologists and management agencies, but difficult to identify—especially at juvenile and young adult life history stages, when different species demonstrate very similar body designs. Species identification within the genus is further complicated by hybridization between coexisting species and putative morphological differences within a species between drainages. Because fishes at later life history stages are more clearly morphologically distinct from one another, we sought to determine which morphological characteristics (if any) can be used distinguish species at juvenile and young adult stages using standard meristic traits and measurements of body proportions taken from digital images of preserved specimens and from live specimens collected in the field. We found that several morphological characteristics varied among young individuals of representative *Gila* species including: caudal peduncle depth, caudal peduncle length and dorsal fin-base length. We note that these characteristics may have functional consequences for aquatic locomotor behaviors; however, further investigation will be necessary determine the biomechanical significance of morphological variation in these traits. In addition, although we noted variability within a species among waterways, it is not yet clear if this variability is genetic, or the result of developmental plasticity. These results could aid in interpreting morphological variability within members of the genus *Gila*, as well as assisting with field identification of these rare and threatened fishes.

14.3 MOREHOUSE, NI*; BARTOCH, CM; LUNA, EN; ROBERTS, NS; SALEH, NW; University of Pittsburgh; *nim@pitt.edu*
Food, Nuptial Gifts and Vaginae Dentatae: Phenotypic Plasticity and Sexual Conflict in a Gift-Giving Butterfly
Considerable recent effort has been devoted to understanding the roles of conflict and cooperation in sexual interactions. Gift-giving insects such as crickets and katydids have proven tractable systems for exploring these issues, with recent research emphasizing nuptial gifts as a source of conflict. In the Lepidoptera, males often transfer large nutrient-rich packages called spermatophores internally to females during mating. In contrast to work in other systems, researchers have typically characterized these nuptial gifts as cooperative contributions of mutual benefit to both partners. Male spermatophores provide essential nutrients that increase female lifespan and reproductive output. In turn, males benefit by delaying female remating and thus increasing their paternity share. However, males of many butterfly species, in an attempt to monopolize female reproductive output, package their spermatophores in hard outer shells. Females have, in response, evolved toothed structures in their reproductive tracts called signa, which serve to “chew” their way through the outer spermatophore coating to access the nutrients within. As a preliminary step in understanding the co-evolutionary dynamics in this system, we explored the environmental and genetic determinants of male spermatophore quality and female signa morphology in the gift-giving butterfly *Pieris rapae* using a split-brood experiment where siblings were reared on artificial diets of varying protein content. We report both high heritability and phenotypic plasticity in both traits. We discuss these results in the context of sexual conflict and co-evolutionary dynamics.

73.5 MORGAN, SG*; SHANKS, A; MACMAHAN, J; RENEIRS, A; BROWN, J; GRIESEMER, C; Bodega Marine Laboratory, Univ. of California, Davis; *sgmorgan@ucdavis.edu*

Differential Transport Across the Surf Zone of Reflective and Dissipative Shores as a Determinant of Larval Supply

We determined whether differences in water exchange across the surf zone on dissipative and reflective shores regulates larval supply to intertidal populations. We surveyed zooplankton daily for one month relative to physical conditions inside and outside the surf zone at a dissipative and reflective beach near Monterey, California. Larvae of some species completed development nearshore while larvae of other species migrated offshore and back. Concentrations of zooplankters were much greater outside than inside the surf zone at the reflective beach, indicating that the surf zone may block onshore transport. Barnacle cyprids were an exception, suggesting that ontogenetic changes in larval behavior may facilitate penetration of the surf zone. In contrast, zooplankters were 1 to 2 orders of magnitude more concentrated inside the surf zone of the dissipative beach. Settlement of barnacles on rocks at both beaches was low, and settlement of sand crabs, *Emerita analoga*, was abundant only on the dissipative beach. Different hydrodynamics of surf zones at dissipative and reflective beaches together with larval behavior may play a major role in regulating larval supply along the West Coast.

P3.138 MORITZ, S.; Brown University; *sabine_moritz@brown.edu*

Rib kinematics during ventilation in Alligator mississippiensis

Lung ventilation in crocodylians is accomplished by a hepatic piston mechanism driven by the m. diaphragmaticus combined with costal and pelvic movements. While the diaphragmatic mechanism is well studied, less attention has been paid to the contribution of costal movements to ventilation. In this study, marker-based X-ray Reconstruction of Moving Morphology (XROMM) was used to analyze rib movements during breathing in American alligators. Spherical metal markers were surgically implanted into the tripartite ribs, the sternum and the dorsal scutes of juvenile alligators. Biplanar x-ray recordings of standing and walking alligators were recorded and ct-scans of the same individuals were taken. By combining both data sets, 3D animations of rib motion during ventilation were created and rib kinematics analyzed. Preliminary results show that rib movements support ventilation both in standing and walking alligators. Rib movements result in dorso-ventral flattening of the rib cage during exhalation and expansion during inhalation. The largest movements occur in the sternal part of the rib, whereas intermediate and vertebral ribs only show small movements. The kinematic data will be combined with EMG recordings to infer the function of the intercostal musculature during ventilation.

10.5 MOROZ, L.L.; University of Florida; *moroz@whitney.ufl.edu*

Genomic Bases for Independent Origins of Neurons and Complex Brains: New Insights from RNA-seq and genomic sequencing of basal metazoans, basal deuterostomes and molluscs

The origin of neurons and complex centralized brains are two major evolutionary transitions in the history of animals. How many times might complex brains and neurons have evolved? Monophyly (e.g. the presence of a centralized nervous system in urbilateria) vs polyphyly (multiple origins by parallel centralization of nervous systems within several lineages) are two historically conflicting scenarios to explain such transitions. To reconstruct the parallel evolution of nervous systems, genomic and metabolomic approaches have been implemented to probe enigmatic neurons of basal metazoans (including 8 ctenophores) and basal deuterostomes, as well as 23 species of gastropod and cephalopod molluscs (including Nautilus, Sepia, Loligo, Octopus). 1) Recent phylogenomic and cladistic analysis of RNA-seq data suggests that complex brains may have independently evolved at least 9-11 times within different animal lineages. Indeed, even within the phylum Mollusca cephalization might have occurred at least 5 times. 2) Cladistic, genomic and metabolomic analyses imply that neurons themselves evolved more than once (e.g. Ctenophores vs other animals). Emerging molecular data further suggest that at the genomic level neural specification might have been achieved by changes in expression of just a few transcriptional factors – not surprising since such events might happen multiple times over 700 million years of animal evolution. Ancestral polarized secretory cells were likely involved in coordination of ciliated locomotion in early animals, and these cells can be considered as evolutionary precursors of neurons within different lineages. Under this scenario, the origins of neurons can be linked to adaptations to stress/injury factors in the form of an integrated regeneration-type cellular response with secretory signaling peptides as early neurotransmitters.

35.1 MORRIS, J.S.*; BRANDT, E.; University of Utah; *j.s.morris@utah.edu*

Sexual dimorphism in the Gray Wolf (Canis lupus): specialization for male-male competition or for male provisioning?

Sexual selection theory predicts that male mammals will be more specialized for physical competition than females. Specialization for aggression, however, may result in functional conflicts with locomotor demands. Characters associated with locomotor economy include long, gracile limbs that reduce the cost of transport by increasing stride length and decreasing the energy required to swing the limbs. In contrast, specialization for aggression appears to result in stout bones and large distal muscles with high mechanical advantage that increase force available to strike or manipulate opponents. Gray wolves (*Canis lupus*) are highly cursorial animals, traveling immense distances to locate and run down prey. Gray wolves also aggressively defend territory through direct competition and kill much larger, highly dangerous prey species. Because both sexes actively participate in these activities, a low level of musculo-skeletal sexual dimorphism is expected. However, males often lead in aggressive encounters with conspecifics and, for a period during the mating season, must kill prey without the assistance of the dominant female to provision her and their young. Thus, male wolves may exhibit a higher degree of morphological adaptation associated with aggressive activities. To assess sexual dimorphism in three distinct subspecies of gray wolves, a series of skeletal metrics were taken from fresh cadavers and museum specimens. All measures were size-corrected and analyzed to detect relative differences in size and shape. Males were found to have broader skulls, more robust limb bones, and higher muscle mechanical advantages than females, suggesting that males are more highly specialized for physical aggression. However, results for each subspecies differed substantially, likely reflecting differences in selective pressures on pursuit versus handling capabilities based on prey size.

P1.128 MORRIS, Z.S.; The University of Texas at Austin; *zsmorris@utexas.edu*

Determining the onset of ossification and reconstructing ontogeny in vertebrates: A comparison of clearing and staining, histological and computed tomography methods.

Analyses of skeletal development that focus on comparisons among a variety of taxa can illuminate the evolution of ontogenies within particular clades. Many recent analyses, particularly of mammals, comprise data about the onset of ossification derived from cleared and stained specimens, histological sections, or computed tomography scanning (CT). It has been noted anecdotally that histological sections may show the appearance of ossification earlier in absolute age than cleared and stained specimens, but comparisons to CT datasets have not been previously made. My study assesses whether systematic biases exist among these three methods using the development of the skull in the marsupial *Monodelphis domestica*. A collection of 80 specimens of known age spanning birth to Day 24, with each day represented by 2-4 specimens, was used to make comparisons among the three methods throughout skeletal development. To account for underlying variation in the onset of ossification among individuals of the same age, 15 cleared and stained specimens were also CT scanned so that comparisons between techniques could be made using the same individual. The onset of ossification was generally observable on the same day using all three methods; however, with CT and histological methods the onset of ossification was often apparent days earlier than with clearing and staining. This disagreement was particularly obvious with dense elements and bones of the palate. In addition to methodological differences, I also found considerable variation in the estimated ossification sequence when only one method was used. Future comparative studies of ontogeny must consider how methodological variation may potentially skew results if ontogenies are not based on comparable datasets, especially in light of real variation in developmental sequence.

S8-1.4 MORROW, C.C.*; REDMOND, N.E.; PICTON, B.E.; ALLCOCK, A.L.; SIGWART, J.D.; MAGGS, C.A.; Queen's University Belfast, NMNH, Smithsonian Institution , National Museums Northern Ireland, Dept. of Zoology, Ryan Institute, National University of Ireland Galway; *christinemorrow@gmail.com*

Molecular phylogenies support homoplasy of multiple morphological characters used in the taxonomy of Heteroscleromorpha (Porifera: Demospongiae)

The most recent attempt to produce a stable classification of sponges was based solely on morphological characters (*Systema Porifera* Hooper & van Soest, 2002) and incorporated the cladistic analyses of van Soest et al., 1987 & 1990; de Weerdt, 1989 and Hooper, 1990 & 1991. The current study uses sequence data from 18S rDNA; 28S rDNA and CO1 barcoding fragment combined with morphology to justify the resurrection of Axinellida Levi, 1973. The abandonment of Axinellida and the establishment of Halichondrida *sensu lato* to contain Halichondriidae, Axinellidae, Heteroxyidae and a new family Dictyonellidae was based on the hypothesis that it was more parsimonious to assume that an axially condensed skeleton evolved independently in four separate lineages than to assume that asters (star shaped spicules); acanthostyles (club-shaped spicules with spines) and sigmata (C-shaped spicules) each evolved more than once (van Soest et al., 1990). Our resulting molecular trees are congruent and contrast with the morphology based trees of van Soest et al., 1990. The results show that axially condensed skeletons, asters, acanthostyles and sigmata are all homoplasious or alternatively that some may be ancestral but lost in certain lineages. We use the molecular trees presented here as a basis for re-interpreting the morphological characters within Heteroscleromorpha.

51.3 MORSE, MPATR; Univ. of Washington, Friday Harbor Labs; *mpmorse@u.washington.edu*

Edward S. Morse 1838-1925. History of scholarly exchanges in marine zoology between US and Japan

Japan and the United States share a distinguished scientist who had a remarkable history with Japan 150 years ago. Edward Sylvester Morse (1838 - 1925) received his understanding of natural history at Harvard University in the laboratory of Professor Louis Agassiz, the founder of the Harvard Museum of Comparative Zoology. Morse is a member of the U.S. National Academy of Sciences and holds four honorary doctorates, from Bowdoin College (1871), Harvard University (1892), Yale University (1918) and Tufts University (1922). Early in his career, in 1877 he visited Japan to collect brachiopods and shortly after his arrival, was invited to be the first Professor of Zoology in Japan and develop natural history and zoological studies at the University of Tokyo. During his time in Japan Professor Morse created the first marine laboratory at Enoshima, established scientific studies on the evolution of the Brachiopoda, and brought the studies of evolution and zoology to Japanese students and into the Japanese science classrooms. He also discovered the ancient shell Mounds of Omori and dug a collection of ancient Japanese pottery still on display at the University of Tokyo. Later at the Peabody Museum in Salem Massachusetts Morse wrote an account of Japan Day by Day, wrote an account with precise illustrations of the Japanese Homes and Their Surroundings, and researched the ancient Japanese pottery formulating a catalog that has also been translated into Japanese. Morse curated two collections of the ancient and modern pottery, one in Japan and one in the Boston Museum of Fine Arts. Professor Morse was president of the American Association for the Advancement of Science (AAAS). Scholarly exchanges between the US and Japan will be reviewed and the importance of Morse discussed.

58.3 MOSELEY, M.A.*; COX, C.L. ; CHIPPINDALE, P.T.; University of Texas at Arlington, University of Virginia; *mmoseley@uta.edu*

Phylogeography of the four0lined skink, Plestiodon tetragrammus

The Edwards Plateau is a sandstone uplift in central Texas that possesses a remarkable number of unique local species and functions as a geographic barrier for many species (Richardson and Gold 1995). Notably, lizards of the *Plestiodon tetragrammus* species group are distributed across this potential geographic barrier. This species group is composed of 3 taxa, *P. tetragrammus tetragrammus, P. t. brevilineatus*, and *P. multivirgatus*. *P. multivirgatus* is distrubted in western Texas, New Mexico, Arizona and northern Mexico, while *P. t. tetragrammus* and *P. t. brevilineatus* are found in Texas and northern Mexico and are separated by the Edwards Plateau. We sequenced 3 mitochondrial and 4 nuclear genes (3361 bp) and reconstructed evolutionary relationships using Bayesian and maximum likelihood methods. We found notable genetic variation across the geographic range of the *P. tetragrammus* species clade. All analyses found that this species group is monophyletic, and that *P. t. tetragrammus* and *P. t. brevilineatus* are genetically divergent and form distinct evolutionary clades. Our results demonstrate the importance of the Edwards Plateau as a geographic barrier that promotes genetic diversity in southwestern animal species.

7.2 MOUCHKA, M E*; LEHNERT, E M; BURRIESCI, M S; SCHWARZ, J; PRINGLE, J R ; Cornell University, Stanford University , Stanford University , Vassar College; *mep74@cornell.edu*

Identification of symbiotic-specific genes reveals a role for host immunity in a cnidarian-dinoflagellate mutualism

Many cnidarians harbor intracellular photosynthetic dinoflagellates in a mutualistic relationship. While some facets of this mutualism have been relatively well studied, we know very little about the cellular and molecular mechanisms that underlie the establishment and maintenance of cnidarian-dinoflagellate symbioses. The stability of this relationship presumably involves a complex interplay between the symbiont and the host immune system. To gain a better understanding of the role of host immunity in mutualistic interactions, we used RNA-Seq to characterize differential gene expression between symbiotic and aposymbiotic anemones. Data from two distinct RNA-Seq experiments were combined to identify a robust set of 1,163 differentially expressed genes. 812 genes were up-regulated in symbiotic anemones, while 351 were down-regulated, with the majority of these genes having functions in metabolism and transport. A subset of differentially expressed genes function in immune-related processes, including inflammation, wound healing, regulation of the JNK cascade, complement activation, and apoptosis. Genes of interest from these categories (based on log2 fold expression) include scavenger receptor B1 (infinitely up-regulated), TNF receptor superfamily member 27 (5.9), and mannan-binding lectin serine peptidase 1 (-1.6). Our results suggest a role for the host immune system in the maintenance of the symbiotic relationship. In addition, we have generated a list of candidate genes whose function in the onset, regulation, and breakdown of the symbiotic state can be investigated in further detail. Our results offer new insights into genes that play a role in symbiotic homeostasis and will leverage a better understanding of cnidarian-dinoflagellate interactions.

64.3 MOUNTCASTLE, AM*; COMBES, SA; Harvard University; *mountcastle@fas.harvard.edu*

When wings collide: how collisions cause wing wear in bees and wasps

Many flying insects suffer periodic wing damage and exhibit a cumulative loss of wing area over their lifespan. Wing area loss reduces aerodynamic force production, load carrying capacity and flight maneuverability, and thus can have important fitness consequences for an individual and colony. In bumblebees, loss of wing area is associated with an increased rate of mortality, and wing wear has been linked to frequency of wing collisions with vegetation during foraging activity. However, little is known about how insect wings dynamically respond to collisions during flapping flight, the factors that contribute to wing damage during collisions, and the rate at which damage occurs. Here we explore how rapid collisions with a rigid surface cause wing damage in bees and wasps. Using a high-speed motor, we spin wings at their natural flapping velocity and force them to repeatedly collide with a surface obstacle in their path. We investigate how wings dynamically bend during collisions, and quantify wing wear over time. Our results show that rapid collisions can eventually cause significant wing damage, although wing morphology may reflect adaptive mechanisms that help reduce the damaging affects of collisions.

135.1 MOUSTAKAS-VERHO, JE*; ZIMM, R; CEBRA-THOMAS, J; SEPPäLä, NK; KALLONEN, A; MITCHELL, KL; HäMäLäINEN, K; SALAZAR-CIUDAD, I; JERNVALL, J; GILBERT, SF; Institute of Biotechnology, University of Helsinki, Biology Department, Millersville University, Department of Physics, University of Helsinki, Biology Department, Swarthmore College, Departament de Genètica i Microbiologia, Universitat Autònoma de Barcelona; *Jacqueline.Moustakas@helsinki.fi*

The origin and loss of periodic patterning in the turtle shell

Testudines (turtles and their relatives) originated in the Triassic Period and became one of the most successful groups of tetrapods, radiating into terrestrial, semiaquatic, and marine environments on all continents. The developmental mechanisms responsible for the formation of the turtle shell remain one of the great mysteries in evolutionary biology. The keratinous scutes of the turtle shell are novel epidermal structures, the patterns of which are diagnostic of different taxa. These scutes become the modular elements of turtle shell epidermal growth. We show that scutes develop from an earlier array of patterned placodal signaling centers and that these placodal signaling centers are absent from a soft-shelled turtle species in which scutes were lost evolutionarily. Furthermore, inhibiting Shh and BMP signaling experimentally results in the loss of these signaling centers and scutes. We propose that these signaling centers are formed by the reaction-diffusion dynamics of activator-inhibitor systems and show that both natural and abnormal variation can be modeled by changes in growth and timing. We propose that these signaling centers represent developmental modules responsible for the evolution of scutes in turtles and that the regulation of these centers have allowed for the diversification of the turtle shell.

P1.123 MOUSTAKAS-VERHO, JE*; CHRISTENSEN, M; KALLONEN, A; HäMäLäINEN, K; JERNVALL, J; Institute of Biotechnology, University of Helsinki, Department of Physics, University of Helsinki, Department of Physics, University of Helsinki; *Jacqueline.Moustakas@helsinki.fi*

Supersize Me: Cellular dynamics controlling size in the mammalian molar

A central question in evolutionary morphology and developmental biology is how diversity in the size of structures is achieved. Mammalian molar teeth are developmentally integrated such that they form sequentially along the distally elongating dental lamina and are typically graded in size anteroposteriorly. Tooth development proceeds through a series of morphogenetic movements and signaling interactions between ectodermal epithelium and neural crest-derived mesenchyme. Evidence on mouse molar development has shown that the initiation and size of distal molars depends on previous molars through a dynamic balance between intermolar inhibition and mesenchymal activation. We compare molar development in two rodent species with similar tooth shape, but a twofold difference in size: mouse and rat. We combine this interspecies comparison with experimental evidence from transgenic mice to investigate the cellular dynamics controlling tooth size.

P2.137 MUDRON, M.R.*; CHANG, E.S.; MYKLES, D.L.; Colorado State University, UC Davis Bodega Marine Laboratory; *megan.mudron@gmail.com*

Myostatin expression in the blackback land crab (Gecarcinus lateralis) Y-organ during the molt cycle

Ecdysteroids produced from the molting gland (Y-organ or YO) induce molting in decapod crustaceans. Reduction in molting-inhibiting hormone (MIH) activates the YO and animals enter premolt. At mid-premolt, YOs transition to the committed state, in which ecdysteroid production increases further. In blackback land crab (*Gecarcinus lateralis*), SB1431542, an inhibitor of Activin receptors, decreases hemolymph ecdysteroid titers in premolt animals, suggesting that an Activin-like transforming-growth factor (TGF-β) is produced by the activated YO and drives the transition of the YO to the committed state. Myostatin (Gl-Mstn) is an Activin-like factor that is highly expressed in skeletal muscle. As Gl-Mstn is expressed in tissues in addition to muscle, the effects of molting on the Gl-Mstn expression in the YO were determined. Endpoint RT-PCR established that Gl-Mstn was expressed in the YO. Quantitative PCR was used to quantify the effects of molt induction by eyestalk ablation (ESA) on Gl-Mstn expression. YOs were harvested from intact (intermolt) animals and from animals at 1, 3, 7, and 14 days post-ESA. Gl-Mstn expression peaked at 3 days post-ESA ($p = 0.025$), which is before the transition to the committed state at 7 days post-ESA. Expression of elongation factor-2 (EF2) is significantly increased 7 days post-ESA ($p = 0.014$), indicating an increase in protein synthetic capacity. Future research will examine the regulation of Gl-Mstn by ecdysteroids. Supported by NSF (IOS-0745224).

39.6 MUIJRES, FT*; JOHANSSON, LC; BOWLIN, MS; WINTER, Y; HEDENSTRöM, A; Univ. of Washington, Seattle, Lund Univ., Sweden, Univ. of Michigan-Dearborn, Humboldt Univ, Berlin, Germany; *fmuijres@uw.edu*

Comparing Aerodynamic Efficiency in Birds and Bats Suggests Better Flight Performance in Birds

Has the independent evolution of powered flight in birds and bats, with the apparent convergence in size, shape and flight style, resulted in the same overall flight performance? Or do they differ due to morphological peculiarities, such as feathers and membranous wings? We test which of these scenarios fit to two measures of aerodynamic flight efficiency in two passerine bird species and two New World leaf-nosed bat species. Using time-resolved particle image velocimetry measurements of the wake of the animals flying in a wind tunnel, we derived the span efficiency, a metric for the efficiency of generating lift, and the lift-to-drag ratio, a metric for mechanical energetic flight efficiency. We show that the birds significantly outperform the bats in both metrics, and that the difference in performance is primarily caused by differences in body shape and wing upstroke function. The bats have less streamlined bodies than the birds, partly due to the presence of protruding ears used for echolocation in bats. During the upstroke, birds retract their wings and spread the wing feathers making the wing aerodynamically inactive, while the bats have a more complex upstroke motion where the membranous wing generates thrust and negative lift. Our findings suggest that, despite millions of years of evolution, bats may have not reached the same flight performance levels as birds, and that this could be due to conflicting selection pressures for echolocation and flight in bats. The results may help explain ecological differences between birds and bats, such as why birds typically fly faster, migrate more frequently and migrate longer distances than bats.

P1.70 MUIJRES, FT*; DICKINSON, M; Univ. of Washington, Seattle; *fmuijres@uw.edu*

Escape responses in freely flying fruit flies

Fruit flies and other insects possess a range of stereotypic flight responses that are triggered by particular sensory stimuli. One such example is an evasive maneuver in response to looming stimuli, which enables a fly to avoid collisions as well as for escape from approaching predators. During flight, objects may loom from any direction and an animal must generate an evasive maneuver in the correct direction if it is to avoid impact or escape. Thus, the circuitry that underlies evasive maneuvers must encode the direction of the looming stimulus and trigger an appropriately directed motor response. We are studying the aversive maneuvers of free-flying fruit flies (Drosophila spp.) to virtual looming objects in a flight arena lined with an electronic visual display. Using a set of three high-speed cameras (7,500 frames per second), we track body and wing movements before, during and after the presentation of a looming circular object. The location of the looming object in the flies' frame of reference varies between trials, allowing us to study the relationship between stimulus direction and motor response.

P1.60 MUIR, CD*; DAVIS, PA; CONESA, MÀ; ROLDÁN, E; GALMÉS, J; MOYLE, LC; Indiana University, University of the Balearic Island's, University of the Balearic Island's; *cdmuir@indiana.edu*

Through thick and thin: the adaptive significance of leaf trait variation in wild tomatoes

Trait-environment correlations are frequently used to infer adaptation if confounding factors, such as shared ancestry, can be ruled out. It is generally observed that thicker and/or denser leaves, indicated by high leaf mass per area (LMA), are more common in dry habitats because they confer greater tolerance to drought. I tested this hypothesis using a common garden study of 16 wild relatives of cultivated tomato. Contrary to my *a priori* prediction, I found that LMA was lower in species from drier habitats. Since species were measured in a common garden, this variation is genetic rather than a plastic response to the environment. I took an ecophysiological, mechanistic approach to understanding what could explain this pattern. One consequence of high LMA is that it hinders CO_2 diffusion from the substomatal cavities to the chloroplasts. Using standard ecophysiological methods, I found that lower internal CO_2 diffusion, commonly measured as mesophyll conductance (g_m), reduces photosynthetic rates and intrinsic water-use efficiency (WUE) in these species. Low LMA may therefore allow plants from dry habitats to balance the competing demands of rapid growth and high WUE. My working hypothesis is that in this system, low LMA enables plants in dry habitats to avoid drought by growing rapidly, yet efficiently, to use a limiting resource wisely. Since wild tomatoes are a genetically tractable, emerging model system for ecological and evolutionary genomics, future work will examine the genetic basis of traits associated with increased CO_2 diffusion that were identified in this common garden study. I have begun by locating QTL for LMA and stomatal distribution, another trait affecting CO_2 diffusion, in interspecific crosses.

131.2 MULLER, T.*; WINDSOR, S.P.; TAYLOR, G.K.; University of Oxford, UK; *tonya.muller@zoo.ox.ac.uk*

Optomotor flight control of hawkmoths in the context of their flight dynamics.

The sensorimotor systems involved in controlling an insect's flight are tightly coupled with its flight dynamics. The properties of the flight control system must therefore be interpreted in the context of the insect's flight dynamics in order for the functional properties of the system as a whole to be understood. The properties of the flight control system of hawkmoths *Manduca sexta* were investigated using a virtual reality flight simulator to measure the flight forces produced by tethered moths in response to wide-field, oscillating visual stimuli. For a given axis of visual rotation, the moths' response proved to be linear over a range of stimulus frequencies in respect of both homogeneity and superposition. This is particularly interesting given the highly non-linear properties of the neuronal elements of these sensorimotor pathways. Visual stimuli were also presented with six different axes of rotation, in order to present combinations of roll, pitch and yaw stimuli and to explore the limitations of the linearity of the flight control system. Examining the moths' responses to these combined stimuli in the context of their flight dynamics showed that the measured responses were strongly tuned to the insects' flight dynamics.

P1.21 MUNGUIA, A*; MOOI, R; Univ. of California, Davis, California Academy of Sciences, San Francisco; *rmooi@calacademy.org*

The Philippines as the center of sea urchin diversity: An in depth study from intertidal to abyss

As a biodiversity hotspot, the Philippines currently holds the gold medal in species richness. Species inventories are critical to analyzing biodiversity loss but are at the mercy of data quality. Resources such as GBIF, iNaturalist, postings by underwater photographers, and even commercial websites such as eBay allow data to accumulate, but require vetting by taxonomists. We focus on Philippine Echinoidea (sea urchins, heart urchins, and sand dollars) by adapting recognized ecoregions within the Indo-Pacific, then merging data on Philippine echinoids, incorporating updated information on bathymetry. Data from other global regions were compared to evaluate significance in Philippine species richness. A list of approximately 230 species of echinoids recorded to occur in the Philippines was developed using information from Mortensen's *Monograph of the Echinoidea*, the recent Hearst Expedition, and ancillary sources, then taxonomically updated using the *World Echinoidea Database*. The Philippines alone has three times as many known species of echinoids than in the entire Gulf of Mexico, and nearly four times as many as in the Red Sea. Updated inventories, along with new data from recent expeditions and exploration of the "Twilight Zone" (100-1000 m depth), are crucial in picturing Philippine echinoid biodiversity. New Philippine records and species new to science are coming to light, suggesting that the present numbers are conservative. Research suggests that the unsurpassed Philippine diversity is rooted in geologic history, overlap of faunas from adjacent ecoregions, and local oceanographic factors. Well-informed evaluation of the Philippine echinoid fauna will help determine new approaches to conservation efforts aimed at retaining biodiversity threatened by global change and anthropogenic influence.

17.1 MUNK, Y*; WILKINSON, S; DANIEL, TL; Univ. of Washington, Morehouse College; *yomunk@uw.edu*

Hawkmoths of Endor: Navigational decision policies for obstacle navigation in Manduca sexta

Insects flying within complex environments avoid obstacles by making decisions primarily on the basis of visual information. To study how the availability of visual information about obstacles affects course planning, we constructed a virtual flight simulator in which tethered *Manduca sexta* hawkmoths were able to control their trajectories through a virtual 3-D forest environment by applying yaw torques measured by a torquemeter. We investigated how visual information regarding local obstacles influenced navigational decision policies by using the display software to reduce contrast between obstacles and the background on the basis of their virtual distance from the moth, effectively introducing a virtual fog into the environment. For each subject, we applied five levels of virtual fog at two flight speeds, with three replications for each combination, for a total of thirty trials per subject. For 8 subjects a variety of behaviors were recorded, including obstacle avoidance and attempted landings on virtual trees. Heavy virtual fog limited navigation for all subjects, leading to reactionary avoidance behavior without evidence of course planning. At light fog levels with longer range visibility, trajectories showed evidence of short range planning. Trajectories gathered for very long visibility ranges did not exhibit obvious differences compared to medium visibility trials. Our virtual reality system demonstrates a viable platform for investigating decision making on the basis of visual information, broadly applicable to a wide range of biological subjects and capable of easily generating extraordinarily rich datasets.

25.2 MUNOZ, MM*; STIMOLA, MA; LANDESTOY, MA; CONOVER, A; RODRIGUEZ, A; ALGAR, AC; LOSOS, JB; Harvard University, Columbia University, Sociedad Ornitologica de la Hispaniola, Stuyvesant High School, University of California, Davis, University of Nottingham; *mmunoz@oeb.harvard.edu*

Does thermal specialization accompany environmental differentiation in a diverse clade of Caribbean Anolis lizards?

Despite lacking physiological heating and cooling, vertebrate ecotherms can be found across a wide spectrum of thermal environments. The degree to which ectotherm diversification along thermal gradients is accompanied by evolution in thermal physiology remains a pervasive question in evolutionary biology. The adaptive radiation of *Anolis* Caribbean lizards in the Greater Antilles has been most often studied along a single axis – morphological and behavioral adaptation to microhabitat (i.e., the 'ecomorphs'). However, most of the species richness of these anoles occurs through within-ecomorph radiations along a separate axis of specialization – thermal preferences along macrohabitat gradients. The cybotoids are a clade of Hispaniolan trunk-ground anoles that present the most extreme case of radiation along macrohabitat gradients. Members of this group are found from sea level to almost 3,000 meters and span a wide gamut of thermal environments. In this study we use environmental niche modeling (ENM) to quantify diversification in the thermal niche among seven species of Dominican cybotoids. We employ a phylogenetic framework to measure the extent to which diversification in the thermal environment has been accompanied by differentiation in the thermal sensitivity of three metrics – the critical thermal minimum (CTmin), critical thermal maximum (CTmax), and the mean field-active body temperature (Tb). We find that environmental diversification is accompanied by thermal specialization in some, but not all, physiological traits, and likely reflects tradeoffs between optimal performance and performance breadth in variable thermal environments.

48.3 MUNRO, D.*; PICHAUD, N.; PAQUIN, F.; BLIER, P.U.; Univ. du Québec à Rimouski, Canada, Univ. of New South Wales, Sydney, Australia; *dmunro70@hotmail.com*

Low hydrogen peroxide production in mitochondria of the long-lived Arctica islandica: underlying mechanisms of increased longevity

The inverse correlation between lifespan and mitochondrial ROS production rate observed in vertebrates represents a major pillar of the oxidative stress theory of aging. Bivalve molluscs are routinely exposed to environmental constraints such as microbial H_2S, anoxia/reoxygenation and temperature variations that would normally elicit oxidative stress in mammals. Hence, they represent an interesting taxon to challenge the existence of this correlation in remote phyla. We compared the mitochondrial H_2O_2 production rates between the longest-lived metazoan, the bivalve *Arctica islandica* (maximum reported longevity = 507 years) and two taxonomically related short-lived species of comparable size. We also compared the oxygen consumption of intact mitochondria and the enzymatic activity of different complexes of the electron transport system. Mitochondria of *A. islandica* produced significantly less H_2O_2 than those of the two short-lived species in different conditions of mitochondrial respiration which includes forward, reverse, and convergent electron flow. A reduced complex I content in *A.I.* can provide a partial explanation for the results during reverse electron flow. However, a lower electron flux control, leading to lower degree of electronic reduction of complex I and III, as well as a lower activity of complex II in *A.I.* may yield another explanation for the results obtained during forward and convergent electron flow, respectively. Overall, our study suggests that the relationship between ROS production rate and longevity may be generalized among metazoan and the adaptative mechanisms to achieve it may be remarkably conserved.

P1.194 MURPHY, B.J.*; ENSTROM, D.A.; COCHRAN, W.W.; BOWLIN, M.S.; University of Michigan-Dearborn, Illinois Natural History Survey; *murphyjb@umd.umich.edu*

Wingbeat frequency and altitude shifts in the migratory flight of the Swainson's Thrush Catharus ustulatus

It has been hypothesized that small birds reduce their flight altitudes by first reducing their wingbeat frequency and then by briefly but repeatedly pausing during flapping, generating an intermittent flight (flap-pause) pattern. The aim of this project was to examine the relationship between wingbeat frequency, flap-pause flight, and the changes in altitude that we have observed during the migratory flight of Swainson's Thrushes (*Catharus ustulatus*). We attached radiotransmitters to the backs of thrushes and collected data during their subsequent migratory flights by following them with a tracking vehicle. The signals from these transmitters contained altitude data (via temperature and pressure measurements) and wingbeat recordings. From this, we were able to measure wingbeat frequency and observe flap-pause behavior. We found a strong correlation between shifts in altitude and wingbeat frequency and flap-pause flight. However, changes in the pattern of flight were not always immediately reflected in the birds' altitude. Reductions in wingbeat frequency and increases in pause percentage were quickly followed by descent, but increases in wingbeat frequency and cessation of pausing occurred some time prior to increases in flight altitude. Understanding the mechanism behind altitude selection may ultimately help us understand why thrushes make these unexpected shifts in altitude.

30.5 MURPHY, K.K*; WALKER, S.E. ; California State University, Fullerton ; *kerimurphy@csu.Fullerton.edu*

The impact of age and mate quality on resource allocation in the house cricket, Acheta domesticus

Sexual conflict occurs when the interests of males and females diverge and the sexes have evolved tactics that manipulate the other sex in order to increase their immediate reproductive success. These tactics can be plastic and vary with individual quality. Organisms are faced with a tradeoff between allocating resources to somatic maintenance or reproduction. The balance of this trade of may be impacted by the quality of an individual's mate and age at first reproduction. However, few studies have examined how mate quality and age impact reproductive decisions. Reproductive allocation varies with age, mating status and mate quality. Two hypotheses try to explain how mate attractiveness affects reproductive allocation. Reproductive compensation (RC) predicts a female will allocate more resources towards reproduction when her mate is unattractive. Differential allocation (DA) predicts females will allocate more resources when her mate is attractive. We sought to determine which strategy of reproductive allocation is used by house crickets, *Acheta domesticus*, how it varies with age and if females have higher fitness when young and mated to an unattractive male, or older and mated to an attractive male. Older females lay fewer eggs than young females. Regardless of age, female house crickets mated to unattractive males have higher initial rates of egg production compared to females mated to attractive males. Hatching rates don't vary with female age or male attractiveness. However, fertilization rates were highest in young females mated with attractive males and lowest for old females mated with attractive males suggesting attractive males may vary their reproductive investment in response to female age but unattractive males do not. Clearly, house crickets do not strictly adhere to either DA or RC and both male and female strategies vary depending on the context.

99.5 MUSSER, JM*; WAGNER, GP; PRUM, RO; Yale University, Yale University, Yale Systems biology Institute, Yale University, Peabody Museum of Natural History; *jacob.musser@yale.edu*

The Homology of Feathers and Scales: Using New High-throughput Methods to Address a Classic Question

Feathers are an important anatomical innovation that evolved in the ancestors of birds and facilitated the evolution of flight, greater thermoregulation, and other facets of modern avian life. However, the molecular basis for the evolution of feathers is poorly understood, and the homology of feathers to other skin derivatives, especially scales, remains contentious. Here, we take a new approach to answering these questions by comparing transcriptomes from different stages of developing feathers, different avian and reptilian scales, and claws. We performed mRNA-seq on different stages of skin appendage development collected from two distantly related birds, Chicken (*Gallus gallus*) and Emu (*Dromaius novaehollandiae*), and from American Alligator (*Alligator mississippiensis*), a member of the extant clade most closely related to birds. Comparison of these transcriptomes allows us to investigate the homology of feathers and scales at different developmental stages. Further, they allow us to identify candidate regulatory molecules, including transcription factors and members of signaling pathways, which underlie feather novelty. Finally, to complement our transcriptome data, we used immunohistochemistry to compare patterns of expression and subcellular localization of the transcription cofactor &beta-catenin, the earliest known molecule expressed in feathers. Our preliminary evidence suggests &beta-catenin is also present in early developing avian scales and alligator scales, suggesting these skin appendages use similar molecular pathways at the beginning of their development. Together, our data presents a new and comprehensive look at the homology of feathers and scales and the molecular basis of feather novelty.

P1.212 MUZZIO, A.M.*; NOYES, P.D.; STAPLETON, H.M.; LEMA, S.C.; CalPoly, San Luis Obispo, Duke University; *slema@calpoly.edu*

The Organic Anion Transporting Protein (OATP) Family in a Teleost Fish Model

Organic anion transporting proteins (OATPs) are a family of transmembrane polypeptides that regulate the sodium-independent cellular transport of amphipathic organic compounds including xenobiotics, hormones and pharmaceuticals. Recent studies in mammals have demonstrated a role for OATPs in the endocrine disrupting effects of environmental pollutants, yet many basic questions remain unaddressed about the evolutionary diversity, function and regulation of OATPs in other vertebrate taxa. Here, we identified and confirmed ESTs encoding eight distinct OATPs in a teleost fish model, the fathead minnow (*Pimephales promelas*). We then used quantitative real-time RT-PCR methods to examine the relative abundance of OATP mRNAs in the brain, liver, gonads, spleen, heart, skeletal muscle, kidney, gills, and GI tract of adult fish. Gene transcripts encoding OATP2a1 and 5a1 transporters were ubiquitous in all minnow tissues examined, with 2a1 mRNAs most abundant in the liver and 5a1 transcripts at highest levels in the brain, gonad and heart. Transcripts for OATP1c1 were most abundant in the liver but also found at elevated levels in the brain, while OATP3a1 mRNAs were greatest in heart and muscle and OATP2b1 mRNAs highest in heart and gills. Transcripts for OATP4a1 were detected at greatest abundance in the brain, with high levels in optic tectum, moderate levels in hindbrain and forebrain, and lower levels in the cerebellum. OATP4a1 mRNAs were also abundant in the ovary but not in the testes. Transcripts for OATPs 1f4 and 1f2 were highly abundant in the kidney but nearly absent in other tissues. Taken as a whole, our findings help establish the tissue distribution of the OATP family and provide a foundation for exploring the regulation of OATP transcriptional dynamics by hormones and xenobiotics.

S5-2.1 NAGAHAMA, Y.; Ehime Univ.; *nagahama.yoshitaka.mh@ehime-u.ac.jp*

Genetic and hormonal regulation of gonadal development and sexual plasticity in fish

Among the vertebrates, teleost fishes display the greatest diversity of sexual phenotypes, thus providing an excellent model to study molecular mechanisms of sex determination, sexual differentiation and sexual plasticity. We identified *dmy* as the sex-determining gene of the medaka (*Oryzias latipes*). Recently, we developed a gene-specific transgenic RNA interference (RNAi) technology for the analysis of loss-of-function phenotypes that develop over long periods of time, and used it to knock down the *dmy* gene in genetically male (XY) fish. Knockdown of *dmy* strongly downregulated the expression of only other male-associated genes, and upregulated the expression of female-associated genes in XY gonads during the early stages of sexual differentiation. We previously showed that a sharp decrease in estrogen production triggers female to male sex reversal in an adult sex-changing fish, the saddle-back wrasse (*Thalassoma duperrey*). Therefore, in this study, we used aromatase inhibitors (AIs) to block the conversion of androgens to estrogens and examined whether lack of estrogen can reverse the gonadal morphology in two adult, sexually-mature gonochoristic species, medaka and Nile tilapia (*Oreochromis niloticus*). Interestingly, we found that AIs were effective in blocking estrogen production and induced a complete sex reversal from females to males in both medaka and tilapia. Further, AIs were sufficient to induce not only the testicular structure, but also the phenotypic transformation including sexual behavior. Our data, for the first time in any vertebrates, has shown that sexual plasticity is preserved even in adulthood.

1.1 NAGY, KA; University of California, Los Angeles; *kennagy@biology.ucla.edu*

Reflections and Projections on Becoming a Physiological Ecologist

The most important events on my path to becoming a physiological ecologist were: 1) recognizing that I was unusually strongly interested in wild animals and how they survived each day in nature, 2) learning that having such an “obsession” was OK and that there was a place for people like me, and 3) getting praise, encouragement and help from my teachers as an undergraduate and beginning graduate student. Those supporters included Bill Mayhew, Frank Vasek, Gene Cota-Robles, Carlton Bovell, Rudy Ruibal and especially Vaughan Shoemaker, all at UC Riverside, Bill Dawson at Univ. of Michigan, Lon McClanahan at Cal State Fullerton, and George “Bart” Bartholomew at UCLA. All I did was ask them question about their lectures and research, and in response, they went out of their way to encourage me. I am extremely grateful for their validation of my “odd” fascination, their facilitation of my academic progress, and their confidence in me. Later, when I became a teacher of undergraduates and a mentor of graduate students, post-docs, and anyone else who got close enough, I simply tried to pass on what was so enthusiastically given to me. For the new person who is unusually curious and interested in how wild animals work, I suggest that you put yourself in the company of physiological ecologists, listen to them, and ask them thoughtful questions. Allow yourself to be driven by your curiosity, and by the excitement that comes from getting a satisfying (“Ah-hah”) answer. Your teachers and colleagues will probably be delighted to encourage and aid your progress towards becoming a physiological ecologist. And later, your professional help will be much needed as Earth’s climate and ecology continue to change, forcing wild animals to face new challenges to survival and reproduction.

66.1 NAIR, S.*; BAROCAS, J.; HADJISOLOMOU, S.; GRASSO, F.W.; Brooklyn College, City University of New York; *savithrinair@yahoo.com*

Chemosensory and Mechanosensory Mediation of Inter-sucker Coordination in Octopus bimaculoides

Coleoid cephalopods possess suckers on their arms and tentacles but *Octopus* suckers are distinguished by their extrinsic muscles which permit the animal to move them independently of arm motions. The neuroanatomical sensory-motor structures (ganglia, nerve roots and tracts) of the suckers and arms that support arm-sucker coordination have been mapped, but the information that is shared between them has not been thoroughly explored. We hypothesized that mechanical and chemical stimulation of a single sucker would be communicated to adjacent suckers. We found significant responses (movements made after stimulus application) to both types of stimuli in neighboring suckers. This relationship diminished with distance from the stimulated sucker. We also hypothesized that different chemical stimuli and different mechanical loads would elicit different types of reactions from the nearby suckers. Different types of chemical stimuli (low or high pH, octopus extract and artificial sea water, a neutral stimulus,) suspended in agar elicited differential reactions from neighboring suckers when placed in contact with a focal sucker. Different mechanical loads also produced differential responses in that recruitment of responses from suckers neighboring the stimulated sucker increased with load. We found a tendency for suckers proximal and distal to the stimulated sucker to respond differently to a given level of stimulation (chemical or mechanical). Our results demonstrate new functional properties of the sensory-motor neural networks that underlie arm-sucker coordination in *Octopus*.

P1.69 NAIR, A.M.*; STEWART, W.J.; MCHENRY, M..J.; Univ. of California, Irvine; *amnair@uci.edu*
Optimal approach strategies for fish predators based on lateral line sensation
In order to survive, predatory fish must effectively strike and capture prey. In a darkened environment, prey fish can use their lateral line system to sense a disturbance in the water created by a predator's approach. Given this ability, it is in the best interest of the predator to minimize this perturbation by decreasing its approach speed. However, a slower approach gives the prey more time to react. Given this trade-off, is it beneficial for a fish predator to move fast or slow? We addressed this question by varying the approach speed of a robotic predator while measuring the response of prey with high-speed video. Particle image velocimetry (PIV) was used to measure the extent of the flow perturbation, known as the bow wave, around the predator. These measurements revealed that the bow wave's size and intensity increases with speed. Given the prey's sensitivity, the smallest change in flow that the prey can detect, we measured the distance between the prey and the oncoming predator when the prey detects the bow wake, from which we determined to time to strike the prey (TTL). We identified two major strategies that predators may adopt to maximize their capture success. One strategy would be for the predator to advance slowly enough that the prey will never sense the bow wave. Ideally this strategy guarantees a successful capture but may be difficult for the predator to realistically accomplish with highly sensitive prey. The other strategy is to approach the prey at maximal speed to minimize TTL, but allow the prey to detect the predator. Ultimately, the sensitivity of the prey and the predator's maximum speed determines which of these two strategies is optimal.

P2.88 NAKANISHI, N*; SOGABE, S; DEGNAN, B; University of Queensland; *n.nakanishi@uq.edu.au*
Metamorphosis in the Demosponge Amphimedon queenslandica
We examined the pattern of cell proliferation, differentiation, migration and death during metamophosis from a free-swimming larva into a juvenile in the demosponge Amphimedon queenslandica. Our experimental approach combined immunohistochemistry (e.g. anti-phosphorylated histone H3), dye labeling (e.g. DiI), EdU pulse and chase experiments, TUNEL assay, and confocal and electron microscopy. The free-swimming larva consists of a ciliated outer epithelium, a subepithelial layer of cells, and an innermost group of mesenchymal cells referred to as the inner cell mass. In larvae, cell proliferation is restricted to archeocytes in the inner cell mass, while apoptosis is limited to epithelial cuboidal cells at the anterior-most (with respect to the swimming direction) region. During metamorphosis into a juvenile, spherulous cells of subepithelial and/or inner cell mass origin emigrate and form an outer layer that encloses the larval epithelial cells. A large fraction of the larval epithelial cells undergo programmed cell death, and their apoptotic bodies are taken up by the surrounding cells, including the migratory archeocytes of the larval origin. Non-apoptotic, ciliated larval epithelial cells migrate and differentiate into such cell types as the pinacocyte in the outer layer pinacoderm, the archeocyte in mesohyl, and the choanocyte in the inner layer epithelium that constitutes feeding structures known as the choanocyte chambers. Also, larval archeocytes give rise to a set of differentiated cell types including the pinacocyte. Cell proliferation is prominent in developing choanocyte chambers, indicating that the chambers grow by mitosis of choanocytes. A single choanocyte chamber does not always originate from a single precursor cell; multiple precursor cells are often involved in forming a single chamber.

P1.193 NAKATA, T.*; HENNINGSSON, P.; LIU, H.; BOMPHREY, R.J.; Univ. of Oxford, Chiba Univ.; *toshiyuki.nakata@zoo.ox.ac.uk*
Aerodynamic performance of gliding dragonflies with three-dimensional corrugated wings
Dragonfly wings are not smooth surfaces but have distinct corrugations that stiffen the wings against high aerodynamic and inertial bending moments. Corrugations may also directly enhance the aerodynamic characteristics of the wings by modifying lift to drag ratios or indirectly by enabling high aspect ratios – thereby reducing induced drag – without greatly increasing material volume or spanwise torsional stiffness. The aerodynamic effect of insect wing corrugations in gliding or flapping flight has been reported previously with most analyses performed in two-dimensions or three-dimensions based on extrusions of a common corrugated profile along the wings' length, overlooking the consequences of spanwise variation in corrugation pattern and three-dimensional aerodynamic effects. In this study, a computational fluid dynamic analysis of gliding dragonflies was performed using a selection of three-dimensional wing shapes measured as a series of cross-sections along the wing span, by projecting a laser light sheet onto the wing surfaces of museum specimens and freshly captured individuals and recording the topography using a digital camera. Corrugation was digitally reconstructed from the laser scan images and found to vary markedly along the spanwise axis.Its effect on aerodynamic performance was evaluated by comparing the full-fidelity models with alternative wing topographies. The results indicate that the inherent corrugation in dragonfly wings does not lead to an abrupt decrease in aerodynamic performance and may be a compromise between aerodynamic and structural requirements.

73.4 NATER, O.H.A.*; DILLON, M.E.; Univ. of Wyoming, Laramie; *onater@uwyo.edu*
Thermal time: a tool for predicting climate-induced shifts in native bee phenology
Climate change can decouple the relationship between insect pollinators and their host plants by differentially shifting their phenologies (abundances over time), raising fear of a potential 'pollinator crisis'. For many insects, spring emergence is directly dependent on temperature, but we lack data on the relationship between climate and phenologies of most pollinators. Here we present a novel thermal time approach to estimate climate change-induced shifts in the spring emergence of four locally abundant native bee taxa (*Agapostemon angelicus/texanus*, *Lasioglossum Dialictus* spp., *Lasioglossum trizonatum* and *Halictus rubicundus*) in southeast Wyoming. We used 2011 bee abundance data to estimate degree days necessary for 50% population emergence. These degree-day estimates accurately predicted 2012 emergences to within ten days. Since 1975, annual mean, minimum, and maximum temperatures in the area have increased by 1.3, 2.7, and 1.3 °C respectively. Based on 2011 degree-day estimates and assuming no evolution, we estimate springtime phenology of native bees to have advanced by roughly two weeks over the same period. While this approach is not perfect, likely because it does not account for other abiotic and biotic phenological drivers, it is nevertheless a straightforward, low-cost tool for predicting insect species' responses to climate warming. In light of the paucity of historical data for most species of interest, this approach could prove useful for identifying and mitigating potential disruption of crucial plant-pollinator interactions.

P3.193 NAUWELAERTS, S.*; AERTS, P.; CLAYTON, H.M.; University of Antwerp, Belgium; *sandra.nauwelaerts@ua.ac.be*

Ground reaction forces during transition from trot to canter

Gaits are defined based upon specific inter-limb coordination patterns characteristic to a limited range of speeds and of which one or more defining variables change discontinuously at a transition. With changing speed, horses perform a repertoire of gaits, walk, trot, canter and gallop, with transitions between gaits. The underlying mechanics involving such transitions are still unclear. In a previous study on the kinematics of the transition from trot to canter in miniature horses, early and short placement of the forelimb that becomes the leading limb in the canter was observed due to a shortened swing phase prior to the stride where the first phase shift (dissociation) away from the trotting pattern occurs. Based on this observation, we proposed that the transition was initiated by the fore limb perturbing the cyclical patterns of the trot resulting in a cascade of dynamic changes designed to restore the dynamic stability of the system. We expect the dynamic changes to become apparent by a change in the loading of the leading forelimb in the transition stride. To test this hypothesis, we measured joint kinematics and ground reaction forces of the forelimbs of four miniature horses transitioning from trot to canter. Twenty-four trials were recorded using a ten camera MotionAnalysis camera system and four Bertec force plates. Peak force, impulse and force rate at impact were measured for each hoof at each stride in the trial. Stride zero was defined as the stride, starting with contact of the leading forelimb and included the first dissociation in the swing phase of the dissociating diagonal limb pair. Vertical ground reaction forces under the leading, dissociating fore limb were lower in stride zero compared to the other strides, but horizontal forces did not change. The change in force magnitude and orientation will be coupled with kinematics and implications for motor control will be discussed.

S5-1.3 NAVARA, KJ; Univ of Georgia; *knavara@uga.edu*

Stress, hormones, and sex: How do we solve the puzzle of sex ratio adjustment in birds?

Ecologists and evolutionary biologists have shown time and again that birds have a striking ability to vary the ratios of male and female offspring they produce in response to environmental and social conditions. However, even after decades of similar observations, the physiological mechanisms responsible for the adjustment of offspring sex by birds remain elusive. What we do know is that female birds target hormones to the egg contents and utilize them to program the growth, development, and other phenotypic variables of their offspring for the environment into which they will hatch. It seems logical, then, that they might also use these hormones to adjust the sexes of offspring as well. Indeed, several studies have shown that situations that provoke the release of reproductive and stress hormones also provoke skews in offspring sex ratios, and that direct treatment with these hormones can also induce similar skews. We now need to address how the hormones may be acting, and at what point in the reproductive process offspring sex is being manipulated. We have shown that both testosterone and corticosterone can influence which sex chromosome is donated by the heterogametic female bird, however these effects require exposure at a very specific time during ovulation and at a very specific dosage. In addition, the effects of these hormones are often inconsistent and likely depend upon other factors such as body condition and environmental variables. The adaptive significance of using hormones to mediate sex ratio adjustment depends on both the cellular mechanisms by which the adjustment of offspring sex occurs as well as how the use of those hormones fits into the larger environmental picture.

P1.223 NAVARA, KJ*; PINSON, SE; LITTLE, T; The University of Georgia; *knavara@uga.edu*

High dose testosterone causes oocyte reabsorption in chickens

It has been shown that hormones, including testosterone and corticosterone, influence offspring sex when given during a very critical window surrounding ovulation in birds. One of the potential mechanisms posited for this influence is that females may preferentially discard oocytes of the unwanted sex before fertilization and development can occur. It is known, particularly in the poultry industry, that even in normal reproductive hens, a small percentage of oocytes are ovulated into the peritoneal cavity rather than the infundibulum of the reproductive tract, a phenomenon called oocyte reabsorption. It is not known, however, to what extent testosterone and corticosterone exert control over the process of oocyte reabsorption in chickens. We treated hens with pharmacological doses of testostosterone and corticosterone as well as a control vehicle 5h prior to ovulation and monitored egg-laying behavior in all treated hens as well as a set of hens that went untreated. Significantly more testosterone-treated hens failed to lay the egg that would have been ovulated compared with control, corticosterone-treated, and untreated hens. We then killed and dissected a subset of hens from the testosterone group that laid (n=10) or failed to lay (n = 18) as well as hens that failed to lay from the corticosterone and control groups (n = 9) and untreated hens that laid eggs at the time the treated hens were expected to lay (n = 11). Ruptured yolks lined the peritoneal cavities of 11 of 18 testosterone-treated hens that did not lay eggs, while only three out of all 47 remaining hens had yolk in the peritoneal cavity. These results suggest that high-dose testosterone causes oocyte reabsorption, perhaps by uncoupling the infundibulum from the ovary. The next step is to examine whether oocytes are reabsorbed in a sex-specific manner.

61.2 NAVEH, G.; BRUMFELD, V.; CHARLES, C.; KLEIN, O.D.; WEINER, S.; DRUZINSKY, R.E.*; Weizmann Institute, Rehovot, Israel, École Normale Supérieure de Lyon, France, Univ. of California, San Francisco, Univ. of Illinois at Chicago; *druzinsk@uic.edu*

The role of enamel in the mechanical properties of the incisors of rodents

Rodents sharpen their incisors by grinding the lingual and buccal surfaces of opposing teeth. Normally the buccal (labial) surface is covered with enamel, whereas the lingual surface is not. While grinding enamel against dentin, the dentin wears away and a sharp tip is formed. We compared bending (deformation) of lower incisors under compressive loads in normal (wild type) and two strains of transgenic mice that carry mutant alleles that have different effects on the production of enamel. The first strain that we studied is a sprouty loss-of-function transgenic mouse (*Spry4*$^{-/-}$; *Spry2*$^{+/-}$). These mice have enamel on the lingual surfaces of the incisors. The second strain that we studied is an amelogenin knock-out mouse (*AMEL* $^{-/-}$). These mice have little or no enamel on the surfaces of the teeth. Teeth were axially loaded and scanned within a micro-CT (Xradia). Normal (wild type) incisors, without lingual enamel, bent lingually, primarily at the worn and sharp distal end of the tip, whereas sprout teeth with enamel on both sides bent around a more proximal point, with the result that the entire tooth bent. Amelogenin knock-outs, with little or no enamel, also bent around a point proximal to the tip, similar to the sprouty incisors. Much smaller excursions of the loading device were required to fracture the incisors with enamel on both sides than in the other teeth. Our results demonstrate that enamel deposited on the lingual surface lowers the extent to which teeth bend and elevates the brittleness of the teeth. The purposeful sharpening activities of rodents do not just make the tips sharp, they make the tips flexible.

99.2 NAWROCKI, A.M.*; CARTWRIGHT, P.; Pomona College, Claremont, CA, University of Kansas, Lawrence, KS; *annarocky@gmail.com*

Expression of Wnt pathway genes in Ectopleura larynx (Hydrozoa: Aplanulata) and implications for their potential role in hydrozoan life cycle evolution

The canonical Wnt signaling pathway is conserved in its role in axial patterning throughout Metazoa. In hydrozoans (Phylum Cnidaria), Wnt signaling is implicated in oral-aboral patterning of the planula, polyp and medusa. Here, we present gene expression data for Wnt pathway components in the hydrozoan species *Ectopleura larynx*. Using next-generation sequencing, we isolated genes from the canonical Wnt signaling pathway and examined their expression in *E. larynx*. Unlike most hydrozoans, *E. larynx* lacks a larva and the polyp instead develops directly from a brooded embryo. These embryos develop within gonophores that represent a truncated medusa stage of the hydrozoan life cycle, with gonophores of *E. larynx* retaining evolutionary remnants of medusae, including tentacles. Our data are consistent with the Wnt pathway being involved in axial patterning of both the polyp and elements of the truncated medusa. Specifically, changes in the spatial expression of Wnt pathway genes are correlated with the development of different oral structures in male and female gonophores. The absence of expression of components of the Wnt pathway, and presence of a Wnt pathway antagonist in the developing anterior end of the gonophore, suggest that downregulation of the Wnt pathway may be implicated in the evolution of medusa reduction in Hydrozoa.

96.3 NEDVED, B.T.*; WILLSEY, E.D.; COURY, R.; HADFIELD, M.G.; Kewalo Marine Laboratory, Uni. of Hawaii, University of Toronto, Kewalo Marine Laboratory, Uni. of Hawaii, Kewalo Marine Laboratory, Uni. of Hawaii; *nedved@hawaii.edu*

Regulation of metamorphosis in Hydroides elegans: not what we thought

Larvae of the serpulid polychaete *Hydroides elegans* require contact of their episphere with specific bacterial substrata to initiate metamorphosis. While apical sensory organs (ASO) have long been thought to bear receptors for metamorphic cues, we have recently shown that laser-ablation of the ASO in these larvae does not inhibit metamorphosis. To investigate alternate sites of this chemoreception, we used immunohistochemistry and pharmacological assays to determine if cells expressing catecholamines or nitric oxide (NO) are necessary for the induction of metamorphosis. Antibodies raised against tyrsosine hydroxylase, an enzyme required for catecholamine biosynthesis, labeled numerous sensory cells within the larval episphere. One or two hr exogenous pulses of the catecholamines dopamine (DA), noradrenalin (NA) and adrenalin (AD) induced larvae of *H. elegans* to metamorphose in the absence of biofilms. Because AD is synthesized from both DA and NA, it may be used to transmit inductive cues within the central nervous system of *H. elegans*. Consistent with these data, antagonists to α-adreno-receptors inhibited metamorphosis. Contrary to the responses of other invertebrate larvae, application of agents that act as NO synthase inhibitors, NO scavengers, and NO donors had no effect on metamorphosis, suggesting that NO may not play a role in regulating metamorphosis in *H. elegans*. Taken together, these data suggest that, within Lophotrochozoans, there is evolutionary plasticity in the detection of metamorphic triggers, transmission of inductive cues, and the responses of target tissues to metamorphic signals.

P3.37 NEEMAN, N.*; ROBINSON, N.J.; O'CONNOR, M.P.; SPOTILA, J.R.; PALADINO, F.V.; Drexel University, Purdue University; *nn72@drexel.edu*

Do leatherback turtles shift their nesting seasons as a response to changes in sea surface temperature?

Modern species of sea turtles have survived past shifts in climate. However, current rates of increase in atmospheric greenhouse gases and associated temperature changes are very rapid and it remains unclear whether sea turtles, limited by their long generation times, will be able to adapt to new conditions. If they do, it may be by changing their nesting; either by moving to new beaches or by shifting their nesting season. The aim of this study is to determine whether the leatherback populations nesting at two Caribbean beaches (Tortuguero, Costa Rica and St. Croix, US Virgin Islands) are shifting their nesting seasons in response to changing sea surface temperatures. Correlations were made between sea surface temperatures both at nesting and foraging sites and Julian date by which certain percentiles (10th, 25th and 50th) of nests have been laid on each beach. The correlation between temperature and net primary production (NPP) was also studied for each site. The temperature at the nesting sites did not have an effect on nesting dates. However, changes in temperature (higher or lower, depending on the site) at two of the foraging sites for Tortuguero led to higher NPP and to later nesting. One of the foraging sites for St. Croix had suggestive results, consistent with those for Tortuguero. To better determine if this observed trend is real, the study will be repeated for Playa Grande, Pacific coast of Costa Rica.

P3.14 NEKOLNY, S.*; GIBSON, Q.; ERMAK, J.; RICHMOND, J.; University of North Florida; *s.nekolny@unf.edu*

Don't Bite Your Mother: Seasonality and Sex Differences in Dolphin Tooth Rake Marks

Although aggressive encounters among conspecific dolphins are rarely observed, tooth rake marks that result from such interactions serve as a useful tool for evaluating aggression levels in a population. This study examined seasonality and sex differences in recency and body coverage of tooth rake marks on bottlenose dolphins (*Tursiops truncatus*) in Jacksonville, Florida (n=278 dolphins). Photographs (n=2395) from March 2011 through February 2012 were examined for dorsal surface rake marks. The dolphin body was divided into seven sections and each section was assigned a code for the percentage of rake mark coverage (> or < 50%). Rake marks were categorized as new, obvious, or faint. The female sex category included individuals with confirmed calves, while unknown sex included behaviorally presumed males and a few possible females not yet observed with a calf. The percentage of dolphins with rake marks was high in all seasons (range=92.6—99.2%). Both females (96.9%) and unknown sex (100%) were most likely to have rake marks in winter, but spring also had a high percentage of females with rakes (95.8%). In all seasons except spring, fewer females than unknown sex had rake marks. Winter had the greatest incidence of new rakes for both females (22.6%) and unknown sex (50.5%). Winter also had the highest percentage of both females (61.3%) and unknown sex (65.6%) with extensive coverage of rakes in at least one body section. Individuals with rakes present on at least four body sections were most abundant in spring for females (16.7%) and winter for unknown sex (24.7%). These results indicate that conspecific aggression occurs more frequently in winter and among individuals of unknown sex than females.

P2.58 NELSON, H.R.*; GRIFFIN, J.N.; MCCOY, M.W.; NIFONG, J.C.; SILLIMAN, B.R.; Brown Univ., Univ. of Florida; *hannah_nelson@brown.edu*

Despite resource partition, multiple predators reduce mortality risk for foundation species

Multiple predators often interact in non-linear ways, which can enhance or reduce the risk for their shared prey. Many studies have investigated emergent multiple predator effects, but the role of prey size in shaping the interactions between predators has received little focus, even though prey-size preferences could strongly intensify or dampen the competition between predators. We studied the prey size preferences of two dominant predators common to Florida's estuarine intertidal oyster reefs, the blue crab (*Callinectes sapidus*) and the crown conch (*Melogena corona*), and used the results to predict the type of impact multiple predators would have on oyster mortality. In our laboratory experiment, conchs showed a preference towards large oysters, while blue crabs preferred small oysters, suggesting that their combined effects on oyster mortality rates would be positively synergistic or additive. Results from our factorial mesocosm experiment, however, contrasted with these predictions by demonstrating that these two predators actually have antagonistic effects. Thus, despite evidence for a size-based resource partition, there was a significant risk-reduction in mortality with the combination of both predators, revealing the presence of an emergent multiple predator effect. While blue crabs did not kill conchs, their presence resulted in a non-significant trend in escape behaviors by conchs and reduced feeding, suggesting that the mechanisms underlying the negative multiple predator effect could be non-consumptive. This work cautions extrapolation of correlational data suggesting predator resource partitioning without experimental testing, and suggests that the impacts of recent increases in conch numbers on oysters can be diminished in areas where blue crabs are abundant.

P3.187 NELSON, L.; COX, L.; HYMES, S.; WOODWORTH, E.; BOWLIN, M.S.*; University of Michigan-Dearborn; *melissabowlin@gmail.com*

The effects of chronic stress on sleep in house sparrows (Passer domesticus)

Sleep is an important phenomenon in the animal kingdom, yet its function(s) and origin remain elusive. We investigated the relationship between stress and sleep in birds by exposing four house sparrows (*Passer domesticus*) to a chronic stress protocol, *sensu* Cyr et al. (2007). Using an infrared camera system, we recorded the nighttime sleep behavior of these birds for two weeks before, during, and after the chronic stress protocol. We are currently in the process of measuring the latency to sleep, the number, timing, and length of arousals, and the amount of head-forward and head-backward sleep each bird exhibited each night. To date, we have found few clear changes in the quantity or quality of sleep during the chronic stress period compared to the initial control period. This may be because there is little or no effect of chronic stress on sleep in house sparrows; alternatively, the sparrows may not have been fully acclimated to captivity or to the experimental setup prior to the initiation of the chronic stress protocol. We plan to repeat the experiment on birds that have spent more time in captivity and in the plexiglass cages we use to record sleep behavior.

131.3 NELSON, FE*; DASARI, V; HSIEH, T; Temple University, University of Pennsylvania, University of Pennsylvania, Temple University; *f.e.nelson75@googlemail.com*

Differential limb function during locomotion on the level and over obstacles in the tarantula

Understanding how the motor control system maintains sufficient flexibility to navigate the natural variability of the environment is important for elucidating evolutionary mechanisms, robotic design, and understanding disease states. The goal of this study was to determine the function of different limbs during steady state running and obstacle maneuvering in spiders. We ran five juvenile Usambar Orange Baboon tarantulas (Pterinochilus murinus) (body length: 1.1±0.1 cm) along a flat trackway while filming the dorsal view. We also ran the spiders across obstacles of 0.5x, 1x, and 2x knee height. On average, spiders ran at 25 ± 3 cm/s and did not appear to slow down on the 0.5x and 1x obstacle treatments. We found limb function differed among the four sets of limbs. The posterior (fourth set) of legs functioned as propulsors, as evidenced by large changes in effective limb length (ΔeLL; 43.2±5.13 %) and the small angle of excursion (20.4±3.4°) during a stride. Similarly, the first (anterior set) and second set of limbs also exhibited large ΔeLL (57.3±2.26% and 49.5±8.9%, respectively), but swept through a greater excursion angle (61.6±4.81° and 59.4±5.8°, respectively), suggesting they played both a propulsive and stabilizing function. In contrast, the third set of legs were mostly extended throughout a stride (ΔeLL: 15.4±1.6 %) and followed a large excursion angle (44.3±4.0°), consistent with a stabilizing function. Preliminary results suggest some change in limb function during obstacle crossing, with the first set of legs taking on a sensory – in addition to locomotory – role, while the fourth set of limbs maintain a primarily propulsive function.

P1.217 NEMETH, Z.*; RAMENOFSKY, M.; University of California, Davis; *znemeth05@gmail.com*

Blocking testosterone action indirectly increases migratory restlessness during fall migration

Unlike vernal migration, the role of testosterone in initiating and organizing fall migration is unknown. Although gonads are regressed and plasma levels of androgen are low at the outset of fall migration, nongonadal (adrenal or brain) testosterone may direct the physiological processes that facilitate the development of migratory behavior. We tested this hypothesis in gonadectomized male White-crowned Sparrows (*Zonotrichia leucophrys gambelii*) by blocking the action of testosterone in birds completing post-breeding molt just prior to the initiation of fall migration. We monitored the development of molt, premigratory fattening and flight muscle hypertrophy as well as levels of plasma androgen (T and DHT) and estradiol (E_2) and migratory restlessness (*Zugunruhe*) and daytime activity throughout the course of a seven-week period. We compared these parameters across three groups of birds: (i) castrates implanted with Fadrozole (aromatase inhibitor) and Flutamide (androgen receptor blocker), (ii) castrates with blank implants, and (iii) sham operated birds. All three groups completed molt, fattened and developed migratory behavior. They only differed in plasma T levels (Fad/Flut birds being lower than the other two groups) but this difference was present even before the implants were introduced. Interestingly, once the implants were removed, the Fad/Flut group significantly increased migratory restlessness over the other two groups, which also showed activity but to a lesser extent. Our results suggest that (a) gonadal T is not necessary for the development of fall migration; (b) the reduction or clearance of sources of T may be required to allow migratory restlessness to develop fully. Taken together our results indicate that migratory restlessness seems to be controlled by different pathways than either premigratory fattening or muscle hypertrophy during the fall stage.

P3.28 NEUMEYER, C.H.*; GILDERSLEEVE, S.M.; COVI, J.A.; Univ. of Wisconsin-Stevens Point, Univ. of North Carolina at Wilmington; Univ. of Wisconsin-Stevens Point; *covij@uncw.edu*

Identifying Abnormal Morphologies Associated with Chemical Challenges in the Brine Shrimp, Artemia franciscana

Artemia franciscana is a commercially harvested model organism with a broad distribution and long history of use for biochemical, molecular, developmental and ultrastructural research. Early development in *A. franciscana* is classically divided into four stages: encysted embryo, emergence 1, emergence 2 and nauplius larva. These stages are separated by successive cuticular shedding, and are difficult to apply when aberrations in emergence are observed. Such developmental abnormalities have been documented in the presence of decreased levels of sodium bicarbonate or increased levels of heavy metals or toxins. Importantly, abnormal embryos resulting from divergent chemical challenges share similar gross morphological characteristics. Shared aberrant morphology may originate from a common problem. This appears to be an inability for the embryo to emerge from the first or second embryonic cuticle; embryos demonstrate structural characteristics in line with continued development in the confined space of the unshed embryonic cuticle(s). A modified nomenclature was developed to account for these shared aberrant morphologies. By providing a common set of characteristics, this more detailed description of morphology facilitated testing of the hypothesis that divergent chemical treatments result in common morphology by making it difficult to emerge from the embryonic cuticle. Embryos were dechorionated (viable embryos stripped of the proteinaceous chorion) and placed in 20, 25, 30, or 35ppt sterile artificial seawater for 72 h. Preliminary data demonstrate that conditions promoting aberrant morphology decrease hatch rates to a greater extent at higher salinities.

18.3 NEUTENS, C*; ADRIAENS, D; CHRISTIAENS, J; VAN LOO, D; DE KEGEL, B; BOISTEL, R; VAN HOOREBEKE, L; Ghent University, Belgium, Université de Poitiers, France; *c.neutens@ugent.be*

Evolutionary morphology of the prehensile tail in syngnathid fishes: from pipefish to seahorse

Seahorses and pipehorses both possess a prehensile tail, a unique character among teleost fishes, allowing them to grasp and hold onto substrates, like sea grasses. Recent phylogenetic studies suggest that the prehensile tail in syngnathid fishes evolved more than once and also suggest the existence of intermediate forms in the lineage giving rise to the seahorses. The caudal system of the seahorse is characterized by parallel myoseptal sheet spanning multiple - up to eight - vertebrae (compared to a conical organization in pipefishes), the presence of medial ventral muscles (absent in pipefishes) and by the reduction of the caudal part of the dermal plates covering the body (compared to solid bony armor in pipefishes). How this system could evolve is still unknown. In this study, we compared the tail morphology of seahorses and pipefishes with (1) the musculoskeletal system of two species belonging to the lineage giving rise to the seahorses, *i.e.* the bastard seahorse (*Acentronura gracilissima*) and the ribboned pipehorse (*Haliichthys taeniophorus*), expecting to find an intermediate morphology with characteristics of both seahorses and pipefishes and (2) the tail morphology of three pipehorse species that are nested within the pipefish lineages, expecting to find different convergent strategies to obtain a prehensile tail. To test these hypotheses, µCT-scanning and histological sectioning were combined with 3D-reconstructions.

41.2 NEVELN, ID*; BALE, R; BHALLA, APS; CURET, OM; LAUDER, GV; PATANKAR, NA; MACIVER, MA; Northwestern University, Brown University, Harvard University; *ineveln2@gmail.com*

Knifefish surge like eels while heaving like trout

Knifefish generate thrust with their elongated ventral anal fin. This ribbon fin has over 100 bony rays, which oscillate laterally around the fulcrum at the base of the fin. When viewing a transverse section of the fin, the oscillatory kinematics of one ray resemble the flapping motions of the caudal fin of a trout. However, the rays oscillate with certain relative phases to one another, creating a traveling wave along the longitudinal axis of the fin similar to the undulatory body motions of a swimming eel. Using a robotic ribbon fin with 32 oscillating rays connected with a fabric fin, we investigate how the flow structure generated by the ribbon fin compares with flow structures generated by eel-like and trout-like swimming. We use particle imaging velocimetry to visualize orthogonal planes transecting the wake of the fin. A propulsive jet emanates at an angle ventral to the ribbon fin, with the strongest part of the jet occurring just posterior of the fin. A horizontal slice through the jet shows a reverse Von Kármán vortex street, the same vortex pattern that is shed off of the oscillating caudal fin of a trout. 3D simulation of the fin-fluid interaction confirms that this vortex pattern originates from trout-like flow structures which are shed off of the fin ventrally along the heave axis. The eel-like traveling wave of the fin adds momentum to the fluid longitudinally along the surge axis, reorienting the ventrally shed trout-like structures along the angled axis of the jet. This reorientation could be an accidental side effect with negative consequences for thrust, or it could actually accentuate the thrust. Regardless, the resulting flow structure combines features evident in the wake of both the trout and the eel.

P2.92 NEWEL, M.S.*; BOURNE, G.B.; Univ. of Calgary, AB, Canada; *bourne@ucalgary.ca*

The 'assassin' snail, Clea (Anentome) helena (Gastropoda: Buccinidae), as a model for developmental and environmental physiology

Clea helena is an unusual buccinid gastropod, as it has successfully invaded freshwater lakes and streams throughout Southeast Asia and Indonesia. The ability to eliminate other undesirable snails (hence 'assassin') and scavenge carrion have made these snails popular among aquarium hobbyists, but their treatment in the scientific literature continues to be negligible. Thus, we combine observations of the behavior of captive snails, with descriptions of their morphology, reproduction and development. Usually, *C. helena* is found buried in the aragonite sand, which we use as our aquarium substrate. Once we introduce food the snails immediately emerge *en masse* and begin foraging, which suggests that they possess a keen olfactory sense. Our snails reach a maximum shell length of 15-20 mm and although their shells are thinner than those of similar marine species; they are quite robust compared to other freshwater snails. Otherwise, the morphology of 'assassin' snails is consistent with features typically ascribed to the Buccinidae. We observed that *C. helena* deposits isolated vasiform egg capsules, containing a single egg of 400-570 µm diameter. These capsules, which appear white to the naked eye but are nearly transparent when observed under the microscope, are 1-1.5 mm in length and height with convex sides marginally wider than the diameter of the enclosed egg. The encapsulated embryo undergoes complete non-feeding, benthic development and hatches as a crawl-away juvenile. Finally, we suggest that the 'assassin' snail should become a valuable model, providing a window into the features and mechanisms that have allowed certain caenogastropod molluscs to colonize and adapt to freshwater environments.

60.3 NEWTON, C*; GUIDONE, M; THORNBER, CS; Northeastern University, Sacred Heart University, University of Rhode Island; *newton.c@husky.neu.edu*

Impacts of invasive Gracilaria vermiculophylla on the reproductive ecology of native benthic invertebrates

The recent invasions of the red alga, *Gracilaria vermiculophylla*, to the Atlantic and Eastern Pacific Oceans have the potential to significantly alter intertidal soft sediment communities. In particular, *G. vermiculophylla* increases habitat complexity and provides a novel hard substrate in an otherwise two dimensional habitat. Following our observations that the native omnivorous mud snail *Ilyanassa obsoleta* utilizes *G. vermiculophylla* for egg capsule deposition, our field surveys demonstrated that the *in situ* abundance of egg capsules on *G. vermiculophylla* matched abundances on a native red alga *Ceramium virgatum* and were at least 11-50 times greater than on all other co-occuring macrophytes. Additionally, through mesocosm experiments, we showed that *I. obsoleta* preferentially deposits eggs on the invasive *G. vermiculophylla* over native substrates. However, despite the thick layer of egg capsules found on *G. vermiculophylla*, no detrimental effects were seen on thalli growth. In contrast, growth of the native red alga, *C. virgatum* was significantly reduced when egg capsules were present, suggesting *G. vermiculophylla* can out-compete native macrophytes in areas of *I. obsoleta* abundance, while facilitating reproduction of the native mud snail. This novel interaction has the potential to significantly alter biological interactions in soft sediment communities through a variety of different mechanisms, including alteration of trophic cascades via the increase in mud snail abundance. Furthermore, facilitation of the reproductive success of *I. obsoleta* may lead to increases in the occurance of cercarial dermatitis (swimmers itch), as *I. obsoleta* is a known intermediate host organism.

98.2 NEWTON, K*; WRAITH, J; DICKSON, K; California State University Fullerton, Southwest Fisheries Science Center; *knewton5@fau.edu*

Visceral endothermy results in elevated digestive enzyme activities in the shortfin mako shark, Isurus oxyrinchus

Lamnid sharks, including the shortfin mako (*Isurus oxyrinchus*), are known to maintain digestive tract temperatures elevated above ambient water temperature (visceral endothermy). These sharks have evolved a vascular counter-current heat exchanger, which conserves metabolic heat produced by digestion and assimilation. We tested the hypothesis that visceral endothermy results in higher digestive enzyme activities in lamnid sharks, by comparing the shortfin mako shark (N=16) with two sharks that cannot elevate visceral temperatures, the thresher, *Alopias vulpinus* (N=6), and the blue, *Prionace glauca* (N=16). Sharks were collected by longline, and then stomach and pancreas samples were frozen in liquid nitrogen and stored at -80°C until enzyme assays were performed. Specific enzyme activities (units g^{-1} tissue) of gastric pepsin, pancreatic trypsin, and pancreatic lipase were measured spectrophotometrically at physiological temperatures. The mean activity of all three digestive enzymes was significantly greater in *I. oxyrinchus* at 25°C than in both *A. vulpinus* and *P. glauca* at 15°C. When compared at the same temperatures (15°C and 25°C), the mean digestive enzyme activities in *A. vulpinus* were significantly lower than in both *I. oxyrinchus* and *P. glauca*. The higher digestive enzyme activities resulting from visceral endothermy in the shortfin mako should result in greater rates of food processing, supporting the high metabolic rates in that species. Maintaining higher digestive enzyme activities may have been a selective advantage leading to the evolution of visceral endothermy in lamnid sharks.

P3.70 NGIRAKESAU, I.K.*; SATO, B.L.M.; COLLIER, A.C.; John A. Burns School of Medicine, University of Hawaii at Manoa; *ivanda.school@gmail.com*

Chlorpyrifos is an endocrine disruptor in the human placenta via effects on steroidogenic and elimination enzymes

Chlorpyrifos (CPF), a widely used organophosphate pesticide, is a chemical of concern to the Environmental Protection Agency. In this study, we hypothesized a direct target of CPF toxicity is placental function and integrity. To determine CPF effects on placental cell viability and function, the BeWo cell line was treated with a log-scale range of Chlorpyrifos 0.1pM – 100 µM, spanning levels determined in maternal blood during pregnancy and including one log below and one log above these levels. Cells were evaluated for cell death (LDH assay) and metabolic/mitochondrial viability (MTT assay). Additionally, CPF effects on essential placental endocrine function was assessed by determining secretions of the sex hormones progesterone, estradiol, estrone and estriol as well as the placental hormone βHCG. At the concentrations used, CPF did not significantly kill cells or decrease viability, except at 100 µM where cell death/viability was 50% in both assays. Despite this, even in concentrations where cell viability was not compromised, CPF inhibited sex hormone secretion. Progesterone secretion was significantly decreased, but we determined that this was caused by the solvent vehicle (DMSO) not the CPF. In contrast, for the estrogenic hormones, DMSO did not significantly affect sex steroid secretion but estrone secretion from BeWo cells was significantly increased. The mechanisms behind changes in placental steroid secretion were investigated by determining activities of steroidogenic and steroid elimination enzymes (aromatase, 3βHSD, glucuronosyltransferases and sulfotransferases). These studies suggest that CPF may have endocrine disrupting effects in placental cells through deregulation of estrogenic hormone balance. This is a potential mechanism for CPF effects on pregnancy maintenance, fetal development and parturition.

9.4 NGUYEN, H.D.*; DOO, S.S.; SOARS, N.A.; THOMSON, M; BYRNE, M; University of Sydney; *hong@anatomy.usyd.edu.au*

Tolerance of early life history stages of Australian intertidal sea stars to ocean warming and ocean acidification: sensitivity of lecithotrophic developers

Anthropogenic ocean warming and acidification is potentially detrimental to the sensitive early life stages of benthic marine invertebrates. Most studies have focused on the effects of ocean acidification as a single stressor on calcifying planktotrophic larvae with a paucity of data on species with alternate non-calcifying developmental strategies, the early juvenile stage and, on the interactive effects of warming and acidification. To address these knowledge gaps, the development of the non-calcifying lecithotrophic larvae of the sea star *Meridiastra calcar* and the lecithotrophic juvenile of the sea star *Parvulastra exigua* were investigated in the setting of predicted ocean warming (+2-4°C) and acidification (-0.4-1.0 pH units) for 2100 and beyond. For *M. calcar*, pH had a greater negative effect on embryos reaching the hatched gastrula stage than larvae. Mortality and abnormal development in larvae increased significantly even with a +2°C warming and, larval growth was impaired at +4°C. Negative effects on *P. exigua* juveniles occurred only at -1.0 units pH units where there was an increase in mortality and abnormal development. There were no interactive effects of temperature and pH across all stages monitored for either species. For *M. calcar*, warming not acidification was the dominant stressor. In contrast, juvenile *P. exigua* were resilient to projected near future ocean (ca. 2100) acidification and warming. Heat shock protein expression 70 kDa (hsp70) in the embryos and adults of *M. calcar* indicated that the developmental stages do not elevate expression of this protein in response to thermal spikes, but the adults do as a potential defensive strategy to warming in their tide pool habitat.

122.2 NGUYEN, J; HEYLAND, A*; University of Guelph, Guelph; *aheyland@uoguelph.ca*

Histamine functions and distribution in gastrulation and skeletogenesis of the sea urchin S. purpuratus

Earlier studies established a novel function of histamine signaling (HA) in metamorphic competence of the sea urchin Strongylocentrotus purpuratus. Preliminary results suggests that several neuron like cells synthesize HA also in gastrulation and pluteus formation. Here we tested the distribution and function of this important neurotransmitter in gastrulation and skeletogenesis. Our data show that HA is required for proper gastrulation in sea urchin embryos based on the inhibition of histamine receptor protein. Furthermore our data suggest that neuron like cells in the region of the developing apical ganglion produce HA post-gastrulation. When we tested a previously proposed link between HA and programmed cell death (PCD) we found that PCD is not required for gastrulation and HA does not appear to regulate this process in early embryogenesis. Our data further emphasize the importance of HA as a signaling molecule in sea urchin development and suggest that paracrine signaling may play an important role in sea urchin gastrulation in addition to transcriptional regulation.

P3.224 NIERMANN, C*; TATE, T; ROWE, A; ROWE, M; , ; , ; , ; , ; , ; , ; , ; , ; , ; Sam Houston State, Univ. Texas, Austin; *crystal.niermann@gmail.com*

Why do grasshopper mice prefer stripe-tailed scorpions over bark scorpions? Testing the "ouch" vs. "super-size me" hypotheses.

Grasshopper mice (*Onychomys* spp.) are voracious predators on arthropods, including scorpions. While several studies show that grasshopper mice readily attack and consume relatively harmless arachnids, including stripe-tailed scorpions (*Vaejovis* spp.), our results demonstrate that grasshopper mice are equally voracious in attacking and consuming bark scorpions (*Centruroides* spp.), a genus possessing extremely painful stings containing potentially lethal, vertebrate-specific neurotoxins. The mice are completely resistant to the lethal components in bark scorpion venom, but only partially resistant to the venom constituents that cause intense pain; thus, it is perhaps not surprising that grasshopper mice preferentially attack a stripe-tailed scorpion when presented simultaneously with a bark scorpion. While we assume this preference is driven by the more painful sting delivered by bark scorpions (the "ouch" hypothesis), this interpretation is confounded by the larger average body mass of stripe-tailed scorpions. In short, grasshopper mice may simply prefer a half-pound hamburger to a quarter-pounder (the "super-size me" hypothesis). To distinguish between these two competing hypotheses, we are repeating our original choice tests with a simple modification; this time, bark scorpions will have their aculeus (stinger) blocked with a small bead of epoxy, preventing stinger penetration of the mouse's integument and, thus, eliminating envenomation. The "super-size me" hypothesis would be supported over the "ouch" hypothesis if mice still prefer a stripe-tailed scorpion to a bark scorpion even when the latter can no longer inflict a painful sting.

26.1 NIITEPOLD, K*; PEREZ, A; BOGGS, CL; Stanford University; *niitepold@stanford.edu*

Food limited butterflies — Resting and flight metabolic rate, fecundity and longevity

Deciding how much to invest in survival and reproduction is fundamental for all organisms, especially when the available resource pool is limited. Resource availability can be affected by small-scale disturbances such as weather conditions or herbivory, or large-scale environmental changes such as habitat loss and fragmentation, and climate change. To understand the mechanistic basis of population dynamics in a changing world we need experimental work on resource allocation under stressful conditions. We limited adult food intake in two butterfly species with different ecologies and life-history strategies: *Colias eurytheme* and *Speyeria mormonia*. *Colias* is multivoltine and has no larval diapause; *Speyeria* is univoltine and spends the winter as unfed 1st instar larvae. Females were hand-fed twice a day. We measured the unlimited sugar-water intake of control females and gave treatment females half of that. We found that body mass decreased with age in both treatments, but females fed *ad lib* were clearly heavier than food limited females. Mass-corrected peak flight metabolic rate was not affected by food limitation. This indicates that flight capacity is conserved, which may allow dispersal to more favorable areas. Flight is also critical for most other life-history traits. Lifespan was not affected by food reduction. Fecundity was sacrificed in both species. The decrease in fecundity was stronger in *Speyeria*. This may be due to a high ratio of adult-derived carbon in *Speyeria* eggs, a likely consequence of larvae relying on solely maternal resources during the winter. Control females had higher resting metabolic rate in early life. This may reflect the energetic cost of egg production which food limited females could not bear. Food limitation results in lower fecundity and may reduce population growth rate, but the sensitivity of each species is related to its life-history strategy.

16.3 NIMITKUL, S.*; MYKLES, D.L.; CHANG, E.S.; 1Bodega Marine Laboratory, University of California, Davis, 2Department of Biology, Colorado State University; *snimitkul@ucdavis.edu*

Role of cyclic nucleotides, intracellular calcium and nitric oxide in the molt-inhibiting hormone (MIH) signaling pathway in Y-organs of the green shore crab (Carcinus maenas)

Molting is controlled by the X-organs/sinus gland (XO/SG) complex in the eyestalk and the thoracic Y-organs (YO). Molt-inhibiting hormone (MIH), which is produced in the XO/SG complex, inhibits the secretion of the molting hormones (ecdysteroids) from the YO. This in turn, prevents the animal from molting. Reduction in MIH results in the transition of the YO from the basal to activated state and the animal enters premolt. We proposed a model in which the MIH signaling pathway is organized into a cAMP/Ca^{2+}-dependent "triggering" phase and a NO/cGMP-dependent "summation" phase. In this study, we investigated the role of cAMP, cGMP, intracellular Ca^{2+}, and NO in the MIH signaling pathway in YOs from intact intermolt adult animals. cAMP analog 8-Br-cAMP (0.5 mM) and the adenylyl cyclase agonist forskolin (10 μM) did not significantly inhibit ecdysteroid secretion, while cGMP analog 8-Br-cGMP (0.5 mM) and phosphodiesterase inhibitor IBMX (0.5 mM) significantly inhibited ecdysteroid secretion. The fluorescent calcium indicator dye, Fluo-4, was used to detect calcium movement in dissociated YO cells. The results showed no large influx or efflux of calcium in YO cells incubated with SG extract. NO scavenger (cPTIO, 1 mM), NO donor (PAPA-NONOate, 0.1 mM), and NO synthase inhibitor (L-NAME, 1 mM) did not significantly affect ecdysteroid secretion. These data suggest that cGMP plays a role in the inhibitory control of ecdysteroid secretion. In contrast, the contributions of cAMP/Ca^{2+} and NO to inhibitory control may differ between basal and activated states and needs further investigation. Supported by NSF (IOS-0745224).

123.5 NOH, S*; HAHN, DA; MORGAN, TJ; Kansas State University; *suegene.noh@gmail.com*

The genetics of cold tolerance in fruit flies dissected using bulk segregant analysis of artificial selection lines

A species' ability to adapt to cold temperatures can determine species distributions and influence seasonality. *Drosophila melanogaster* falls into a reversible coma when exposed to zero to subzero temperatures. The recovery time is variable among individuals within the species, as well as populations along latitudinal clines, and also among other *Drosophila* spp. Chill coma recovery (CCR) is affected by developmental temperatures as well as previous exposures to cold. More significantly, it is possible to select flies for increased or decreased CCR, reflecting the significant genetic component underlying this trait. We used a bulk segregant analysis to dissect the genetics of this ecologically important complex trait. Previously, two replicate artificial selection lines were created from a single wild-caught population for high and low CCR. Two F2 populations were generated from each replicate and pooled Illumina sequencing libraries were prepared from the top and bottom 2.5% of each replicate phenotypic distribution. 50 bp paired-end reads from these libraries were sequenced on 4 lanes of an Illumina HiSeq 2000 instrument. Reads were aligned using a custom 2 step (stringent, then lenient) alignment procedure. Alignments were realigned around indels, bases recalibrated for platform and experiment-specific covariates, then used for variant calling and recalibration. We used a modified G-test to detect allele frequency shifts in the two replicate F2 populations. Variants exceeding a false discovery rate threshold were used to identify candidate genes that were common to the two replicates in order to identify biological processes relevant to CCR. These candidates were compared to results from a parallel association mapping experiment using the Drosophila Genetic Reference Panel.

P3.81 NOONAN, A*; SANTANA, S.E.; LYNCH ALFARO, J; ALFARO, M.E.; University of California, Los Angeles, University of Washington; *AndrewNoonan@mac.com*

Drivers of facial diversity in strepsirrhine primates

Strepsirrhine primates include a wide diversity of species such as lemurs, bushbabies, aye ayes and tarsiers, which are broadly distributed across Madagascar, continental Africa and Asia. Members of this clade exhibit a startling range of facial diversity though the factors underlying the evolution of this diversity remain poorly understood. In this study, we investigate if sociality and/or ecology can explain the relationship between the diversity in facial color complexity patterns and pigmentation of strepsirrhine primates. We collected detailed data on the facial features, life history, sociality and habitat across strepsirrhine primates, and used these data in phylogenetic comparative analyses to explore the relationship among facial diversity, social structure and ecology. The results of our study indicate that strepsirrhine species living in larger groups and strepsirrhine species living in higher degrees of sympatry with congeners have evolved more complex faces, suggesting a function of facial features in species and individual recognition. Moreover, we found some relationships between facial darkness and canopy density in some groups. Our results support the idea that facial coloration and complexity in strepsirrhine primates may have evolved through multiple selective pressures, including inter-and intraspecies recognition as well as ecological pressures.

13.9 NOREN, SR*; TRIGGS, L; OLAND, L; PASCHKE, J; KRAMER, AW; UDEVITZ, MS; JAY, CV; University of California, Santa Cruz, Point Defiance Zoo and Aquarium, Indianapolis Zoo, Six Flags Discovery Kingdom, U.S. Geological Survey, U.S. Geological Survery; *snoren@biology.ucsc.edu*

Body Condition and Caloric Demand of Female Pacific Walruses (Odobenus rosmarus divergens)

With declining sea ice availability, walruses are increasing their use of terrestrial haul-outs, which could deplete localized prey resources. Estimates of caloric demand and techniques for monitoring body condition are required for assessing the potential for population level effects on walruses. Caloric intake and body condition (length, girth, mass, and blubber thicknesses) were measured monthly over one year from non-reproductive female walruses housed at Indianapolis Zoo (n = 1; T_{air} = 18.7 ± 14ºC, T_{water} = 12.2 ± 0.1ºC), Six Flags Discovery Kingdom (n = 2; T_{air} = 19.6 ± 6 ºC, T_{water} = 13.9 ± 4.5ºC), and Point Defiance Zoo and Aquarium (n = 2; T_{air} = 13.8 ± 7ºC, T_{water} = 10 ± 2ºC). These individuals had an average (±SD) annual body mass of 683 ± 11 kg, 747 ± 14 kg, 764 ± 28 kg, 716 ± 28 kg, and 936 ± 27 kg comprised of 24 ± 2%, 26 ± 2%, 27 ± 2%, 27 ± 1%, and 30 ± 1% blubber, respectively. These body conditions were maintained with an average of 31,249 ± 4,449 kcal dy^{-1}, 25,847 ± 4,100 kcal dy^{-1}, 20,123 ± 4,247 kcal dy^{-1}, 23,062 ± 5,448 kcal dy^{-1}, and 29,403 ± 4,474 kcal dy^{-1}. Based on our published bioenergetics model, these caloric intakes represent 61%, 47%, 35%, 45%, and 48% of those required by wild non-reproductive female walruses of equivalent body size. Much of this discrepancy is likely due to differences in activity level between captive and wild animals, as our bioenergetics model assumed that animals are active 83% of the time. Nonetheless, the basic physiology measured from animals in human care provides bounds on parameters used in bioenergetic models and serves as a basis for developing criteria for assessing body condition of wild walruses.

P2.129 NOWINOWSKI, I *; BALABAN, J; WILGA, C; University of Rhode Island ; *inowinowski@my.uri.edu*

Shape Changes in the Hyoid Arch of Four Shark Species

Hyoid depression aids in oropharyngeal expansion and is crucial for suction generation in sharks. The hyoid elements that guide this movement are the paired ceratohyals (CH) and the single, medial, basihyal (BH). These elements are located medial to the lower jaws and when depressed expand the oral cavity. As the coracohyoideus muscle depresses the BH, the CH experiences substantial bending forces. Because of their critical role in the feeding mechanism, the various shapes of the BH and CH are likely adapted for different feeding behaviors. Suction feeders are expected to have a robust hyoid to withstand intraoral forces generated during suction. Whereas bite feeders are expected to have relatively more gracile elements, since rapid hyoid depression is more critical to prey capture. Shape differences in BH and CH elements were studied in bamboo (suction feeders), sandbar (bite feeders), smoothhound (bite), and dogfish (intermediate) sharks using 2D geometric morphometrics. Four landmarks (BH, CH) and 54 or 58 (BH or CH respectively) semilandmarks were digitized on images of the elements. Principal component analysis, partial least squares, and canonical variate analysis were applied to distinguish the shapes of elements and to determine changes among different species. Principal component and partial least squares scores of bamboo elements varied significantly relative to sandbar, smoothhound, and dogfish element scores. The CH in bite feeders was relatively narrower and longer than in suction feeders. The BH of bite feeders had more surface area than suction feeders. Dogfish had characteristics of bite and suction feeders. Consistent with the respective feeding habits, the short and wide hyoid elements of bite feeders were more robust than the narrow and long hyoid elements of suction feeders.

P1.174 NUHAR, A.*; BOISETTE, B.; CARROLL, M.A.; CATAPANE, E.J.; Medgar Evers College; *catapane@mec.cuny.edu*

Manganese Accumulations in Gill Mitochondria of Crassostrea viginica?

Manganese (Mn) is a neurotoxin causing Manganism in people chronically exposed to elevated levels in their environment. Mn targets dopamine (DA) neurons in basal ganglia. Oxidative stress has been implicated as a factor of Mn toxicity and DA dysfunction. Mitochondria play a role as cause and target of oxidative stress damage. The mechanisms of damage is attributed to Mn's capacity to produce toxic levels of free radicals and induce mitochondrial dysfunction. Others report Mn accumulates in mitochondria and represent the 1□ pool of Mn in cells. Controversy exists to the extent of Mn accumulation in mitochondria. Others report Mn accumulates within nuclei and cytoplasm, but not mitochondria. Our lab is using the oyster, *Crassostrea virginica*, as a test animal to study Mn neurotoxicty. We found Mn disrupts the DA system as well as mitochondrial respiration. To study if Mn accumulates within mitochondrial of gill cells of *C. virginica* we used differential centrifugation and atomic absorption spectrometry. Gills were homogenized and centrifuged to isolate nuclear, mitochondrial and post-mitochondrial fractions. Each fraction was analyzed for Mn. To determine if isolated mitochondria accumulate Mn we prepared treated mitochondrial suspensions with up to 300 mM Mn. Results show a dose dependent accumulation of Mn in mitochondria of up to 5000%. Two day treatments of animals with 500 and 1000 µM Mn increased Mn (µg/gdw) in gill from a baseline of 5.8 to 41.6 and 133.8, respectively, and centrifugation revealed Mn accumulations were primarily in nuclear and mitochondrial fractions. The study shows mitochondria accumulate Mn. *In vivo* treatments reveal accumulations with both the nuclear and mitochondrial fractions.

138.3 NYAKATURA, J.A.*; CURTH, S.; FISCHER, M.S.; Friedrich-Schiller-University, Jena, Germany; *john.nyakatura@uni-jena.de*

Locomotion with constant ventral contact in skinks: a three-dimensional kinematic and dynamic analysis

Fossilized tracks attributed to members of the Capthorinidae, a group of fossil early amniotes, imply a constant ventral contact between the animal and the substrate during locomotion. During this 'belly-walk,' the trunk is not or only partially lifted off the ground. In extant saurians belly-walking is found in many skinks (Lepidosaurier, Scincidae), rendering them as potential extant models for capthorinidid locomotion. We investigated the biomechanics of locomotion in blue-tongued skinks (*Tiliqua scincoides*) in order to better understand how propulsion is generated during locomotion in species with constant ventral contact with the substrate. We combined markerless X-ray of moving morphology (XROMM) with the measurement of single limb substrate reaction forces. Biplanar X-ray recordings of two animals during locomotion on a treadmill were taken in order to three-dimensionally analyze locomotor biomechanics over the complete sustainable speed range of the skinks. Subsequently, the skinks were motivated to transverse a trackway instrumented with two 8 x 9 cm custom built force plates. Bone morphology was reconstructed from CT scans of the same individuals. 3D kinematic profiles and single limb substrate reaction force traces are presented. 3D kinematics demonstrate limbs to function according to the double crank system previously described for salamanders. The vertical component of the substrate reaction force is significant enough to substantially reduce frictional forces between the smooth-scaled belly and the substrate. The substrate reaction force vector is used to assess moment arms acting at the elbow, shoulder, knee, and hip joints over time. An additional analysis of the tracks produced by the skinks implies comparable locomotor mechanics in skinks and the fossil Capthorinidae.

P2.89 O'BRIEN, DM*; SMITH, FW; JOCKUSCH, EL; University of Connecticut; *devin.m.obrien@gmail.com*

An Analysis of the Notch Regulatory Gene fringe in Metamorphic Appendage Patterning of the Red Four Beetle Tribolium castaneum

Modifications of jointed appendages, a defining characteristic of arthropods, have been a major source of diversity and disparity in contemporary insects. In both *Drosophila* and *Tribolium*, the Notch pathway has been identified as the primary developmental mechanism responsible for joint formation. *Notch*, *Serrate* and *Delta*, the primary components of this pathway, are conserved in holometabolous insects. However, the main regulatory component of this pathway, *fringe* (*fng*), has yet to be investigated beyond *Drosophila*. Here, we use RNA interference in *Tribolium castaneum* to analyze the role of *fng* in joint formation. In *Drosophila*, *fng* functions as a suppressor of the Notch pathway, regulating the concentration of the Notch ligands Serrate and Delta. By suppressing the Notch pathway in specific locations, *fng* promotes both proper joint identity and proper location of joint formation. In *Drosophila*, downregulation of *fng* results in ectopic joints, as well as reduction and loss of joints. Congruent with the *Drosophila* phenotypes, preliminary results from *Tribolium* show that knockdown of *fng* can lead to formation of extra joints in the antenna.

106.3 O'BRIEN, CS*; O'QUINN, KE; SCHLUTE, JE; CARLETON, KL; University of Maryland; *csob2@umd.edu*

The genomic basis of variation in cichlid spectral sensitivity

Studies of color vision evolution have primarily focused on coding differences among photoreceptor opsins, though variation in expression levels of opsin can also alter spectral sensitivity. The extraordinarily rapid diversification of the Malawi cichlid fishes has produced significant interspecific differences in the expression of six paralogous opsins, resulting in a wide range of spectral sensitivities. To determine the genomic basis of these differences, we conducted high-resolution genotyping in a hybrid cross that was produced from two Malawi cichlid species. Eleven QTL were identified, at least eight of which are of trans-effect. Several QTL contain candidate genes that have primary roles in vertebrate retinal development and maintenance, demonstrating the value of the cichlid fish model for the study of vertebrate color vision.

69.4 O'BRIEN, K.M.; Univ. of Alaska Fairbanks; *kmobrien@alaska.edu*
Multiplying mitochondria in the cold: how do fish do it and why?
High mitochondrial densities are characteristic of oxidative muscles in cold-bodied fishes. There is a latitudinal trend in mitochondrial abundance, with Antarctic fishes displaying the highest densities. Antarctic icefishes, lacking hemoglobin, lie at the extreme end of this continuum, with mitochondria displacing as much as 52% of the cell volume in some species. High mitochondrial densities enhance ATP production and minimize diffusion distances for oxygen and metabolites in the cold. Previous studies have shown that mitochondrial-rich muscles may be necessary for cold-adapted fishes because mitochondrial function has not completely compensated for the cold. We measured rates of respiration and proton leak in mitochondria from both red- and white-blooded Antarctic fishes and found that state III respiration rates are similar to some temperate fish, and most surprising, proton leak is markedly lower. These results suggest that high mitochondrial densities in muscles of Antarctic fishes may be more important for minimizing diffusion constraints than compensating for inefficiencies. How high mitochondrial densities arose during the evolution of Antarctic fishes, and in icefishes in particular, is largely unknown. Our studies suggest membrane proliferation played a role in icefishes, in a pathway distinct from mammalian mitochondrial biogenesis.

P2.164 O'CONNELL, K.J.*; WALKER, R.A.; DEAROLF, J.L.; Hendrix College, Conway, AR; *oconnellkj@hendrix.edu*
The effect of prenatal steroids on the fast-twitch fibers of the fetal guinea pig rectus abdominis
Glucocorticoids are often used to combat premature infant mortality. Although studies have shown an improvement in lung function in premature infants after their mothers were exposed to glucocorticoids during gestation, the effects of these steroids on breathing muscles are not widely known. A study of the rectus thoracis, an accessory inspiratory muscle, demonstrated an increase in the percentage of fast-twitch fibers, as well as their diameters, in response to prenatal steroid exposure. Therefore, we hypothesize that betamethasone injections will result in an increase in the percentage of IIA fast-twitch fibers and larger IIA and IIX fast-twitch fibers in the rectus abdominis (expiratory muscle) of treated fetuses. Betamethasone (0.5 mg/kg) or sterile water injections were given to pregnant guinea pigs twice a week at 65%, 75%, and 85% gestation. Rectus abdominis samples were collected from fetal guinea pigs and prepared for histo- and immunocytochemistry. Sections of the control and steroid-treated muscles were stained for their reaction to antibodies against slow (A4.951) or IIA fast myosin (2F7). Images of the stained sections were taken, and the 2F7 staining densities of the fast-twitch fibers, as well as their diameters, were measured with Scion Image. Staining densities were converted to Z-scores, which were used to group fibers into those darkly (IIA) and lightly staining for 2F7 (IIX). A supported hypothesis would suggest that the rectus abdominis of premature babies exposed to betamethasone would perform more efficiently in ventilation than the muscles of babies not exposed to the steroid. More IIA fast-twitch fibers and larger IIX and IIA fibers would allow the muscles of treated babies to produce greater and more sustained forces when meeting ventilatory demands.

P2.8 O'CONNELL, C.*; VILLAR-LEEMAN, C.; FRICKE, E.; GANNON, D.; GANNON, J.; MAUCK, R.A.; Kenyon College, Bowdoin College; *mauckr@kenyon.edu*
The heat is on: air temperature, burrow temperature, and reproductive success in a long-lived seabird
One effect of global climate change has been a steady increase in summer temperatures at seabird breeding colonies in the North Atlantic. Leach's storm-petrel (*Oceanodroma leucorhoa*) is a long-lived pelagic seabird that produces a single offspring per breeding season. Over a 44-day incubation period, mates alternate incubation bouts, fasting for up to 7 days in an underground nesting burrow. Developing chicks spend 65-70 days in the burrow before fledging. We investigated the effect of variation in air temperature on burrow microclimate and its effect on reproductive success and adult nutritional condition in a breeding colony of Leach's storm-petrels at Kent Island, in the Bay of Fundy, Canada. Successful burrows tend to be drier than unsuccessful burrows with longer entrance tunnels and larger nest chambers. We used miniature temperature loggers to assess how burrow temperature varied between successful and unsuccessful burrows and whether differences in burrow microclimate remain consistent across the range of air temperatures encountered during the incubation period. Additionally, we investigated the influence of burrow temperature on the energetic costs to incubating adults using ptilochronology; growth rate of feathers served as an index of the incubating adult's nutritional status during that period. Finally, we gauged the effect of burrow temperature on chick growth during the two-month chick-rearing period. By assessing the effect of variation in ambient air temperature on burrow microclimate, reproductive success, and feather growth we can better understand how burrow-nesting seabirds may respond to climate change.

100.3 O'DONNELL, M.J.*; GEORGE, M.; CARRINGTON, E.; Univ. of Washington, Friday Harbor Laboratories; *mooseo@moosecraft.org*
Ocean acidification weakens attachment of Mytilid mussel byssal threads
Organism interactions with the physical environment are mediated by biological structures such as shells, which isolate organisms from the external environment, and adhesives, which keep organisms located in suitable habitat. Like many chemical processes, creating these structures takes place in the context of the local seawater chemistry. Many investigations have explored the effects of altered carbonate chemistry on the rate at which structures are produced, but little is known about the relative quality of these materials for performing their assigned tasks. Here we report on the properties of biological materials created by *Mytilus trossulus* exposed to a range of pCO_2 conditions (from ~400 to 1600 µatm) to elucidate the shape of the response curve. Byssal threads attach Mytilid mussels to the shore. Most regions of these threads showed no variability in response to altered pH with the exception of the adhesive that secures the thread to the substratum which showed a significant decline in tenacity. Additional metrics, including gonad index, shell strength, and overall condition also showed no effect of CO_2. However, byssal thread weakening likely compromises the ability of the byssus structure to hold individuals to the substratum.

S10-1.1 OAKLEY, Todd H; UCSB; *oakley@lifesci.ucsb.edu*

Evolutionary origins of an animal light interaction tool-kit

Eye evolution is touted as a prime example of deep homology, whereby novel structures arise – sometimes convergently - by modification of homologous regulatory circuits that draw upon a common genetic tool kit. What is this genetic tool kit, how common is it, and when and how did its components originate? Here I discuss a light interaction toolkit (LIT) of genes and examine its evolution. LIT genes variously function in sensing, blocking, bending, and reflecting light or in developmental processes to specify cells and organs that interact with light. First, I highlight that LIT genes are often used in cells outside of eyes, for example, in dispersed photoreceptors and in light-producing organs. While some genes like opsin have very ancient origins and conserved light interaction function, several LIT genes have recent origins and/or newly function in light interaction. Light interaction genes indicate that while deep homology is a galvanizing concept of the genomic era that is valid in some instances, we must take care not to over-generalize and miss the rich variation of the evolutionary process.

P1.13 ODIERNO, J. A.*; JACOBS, M. W.; McDaniel College; *jao003@mcdaniel.edu*

Decoration preference in the Pacific crab Oregonia gracilis

Decorator crabs (Brachyura: Majidae) attach resources from their environment to themselves throughout their lifespan. It is thought that this is a form of camouflage to protect the crab from predation. Some species of decorator crabs prefer to decorate with certain materials, while others are generalists and use whichever material is most opportune. Decorating is sexually dimorphic in *Oregonia gracilis*; adult males decorate sporadically while females and juvenile males decorate fully and consistently. To determine if the Pacific crab *O. gracilis* displays a preference in decorating material, crabs were collected, stripped of their existing decorations, and given either red algae, branching bryozoans, yellow *Mycale* sponges, or a mixture of the three. Male and female, and juvenile and adult *O. gracilis* preferred to decorate with the yellow *Mycale* sponges over the red algae and branching bryozoans. Although the reason for this preference is still unknown, we hypothesize that the sponge may be more easily manipulated by the crab, allowing for faster decorating time and in return a decrease in vulnerability time. An alternative hypothesis is that the sponge offers better chemical and physical defenses than the algae or the bryozoans. Unexpectedly, adult crabs decorated more with sponges when they were offered a mixture of materials, than when they were offered only sponges. The adult crabs may be inspired to decorate more when they are in a mixed environment.

P1.176 OGUNNOIKI, J.*; JACKSON, K.; CATAPANE, E.J.; CARROLL, M.A.; Medgar Evers College; *catapane@mec.cuny.edu*

Neurotoxic Effects of Manganese on GABAergic Innervation in the Bivalve Mollusc Crassostrea virginica

High levels of airborne manganese (Mn) cause Manganism, a neurotoxsic, Parkinsons-like disease in humans by interfering with dopaminergic neurotransmission in brain. Recent studies are showing GABAergic neurons also are damaged by Mn. *C. virginica* contains a dopaminergic and serotonergic innvervation of its gill. It is a simple system to study Mn toxicity. Previously we showed Mn disrupts dopaminergic innervation. We also showed the cerebral ganglia (CG) of *C. virginica* contains GABA and within the CG GABA inhibits serotonergic innervation of gill lateral cell cilia. Here we studied if ganglia and peripheral tissues contain GABA receptors, and if Mn has effects on GABA neurons within CG of C. virginica. We used 1° antibodies (GABAA Ra1-6) and 2° antibodies (IgG-FITC) to detect GABA receptors with paraformaldehye fixed, paraffin embedded tissues using a Zeiss epilume fluorescence microscope and ProgRes C3 Peltier cooled camera. We found fluorescence due to GABA receptors in CG , visceral ganglia, palps and digestive tract. We also examined effects of Mn treatments on GABAergic inhibition of serotonin (HT) neurons in CG. Beating of lateral cilia in gill cells were measured by stroboscopic microscopy. Applying HT to CG caused a dose-dependent increase in cilia beating. Applying GABA prior to HT prevented the increase. Acute applications of Mn (50 and 500 µM) prior to GABA prevented GABA from inhibiting HT. The study is showing GABA receptors are present in ganglia and peripheral tissues in *C. virginica*, and acute Mn treatments damage GABA neurons. *C. virginica* preparations are good, simple test preparation to study the GABAergic system and the mechanism underlying the neurotoxic effects of Mn.

P1.180 OJO, C.*; ROGERS, K.; ADAMS, T.; CATAPANE, E.J.; CARROLL, M.A.; Medgar Evers College; *catapane@mec.cuny.edu*

Chelating Agents Reverse Neurotoxic Effects of Manganese on Dopaminergic Innervation of Gill of the Bivalve Mollusc Crassostrea virginica

Lateral cilia of gill of *Crassostrea virginica* are controlled by a serotonergic-dopaminergic innervation. Dopamine is an inhibitory transmitter at gill causing cilio-inhibition. Manganese (Mn)is a neurotoxin causing Manganism in people exposed to high levels in the atmosphere. Clinical interventions for Manganism have not been successful. Recently, p-aminosalicylic acid (PAS) was reported to provide effective treatment of severe Manganism in humans. PAS is an anti-inflammatory drug which has been used to treat tuberculosis. It also has chelating properties. Previously, we showed treatments of *C. virginica* with Mn disrupts dopaminergic innervation of gill. Pre- or co-treatments with PAS or calcium disodium EDTA prevented the neurotoxic effects of Mn. We hypothesized chelating agents would be effective in reversing neurotoxic effects of Mn when applied to gills after Mn. We used gills of *C. virginica* to measure lateral cilia beating rates of preparations treated first with Mn followed by treatments with either PAS, calcium disodium EDTA or DMSA (meso-2,3-dimercaptosuccinic acid). Beating of cilia were measured by stroboscopic microscopy. Dose responses of PAS, calcium disodium EDTA and DMSA (10^{-11} - 10^{-4} M) against beating were conducted after 100 µM of Mn was added to gill. All 3 drugs reversed the neurotoxic effects of Mn in a dose-dependent manner. DMSA was the most potent. The study demonstrates these chelators are effective in reversing acute neurtoxicity of manganese. This information should be of interest to those designing therapeutic drug treatments for Manganism.

P3.114 OLAIVAR, A F*; BROWN, M D; BERG, O; MULLER, U K; California State University, Fresno; *umuller@csufresno.edu*

The scaling of suction feeding mechanics as predicted by inviscid flow models

Suction feeding is a common method of prey capture in aquatic organisms: an imposed pressure gradient causes water (and prey) to flow from the surroundings to an area of negative pressure within the mouth. Suction-feeding organisms described in the literature range in size from ~1 m (baleen whale *Janjucetus hunderi*) to ~1 mm (bladderwort *Utricularia*), with corresponding Reynolds numbers in the range 2000-200. Nevertheless, the peak fluid speeds reported for feeding strikes are strikingly similar: 1-2 m/s at the mouth aperture. In the context of our investigation of bladderwort, we consider the mechanical basis of this observation. In all cases that have been documented in sufficient detail, the suction-feeding flows are found to be effectively inviscid (inertial considerations dominating viscosity) and incompressible. The corresponding Eulerian equations of motion predict that the limiting flow speed will depend on the imposed pressure drop only, not on aperture dimensions. This dependence is furthermore sublinear (pressure$^{1/2}$), so the range of biologically achievable peak pressures translates to a narrow range of peak speeds, as observed. In cases of unsteady flow, the Eulerian analysis makes additional predictions: fluid acceleration will depend only on pressure drop and channel length, and the time required to reach steady state will be vary inversely with pressure drop. We test these predictions using published data and our own studies of bladderwort.

6.6 OLBERDING, JP*; HIGHAM, TE; Univ. of California, Riverside; *jolbe001@ucr.edu*

Three-dimensional joint mechanics and kinematics of jumping lizards

Hindlimb kinematics are often examined and related to locomotor performance in lizards, but establishing a causal link between individual joint movements and whole-animal performance requires an understanding of joint mechanics. This study examines the mechanical contributions of each hindlimb joint movement and the patterns of joint mechanics that result from increased demand on the hindlimb (increased whole-animal performance) during jumping, an ecologically important form of locomotion for many species of lizards. We placed collared lizards, *Crotaphytus collaris*, on a custom 6-axis force plate and encouraged them to jump onto a vertical wall near the force plate. We recorded simultaneous force data and 3D high-speed video, then used inverse dynamic modeling to calculate kinematics, moments, powers, and work for the ankle, knee, and hip of one hindlimb, around each of the three axes of rotation. The correct positioning of the limbs prior to jumping was necessary to effectively generate power at the joints. Prior to jumping, the lizards took a small step forward bringing the hindlimbs into a crouched position with the feet oriented forward along the long axis of the body. A more laterally oriented foot at the start of the jump reduced the angular excursion of ankle extension resulting in a lower peak power and less work from that movement. Ankle and knee extension and femur retraction did the majority of positive work during the jump and more work was done by knee extension and femur retraction in jumps with a higher peak COM velocity. Increasing the angle of the body relative to horizontal at takeoff decreased the work done by knee extension and the peak power output at that joint. These results suggest that the individual joints may be modulated differently when whole-animal performance increases.

99.4 OLIVER, J. C.; TONG, X.; GALL, L.; PIEL, W. H.; MONTEIRO, A.*; Yale University; *antonia.monteiro@yale.edu*

A single origin for nymphalid butterfly eyespots followed by widespread loss of associated gene expression

Understanding how novel complex traits originate involves investigating the time of origin of the trait, as well as the origin of its underlying gene regulatory network in a broad comparative phylogenetic framework. The eyespot of nymphalid butterflies has served as an example of a novel complex trait, as multiple genes are expressed during eyespot development. Yet the origins of eyespots remain unknown. Using a dataset of over 400 images of butterflies with a known phylogeny, and gene expression data for five eyespot-associated genes from over twenty species, we tested origin hypotheses for both eyespots and eyespot-associated genes. We show that eyespots evolved once within the family Nymphalidae, approximately 90 million years ago, concurrent with expression of at least three genes associated with early eyespot development. We also show multiple losses of expression of most genes from this early three-gene cluster, without corresponding losses of eyespots. We propose that complex traits, such as eyespots, may have originated via co-option of a large pre-existing complex gene regulatory network that was subsequently streamlined of genes not required to fulfill its novel developmental function.

S7-1.7 OLIVERI, P*; PETRONE , L; LERNER, A; MATTIELLO, T; University College London; *p.oliveri@ucl.ac.uk*

Evolution of animal clock: an echinoderm prospective

Almost all living organisms show circadian rhythmicity. Endogenous time-keeping mechanisms that regulate daily physiological and behavioral processes are genetically encoded and show a conserved network structure. Comparative studies highlighted a transcriptional-translational oscillator (TTO) based on interlocking negative feedback loops as key circadian clock network architecture. Molecular and cellular components of circadian clocks have been extensively characterized in land animals such as mammals and insects. In contrast, less is known about clocks in marine organisms despite the fact that the marine environment is characterized by an interplay of multiple periodicities and complex life cycles. To better understand metazoan circadian clock evolution, we are undertaking a molecular analysis of clock genes and their expression in the sea urchin, *S. purpuratus*. A genome survey identified in sea urchin both protostome and deuterostome components indicating a more complex origin of the metazoan clock tool-kit. Our comparative genomic analysis revealed a high plasticity of negative players of the TTO during animal evolution. Temporal gene expression analysis during sea urchin development showed that almost all of the clock genes are maternally expressed with decay around blastula stage, consistently with a potential role in gametogenesis. Many of them are also expressed later in development and at free-living larval stages. However, we have found no evidence of oscillatory genes expression during embryonic development. On the contrary, fully differentiated larvae, once exposed to different light regimes, show circadian oscillations of few clock genes. Their cellular localization, using whole mount in situ hybridization, identifies a group of neurosensory cells, which might function as a main light sensory organ. In addition, expression of “clock” genes has been detected in adult tissues.

12.2 OLSEN, AM*; WESTNEAT, MW; University of Chicago, IL, Field Museum of Natural History, Chicago, IL; *aolsen@uchicago.edu*

Dabbling, grazing and diving: Skull shape is related to beak foraging behaviors in the avian order Anseriformes

Anseriforms, the avian order that includes ducks, geese, swans and mergansers have a diversity of beak shapes and foraging behaviors, including grazing, diving and dabbling. This morphological diversity is not limited to the beak, however. Posterior to the upper bill, lie kinetic (mobile) cranial bones that enable rotation of the upper bill relative to the braincase (cranial kinesis) and these bones also have diverse morphologies. Given that these bones transmit force to the upper bill and given the diverse functional requirements of beaks among anseriforms we tested whether the morphological diversity of these bones is explained by the efficiency with which different morphologies transmit force or motion to the upper bill. We collected 3D morphometric data from more than 80 specimens representing more than 30 genera in Anseriformes. Using a custom static force model, we predicted the torque at the upper bill given an input torque to the quadrate. Within Anseriformes, upper bill-quadrate torque transmission ranged from 0.93 to 1.87, where lower values correspond to displacement amplification and higher values correspond to force amplification. Additionally, grouped by foraging behavior, dabblers have lower torque transmission values than grazers and deep divers. Thus, we find support for our hypothesis: anseriforms with foraging behaviors expected to require more force (grazers and deep divers) have linkage morphologies that more efficiently transmit force through the linkage bones to the upper bill relative to anseriforms with beak behaviors expected to require continuous motion and lower force (dabblers).

P2.181 OLSON, TB*; WADDELL, DS; University of North Florida; *d.s.waddell@unf.edu*

Transcriptional Regulation of Muscle Atrophy F-box (MAFbx) by Muscle RING Finger 1 (MuRF1)

Skeletal muscle wasting is a consequence of numerous physiological conditions, including denervation, corticosteroid treatment, immobilization, and aging. Muscle RING Finger 1 (MuRF1) is an E3 ubiquitin ligase that is induced under nearly all atrophy conditions and is believed to play a key role in muscle wasting or atrophy. However, the preliminary data described in this study provides evidence that MuRF1 may act as a transcriptional regulator of a second E3 ubiquitin ligase called MAFbx. The MAFbx gene, also induced under virtually all atrophy conditions, is believed to play an equally important role in modulating skeletal muscle wasting. To characterize the transcriptional regulation of MAFbx, a reporter construct containing a fragment of the proximal promoter region of the MAFbx gene was constructed, co-transfected into C2C12 mouse muscle cells with or without a MuRF1 expression plasmid and reporter gene activity was then measured over four days. The MAFbx reporter showed a significant increase in activity in cells ectopically expressing MuRF1 compared to cells that did not overexpress MuRF1. To further characterize the function of MuRF1 in regulating MAFbx expression, two MuRF1 mutants were created in which either the carboxyl-terminal domain was deleted or the RING finger domain was inactivated. These constructs were co-transfected with the MAFbx reporter construct into C2C12 cells, and reporter gene activity was measured over four days. The MAFbx promoter again showed a significant increase in activation when co-transfected with MuRF1, however the activating effect on the reporter was attenuated in cells that were co-transfected with either of the MuRF1 mutant constructs. This data offers evidence of a potential new function for MuRF1 as a transcriptional modulator of atrophy-regulated genes.

P2.175 OLSON, JM*; KEARNEY, C.; RIVERA, G.; Villanova University; *john.olson@villanova.edu*

Antioxidant enzymes: Acute and chronic responses to exercise-induced oxidative stress in gastrocnemius muscle of mice

High aerobic fluxes during sustained exercise increases generation of reactive oxygen species (ROS) such as superoxide ions, peroxides, and hydroxyl radicals. High ROS levels can have a wide range of deleterious effects in the cell, disrupting redox balance and reacting with and degrading the integrity of nucleic acid, protein, and lipid. This potential for damaging impacts is a strong selective force for developing effective and broad scale cellular defenses. In addition to antioxidants such as vitamins C and E and glutathione, mammals possess several antioxidant enzymes, including superoxide dismutase isoenzymes located primarily in the cytoplasm (SOD1) and mitochondrion (SOD2), and the glutathione peroxidase (GPx) family of enzymes that work in conjunction with SOD by reducing hydrogen peroxide. This study tests the hypotheses that (1) gastrocnemius muscles of trained mice have lower oxidative stress than their untrained counterparts owing to upregulation of key antioxidant enzymes; (2) mitochondrial (mt) forms of SOD and GPx will be especially affected; and (3) the patterns of transcription will vary with training. Trained mice were swum daily for 5 d/week for 2 or 6 weeks; swims lasted 1 h/d for first 2 weeks, then were increased by 15 min/d every two weeks. To induce oxidative stress on day of sampling, mice were swum for 1 h and compared to a subset not swum. Samples were collected at two additional times (5h, 24h) after the swim to assess recovery and patterns of transcription. Oxidative stress in gastrocnemius muscle (measured as level of lipid peroxidation/malondialdehyde) was significantly higher in untrained than trained mice. Levels of mRNA transcripts (assessed with qPCR) of SOD1, SOD2, GPx1, GPx4 (mt), and GPx4 (cytoplasmic) will be discussed.

49.3 ONDRASEK, N.R.*; WADE, A.C.; BURKHARD, T.; HSU, K.; NGUYEN, T.; POST, J.; ZUCKER, I.; University of California, Berkeley, University of Southern California; *nrondrasek@berkeley.edu*

Environmental Modulation and Endocrinological Correlates of Same-Sex Affiliative Behavior in Female Meadow Voles

The prevalence of female-biased affiliations in group-living mammalian species suggests that same-sex relationships are of particular importance for females. However, little is known about the influence of environmental and physiological factors on same-sex social bonds. Female meadow voles present an interesting opportunity for the investigation of these questions because free-living females display seasonal variations in same-sex affiliation. As they transition from summer to winter, females transition from an aggressive, territorial phenotype to an affiliative, group-living phenotype. The thermometabolic advantages of huddling have been offered as an explanation for winter sociality in meadow voles; thus, we designed a study to assess the effects of ambient temperature, day length, food availability, and frequency of handling on same-sex affiliative behavior and several potential physiological correlates. In a separate study, group size and social preferences were evaluated in male and female meadow voles. Our findings suggest that: 1) day length, food availability, and ambient temperature interact to regulate same-sex affiliative behavior in female meadow voles; 2) low temperature exposure can modify social preferences without increasing huddling behavior; 3) differences in handling modulate plasma corticosterone and estradiol without modifying same-sex affiliation; 4) under certain environmental conditions, variations in same-sex affiliative behavior are correlated with plasma corticosterone and estradiol; and 5) the propensity to join a group consisting of novel individuals varies by day length and sex.

P1.178 OPOKU, R.*; CHEKAYEV, Y.; CARROLL, M.A.; CATAPANE, E.J.; Medgar Evers College; *catapane@mec.cuny.edu*

Manganese Treatments Decreases Immunofluorescence Emissions of Post-Synaptic Dopamine D2 Receptors

Manganese (Mn) a neurotoxin causing Manganism, a Parkinsons-like disease, disrupts dopamine (DA) neurotransmission. Gill lateral cell cilia of *Crassostrea virginica* are controlled by serotonergic-dopaminergic innervations. DA causes cilio-inhibition, serotonin cilio-excitation. Our lab showed post-synaptic DA receptors in gill cells are D2 type and Mn blocks cilio-inhibitory effects of DA by blocking DA post-synaptic receptors. Questions exist in the literature if Mn decreases the number of D2 receptors in brain. To test that we used antibody-antigen histoimmunofluorescence techniques to visualize DA D2 receptors in gill and ganglia of *C. virginica*. We used a 1° antibody against D2 receptors followed by FITC linked 2° antibody. Animals were treated with 500 µM of Mn for 5 days. Gill, cerebral and visceral ganglia were excised and exposed to 1° and 2° antibodies. Paraffin embedded sections were viewed with a phase contrast Zeiss epilume fluorescence microscope with a ProgRes C3 Peltier cooled camera. Antibody treated sections showed bright FITC fluorescence in lateral ciliated cells and other areas of gill and ganglia. Sections lacking 1° antibody treatment did not display similar fluorescence. We analyzed fluorescence intensity of 120 control and 80 gill lateral cells from animals treated with Mn using ImageJ software. Intensity of Mn treated cells was 70% less than controls. The study identifies DA D2 receptors in gill cells and cerebral and visceral ganglia, and shows a negative correlation between fluorescence intensity of DA D2 receptors in Mn treated animals and controls. The question if the decrease in intensity is due to decrease in actual number of receptors or if Mn alters protein conformation of D2 receptor and D2-ligand binding sites needs to be further explored.

P2.191 ORNELAS, L; KOK, L; FUSE, M; MOFFATT, C*; University of California, San Diego, San Francisco State University, CA; *moffatt@sfsu.edu*

Effect of Caloric Restriction on Longevity and Neurogenesis in the House Cricket, Acheta domesticus

Caloric restriction increases lifespan in many vertebrate and invertebrate species. However, relatively few studies have examined how caloric restriction affects age-related changes in the nervous system. We addressed this issue by determining how age and caloric restriction affected the rate of cell divisions by neuroblasts, cells that function in a manner similar to mammalian neural stem cells, in cricket brains. In our first experiment, newly emerged adult crickets were either calorically restricted (CR) by feeding them only every other day or they were allowed to feed freely (FF). We found that on average FF crickets died significantly sooner than did CR crickets, at 69 versus 95 days of age, respectively. In our second experiment, we injected FF and CR crickets with bromodeoxyuridine (BrdU) two hours before euthanizing them at either 10 or 90 days of age. Using the incorporation of BrdU into cell nuclei as a marker for cell proliferation, we found that neither age nor caloric restriction affected the number of BrdU-labeled cells. However, we did find evidence that caloric restriction might prevent age-related changes in the gross morphology of the brain. In young crickets, neuroblasts are located in clusters that are symmetrical in appearance and location, while in old crickets these clusters become asymmetrical. Using a Chi-square test to make comparisons between old FF and old CR crickets, we found that fewer old CR crickets than expected had asymmetrical clusters of neuroblasts. Overall, our results suggest caloric restriction may mitigate at least one effect of aging on the cricket brain. Further experiments will determine if the differences in the brain morphology of old FF and CR crickets are correlated with differences in behavior.

P1.93 ORTIZ, LA*; COUGHLIN, DJ; GOODRICH, KR; Widener Univ.; *kgoodrich@widener.edu*

Twisty Twigs: Biomechanics of Storm Resistance in Distal Branches of Pawpaw

Woody plants can incur significant damage as a result of storm events. Following storms, pawpaw (*Asimina triloba*) exhibits distinctive reconfiguration of its distal twigs. Pawpaw, a temperate, hardwood species of the tropical family Annonaceae, has oblanceolate leaves (15-30cm in length) occurring on the distal portion of new growth along thin (3-7mm diam.) branches. Following a wind event, some terminal branches remain “flipped” or rotated 180 degrees. Within 24-48 hrs, these “flipped” branches return to a “right-side-up” conformation. We examined torsional stiffness (GJ), flexural stiffness (EI) and viscoelastic creep in twigs from pawpaw and two co-occuring tree species (tulip poplar and bitternut hickory). These additional species do not exhibit the “flipping” phenomenon, yet have similar leaf areas and distal twig diameters. Pawpaw has lower torsional stiffness compared to tulip poplar and hickory, as indicated by the ratio of EI to GJ (or the “twistiness” to “bendiness” ratio of Vogel). In addition, only pawpaw showed significant torsional creep followed by relaxation or return to initial orientation. We suggest this is a biomechanical mechanism of pawpaw allowing reconfiguration of the leaves in heavy wind/rain in order to reduce damage.

P1.7 OSSIP-KLEIN, A/G*; OYOLA MORALES, J/R; VITAL, C; ZÚÑIGA-VEGA, J/J; HEWS, D/K; MARTINS, E/P; Indiana University, Bloomington, Cornell University, Ithaca, Universidad Autónoma de Ciudad Juárez, Universidad Autónoma de México, Indiana State University, Terre Haute; *aossipkl@indiana.edu*

Cryptic differences in coloration across four Sceloporus lizard species and implications for visual signal evolution

Many animal color patterns appear monochromatic from a human visual perspective, but upon closer inspection differ substantially in their reflectance spectra. Here, we analyze the potential for cryptic (i.e. not visible to the human eye) sexual and interspecific differences in chromatism across four *Sceloporus* lizard species, commonly known as “blue-bellies”. The majority of these species are sexually dichromatic, as males have paired belly patches which are posturally-emphasized during male-male aggressive encounters and females have unornamented, white-bellies. However, there are a handful of independent evolutionary losses of these blue patches in *Sceloporus*, and in these species both sexes appear to be unornamented and sexually monochromatic. We examine the potential for cryptic sexual dichromatism in two unornamented *Sceloporus* species that differ in lineage age (time since the blue loss). We find cryptic differences in coloration across females of four *Sceloporus* species, all with white-bellies. We also find that the evolution of an additional signaling color for males of one species decreases chromatic contrast. Together, these results have interesting implications for visual signal design in *Sceloporus* lizards.

68.3 OUYANG, JQ*; HAU, M; Princeton Univ, Max Planck Institute for Ornithology; *jqouyang@gmail.com*

Corticosterone and brood abandonment in a passerine bird

Hormones regulate decision-making strategies, in particular by translating an individual's physiological state into decisions on major behavioural and life-history processes, such as reproduction. Corticosterone, a glucocorticoid hormone, has been gaining attention as a mediator of reproductive effort, and experimentally elevated corticosterone concentrations have been shown to disrupt reproduction in avian species. Here, we tested whether individual variation in corticosterone concentrations is related to the decision for brood abandonment in free-living great tits, *Parus major*. Because of harsh environmental conditions, many adults abandoned their first broods in 2010, enabling us to ask which physiological, environmental and individual characteristics increased the probability of nest desertion by both males and females. The best predictors of nest desertion were high stress-induced corticosterone levels in males and low average nestling mass. Furthermore, high stress-induced corticosterone levels in 2010 appeared to represent plastic responses to environmental conditions and reproductive investment: individual males that abandoned their nests in 2010 had higher stress-induced corticosterone concentrations and produced nestlings with lower average mass than in 2009, when nesting successfully. Females that abandoned their nests in 2010 had higher baseline corticosterone concentrations than in 2009, when nesting successfully. Also, males that renested after abandonment in 2010 had lower stress-induced corticosterone concentrations and nestlings with higher mass. Finally, pairs that abandoned but renested later in 2010 had similar fledgling success at the end of the season as those that did not abandon. These results indicate that an individual's reproductive decision is the result of a plastic modulation of the corticosterone stress response that influences reproductive decisions according to environmental conditions.

P1.113 OWINGS, A/A*; YOCUM, G; RINEHART, J; KEMP, W; GREENLEE, K; North Dakota State University, Fargo, USDA-ARS Red River Valley Agricultural Research Center, Fargo; *aowings27@hotmail.com*

Critical PO_2 of developing Megachile rotundata, the alfalfa leaf-cutting bee

The alfalfa leaf-cutting bee, *Megachile rotundata*, is a solitary, cavity-nesting bee. Juvenile bees develop inside brood cells constructed out of leaf pieces. During development inside the brood cell, pre-pupae may experience hypoxic conditions from both the cavity nesting behavior and brood cell itself. To test the hypothesis that pre-pupae are tolerant of hypoxia, we measured critical PO_2 in developing *M. rotundata* of varying ages. Critical PO_2 is defined as the minimum atmospheric PO_2 that can sustain a rate process, and provides information about respiratory capacity. Using flow through respirometry, we measured CO_2 emission rates in normoxia, 10%, 6%, 5%, 4%, 3%, 2%, and 1% oxygen, and anoxia. Critical PO_2 was determined by comparing mean CO_2 emission of an insect in each gas mixture. In support of our hypothesis, the average critical PO_2 of all bees was 4% oxygen, similar to that of other insects and to adult *M. rotundata*. Critical PO_2 values ranged from 0 to 10% oxygen. Critical PO_2 was inversely correlated with body mass, which declined as pre-pupae developed. The finding that respiratory capacity decreases with developmental age suggests that tracheal remodeling during metamorphosis may negatively affect hypoxia tolerance. Alternatively, the decrease in hypoxia tolerance with age may be a signal for pupae to undergo adult emergence.

P2.153 OYARZUN, FX*; BRANTE, A; Universidad Católica de la Santísima Concepción; *fernanda.oyarzun@gmail.com*

Brooding behavior, hatching plasticity and intrafamilial conflict in the poecilogonous polychaete Boccardia wellingtonensis

Within families of sexually reproducing species, conflicts of interest are expected to arise given that the optimal distribution of parental resources is different for parents and offspring and among siblings. Previous work done in the poecilogonous polychaete *Boccardia proboscidea* showed that mothers could control the degree of sibling cannibalism via pre- but mainly post- zygotic decisions via nurse egg allocation and control of hatching time. In this research we explore the Southern Hemisphere species *B. wellingtonensis*, which resembles *B. proboscidea* in size, morphology, ecology and reproductive strategy, but differs in capsule morphology and structure. Capsule interconnectivity could potentially increase opportunities for sibling competition and cannibalism and its structure could allow larvae to hatch unaided. We used a combination of common garden experiments, video recordings, in vitro manipulations, and field sampling of three geographically separated populations to test if *B. wellingtonensis* had both greater scope for sibling conflict and decreased maternal control over the embryos once capsules have been deposited. We found, similarly to *B. proboscidea*, predetermined larval fates, sibling cannibalism, and active brooding behavior. Mothers mediated hatching, but the differences in capsule structure resulted in a less precise manipulation of capsules than *B. proboscidea*, and frequent accidental partial hatching during the brooding period. Capsule interconnectivity did increase opportunities for sibling cannibalism, but a wider range of sibling size mediated by nurse egg allocation limited the amount of cannibalism that took place. We compare the variation found in reproductive traits among populations for both species and discuss its implication for the resolution of intrafamilial conflict.

42.1 PACE, CM*; MONROY, JA; NISHIKAWA, KC; Northern Arizona University; *Cinnamon.Pace@nau.edu*

The role of titin in force enhancement along the length-tension curve.

Force enhancement is when steady state muscle forces are larger after stretch and can result in muscle forces that exceed isometric force at Lo, even on the descending limb. This muscle property is not well explained by the sliding filament theory; however, many studies suggest a role for titin in force enhancement via calcium activation of titin. To study titin's contribution to force enhancement, we used an MDM mouse model in which mutant mice have a deletion in the N2A region of their titin protein and exhibit different active and passive *in vitro* muscle properties compared to wildtype and heterozygote mice. Using the MDM mouse genotypes, we asked how does force enhancement change along the length tension curve and does it vary among the genotypes? Soleus muscles from the MDM genotypes were activated and then subjected to a 5% stretch using a servomotor force lever. Force enhancement was calculated as the difference between the steady state force after stretch and an isometric contraction performed at the stretched length. These muscle tests were performed from -10%Lo to +25%Lo in 5% increments. For all genotypes, passive tension was high, and force enhancement was low, when the muscle was stretched greater than +15%Lo. Mutant mice had particularly high passive tensions, which made their force enhancement appear quite large. However, once passive tension was accounted for, mutant mice showed less force enhancement than the other genotypes. This suggests that having a normal N2A region of titin increases force enhancement. Ultimately, we can use our empirical data to test computer simulations of how titin contributes to force enhancement. Supported by NSF IOS-1025806.

28.1 PADIAN, K.*; DIAL, K.P.; Univ. of California, Berkeley, Univ. of Montana, Missoula; *kpadian@berkeley.edu*

Did bat ancestors glide? A phylogenetic approach

The predominant biological view of the evolution of flight is that it is preceded phylogenetically by a gliding stage. Support for this hypothesis has mainly rested on what is presumed to be "easier" or "necessary" based on models. The hypothesis can be empirically tested by examining the comparative phylogenetic positions of gliders and flyers. The three known clades of living and extinct vertebrate flyers are far removed from the 15 known clades of living and extinct gliders. The problem is particularly acute with bats, which are far removed from all eight clades of mammalian gliders, and are nested within a clade that contains only terrestrial and fossorial forms. We used phylogenetic analyses of major clades of bats, and the extinct chiropteran outgroups of crown-group bats, to assess ancestral states for ecological characters related to locomotion, echolocation, diet, and habitat. The ancestor of crown-group bats likely was insectivorous, echolocated as most bats do, could climb quadrupedally, and had poor terrestrial locomotory skills; the ancestral habitat is difficult to determine. Inferences about stem-group bats involve character states of fossil bats. Flight phylogenetically preceded advanced echolocation; the most basal stem-bats could climb, but their habitats are difficult to specify. No outgroups to bats are or apparently were bipedal; thus the forelimbs of bats could only be freed to evolve powered flight if standard quadrupedal locomotion was modified. Ontogeny also speaks against gliding in bat precursors. Bat wings develop by hypertrophy of the manus and chiropatagium (the thrust-producing part of the wing), not the medial part of the wing (brachiopatagium) that produces lift in gliding.

102.6 PADILLA, D.K.*; YEE, A.; Stony Brook University; *padilla@life.bio.sunysb.edu*

Scaling of radular length and replacement rate in the Atlantic slippersnail, Crepidula fornicata.

All organisms undergo changes in size during ontogeny, and, for multicellular animals, morphologies, behavior and performance frequently do not scale simply with size. In addition, throughout ontogeny organisms experience significant changes in their biotic and abiotic environments, and can respond through changes in morphological, physiological and behavioral traits, or phenotypic plasticity. Morphological systems often have size-dependent functions, i.e., all features of organisms cannot be expected to function similarly as individuals change size through ontogeny, creating challenges for organisms with respect food acquisition among other functions. The slippersnial *Crepidula fornicata* is unusual among gastropods in that it is primarily a suspension feeder. It does possess a radula, which is used to move collected food particles, primarily microalgae, bound in strings of mucus into the digestive track. However, some data suggest that very small snails retain the ancestral feeding mode of grazing with the radula. We examined the scaling of radular length with body size in *C. fornicata* from newly metamorphosed juveniles to adults, and quantified radular replacement rates for snails across a wide size range. We found that the radula of *C. fornicata* is shorter relative to body size than many other gastropods with a similar radular form, and that smaller snails have a disproportionately long radula relative to larger snails when compared to other grazers. The rate of tooth replacement in *C. fornicata* was around 0.59 rows per day, much slower than other grazing gastropods. Differences in radular morphology were also found among individuals, suggesting the possibility of radular tooth phenotypic plasticity as well.

46.3 PADILLA-GAMINO, JL*; KELLY, MW; EVANS, TG; HOFMANN, GE; University of California, Santa Barbara; *gamino@lifesci.ucsb.edu*

Multiple climate change variables interact to reduce the physiological performance of sea urchin larvae in future oceans

In marine environments, ocean warming and ocean acidification, both consequences of anthropogenic production of CO_2, will combine to influence the physiological performance of species. In this study, we used an integrative approach to forecast the impact of future ocean conditions on larval purple sea urchins (*Strongylocentrotus purpuratus*) from an area of the Northeast Pacific Ocean already affected by climate change. In laboratory experiments that simulated ocean warming and ocean acidification, we examined larval development, skeletal morphology, metabolism and genome-wide expression under four different temperature (13°C and 18°C) and pCO_2 (400 and 1100 µatm) regimes. Ocean warming and ocean acidification have both singular and synergistic effects on the performance of early life stages of *S. purpuratus*. Simultaneous exposure to increased temperature and pCO_2 significantly reduced larval metabolism and triggered a widespread down-regulation of histone encoding genes. pCO_2 but not temperature impaired calcification and reduced the expression of a major spicule matrix protein, suggesting that calcification will not be further inhibited by ocean warming. Importantly, shifts in skeletal morphology were not associated with developmental delay. Collectively, our results indicate that climate change variables will interact to exceed thresholds for optimized physiological performance in this key marine species.

P2.27 PAGANINI, A.W.*; STILLMAN, J.H.; San Francisco State University, Univ. of California, Berkeley; *paganini@mail.sfsu.edu*

PHYSIOLOGICAL RESPONSES OF THE PORCELAIN CRAB PETROLISTHES CINCTIPES TO SIMULTANEOUS EXPOSURE TO INCREASED VARIABILITY OF pCO2, TEMPERATURE AND EMERSION

Organisms that inhabit the intertidal zone experience large daily fluctuations in temperature, immersion and pH, and those fluctuations are expected to increase along the California coast under future climate scenarios. How intertidal invertebrates will respond to increased environmental variability of multiple abiotic factors is largely unknown. We investigated performance of the Porcelain crab, *Petrolisthes cinctipes*, under conditions of present and future variation in temperature, increased *p*CO2 (low pH), and emersion. Adult *P. cinctipes* were exposed to three levels of simulated low tide exposure during the day: 11°C emersion, 25 or 30°C emersion, or 11°C under immersion as a control. At night the crabs in each treatment were exposed to either low (7.6, 7.15) or ambient (8.1) pH. Following two weeks of acclimation, we measured respiration rates at 11 and 18°C and upper thermal limits of cardiac performance (typically reported as the critical thermal maximum or CT_{max}). When constantly immersed, metabolic rates were higher in crabs experiencing low pH (40 ± 2.1 µmol O2 $h^{-1}g^{-1}$) than crabs that experienced ambient pH. Metabolic depression was observed in crabs that experienced aerial daily heat spikes when compared to crabs that had no heat stress during acclimatization, yet showed no differences between pH treatments. When crabs experienced no thermal, aerial, or pH stress they exhibited the highest CT_{max} (32.8 ± 0.4 ºC) indicating that any single or combined stressor in our experiments lowered the critical thermal maximum temperature that *P. cinctipes* can withstand under these conditions.

79.3 PAIG-TRAN, EWM*; SUMMERS, AP; U Washington; *mpaig@uw.edu*
A filtration mechanism for large vertebrate suspension feeders: fluid flow and filter anatomy in the devil rays (Mantas and Mobulas)
The gross anatomy and microstructure of the filter pad in the 11 species of devil rays are unusual with respect to other filter-feeding elasmobranch fishes. We used a combination of anatomical descriptions, scanning electron microscopy (SEM), histology, and modeling to describe the anatomy and filtration mechanisms in the mobulids rays. The filter pads are chevron-shaped, rigid, cartilaginous structures composed of repeating filter lobes located on the anterior (toward the incoming flow) and posterior (toward the esophagus) surfaces of the epibranchial and ceratobranchial arches. The ultrastructure of the leaf-like, ascending filter lobes varies between species; however, most are keratinous and can be either smooth or covered in micro-cilia, and some include the presence of denticles. The shape and surface of the terminal filtering lobes are distinct in each species and can be used as a tool for species identification. The epithelium has a high density of mucosal cells which we propose serves as a mechanism for sticky sieve filtration. Fluid flow in the mobulid rays is unusual; instead of following a relatively straight trajectory through the buccopharyngeal cavity as in other suspension feeding fishes, it diverges 90° from the incoming flow to pass through the branchial filter pores. Food particles within the incoming water contact the filter lobes via inertial impaction and remain attached to the filter through sticky sieve filtration. The deviation of the streamline results in a modified form of cross-flow filtration where large shearing forces tangential to the surface of the filter pad create a self-cleaning mechanism for the filter lobe and concentrate filtered particles near the esophagus. This is similar to our results from physical models of filter-feeding fishes we quantified multiple mechanisms of filtration working together during a filtering event.

109.5 PAITZ, RT*; BOWDEN, RM; Illinois St. Univ.; *rpaitz@ilstu.edu*
Characterizing the conversion of yolk estradiol to estrogen sulfates during embryonic development in the red-eared slider.
In the red-eared slider turtle (*Trachemys scripta*), the process of sex determination is estrogen sensitive, with the application of exogenous estradiol resulting in the production of female hatchlings. Because the sex of developing embryos is estrogen sensitive in this species, we have been investigating the role that maternally derived estradiol may play in sex determination. We have previously demonstrated that early in development, exogenous estradiol is metabolized via sulfonation to several estrogen sulfate metabolites. Additionally, the application of exogenous estradiol sulfate to developing eggs influences sex determination in much the same manner as estradiol itself. This study examined the metabolic fate of endogenous estradiol by measuring maternally derived estradiol at oviposition and comparing those levels to levels of estrogen sulfates (estradiol sulfate, estrone sulfate, and estriol sulfate) both at the time of oviposition and after 20 days of development. We found that estrone sulfate was the only detectable estrogen sulfate and that levels increased over the first 20 days of development. Also, clutches that had higher estradiol levels in the yolk had significantly higher estrone sulfate levels at both day 0 and day 20. Together these data suggest that maternally derived estradiol is converted to estrone sulfate during development. We are currently investigating the effect of estrone sulfate on sex determination.

29.4 PAKES, M. J. *; MEJíA-ORTIZ, L. M. ; WEISS, A.; CALDWELL, R. L.; University of California, Berkeley, University of Quintana Roo, Cozumel, University of California Berkeley; *pakes@berkeley.edu*
Endosymbiosis in an Anchialine Crustacean
Sulfidic marine habitats, such as the benthic intertidal and hydrothermal vents, are widespread. Fauna in these ecosystems have developed many physiological and morphological adaptations to cope with the depleted oxygen and toxic sulfide levels typical of such habitats. In addition, many invertebrates, such as mollusks, have evolved epi- and endosymbioses with chemosynthetic bacteria for host nutritional benefit. Surpisingly, only epibiotic chemosymbionts have been described in members of the Crustacea. Here, we present the first findings of chemosynthetic endosymbiosis in the Crustacea, as exhibited in *Typhlatya pearsi* (Atyidae; Malacostraca), a shrimp endemic to anchialine caves. In these karst systems, marine layer flows beneath one or more layers of less saline water and water exchange with nearby oceans is severely restricted, creating stable physico-chemical gradients often characterized by anoxia and high sulfide levels. Transmission Electron Microscopy (TEM) of cave shrimp have revealed numerous and likely symbiotic gram-negative bacteria found in specialized bacteriocytes. In addition, Scanning Electron Micrographs (SEM) suggest that Remipedia (*Speleonectes tulumensis*), a class of Crustacea endemic to anchialine systems, as well as *T. pearsi* are also colonized by epibiotic bacteria. TEM analyses of both taxa have also reveal morphological adaptations typical of hosts containing sulfide oxiding symbionts, such as clustered mitochondria in epithelial cells surrounding sulfide oxidizing bodies. Stable isotope analyses further support chemosymbiotic food sources in these crustaceans. These data suggest that a greater phylogenetic diversity of hosts and more ecosystem types support intracellular chemosynthetic mutualisms than we previously thought.

31.5 PALACIOS, MG; CUNNICK, J; BRONIKOWSKI, AM*; Iowa State University; *abroniko@iastate.edu*
Complex interplay of body condition, life-history, and prevailing environment shape immune defenses of garter snakes in the wild
Evidence for links between ecology, immune function, and life-history strategy remains contradictory; especially regarding the ‘pace-of-life’ ecoimmunology hypothesis that proposes that fast-living organisms should invest more in innate immune defenses and less so in adaptive defenses compared to slow-living ones. Some support for this hypothesis has been found in two life-history ecotypes of the garter snake Thamnophis elegans: fast-living individuals show higher levels of three innate immune indices compared to slow-living ones. Here we assess the complementary prediction that slow-living individuals should in turn show stronger adaptive defenses. We also tested the alternative hypothesis that differences in immune defense are the result of contrasting environmental conditions currently faced by the organisms. This ‘environmental’ hypothesis predicts the opposite pattern for the garter snake system: slow-living individuals should show lower levels of immune defenses (both innate and adaptive) compared to fast-living ones given the harsher environmental conditions (lower temperature, lower and less predictable food availability, and presence of trematode parasites) they face in their habitats. In vitro B- and T-lymphocyte proliferation responses were on average higher in slow-living snakes, opposing the ‘pace-of-life’ and supporting the ‘environmental’ hypothesis. Nevertheless, our results do not negate an influence of life-history on immune defenses: while proliferation of B- and T-lymphocytes increased with increasing body condition in slow-living snakes, the opposite relationship was found in fast-living ones.

P3.122 PALES ESPINOSA, E; JING, X; PERRIGAULT , M; ALLAM, B*; Stony Brook University, Stony Brook, NY; *Bassem.Allam@stonybrook.edu*

Mucosal C-type lectins in the eastern oyster Crassostrea virginica: Potential involvement in particle capture and mucosal immunity

Lectins are known to participate in the defense function of invertebrates where they play an important role in the recognition of foreign particles. They also contribute to other processes requiring carbohydrate-protein interactions such as symbiosis and fertilization. Our recent work has demonstrated the presence of lectins in the mucus covering bivalve pallial organs (gills, mantle, etc.) and showed the participation of these molecules in food particle sorting in suspension-feeding bivalves. Here we describe a novel mucosal lectin from the oyster *Crassostrea virginica* (CvML) and present evidence for its involvement in oyster physiology. The sequence of this lectin presents a signal peptide, a single carbohydrate recognition domain, and two putative conserved sites for calcium binding indicating some levels of homology with previously described C-type lectins in molluscs. CvML transcripts were specifically expressed in mucocytes lining the epithelium of the digestive gland and the pallial organs but were not detected in other tissues including hemocytes. Further investigations demonstrated that the expression of CvML was significantly up-regulated following starvation or bacterial bath exposure but not after injection of bacteria into oyster's adductor muscle. These results highlight the potential role of CvML in the interactions between suspension-feeding bivalves and waterborne microorganisms at the pallial interfaces with possible involvement in primary physiological functions such as food particle capture or mucosal immunity. Findings are discussed in light of our latest findings on the repertoire of mucosal lectins in marine mollusks.

13.2 PAN, F.*; APPLEBAUM, S.L.; MANAHAN, D.T.; Univ. Southern California, Los Angeles; *tienchip@usc.edu*

Amino acid transport as an index of growth potential in larvae of the Pacific oyster, Crassostrea gigas

All soft-bodied marine invertebrates are capable of transporting dissolved free amino acids from low concentrations found in natural seawater. While the physiology of this process has been well characterized over the past 50 years, little is known about the genetic and molecular biological bases of transport capacity. In this study, bivalve larvae with contrasting growth phenotypes were produced by experimentally crossing purebred adults from pedigreed families. Eight larval families reared under similar environmental conditions showed contrasting growth rates, ranging from 5.4 ± 0.6 (SEM) to 14.8 ± 0.4 micrometers per day. Amino acid (glycine) transport rates were measured during growth of these larval families at substrate concentrations near K_t (concentration of substrate resulting in half-maximum transport rate) and J_{max} (maximum transport rate). Transport rates at both substrate concentrations increased with larval size. Rates measured at K_t remained the same between phenotypes; however, size-specific J_{max} was higher in larvae with fast-growing phenotypes. These findings suggest that there is a genetic basis for physiological variation in transport rate. Current research is focused on the quantification of the genes encoding amino acid transporters. The positive correlation of growth phenotype with transport capacity indicates that expression of transporter genes could provide a physiological index of growth potential early in development.

P1.77 PANDIT, MM*; WEILAND, TJ; SWITZER, C; IWASAKI, JM; COMBES, SA; Indiana University Bloomington, Middlebury College, Harvard University, Harvard University; *mpandit@indiana.edu*

Costs and benefits of aerial predation in dragonflies

Predator-prey interactions are a major driving force in evolution, affecting the fitness of both participants. For prey, escape is essential; but for predators, the potential benefit of a successful capture is offset by the energetic cost of pursuit and the risk of failure. Many ecological studies have documented capture success rates of predators pursuing different types of prey, and biomechanical studies have examined the dynamics of predator-prey encounters. However, few studies have combined these approaches to gain insight into the relative costs and benefits to predators of pursuing different types of prey. In this study, we examined aerial predation in Libellulidae dragonflies pursuing four different types of dipteran prey (fruit flies, mosquitoes, houseflies and deerflies) in an outdoor artificial habitat. We quantified capture success rates and estimated energetic cost by analyzing 3-D high speed videos of predation encounters to determine the time from takeoff to capture, as well as the total distance traveled from the perch. We asked how the cost-benefit relationship changes when dragonflies pursue different types of prey, and compared trials from five species of dragonflies to determine whether the relative difficulty of catching certain types of prey is universal, or whether particular dragonflies are specialized for catching particular prey. We found that capture success varies between dragonflies, with larger species generally being more successful predators. However, the gross parameters of the interaction (time and distance to capture) are determined primarily by the type of prey, which may place larger predators at an energetic disadvantage in some situations.

P3.141 PANG, B*; GREEN, P; BIRD, D; HALPERN, Z; CURTIS, A; VAN VALKENBURGH, B; University of California,Los Angeles, University of Massachusetts Amherst; *benisonp@gmail.com*

Comparison of Nasal Turbinal Surface Area in Caniform and Feliform Carnivorans

The nasal cavity of mammals houses a complex set of bones known as turbinals that are involved in olfaction and respiration.In long snouted species,such as canids,the two functions are largely spatially separated.Olfactory epithelium is confined to the posterior ethmoturbinals and dorsal nasoturbinals,while respiratory epithelium is located on the anterior maxilloturbinals within the respiratory pathway.In short-snouted species,the separation is less distinct,with ethmoturbinals overlapping maxilloturbinals.We studied the scaling of maxilloturbinal and ethmoturbinal surface area (SA) with body size in caniform and feliform carnivorans to determine whether the latter exhibit reduced maxilloturbinal SA.Using CT scans and 3-D visualization software,we measured turbinal surface area in 22 caniform and 13 feliform species and found that feliforms have less maxilloturbinal SA and more ethmoturbinal SA than caniforms.This might indicate greater olfactory abilities in feliforms,but not if anterior ethmoturbinals are co-opted for respiratory function.Visual inspection of the 3-D models suggest that this is the case.After correcting for skull length,we found that the hypothesized recruitment of ethmoturbinals occurs to a greater extent in short-faced feliforms,possibly due to reduced nasal chamber volume.Among the feliforms,the spotted hyena (*Crocuta crocuta*),brown hyena (*Parahyaena brunnea*) and striped hyena (*Hyaena hyaena*)are similar to large canids in having an exceptionally large ethmoturbinal surface area.This could reflect expanded home range size as well as intense scent marking behavior,both of which demand heightened olfactory ability.Confirmation requires histological analysis to determine the distribution of olfactory and respiratory epithelia and flow visualization to assess its functional implications.

10.1 PANKEY, MS*; OAKLEY, TH; Univ of California, Santa Barbara; *sabrina.pankey@lifesci.ucsb.edu*

Parallel molecular signatures underlie convergent evolution in two bioluminescent squid

The phenomenon of convergent phenotypic evolution fascinates biologists, largely because the extent to which convergent molecular processes drive convergence at the phenotypic level remains unclear. Natural selection is frequently invoked to explain how taxa facing similar biotic or abiotic pressures may arrive at similar phenotypic solutions. This study seeks to understand if the range of possible 'molecular solutions' for a complex trait is similarly limited. Cephalopod molluscs include two distinct clades of squid that harbor closely related strains of luminous bacterial symbionts within elaborate, optically enhanced organs called "photophores". Using next-generation sequencing, we have generated transcriptomes from two divergent squid to characterize the gene expression patterns of bacterial photophores that have originated independently. Comparisons between these transcriptomes have uncovered striking similarities in the molecular profiles underlying these distinct traits. Notably, homologous genes known to be involved in mediating pathogenicity, bacterial recognition, and light perception are highly expressed in both organs. Within each species, additional transcriptional similarity between eyes and photophores suggests a molecular mechanism for the functional convergence observed in these traits. This study contributes not only to symbiosis biology, but also to our understanding of how similarity in molecular profiles relates to morphological and functional similarity.

P2.201 PARELLI, S*; DOLCEMASCOLO, P; MONSEN, K; Montclair State University; *sparelli@gmail.com*

Examining Mitochondrial Genetic Diversity in a Population of Eastern Hognose Snakes in Cape Cod, MA

The Eastern Hognose snake (*Heterodon platirhinos*) is a relatively poorly studied species found in the eastern half of the United States from southern New England and Ontario south along the Atlantic coast to Florida and west to Texas, Kansas, Nebraska, and South Dakota. In the Northeastern part of their range they are considered to be a species of regional conservation concern by the Northeast Endangered Species and Wildlife Diversity Technical Committee, and are protected by conservation measures in the states of Rhode Island, Connecticut, and Massachusetts, and are listed as endangered by the state of New Hampshire. The purpose of this study was to examine the genetic diversity of a population of *H. platirhinos* in Cape Cod National Seashore, Barnstable, MA in order to determine whether this population was being impacted by habitat fragmentation. Tissue samples were collected from snakes in conjunction with a radio telemetry study which covered three major towns in Cape Cod and approximately 120 sq km of the northernmost part of the peninsula. We obtained DNA from a total of twenty-three snakes and compared partial sequences of the mitochondrial control region. All sequences were joined in a statistical parsimony network using TCS 1.21 with a 95% confidence connection limit. Five unique haplotypes were distinguished which differed by no more than three base pairs, and there was no correlation between geographic location and haplotype occurrence. These results suggest that this population in Cape Cod may not experience any barriers to gene flow or that barriers may have been recently established. To our knowledge, this is the first genetic analysis of the Eastern Hognose snake.

P1.219 PARK, D.*; DANIELS, K.D.; FREEL, K.L.; PROPPER, C.R.; Kangwon National Univ., South Korea, Northern Arizona Univ., Flagstaff; *parkda@kangwon.ac.kr*

Small Diel Temperature Increases Affect the Time to Metamorphosis in the Arizona Tiger Salamander (Ambystoma tigrinum) Alone and in Combination with Ammonium Perchlorate Exposure

To determine if small diel water temperature increases affect the developmental process of the Arizona tiger salamander alone and/or in combination with endocrine disrupting compounds, larvae of developmental stages 8-13 (Watson and Russell, 2000) were exposed to 0, 20, or 200 ppb ammonium perchlorate (AP), a known thyroid hormone disruptor and maintained at ambient temperature (control) or increased 0.9 ºC (daily mean temperature) above ambient temperature for 11 weeks in outdoor enclosures. Developmental stage, body growth, and startle response of the larvae were measured at the end of each exposure week. The date of metamorphosis was also recorded for each larva. At collection the following measurements were taken: head size, snout-vent length, body mass, thyroid gland size, and gonad mass. The results demonstrate that an increase in diel water temperature and exposure to AP affect the time to metamorphosis during a specific time period and interact with each other. At ambient temperature, 20 ppb AP exposure shortens the time to metamorphosis, but at increased diel temperature, AP does not affect metamorphic timing. Increased diel temperature shortens the time to metamorphosis. In addition, temperature had no effect on gonadosomatic index, but 200 ppb AP exposure decreased gonad mass. We did not observe any significant differences between treatments in the remaining measurements collected. Our results suggest even small shifts in climate such as small diel temperature increases affect the developmental process of salamanders in the field. Furthermore, this shift could interact with exposure to common pollutants that interact with the endocrine system and affect development.

143.3 PARRILLA, L.*; OWERKOWICZ, T.; OMORI, M.; HICKS, J.; ROURKE, B.; California State University, Long Beach, California State University, San Bernardino, University of California, Irvine; *leah.parrilla@student.csulb.edu*

Myocardial stress and Myoglobin expression in cardiac tissue of Hypoxic and Hyperoxic reared Alligator mississippiensis (A.m.)

We use Alligator mississippiensis (A.M.) as a model species of longevity and adaptability. Incubated A.M. eggs were raised in oxygen conditions of 16%, 21%, 26%, 31%, and 36% representative of oxygen levels over the last 500my. We hypothesized that A.m. raised in hypoxic environments would have constraints on cardiovascular load thus increasing oxygen related protein expression and myosin heavy-chain (MyHC) plasticity related to cardiovascular demands. Heart was examined at embryonic, hatchling and post-hatchling time points as indicators of phenotypic plasticity to differing oxygen environments. No differences in MyHC expression were found between hypoxic and hyperoxic treatment groups although typical growth related shifts from fast contracting alpha isoforms to the slower more economical beta isoforms were seen only in right atria. Myoglobin (Mb), a major oxygen storage protein in cardiac muscle was identified in the hyperoxic treatment groups using 2-D proteomic analysis. Hyperoxic alligators also expressed heat shock proteins 70A, 70B, and 27 suggesting increased loading as a contributor to myocardial stress. Additional identification and quantification using SDS-PAGE mini gels combined with mass spectroscopy found hypoxic treatment groups were expressing significantly higher levels of Mb in the right ventricle. Mb may be contributing to a compensatory response in hypoxic alligators.
Funded by NSF grant:IOS-0922627 NSF RUI

41.5 PARSLEW, B; The University of Manchester, UK; *ben.parslew-2@postgrad.manchester.ac.uk*

Simulating and Visualising Flapping-Wing Flight

Predictive simulation methods have previously been used to model animals walking, running, galloping and hopping. These methods have been applied extensively to the prediction of kinematics of human terrestrial locomotion and, more recently, have been used to simulate animal flight. One of the key challenges in applying this approach to flight is selecting a modelling strategy that accurately predicts fluidic forces, which are more significant than inertial forces in most flight conditions. Many of the available methods of fluid dynamic analysis are computationally expensive and therefore not appropriate for use in a predictive simulation approach. This presentation reports on the progress made in developing a generic theoretical model that can be used to simulate a range of flapping-wing species in different flight conditions. The results of this work are illustrated through animated visualisations of the Rock Pigeon in cruising, accelerating and climbing flight. Predicted flight kinematics are validated through comparison with experimental data and the model is shown to be capable of capturing the strong kinematic similarity that is observed between flying animals of varying scale.

110.3 PARSONS, KJ; POWDER, KE; ALBERSTON, RC*; Univ. of Glasgow, Univ. of Massachusetts, Amherst; *rcraigalbertson@gmail.com*

Wnt-signaling and the evolvability of cichlid craniofacial diversity

Evolvability refers to a population or clade's ability to evolve in space or time. It deals with both constraint and opportunity, and has profound implications for how biodiversity arises and is maintained over time. East-African rift-lake (EA) cichlids are unquestionably one of the most successful adaptive radiations of any living organism, making them an ideal system in which to examine evolvability in the context of rapid diversification. Here we show that expanded Wnt-signaling has facilitated the evolution of phenotypic novelty and ecological opportunity in this group, but has done so at the expense of evolvability. Specifically, we show that increased Wnt-signaling is associated with the development of lineage specific craniofacial morphology, and that experimental modulation of Wnt-signaling recapitulates natural variation in craniofacial form. We demonstrate further that relative to other closely related and phenotypically similar species the lineage at the extreme end of EA cichlid craniofacial diversity expresses an adult phenotype much earlier in development, suggesting that the source of novel craniofacial variation may involve shifts in developmental timing. Moreover, this species expresses a phenotype that is both more robust to environmental change and more sensitive to molecular perturbation, which should act to limit adaptive responses. In short, the evolution of phenotypic novelty has increased ecological opportunity, but potentially at the expense of future evolution. These data offer some of the first empirical support for long-standing theories in evolutionary biology, and have important implications for the evolution and maintenance of biodiversity.

P2.31 PASPARAKIS, C.*; BJELDE, B.E.; TODGHAM, A.E.; San Francisco State University ; *cpas@mail.sfsu.edu*

Effects of repeated heat stress and recovery on thermal tolerance of the fingered limpet, Lottia digitalis

The ability of a species to respond to both increases in mean temperature as well as the increased frequency of extreme high temperature exposures will affect its survival in a changing environment. The rocky intertidal zone is among one of the most highly variable environments on Earth, with rapidly shifting conditions dependent on the tidal cycle. Therefore, intertidal organisms must be able to tolerate extreme and stochastic changes in temperature on a daily basis. Although there have been numerous studies investigating the thermal physiology of intertidal animals, few have focused on an organism's physiological capacity to withstand repeated heat stress and how previous exposure to sublethal heat stress may shift an organism's upper temperature tolerance. *Lottia digitalis*, a species of limpet ubiquitous along the coast of California in the upper middle intertidal zone, were collected from Fort Ross California in early June 2012 and brought back to the lab to acclimate to ambient ocean conditions for two weeks. To investigate the effect of a preliminary mild heat shock of differing magnitudes on upper thermal tolerance, limpets were aerially exposed to 15°, 25° and 30°C on Day 1. The following day, in sync with the start of the midday low tide period, electrodes were placed into the limpets to record heart rate as temperatures were increased at a rate of 6°C/h to 48°C, a severe, lethal heat shock. Previous exposure to a mild thermal stress had no effect on the upper temperature tolerance of limpets as determined by a break in cardiac function. Next steps include examining Hsp70 protein levels following the preliminary mild heat shock and repeating this experiment using higher preliminary heat stress temperatures.

S10-1.3 PASSAMANECK, Y.J.*; MARTINDALE, M.Q.; University of Hawaii; *yale@hawaii.edu*

Opsins in brachiopod embryos and larvae

In the larvae of most protostome invertebrates, detection of directional light is facilitated by simple pigmented eyes containing rhabdomeric photoreceptor cells. To extend the understanding of protostome eye evolution, we have investigated photoreceptor morphology, opsin expression, and photoresponse behavior in the articulate brachiopod *Terebratalia transversa*. *Terebratalia* develops as a distinctive, free-swimming trilobed larva with multiple pigmented eye spots, before metamorphosing into the sessile benthic adult form. Our analysis of the cells of the *Terebratalia* larva eyes has shown that they have the morphology of ciliary photoreceptors, distinct from the rhabdomeric photoreceptors in the eyes of most other protostomes. Consistent with this, we have also found that a ciliary opsin gene is expressed in these cells. In addition, both the ciliary opsin gene and a Go opsin gene are expressed early on in embryonic development, before neural differentiation is observed. This early expression is associated with a positive photoresponse by the embryo, suggesting this behavior may be mediated by a cell-autonomous modification of ciliary beating in response to light. These finding provide novel models for understanding the increase in complexity during the course of eye evolution.

P1.153 PASSOW, C.N.*; KELLEY, J.L.; TOBLER, M.; Oklahoma State University , Stanford University; *Courtney.passow@okstate.edu*
Characterization of the Poecilia mexicana transcriptome: a model for adaptation and speciation research
Adaptation and speciation are key processes in evolution and elucidating the genomic basis of traits involved in these processes remains a major task for the field. Poecilia mexicana (Poeciliidae) is a livebearing fish that lives in normal streams as well as in toxic, hydrogen sulfide springs throughout southern Mexico. Sulfide springs were colonized by evolutionarily independent lineages that exhibit strong patterns of convergent, adaptive trait divergence and are reproductively isolated from adjacent stream populations. Due to the recent divergence of ecotypes inhabiting different habitats, this system is ideal to study the potential underlying genetic basis of adaptation and speciation. Identifying genetic changes involved in adaptive trait divergence involves quantifying coding changes in the genome and changes in gene regulation. We used RNA-sequencing on an Illumina HiSeq platform to assemble and annotate a reference transcriptome for P. mexicana based on transcripts from 36 wild-caught females. The assembled transcriptome showed high congruence with other published fish transcriptomes, such as medaka, zebrafish, and stickleback. Using BLAST, we focused on identifying candidate genes that are potentially under positive selection between populations from non-sulfidic and sulfidic populations, and identified genes involved in general and oxidative stress responses, as well as in sulfide metabolism and hypoxia tolerance. We validated several candidate gene sequences with RT-PCR and sequencing. The P. mexicana transcriptome provides a valuable genomic resource for studying the underlying genetics of adaption and speciation, and contributes to the growing number of genomic resources in the family Poeciliidae, which is used in a wide range of behavioral, ecological, evolutionary, and medical genetic studies.

S1-2.4 PATEK, S. N.*; DEVRIES, M. S.; MURPHY, E.A.K.; University of Massachusetts Amherst, University of California Berkeley, University of Virginia; *patek@bio.umass.edu*
What is fast?
Predators are often assumed to be the fastest organisms and being fast is typically associated with speed. However, the notion of fast involves multiple kinematic parameters, such as duration, speed and acceleration, and not all of these parameters are necessarily relevant for particular predatory strategies. In the context of this symposium’s focus on the motor systems underlying predatory attacks, this study examines the definition of fast, the macroevolution of fast organisms, and addresses which facets of fast are actually relevant to predatory movements. In addition, we examine mantis shrimp (Stomatopoda), a group of extreme marine predators that exhibit substantial variation in the kinematics, morphology and strategies of prey capture. The results of these analyses show that the fastest movements are not synonymous with classic notions of predatory attack and that using the appropriate kinematic measure is key to correctly interpreting the function of fast movements.

P2.188 PATERSON, T.L.*; DAVIS, J.E.; Radford University; *tpaterson@radford.edu*
Effect of captivity on hippocampal volume of Passer domesticus.
The hippocampus plays an important role in memory and learning. The link between chronic exposure to corticosteroids and resultant reductions in hippocampal volume is well-studied in mammals. However, similar studies in passerine species have found little effect of chronic stress on hippocampal size. These studies, however, have relied largely on species that exhibit large amounts of caching behavior, and as such may have a different interaction between memory and stress than species which do not cache. The project described here explores the relationship between stress and hippocampal function in a non-caching passerine. Specifically, we will describe studies exploring the effect of captivity and moderate chronic stress on hippocampal volume in the house sparrow (*Passer domesticus*).

S1-3.1 PATTERSON, B.W.; ABRAHAM, A.; MCLEAN, D.; PATANKAR, N.A.; MACIVER, M.A.*; Northwestern University; *maciver@northwestern.edu*
Vision versus electrosense: Mechanics and sensing in prey capture behavior in larval zebrafish compared to electric knifefish
We have collected motion capture data on a non-visual hunter, the weakly electric knifefish (*Apteronotus albifrons*) as well as a visual hunter, the larval zebrafish (*Danio rerio*) during prey capture behavior. Kinematic analyses have provided a detailed picture of how both fish hunt their prey. We have also analyzed their biomechanics through a combination of computational fluid dynamics, particle imaging velocimetry, and biomimetic robotics. What do these distinctively different animals and prey, differing in size by two orders of magnitude and using very different sensory systems, tell us about the biomechanics and sensory constraints of prey capture? I’ll talk about a few of the emerging lessons, highlighting differences between the sensory volumes and mechanics of these two fish.

P2.185 PATTON, M.S.*; MEGAHED, T.; JOHNSON, M.A.; Trinity University; *mpatton@trinity.edu*
Lateralization in aggressive behavior and brain morphology in the green anole lizard (Anolis carolinensis)
Lizards are an ideal organism for studies of laterality in brain and behavior due to the lizard visual system; each eye is located on opposing sides of the head, and the retinal ganglion cells within the eyes project to the contralateral visual cortex for sensory processing. In addition, there is limited integration between the two hemispheres of the lizard brain. Thus, visual signals received by the left eye are primarily processed by brain regions in the right hemisphere, and vice versa. Previous research suggests that both behavioral and brain lateralization occur within the green anole (Anolis carolinensis). In this study, we build upon these data by studying both types of traits in the same individuals. We conducted 10 min laboratory arena trials, in which pairs of males interacted in a single cage, to determine eye orientation during male-male interactions. Our results showed that the majority of lizards exhibited a bias for left eye orientation during aggressive displays. In addition, dominant males in the trials displayed from a left eye orientation more than twice as frequently as subordinate males. Preliminary data on brain morphology suggest a 16% difference between the sizes of the neurons on the two sides of the brain within the preoptic area, a region involved in the motivation to perform displays. Our current work focuses on assessing the relationships between morphological laterality in the preoptic area and the amygdala in the brain, and both individual and species-level laterality in aggressive behavior.

75.5 PENDAR, H*; SOCHA, JJ; Virginia Tech; *hpendar@vt.edu*
The mechanism of tracheal collapse in beetles: a multi-linked system
Many insects are known to augment their respiration via rhythmic tracheal compression and reinflation. A significant decrease in the volume of tracheal tubes during compression displaces air out of the body and likely mixes air within the tracheal system, thereby enhancing gas exchange. In carabid and tenebrionid beetles, compression of tracheae occurs mostly in the head and thorax, and only some tracheae collapse in the abdomen. Different mechanisms have been suggested to explain tracheal collapse, including collapse by contraction of surrounding muscles, abdominal or thoracic pumping, auto-ventilation by leg or wing movement, and hemolymph transport. None of these hypotheses have been investigated in detail, and the mechanism of tube collapse in most insect taxa remains unknown. To determine the mechanism of collapse in beetles, we have been probing multiple physiological processes that are correlated with tube collapse to explore possible mechanical linkages in the system. Although previous work has used synchrotron x-ray imaging to observe tracheal compression, we have been able to take advantage of small locations of transparent cuticle in the thorax, abdomen, and legs to observe compression within the lab. Additionally, we use synchronous measurements of movement, pressure, and CO2 to quantify internal and external processes while tracheae collapse. These measurements have revealed the relationship of collapse with abdominal pumping, hemolymph pressure, gut movement, and CO2 release. Simultaneous pressure pulses of different magnitude throughout the body suggest that the abdominal pump helps to produce pressure, which is mediated by gut movements and regional compartmentalization. This research demonstrates how the use of multiple coordinated processes can result in collapse of tracheal tubes and the augmentation of gas exchange. Support: NSF 0938047 (JJS).

139.3 PENNOYER, K.E.*; FREDERICH, M; Univeristy of New England, Biddeford, ME and Texas A and M University Corpus Christi, TX, Univeristy of New England, Biddeford, ME; *kpennoyer@une.edu*
Differential physiological tolerance to low salinity exposure in two color morphs of the green crab, Carcinus maenas
The European green crab, *Carcinus maenas*, is variable in ventral carapace coloration. Crabs are green after molting and become dark red after prolonged intermolt. Previous studies have shown that red morphs are weaker osmoregulators and have poorer tolerance to low salinity exposure than green morphs. Cellular data to complement this organismic response is lacking. We exposed crabs to 10ppt seawater to assess hemolymph osmolarity, oxygen consumption, righting response and treadmill running endurance. Changes in mRNA expression were assessed for ion transporters (carbonic anhydrase, Na^+/K^+-ATPase, Na^+ -K^+-$2Cl^-$-cotransporter, and Na^+/H^+ antiporter), stress marker (HSP70) and indicators of cellular energy status (AMPK, arginine kinase). At 10ppt red morphs exhibited lower hemolymph osmolarity and poorer whole animal performance. Concurrently, greens morphs exhibit a greater upregulation of genes responsible for ion regulation, cellular stress response and cellular energy status. Whereas red morphs crabs show minimal if any upregulation in these genes. To test the hypothesis that the red morphs reached a physiological limit of ion regulation at 10ppt, suggested by higher morality, green morphs were exposed to 10ppt and red morphs to 12ppt, resulting in a similar hemolymph osmolarities of 750 mOsm in both morphs. After matching the hemolymph osmolarity both morphs showed similar mRNA upregulation. Therefore, the two color morphs seem to have different ion regulatory capacities and reach a critical point of no longer being able to upregulate the respective transporters at different salinities. Funded by NSF IOB0640478 and DGE0841361.

80.4 PEPPER, R.E.*; VARIANO, E.A.; KOEHL, M.A.R.; Univeristy of California, Berkeley; *rachel.pepper@berkeley.edu*
Turbulence from a microorganism's perspective: Does the open ocean feel different than a coral reef?
Microorganisms in the ocean live in turbulent flows. Swimming microorganisms navigate through the water (e.g. larvae land on suitable substrata, predators find patches of prey), but the mechanisms by which they do so in turbulent flow are poorly understood as are the roles of passive transport versus active behaviors. Because microorganisms are smaller than the Kolmagorov length (the smallest length scale of eddies in turbulent flow), they experience turbulence as a series of linear gradients in the velocity that vary in time. While the average strength of these gradients and an average timescale can be computed from some typical characteristics of the flow, there are indications that organisms are disproportionally affected by rare, extreme events. Understanding the frequency of such events in different environments will be critical to understanding how microorganisms respond to and navigate in turbulence. To understand the cues from fluid flow that microorganisms experience in the ocean we must measure velocity gradients in realistic turbulent flow on the spatial and temporal scales encountered by microorganisms. We have been exploring the effect of the spatial resolution of Particle Image Velocimity (PIV) measurements of turbulent flow on the presence of velocity gradients of different magnitudes at the scale of microorganisms. Here we present some results of PIV taken at different resolutions in turbulent flow over rough biological substrata to illustrate the challenges of quantifying the fluctuations in velocity gradients encountered by aquatic microorganisms.

P1.46 PEREZ, JH*; WINGFIELD, JC; RAMENOFSKY, M; Univ. of California, Davis; *jhperez@ucdavis.edu*

The effects of Methimazole treatment on vernal migration, in White-crowned Sparrows

Each year billions of birds undertake migratory journeys to and from seasonal breeding grounds. This journey requires major changes in physiology, morphology and behavior governed by endocrine and neuro-endocrine mechanisms. However, the precise control mechanisms remain poorly understood. Prior research has suggested a role for thyroid hormones in the development and control of spring migratory behavior in Old World Passerines. Particularly in regards to the onset of migratory restlessness, a behavior considered to represent the urge to migrate in captive birds. Also, the thyroid plays an instrumental role in the control of photorefractoriness in European Starlings. Both sets of findings link the thyroid to photoperiodic functions which may be a clue to onset of migration. To begin to understand the role of thyroid hormones in migratory behavior of New World migrants, without the need to resort to surgical or radiological thyroidectomy we utilized the anti-thyroid agent Methimazole, which reversibly inhibits thyroperoxidase. This study explored the effects of continuous administration of Methimazole on the development of migratory condition and nocturnal restlessness in captive white-crowned sparrows (*Zonotrichia leucophrys gambelii*) following photostimulation with 18L:6D. Methimazole was administered via silastic implants. Here we present the effects of thyroid knockdown on three physiology and behavioral events associated with the development of migratory disposition: fattening, hypertrophy of the pectoralis muscles, and expression of migratory restlessness.

S6-1.2 PERFITO, Nicole*; CALISI, Rebecca; HAU, Michaela; BENTLEY, George E.; Univ. of California, Berkeley, Univ. of California, Davis, Max Planck Institute for Ornithology, Germany; *nperfito@berkeley.edu*

Integrating environmental signals for reproductive timing

Most animals are required to respond to a changing environment on a daily and seasonal basis to survive and produce young successfully. In order to match internal physiology with external requirements for survival and reproduction, animals have evolved systems that allow them to anticipate and respond to changing environmental conditions. The neuroendocrine system represents the critical relay between transduction of environmental cues via sensory systems into functional changes in physiology, morphology and behavior. In order to understand how climate change impacts this process of matching internal physiology with the external environment, we must first better understand which environmental cues are relevant and how they are transduced within an animal. I will discuss how environmental cues related to activation of the reproductive system for breeding (and specifically in female birds for egg laying) elicit changes in gene expression in the brain and in peripheral tissues. Further, I will demonstrate how a single cue provided to a single species can have different effects depending on gender and on population.

102.4 PERINO, L..L.; PADILLA, D.K.*; Stony Brook University; *dianna.padilla@stonybrook.edu*

Scaling of the ctenidium in juvenile suspension feeding bivalves

The ctenidium, or gill, of suspension-feeding bivalves has two major functions. It is a respiratory organ, but is it also the primary organ used for feeding. Cilia on the ctenidium form the pump that circulates water past the ctenidium, and, in most cases, also function to move particulates, primarily microalgae, caught on mucus to the mouth for feeding. Although the effects of size and form of the ctenidium on these functions has been explored in adult bivalves, the scaling of the elements of this organ and possible consequences on function, especially in newly metamorphosed bivalves has not. As juveniles, the ctenidium is a simple curtain of straight filaments, and animals do not attain the complex form of adults for months past metamorphosis. We studied the size scaling of ctenidia in juveniles (from 0.2 mm - 2 mm) of *Argopecten irradians*, *Mytilus edulis* and *Crassostrea virginica*. Although ctenidia filament diameter differed among species, within a species the width of the filaments did not change with body size. However, the length of ctenidial filaments for each species increased linearly with body size, and the body size-specific length of filaments was the same across species.

76.3 PERLMAN, BM*; KAWANO, S; BLOB, RW; ASHLEY-ROSS, MA; Wake Forest University, Clemson University; *perlbm0@wfu.edu*

Citius, altius, fortius: jumping kinematics and kinetics in two distantly related teleosts

Many fish stranded on land will use axial movements to generate C-jumps in efforts to return to water. However, mangrove rivulus, *Kryptolebias marmoratus* (Cyprinodontiformes), generate coordinated jumps on land using a tail flip to locate new food resources, avoid predators, escape poor water conditions, or return to water. How do the mechanics of such directed jumps differ from those of typical stranded fishes? We quantified and compared the ground reaction forces (GRF) generated during directed jumps by *K. marmoratus* with those produced by similarly-sized largemouth bass, *Micropterus salmoides* (Perciformes), performing typical jumps of stranded fishes. Individual specimens were placed on a force platform that recorded the GRF in three dimensions (fore-aft, mediolateral, and vertical). Forces were normalized to the body weight of each animal. Two Phantom high-speed video cameras recorded the duration of the jump (from initial movement to launching off the force platform) and the jump trajectory with respect to the ground. Horizontal forces were greatest for *K. marmoratus* with peak GRF occurring at ~75% through the jump. *M. salmoides* had the greatest vertical GRF, occurring at ~60% of the jump. The trajectory of the bass C-jump was ~90° with respect to the ground compared to lower jump trajectories in *K. marmoratus*, leading to greater horizontal displacement in the latter. *M. salmoides* had faster jump durations (~40 ms to reach maximum body curvature), whereas *K. marmoratus* reached maximum body curvature at ~75 ms. While the jumps of *M. salmoides* strongly resemble aquatic fast starts, differences in force production and motion trajectory in *K. marmoratus* may indicate the use of different motor patterns to increase duration (and thus impulse) of the jump.

S4-2.2 PESPENI, M.H.; Indiana University;
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Evolutionary and ecological genomics in a changing world: integrating Next-Gen data with environmental variation to reveal local adaptation

Understanding how populations respond to and are shaped by their environment is of fundamental importance to revealing the mechanisms of local adaptation in general and for predicting the impact of a rapidly changing climate in particular. Species distributed across heterogeneous landscapes present rich opportunities and challenges for uncovering the targets of natural selection, particularly when there is substantial gene flow among populations, as is the case in many marine, plant, insect, and microbial species. These ecologically interesting species have until recently been without the genomic resources needed to comprehensively explore their physiological and genetic means of persistence in complex ecosystems and changing environments. Here I highlight a recently developed pipeline for generating and analyzing RNAseq data. Using several case studies in the purple sea urchin, *Strongylocentrotus purpuratus*, I illustrate how polymorphism, gene expression, gene function, and environmental data can be integrated to identify physiological phenotypes while simultaneously testing for signals of natural selection. This broad melding of very different data sets identifies adaptive phenotypes in gene regulation as well as signals of selection in specific genes across environmental mosaics. This approach detected extensive selection on innate immunity proteins in areas of elevated disease incidence, showed strong population differentiation of biomineralization proteins in response to elevated CO_2, and showed distinct gene regulatory adaptations in different coastal populations. Collectively, these efforts illustrate how genomic, transcriptomic, and environmental data can be integrated to reveal the targets of natural selection in complex environmental mosaics and can help evaluate the possibility of future evolution to climate change.

P1.27 PETERS, J. M.*; CARLETON, S. A.; CRAIG, C.; MARTINEZ DEL RIO, M.; Harvard Univ. , New Mexico State Univ., USGS, Univ. of Wyoming; *jcbptrs@gmail.com*

Effects of land use on seasonal foraging behavior in white-winged doves of Arizona: Insights from stable isotope analysis

White-winged doves are critical pollinators of saguaro cacti, as well as an important seasonal game species in the southwestern United States. Each year, these doves leave their wintering grounds in southern Mexico to spend the summer months on their breeding grounds in northern Mexico and the southwestern U.S. As the human population of urban Arizona expands and agricultural lands are developed, the habitat of white-winged doves is constantly in flux. Over the last decade, individual doves appear to have specialized for feeding on either saguaro products in the Sonoran Desert or on crops from agricultural lands within their breeding grounds. Recent studies suggest that these two groups may be developing into distinct subpopulations. Saguaro cacti products, crops and sources of drinking water in this region differ significantly in isotopic signature (δD and δ13C), and because these isotopes are incorporated into the feathers of birds that feed on them, one can determine which of the two food sources comprise an individuals dove’s diet by analyzing the isotopic composition of their feathers. White-winged doves molt their primary flight feathers sequentially throughout the breeding season, so the isotopic signature of a freshly grown flight feather indicates the dove’s diet during the current year, while an un-molted feather reflects its diet from the previous year. In this study, we compared the isotopic signatures of freshly grown and unmolted flight feathers from white-winged doves on both desert and agricultural lands, to determine whether individual doves retain their feeding preferences from year to year. Our data will provide insights into how anthropogenic changes to Arizona’s landscape have affected the foraging behavior and spatial distribution of white-winged doves.

P2.184 PETERSEN, C.L.*; TIMOTHY, M; KIM, S; BHANDIWAD, A.A.; MOHR, R.A.; SISNEROS, J.A.; FORLANO, P.M.; CUNY, Brooklyn College , Univ. of Washington, Seattle ; *cpetersen@brooklyn.cuny.edu*

Exposure to Conspecific Mate Calls Increases cFos Response in Catecholaminergic Neurons and Vocal-Acoustic Circuitry in Male Midshipman Fish

Male plainfin midshipman fish, *Porichthys notatus*, establish nests under rocks in close proximity to one another and vocally court females by producing long duration advertisement calls. Here we test the hypothesis that males who hear the calls of other males should show increased colocalization of cFos, an immediate early gene product used as a marker for neural activation, with catecholaminergic (CA) neurons which are known to regulate both arousal and motivation in the CNS of other vertebrates. We examined the ascending auditory pathway and two vocal-acoustic integration sites for increased neural activation in sound stimulus versus control males. We collected males during low tide and subjected them to the playback of advertisement calls for 30 minutes. Control males were subjected to ambient noise (no sound stimulus) for 30 minutes. All males were sacrificed, and their brains labeled by double immunofluorescence for tyrosine hydroxylase (TH) the rate limiting enzyme in CA synthesis and cFos. Males exposed to the mate calls showed significantly greater colocalization of cFos in TH-ir cells in the noradrenergic locus coeruleus (LC) and the dopaminergic periventricular posterior tuberculum (TPp), as well as increased cFos-ir in several levels of the auditory/vocal-acoustic pathway. Increased activation of TH-ir neurons in LC and TPp could underlie motivational state changes in listening males, and these results may provide insight to the role of these neuromodulators in teleost social behavior and in social acoustic behavior across vertebrates.

P1.16 PETERSON, A.N.*; SUMMERS, A.P.; BIZZARRO, J.J.; University of Washington, Friday Harbor Labs;
anpetey@gmail.com

Substrate preference of the Pacific sand lance, Ammodytes hexapterus

Commercial fish stock populations can be linked to the health of forage fish populations. The Pacific sand lance, *Ammodytes hexapterus*, is an essential link between zooplankton and higher trophic levels such as birds, marine mammals, and fishes. As a burrowing fish, understanding the behavior and habitat is key to ensuring the long-term sustainability of sand lance populations. Sand lance spend most of their time either schooling in the water column or buried beneath the substrate. We performed paired preference trials during daylight hours to compare burrowing tendencies between sediment sizes. Sediments were collected on San Juan Island and sorted using a RoTap sediment analyzer. The grain sizes chosen for the trial were medium sand (0.25 – 0.5 mm), coarse sand (0.5 – 1.0 mm), very coarse sand (1.0 – 2.0 mm), and very fine gravel (2.0 – 4.0 mm). The study was conducted on sub adults (8.5-11.5cm TL) to account for any ontogenetic variability in burrowing behavior. We found that sand lance could burrow into all of the provided substrates, but they prefer coarse sand. Observations have shown that Pacific sand lance spend the majority of the night buried under the sediment. We also conducted nocturnal preference experiments during night time hours (23:00 – 03:00). At night, *A. hexapterus* displayed no preference between coarse sand and very coarse sand, but did prefer coarse sand over medium sand. Apparently at night, when visual clues are eliminated, the preference for substrate type is relaxed. However, preference is also being evaluated by other sensory systems as there is still a notable distinction in the proportion of buried sand lance between substrates.

5.3 PETERSON, S.*; HASSRICK, J.; DEBIER, C.; CROCKER, D.; COSTA, D.; University of California, Santa Cruz, Universite catholique de Louvain, Belgium, Sonoma State University; *saepeter@ucsc.edu*

Polychlorinated biphenyl (PCB) bulk concentrations and congener profiles in a highly migratory marine mammal

PCBs are widely distributed and detectable far from anthropogenic sources. Northern elephant seals (*Mirounga angustirostris*) travel thousands of kilometers to forage in coastal and pelagic regions of the North Pacific. Our study (1) quantified PCB concentrations in adult female northern elephant seals at the start and end of their biannual foraging trips to assess if age, foraging region, or the fasting state and time of year had significant relationships with tissue concentrations, (2) examined PCB congeners relative to age, foraging region, and fasting state, and (3) examined correlations between tissue concentrations. Between 2005 and 2007 we sampled blubber (inner and outer layers) and serum before and after a foraging trip from 58 seals that carried satellite-tags and time-depth recorders. PCB concentrations in the inner blubber were significantly affected by the foraging trip and fasting state of the animal, with the highest concentrations observed at the end of the molting fast. Age did not significantly affect bulk PCB concentrations; however the proportion of PCB congeners with different degrees of chlorination was significantly affected by age, especially in the outer blubber. Younger animals had a significantly greater proportion of low-chlorinated PCBs (tri-, tetra- and penta-CBs) than older seals, with the opposite trend observed for hepta-CBs, indicating that an age-associated process significantly affects congener profiles. These results highlight the importance of sampling across the entire blubber layer when assessing toxicant levels in seals and taking into account both the fasting state and reproductive status of an animal when conducting contaminant research.

72.5 PETERSON, K.*; DUDLEY, R.; FEARING, R.S.; Univ. of California, Berkeley; *kevincp@eecs.berkeley.edu*

Hybrid aerial and terrestrial robots and their implications for avian flight evolution

DASH+Wings and BOLT are small hybrid legged and winged robots capable of both aerial and terrestrial locomotion. Investigation of the effects of the robots' wings on both their aerial and terrestrial locomotion allows the direct evaluation of the consequences of wing flapping for locomotor performance. By contrast, current support for the diverse theories of avian flight origins derive from limited fossil evidence, the adult behavior of extant flying birds, and developmental stages of already volant taxa. DASH+Wings originally derives from a hexapedal running robot, and allows the consequences of adding wings to a cursorial locomotor to be examined. Experimental controls for the effects of flapping wings are provided by the use of inertial spars and passive airfoils. The addition of flapping wings increased the maximum horizontal running speed from 0.68 m/s to 1.28 m/s along with increasing the maximum incline angle of ascent from 5.6 degrees to 16.9 degrees. Free measurements also show a decrease of 10.3 degrees in equilibrium glide slope between the flapping wings and passive airfoils. In contrast with DASH+Wings, BOLT is a bipedal robot designed with a focus on flight performance. To better examine avian flight evolution, we modify the original design to more closely resemble avian precursors. The design of BOLT also enables the evaluation of the effects of wing amplitude, flapping frequency, and wing area on both aerial and terrestrial performance. Computer models elucidate the effect of interactions between periodic leg and wing forces during high speed wing-assisted running. We discuss our findings in the context of existing hypotheses for the origins of flapping flight in vertebrates.

104.5 PETIT, M.*; VEZINA, F.; Université du Québec à Rimouski, Groupe de recherche sur les environnements nordiques BORÉAS, Centre for Northern Studies, Québec Centre for Biodiversity Science; *Magali.Petit@uqar.qc.ca*

Phenotype manipulations confirm the role of pectoral muscles in avian thermogenic capacity

In winter, resident bird living at northern latitudes exhibit changes in body composition and metabolic performance in response to cold. Whole body mass, digestive organs and muscles mass as well as basal metabolic rate (BMR, reflecting minimal maintenance energy costs) and maximal thermogenic capacity (MSUM, a measure of cold tolerance) have been shown to be higher in winter relative to other seasons. Because birds undergoing cold stress produce heat by shivering, correlational studies suggested that MSUM directly depends on pectoral muscle size. However, this relationship has yet to be experimentally demonstrated. To investigate the relationship between pectoral muscle size and MSUM, we manipulated pectoral muscle size in free-living wintering black-capped chickadees (*Poecile atricapillus*). We removed half of the flight feathers of experimental individuals and compared their muscle morphology and metabolism with control birds captured over the same period. Results show that 1) "clipped" chickadees (n=12) had similar body mass (+1.8%), fat reserves (-13.4%), hematocrit level (+2.0%), BMR (+5.8%) and MSUM (+8.2%) but expressed larger pectoral muscles (+17.0%) than "controls" birds (n=15) and 2) that mass-independent MSUM varied with muscle score and was positively related to hematocrit. Birds showing the highest muscle scores had in average a MSUM +20.4% higher than birds with the smallest scores. These findings therefore support previously observed correlations. Large pectoral muscles are indeed associated with a better mass-independent thermogenic capacity in small resident birds.

116.5 PETT, W*; LAVROV, D; Iowa State University; *willpett@iastate.edu*

A mitochondrial sponge gene unique among animals: the evolution of the Tat pathway in Oscarella

The twin-arginine translocation (Tat) pathway is a protein transport system that serves in moving folded proteins across energy-transducing membranes, and is widespread in all domains of life. Genes encoding different components of the pathway have been found in the genomes of many bacteria, archaea, plants, and plant mitochondria. However, the same genes have been lost from most other mitochondrial genomes, including nearly all animals. The only exception in animals is the homoscleromorph sponges in the genus *Oscarella* (family Oscarellidae), whose mitochondrial genomes encode a gene for TatC, the subunit with the largest number of transmembrane helices. However, the functional significance of the presence of this gene in Oscarellidae remains unclear. Here we characterize the genetic makeup of the Tat pathway in Oscarellid sponges, and address the origin and evolution of the mitochondrial TatC gene. Since previous studies have found the entire Tat pathway to be missing from mammalian genomes, we will address the question of whether other components of the Tat pathway have been transferred to the nucleus in Oscarellidae, or if TatC is operating alone with a possibly different function. The possibility that the Tat pathway was inherited from the ancestral eukaryotic mitochondrial genome and is present in Oscarellidae would imply multiple independent losses of the entire mitochondrial Tat pathway during the evolution of animals, and an unprecedented high rate of loss for an animal mitochondrial gene.

89.6 PFEIFFENBERGER, JA*; HSIEH, ST; Temple University;
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Effects of limb autotomy on locomotor performance of ghost crabs

Autotomy, or limb loss, is a mechanism frequently used in response to aggressive inter- and intra-specific interactions, despite the possibility of negatively impacting fitness by hampering an animal's ability to run, walk, or swim. Although Atlantic ghost crabs (*Ocypode quadrata*) are decapods, they use only eight of their ten legs when running and maneuvering. Differential use of the locomotor limbs may thereby place different amounts of functional importance on each of the limbs, requiring functional compensation for limb loss and/or a decrease in locomotor performance. The goal of this study was to quantify natural patterns and frequencies of limb loss, and to determine whether these patterns reflect the ability for crabs to compensate more effectively for the absence of certain limbs over others. Patterns of limb loss were quantified at five independent sites in Brevard County, Florida for 159 crabs over 22 nights. Interestingly, limb loss was infrequent among the nocturnally-active individuals. We used the highest (3rd leg: 37.5 %) and lowest (1st leg; 6.25%) observed limb loss frequencies to define the two autotomy treatments for laboratory-based performance studies. Each crab was first run with all limbs intact to serve as its own control before limb autotomy. Ten crabs (five per treatment) were run on a track filled with 200 µm diameter glass particles characteristic of a fine sand beach, and filmed with a single dorsal view at 250 fps (Redlake). The three fastest, constant velocity runs per individual for treatment and control were analyzed for differences in limb use and performance. Results indicate that limb loss reduces sprint speed, in comparison to when running with all limbs intact. How limb autotomy affects function of the remaining limbs, as well as its potential impact on its behavioral ecology will be discussed.

100.8 PHILLIPS, N.*; KNOWLES, K.; BOMPHREY, R. J.; University of Oxford, Cranfield University;
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The effect of aspect ratio on the stability of leading-edge vortices over insect-like wings

Flying insects exhibit a vast range of wing planform shapes which vary widely in aspect ratio. In past CFD studies, it has been shown that the aspect ratio of an insect wing is a potentially important parameter in determining the stability of the leading-edge vortex (LEV), a lift-augmenting flow structure exploited by many insects, bats, and birds. Here, a stable LEV implies that it remains present on the upper surface of the wing throughout the wing stroke and does not detach and shed into the wake. An experimental investigation was conducted to investigate the potential effect of wing aspect ratio on the stability of the LEV. Experiments were accomplished with a custom-designed, mechanical flapping-wing apparatus (the 'Flapperatus') that mimics insect-like flapping-wing motion, with adjustable kinematics up to a 20 Hz flapping frequency in air. This approach enables highly repeatable wing kinematics to be achieved between test cases, thereby allowing the effects on flow structures caused by changes in wing aspect ratio to be observed in detail. Stereoscopic Particle Image Velocimetry (stereo-PIV) measurements of the flow field generated by wing planform shapes varying in aspect ratio were performed to characterize the formation, growth and stability of the LEV.

15.3 PHUONG, M. A.*; LIM, M.; WAIT, D. R.; ROWE, K. C.; MORITZ, C.; University of California, Berkeley, Museum Victoria, Melbourne, Australian National University;
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Understanding discordance among diverse datasets in an integrative taxonomy: a case study in ground squirrels

Species represent the fundamental taxonomic unit in nearly all disciplines of biology. Integrative taxonomy is a relatively new approach to identify lineages in which multiple lines of evidence are gathered to diagnose species and discordances between diverse datasets are resolved by invoking evolutionary explanations. Recent molecular work using mitochondrial DNA on species within the genus *Otospermophilus* showed discordant inferences of species boundaries relative to the current taxonomy. As such, genetic (1 mitochondrial locus, 11 nuclear loci, and 11 microsatellite markers), ecological (8 bioclimatic variables), and morphological (23 skull measurements) data were collected and analyzed to delimit species within the genus *Otospermophilus*. Genetic results support the presence of four species of paraphyletic origin with very little differentiation along morphological and ecological axes. Discordances between these lines of evidence can be explained by a model of peripatric speciation. Our results demonstrate the utility of considering models of speciation in understanding conflicting species boundary inferences from diverse lines of evidence.

135.2 PIEKARSKI, N.*; HANKEN, J.; Harvard University;
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Neural crest derivation of the bony skull of the Mexican axolotl and its implications for vertebrate skull evolution

Cartilages and bones of the craniate skull are derived from two embryonic sources, neural crest and mesoderm. Contributions of these tissues to the skull have been revealed in great detail in one amniote model using the quail-chick chimeric system, and to lesser extent in a few other species. However, the degree to which patterns of embryonic derivation are evolutionary conserved or labile remains an intriguing question, given the extensive variability in skull morphology observed among craniates. Living amphibians are a non-amniote tetrapod group with a highly derived skull morphology and ontogeny. Recent technical advances enable us to derive fate maps at a level of detail previously known only from avian studies. We employed embryonic transplantations, using GFP-transgenic axolotls as donors, to document the nature and extent of neural crest contribution to the adult osteocranium. Comparisons between axolotl, chicken and mouse reveal a highly conserved embryonic origin of the tetrapod skull. Conversely, a comparison between axolotl and *Xenopus* reveals tremendous differences in the embryonic origin of skull bones between these two taxa. The unique features seen in *Xenopus* may be a consequence of the dramatic transformation of cranial morphology that is associated with the extreme posthatching metamorphosis characteristic of most anurans.

S3-1.3 PIERCE, SP*; HUTCHINSON, JR; CLACK, JA; The Royal Veterinary College, UK, University Museum of Zoology, Cambridge, UK; *spierce@rvc.ac.uk*

Historical evolution of early tetrapod movement

Conceptualizations of the evolution of tetrapod locomotion have changed drastically in the past 50 years. When early tetrapod fossils were first discovered, the animals were reconstructed as salamander-like in their mode of locomotion, walking around on four sturdy legs. In fact, the "prototetrapod" was envisaged as a terrestrially capable creature with a fish-like body and modified pectoral/pelvic fins equipped with weight supporting joints and the beginnings of digits, but no sacrum. 'Conquest of land' was seen as the driving force in the evolution of limbs. However, intensive re-examination of fossil material and the discovery of key specimens has gradually redefined our perception of the tetrapod bauplan. The prevailing theory is that early tetrapods were primarily aquatic in habit and that limbs evolved before the ability to 'walk' on land. New fossil footprints have challenged this idea by inferring early tetrapods were walking - perhaps partially supported by water - 20 million years before any known tetrapod body fossils. Another recent study has posited that sarcopterygian fishes evolved hindlimb powered locomotion, which was later exapted for usage in tetrapods. However, our recent work on the late Devonian tetrapod *Ichthyostega* has demonstrated that its limb joints did not permit a walking gait like that of a living salamander, and that land locomotion was forelimb-driven. Considering that other closely related stem tetrapods seem to have had a similar limb joint structure, this may have been an ancestral state, although the anatomy of earlier Devonian tetrapods remains unknown. The historical transformation of locomotion potential, and the drivers of land dwelling in the earliest limbed vertebrates, has thus changed drastically, with several different hypotheses having been put forward over the past few years. New information and methodological techniques are helping to refine and shape our understanding of this pivotal evolutionary event.

P2.91 PINCUS, NB*; DEMARAIS, AA; Univ. of Puget Sound; *npincus@pugetsound.edu*

Determining the Potential Activity of Wnt Signaling in Zebrafish Oocyte Maturation Through Examination of β-catenin and Dishevelled mRNA Concentrations

During oocyte maturation, the oocyte progresses from prophase I to metaphase II of meiosis, and a multitude of other cellular changes occur. The mechanism for oocyte maturation is not yet fully characterized. We are examining the role of Wnt signaling pathways in oocyte maturation in zebrafish ovaries. Specifically we are examining two Wnt signaling pathway components: β-catenin (*ctnnb1*) and Dishevelled (*dvl2*). β-catenin is a an interesting protein to study because it plays a dual role as both a cell adhesion protein when attached to membrane-bound complexes, and a coactivator for transcription by the Wnt pathway when free in the cytoplasm. Dishevelled is the "hub" of Wnt signaling and plays a key role in relaying external signals to internal pathway components. β-catenin protein appears to increase in relative cytoplasmic concentration after maturation; however, this change is not the result of migration from cytoskeleton associated membrane-bound complexes. We conducted analyses of mRNA levels of Wnt pathway genes during zebrafish oocyte maturation using RT-qPCR. We examined β–actin, GAPDH and ef1-α as potential reference genes for oocyte maturation, since these were found to have constant expression during zebrafish embryo development or bovine oocyte development. We then examined the changes in mRNA concentrations for β-catenin and Dishevelled over the course of oocyte maturation. It appears that levels of β-catenin and Dishevelled mRNA increase during maturation. The results of our research will contribute to our understanding of the cellular processes which occur during oocyte maturation, and the importance of signaling pathways such as the Wnt pathway in these processes.

31.2 PINZON, JH*; BEACH-LETENDRE, JM; CAWTHORNE, A; WEIL, E; MYDLARZ, LD; Univ of Texas, Arlington, Univ of Puerto Rico - Mayaguez; *pinzon@uta.edu*

Why does immunity vary? Linking phylogenetics and life history traits to immunity in reef-building corals

Changes associated with global climate change are affecting ecosystems through the planet, one example in the oceans are coral reefs. Increased sea surface temperatures are favoring the emergence of coral disease and environmental stressors in these ecosystem engineers. Disease outbreaks and frequent fluctuations in temperature have resulted in reduce coral cover and community shifts to either less sensitive coral species and/or algae. Basal immune levels, as well as inducible immune responses, have proven variable and species-specific suggesting that this variability might be associated with both interspecific genomic differences and evolutionary histories. Recently the phylogeny of corals have been under review thanks to the advent of molecular technique and the development of both molecular and population genetics markers. The most current analysis recommended a reorganization of the scleractinian phylogeny at several taxa, which resulted in a relatively accepted new classification of most families and genera. Based on this new taxonomic organization, our endeavor here is to analyze constitutive immune levels and explore its relation with the current classification, across distinct scleractinian groups (i.e. well defined families and genera). Initial results suggest that constitutive immunity in reef-building corals has a significant relation with their evolutionary history. Although, within each group other biological factors, such as reproduction (hermaphrodites vs. gonochoric) and growth form (massive vs. branching), might provide an advantage to certain species to fight and overcome current challenges from pathogenic infections and/or environmental stressors.

53.6 PIRES DA SILVA, A*; CHAUDHURI, J.; KACHE, V.; BOSE, N; SCHROEDER, F; VON REUSS, S.; Univ. of Texas at Arlington, , Univ. of Texas at Arlington, Cornell University, Ithaca, Max Planck Institute for Chemical Ecology, Jena, Germany; *apires@uta.edu*

Evolution of selfing and the extension of lifespan

It has been difficult to determine the factors that affect life span in different genders because they are often genetically and morphologically different. We are studying a so far undescribed nematode that provides a useful model to study this question because it produces hermaphrodites and females that are genetically identical and have the same body size. Hermaphrodites differ from females by their ability to produce a limited amount of sperm that is used for self-fertilization. We found that the decision to become either female or hermaphrodite is plastic and environmentally determined, and that hermaphrodites live a third longer than females. A hypothesis for the evolution of different life span between genders is that females have a higher rate of extrinsic mortality caused by mating with males. We found that mating shortens life span of both females and hermaphrodites, and that the secretion of male attractants by females makes them more susceptible to extrinsic mortality. Older hermaphrodites that exhaust their self-sperm also produce sex pheromones, indicating that the longer lifespan of hermaphrodites is an adaptive trait.

75.3 PISCITELLI, M.A.*; LILLIE, M.A.; RAVERTY, S.A.; SHADWICK, R.E.; Univ. of British Columbia, Vancouver, British Columbia Ministry of Agriculture, Food, and Fisheries; *piscitellim@gmail.com*

A Comparative Study of Cetacean Respiratory Mechanics: Implications for diving and health assessment

The cetacean respiratory system has undergone diverse and highly specialized anatomical and mechanical adaptations to accommodate a strictly aquatic lifestyle. In contrast to terrestrial mammals, the cetacean respiratory system is adapted to operate on an inspiratory breath-hold. During a dive, air in the lungs is carefully managed to perform multiple, simultaneous functions, including gas exchange, buoyancy control, echolocation, vocalization and foraging. Because their respiratory system carries out multiple roles, respiratory diseases have the potential to greatly impact a cetacean's ability to thrive in the wild. *Cryptococcus gatti* , an endemic fungus to the Pacific Northwest has been the source of mortality in human, terrestrial and cetacean cases, and is a focus of diseased cases in this study. Excised lungs from 8 cetacean families were collected during necropsy. A multi-faceted approach was utilized to examine structural, biomechanical and pathological differences across species. Each lung was imaged in three inflated states using computed tomography followed by static pulmonary mechanics to generate pressure-volume curves. Across families, mass-specific total lung capacity (TLC) decreased with increased diving ability, and opening airway pressures increased with smaller alveolar diameters. Severe infections in diseased lungs decreased mass-specific TLC by up to 93%, increased lung mass four-fold, and decreased compliance. In conclusion, pulmonary mechanics is a useful tool in both understanding the normal physiology of diving mammals and in assessing the pathophysiology of stranded marine mammals.

P2.135 PITTS, NL*; MYKLES, DL; Colorado State University; *natalie.pitts@colorado.edu*

Examining the role of nitric oxide in the control of molting of the blackback land crab, Gecarcinus lateralis

Nitric oxide (NO) is a unique gaseous signaling molecule involved in variety of biological processes. NO is synthesized from L-arginine, oxygen, and NADPH by nitric oxide synthase (NOS). In decapod crustaceans, we hypothesize that NO modulates the secretion of a neuropeptide, molt-inhibiting hormone (MIH), from the X organ (XO) in the eyestalk ganglia (ESG). Release of MIH from the XO inhibits the synthesis of molting hormones (ecdysteroids) by a pair of Y organs (YOs) in the anterior cephalothorax. A model of MIH signaling involves NO. A reduction in MIH activates the YO, increasing secretion of ecdysteroids and initiating premolt. NOS is expressed in the YO and becomes phosphorylated in the activated YO, reducing the production of NO. NO donors and guanylyl cyclase agonist can inhibit YO ecdysteroidogenesis, suggesting that NO-dependent guanylyl cyclase is a downstream target of the MIH pathway. Eyestalk ablation of intermolt animals up regulates NOS expression in both YO and muscle. The purpose of this study is to determine the effects of molting on the expression of NOS in the YO and ESG. Molting is induced by multiple limb autonomy (MLA) and ESG and YOs are harvested at premolt and postmolt stages. NOS mRNA levels are quantified by Real Time PCR. Localization of NOS uses immunofluorescence. This is the first study to explore the expression of NOS in the ESG and YO over the molt cycle. Supported by NSF (IOS-0745224).

47.4 PLACE, S.P.; Univ. South Carolina; *places@mailbox.sc.edu*

Using functional genomics to characterize the physiological response of polar fishes to a multi-stressor scenario

Antarctic fishes of the suborder Notothenioidei have displayed incredibly narrow physiological limits in previous single stressor studies and may be particularly vulnerable to the impacts of global climate change. Given the propensity for both adaptive and potentially mal-adaptive traits found among many notothenioid species, this system provides a unique opportunity to examine physiological trade-offs associated with acclimation to a multi-stressor environment. Using both field and laboratory-based analyses, we have combined approaches from the fields of functional genomics and organismal physiology to examine how global climate change may impact species performance. Our previous data has shown the emerald notothen, *Trematomus bernacchii*, displays a rapid acclimatory response with respect to resting metabolic rates following exposure to elevated temperature or $p\mathrm{CO}_2$, and that these two stressors can act synergistically to further impact their physiological response. Here, we highlight the molecular mechanisms underlying the physiological response of *T. bernacchii* after long-term acclimation to elevated $p\mathrm{CO}_2$ and temperature. RNAseq analysis of mRNA levels in gill, liver and brain tissue from fish acclimated up to 28 days under the multi-stressor treatment revealed a tissue specific response in this notothenoid species. Prominent cellular pathways identified in the analyses include metabolic adjustments involving mobilization of lipid stores and a moderate up-regulation of genes involved in the classical cellular stress response. These transcriptome profiles give us insight into the physiological impacts of sub-lethal stress and may provide an indication of the costs associated with adapting to global climate change.

93.3 PLACE, NJ*; PARK, S-U; ZYSLING, DA; Cornell University; *njp27@cornell.edu*

Assessments of immuno- and inflamm-aging following a photoperiodic regime that delays female reproductive aging in Siberian hamsters

Aging and reproductive senescence are thoroughly intertwined, as evident by the ability of calorie restriction to both increase longevity and delay reproductive aging in a variety of animal models of aging. We have previously shown that exposure to short days (SD) between 3 and 9 months of age delayed reproductive aging in 12-month-old, female Siberian hamsters (*Phodopus sungorus*). Herein we report our initial assessments of somatic aging in male and female hamsters under the same photoperiodic conditions. Because hamsters held in SD decrease food intake and body mass, and also inhibit reproduction, we predicted that 6-months of SD would attenuate the age-associated changes in some biomarkers of somatic aging. We evaluated biomarkers of immuno- and inflamm-aging in hamsters that have been shown to be reliable indicators of aging in mice. The ratio of T-helper (CD4) to total T-cells (CD3) declined with age in hamsters held in long days (LD), as was previously demonstrated in mice. However, 12-month-old hamsters held in SD from 3 to 9 months of age had a CD4:CD3 ratio that was not significantly different than in age-matched hamsters held in LD. Thus, this measure of immuno-aging was not modulated by the previous exposure to SD. Ongoing research is now determining if age-associated changes in pro- and anti-inflammatory cytokines (e.g., interleukin-6 and -10, respectively) occur in Siberian hamsters held in LD, and if 6 months of SD delayed the transition to a pro-inflammatory state in 12-month-old hamsters. The outcomes of these investigations will help determine if the physiological and behavioral changes associated with decreasing photoperiod modulate somatic aging, or if the benefits of SD are limited to a deceleration of reproductive aging in female hamsters.

S10-1.4 PLACHETZKI, D/C; UC Davis; *plachetzki@ucdavis.edu*
The control of cnidocyte discharge by light
Cnidocytes facilitate both sensory and secretory functions among cnidarians and have been heralded as the most complex animal cell type. Cnidocyte discharge is known to integrate both chemical and mechanical cues from the environment, but, despite more than a century of work aimed at understanding the sensory biology of cnidocytes, the specific sensory receptor genes that regulate their function have remained unknown. Here, in studies of the freshwater hydrozoan *Hydra magnipapillata*, we show that light constitutes another environmental cue that regulates cnidocyte function and that this property is driven by an opsin-mediated phototransduction cascade. We report that several components of the ciliary phototransduction cascade, including opsin, arrestin and cyclic nucleotide-gated (CNG) ion channel are specifically expressed in a previously described sensory-motor neuronal cell type that enervates components of the hydrozoan battery complex, including cnidocytes and ganglion cells. Next, we describe behavioral data from cnidocyte discharge experiments that were conducted under different light conditions. Our results show that a significant attenuation of cnidocyte discharge is induced by bright light, and that this behavior is ablated when experiments are conducted in the presence of a CNG ion channel inhibitor. Our findings suggest a new, likely ancestral, role for phototransduction in the coordination of cnidocyte discharge amongst cnidarian taxa. The implications of these and other recent findings for our understanding of the sensory attributes of the hydrozoan battery complex are discussed.

96.4 PODOLSKY, R.D.; College of Charleston; *podolskyr@cofc.edu*
Plasticity of egg mass architecture: effects of spatial oxygen gradients on the density and distribution of embryos
The grouping of encapsulated embryos in dense clutches can impose several physical challenges on early development. For example, oxygen delivery to embryos can be limited by diffusion, creating a spatial gradient of increasing hypoxia from peripheral to central positions within a clutch. Such limitations are thought to constrain the thickness of egg masses and could alter other aspects of egg mass architecture related to the density or positioning of embryos. The balloon shaped egg masses of *Melanochlamys diomedea*, an opisthobranch mollusc that oviposits on the surface of tidal flats, have embryos distributed throughout a gel matrix. This architecture allows for fine-scale analysis of changes in embryo positioning in response to environmental conditions. I examined whether the radial distribution of embryos changes in parallel with the radial gradient of hypoxia, predicting that embryo densities would be lowest toward the center of masses. I also manipulated oxygenation levels experienced by adults to determine whether they effect plastic changes in the density or positioning of embryos in their masses. As predicted, embryo density declined toward the center of egg masses and decreased as an inverse function of adult oxygenation. Contrary to expectations, adult oxygenation levels did not generally alter the slope of embryo density as a function of radial position. These results suggest that adults tend to position their embryos away from more hypoxic positions but respond to changes in ambient oxygen by altering overall densities rather than the steepness of density gradients. Prior work found that in some populations, egg mass architecture is altered by changing the number of embryos packaged per capsule, but multi-embryo encapsulation was not apparent in the population used in this study.

P3.38 POLICH, R/P*; SEARCY, C/A; SHAFFER, H/B; Iowa State University, University of California, Davis , University of California, Los Angeles; *rlpolich@iastate.edu*
The effects of tail clipping on larval Ambystoma californiense
The California tiger salamander (*Ambystoma californiense*, CTS) is a salamander native to central and coastal California. This salamander faces many threats to its survival, including habitat loss and hybridization with barred tiger salamanders from Texas (*Ambystoma tigrinium mavortium*). As a result, CTS is listed as endangered by the U.S. Fish and Wildlife Service. Numerous laboratories study CTS genetics to gain a better understanding of this threatened species, which requires that tissue samples be collected from the tails of larval CTS. Because the CTS is federally protected, there are regulations in place for CTS tail clipping: researchers are only allowed to remove 5mm of tail from individuals over 50mm in length. However, these regulations are not based on prior research and the impact of tail clipping on CTS survivorship is unknown. To rectify this, we experimentally examined if tail clipping affects larval CTS snout-vent-length, mass, or survivorship. We studied these effects by removing the tails of 160 larval CTS to different lengths: a small clip (5mm), a medium clip (10mm), and a large clip (15mm). We then raised the larva in 10 cattle tanks with four representatives from each treatment group until just before metamorphosis, at which point we measured individuals. We expected that increased tail clipping would negatively impact the salamanders; however, we found that there was no difference between larva that had been tail clipped and the control group for any variable measured. We attribute our results to the regenerative abilities of the salamanders and their ability to effectively swim even with a portion of the tail missing.

116.3 POMPONI, S.A.*; JEVITT, A; PATEL, J; Florida Atlantic University, Fort Pierce, Florida State University, Tallahassee; *spomponi@hboi.fau.edu*
Sponge Hybridomas: Applications and Implications
Many sponge-derived natural products with human health applications have been discovered over the past three decades. *In vitro* production has been proposed as one biological alternative to ensure adequate supply of marine natural products for preclinical and clinical drug development. Although primary cell cultures have been established for many marine invertebrate phyla, no cell lines with an extended life span have been established for marine invertebrates. For human health applications, hybridoma technology is used for production of monoclonal antibodies. We hypothesized that a sponge cell line could be formed by fusing sponge cells of one species with those of another, or by fusing sponge cells with rapidly dividing, marine-derived, non-sponge cells. Using standard methods for formation of hybridomas (i.e., incubation with polyethylene glycol), with appropriate modifications for temperature and salinity, cells from individuals of the same sponge species, as well as cells from individuals of two different sponge species, were successfully fused. Although other research has demonstrated that sponges are capable of cellular immune responses, our experiments demonstrate that no rejection occurred between the sponge species we tested. We conclude that either rejection responses are species-specific or the fusion technique suppressed cellular immune responses. Research in progress is focused on optimizing fusion to produce a cell line and to stimulate production of natural products. Hybridomas may also be used to stimulate production of novel natural products, as well as an experimental platform to test questions related to sponge chimeras in nature.

P2.216 POPKIN-HALL, ZR*; BOYER, SL; Macalester College; *zpopkinh@macalester.edu*

New species of mite harvestmen from Southeast Queensland, Australia greatly extend the known distribution of the genus Austropurcellia (Arachnida, Opiliones, Cyphophthalmi)

Cyphophthalmi, commonly known as mite harvestmen, are a globally-distributed lineage of small arachnids that inhabit leaf-litter habitats. Austropurcellia Juberthie 1988 is a genus of mite harvestmen known from numerous localities in the Wet Tropics and now a few localities in Southern Queensland, Australia. We describe three new species of Austropurcellia (A. acuta, A. barbata, A. superba) from museum lots; each new species is known from only a single collection and few specimens. We present a new distribution map of the genus, greatly expanding its known range to almost the entire east coast of Queensland and discuss the importance of the Burdekin Gap (Kikkawa & Pearse 1979) in its current distribution. We have begun to understand the biogeography and morphological variation of mite harvestmen in Queensland, but that understanding would be greatly augmented with the addition of genetic data and additional sampling in southeastern Australia, extending throughout Queensland but also into New South Wales.

61.3 PORRO, L.B.*; IRIARTE-DIAZ, J.; O'REILLY, J.; ROSS, C.F.; University of Chicago, IL; *lbporro@gmail.com*

In vivo cranial bone strain during feeding in the agamid Uromastyx geyri

Due to its specialized skull and dental morphology, the herbivorous lizard *Uromastyx* has been the subject of numerous feeding studies. Previous research has collected data on cranial, mandibular and tongue kinematics, jaw and tongue muscle activity, and bite force generated under stimulation. Additionally, the computer modeling techniques of multibody dynamics analysis and finite element analysis have been applied to the skull of *Uromastyx*, allowing researchers to test hypotheses regarding the link between bone/suture morphology and mechanical behavior. To date, no data have been collected on bone strain in the skull of any herbivorous lizard, including *Uromastyx*. Bone strain data provide the most direct evidence of deformation, stress, and strain regimes in the skull under loads. We collected *in vivo* bone strain data from the crania of three *Uromastyx geyri* (along with simultaneously recorded electromyographic, videofluoroscopic and bite force data) during feeding on a variety of foods and while exhibiting different feeding behaviors (capture, chew, swallow, etc.). Analysis of principal and shear strains over 1300 individual gape cycles reveal that principal strain orientations vary little between individual animals, or with changes in food type and bite point; instead, variability in both principal strain orientations and magnitudes is primarily determined by feeding behavior. Furthermore, cranial bone strain magnitudes recorded in *Uromastyx* during feeding are substantially higher than those recorded in mammalian crania. These results shed new understanding on cranial biomechanics in *Uromastyx* during feeding and will be used to validate and improve the accuracy of previous computer models.

130.1 PORTER, ME*; DIAZ, C; LONG, JH; Vassar College, University of Akron; *meporter@vassar.edu*

Extracellular matrix dominates the mechanical properties of shark vertebral columns in bending

In contrast to the acellular bone in fishes, cells are present in the calcified cartilage of the skeletons of sharks. In the vertebral column (VC), chondrocytes are arrayed in the centra and fibroblasts are present in the intervertebral ligaments. These cells build the surrounding extracellar matrix (ECM). We hypothesized that these cells also structurally contribute to the mechanical properties of the VC. To test this hypothesis, we lysed cells by freezing the tissues. We compared mechanical properties in dynamic bending before and after by freezing from phylogenetically distant, conspecific, shark species, *Squalus acanthias* and *Mustelus canis*. We hypothesized the mechanical properties of the fluid-filled intervertebral joints will be impacted by cell lyses resulting in an overall change in the vertebral column properties. We used a customized rig on dynamic testing machine (MTS Tytron 250) to translate single axis movement into bending. In an environmental chamber filled with Elasmobranch ringers, we tested fresh segments of ten centra over a range of frequencies and curvatures, similar to those experienced by these species during swimming. Segments were frozen at -18ºC for six months, defrosted to room temperature (22ºC) under hydration and tested over the same range of curvatures and frequencies. We found that freezing the specimen does reduce both work, W (J), and structural stiffness, K (Nm-1), of frozen vertebral columns. This work was supported by NSF IOS-0922605.

S10-1.6 PORTER, M.L..*; CALDWELL, R.L.; OAKLEY, T.H.; CRONIN, T.W.; University of South Dakota, University of California, Berkeley, University of California, Santa Barbara, University of Maryland Baltimore County; *Megan.Porter@usd.edu*

Transcriptomics and the evolution of stomatopod visual systems

Stomatopod crustaceans have complex and diverse visual systems, containing unique features that exist in no other animals. These features include a specialized ommatidial region, intrarhabdomal filtering of photoreceptors, and receptors devoted to polarized light detection. The most complex stomatopod eye type contains 16 physiologically different photoreceptor classes, although there is variation in eye complexity among species. In order to investigate this visual system diversity and complexity at the molecular level, transcriptomes have been sequenced from 4 species exhibiting variations in eye design. Transcripts from genes involved in visual signal transduction were identified from assembled transcriptomes using sequences of full-length genes from the *Drosophila melanogaster* genome as queries. The stomatopod species investigated vary in the number of arthropod visual-pigment (R-Type) opsin genes expressed from 12 (*Hemisquilla californiensis*) to 25 (*Neogonodactylus oerstedii*). Based on these results we hypothesize that the diversity of opsin genes expressed has increased during the evolution of the group, with the largest expansion of copy number occurring in the short-wavelength sensitive opsin classes. In all four species sequenced (*H. californiensis*, *N. oerstedii*, *Squilla empusa*, and *Pseudosquilla ciliata*) more opsin genes are expressed than physiologically documented photoreceptors present in the visual system; preliminary *in situ* hybridization work in *N. oerstedii* shows that many photoreceptor types express multiple opsin genes. Additionally, there is variation among species in the number of expressed transcripts of other key cascade components, including G-proteins and visual arrestins, suggesting further complexity in visual signal transduction.

20.2 PORTUGAL, S*; HUBEL, T; FRITZ, J; WILSON, A; USHERWOOD, J; ROYAL VETERINARY COLLEGE, UNIVERSITY OF LONDON, UK, ROYAL VETERINARY COLLEGE, WALDRAPPTEAM, AUSTRIA; *sportugal@rvc.ac.uk*
The aerodynamics of flapping V formation flight
The characteristic 'V' formation flight of birds has fascinated scientists for centuries. One of the main theories that has persisted to explain this distinctive V-formation is that birds are attempting to conserve energy by taking advantage of the upwash vortex fields created by the wings of the other birds within the flock. A fixed wing aerodynamic theory has traditionally been applied to understand V-formation flocking in birds, very much unlike that of the actual scenario of a flapping bird and wing. Previously, little consideration, either theoretically or empirically, has been possible concerning the effects of flapping on V-formation aerodynamics. Recent technological advances have now made it possible to explore factors of V-formation flapping flight for extended periods of time, in free-flying birds. Using high-frequency sampling GPS and accelerometer units, we will present data from two migratory flights of the critically endangered Waldrapp Ibis. This opportunity was made possible by human-led migrations taking place as part of a reintroduction scheme, whereby imprinted young ibis are taught to follow a microlight. These data allow us to investigate aspects of V-formation flocking previously not possible, in particular the temporal and spatial wing-beat phasing of flock members during flapping V-formation flight. Furthermore, it is possible to examine height differences between individual flock members, a feature predicted by aerodynamic theory but previously impossible to test in free-flying birds.

84.6 POTTER, K. A.*; PINCEBOURDE, S.; WOODS, H. A.; University of Montana, Université François Rabelais; *kristen.potter@mso.umt.edu*
Microclimatic research priorities for predicting the effects of climate change
Considerable effort now focuses on predicting how species will respond to climate change. Nonetheless, statistical models that predict species' distributions remain difficult to generalize, both from one species to another and into novel sets of environmental conditions. One reason is the conceptual difficulty of connecting macro and micro scales: there is an enormous gap between the spatial and temporal scales at which biologists analyze landscapes and the scales at which organisms live. Most organisms are small enough that they live in microclimates, which can be highly heterogeneous in space and time, and often quite different than surrounding macroclimates. To resolve the spatial and temporal mismatches between models versus organisms, we advocate: 1) gathering better microclimate data using automated devices, 2) developing better mechanistic models for downscaling coarse environmental data, and 3) improving our statistical understanding of variation at the finest scales. We will discuss why these approaches should be high priorities for future work, and how they will increase our ability to predict the biological effects of climate change.

41.4 POTVIN, J*; REYES, P; MCQUILLING, M; GOLDBOGEN, J A; SHADWICK, R E; Saint Louis University, Cascadia Research Collective, Univ. of British Columbia; *potvinj@slu.edu*
Rorqual whale hydrodynamics and body drag during non-feeding transport, as revealed by Computational Fluid Dynamics (CFD)
Rorqual whales (Balaenopteridae) represent a group of marine mammals that include the largest vertebrates to have ever lived and thus to have necessitated the highest absolute energy requirements. Recent hydrodynamic modeling (Goldbogen et al 2012 Func. Ecol.; Potvin et al. 2012 PLoS One; Weidenmann et al 2011 Ecol. Model.) has shown how these are met, thanks to high body streamlining and efficient hunting (lunge feeding). The obvious impossibility of studying the energetics of large whales in laboratory settings makes computer modeling the only tool available for assessing the factors driving the costs of both feeding and non-feeding transport. A crucial input for non-feeding travel, diving and prey-approach simulation is the drag coefficient of the body, which for rorquals can be meaningfully defined (i.e. as decoupled from thrust), with their propulsion originating from the oscillatory motion of short chord-length appendages located aft of the body (the flukes). So far rorqual drag has been estimated from a flat plate-based approach dating from the 1930's (Gray 1936 J. Exp. Biol.). This is revisited here in terms of the more modern approach of CFD, with a presentation of preliminary drag calculations obtained from simulations performed about realistic body shapes representative of the genus balaenoptera, and over the body length and morphology spectrum characteristic of fin whales (B. physalus). Other issues to be discussed include (digital) model construction and manipulation, boundary layer modeling and sensitivity on body shape details (including tail flexion).

40.5 POTVIN, J*; GOLDBOGEN, J A; SHADWICK, R E; PYENSON, N D; Saint Louis University, Cascadia Research Collective, Univ. of British Columbia, Smithsonian Institution; *potvinj@slu.edu*
Fish versus krill — Comparing the energetic costs of engulfment by rorqual whales lunge-feeding on slow and fast prey
Lunge feeding is a strategy employed by rorquals (Balaenopteridae) to catch schooling krill or (small) fish in bulk, via the engulfment of the water in which the prey is embedded. Recent modeling informed with kinematic and morphological data (Goldbogen et al 2012 Func Ecol; Potvin et al. 2012 PLoS One) indicate that lunge feeding on krill comes at high costs, largely incurred from quickly setting into motion a very high mass of water. Particularly with regards to the expended metabolic power, such costs are high enough at large body lengths to impose a physical limit on the largest size attainable by these whales. Whether the same mandible kinematics (mouth opening rates and maximum gape), body-water dynamics and body size limit involved in krill-feeding apply to the engulfment of fish has never been assessed. Here we show via modeling that, due to the significantly higher escape speeds of the prey, such extrapolation involves unrealistically high metabolic outputs, as well as mouth opening rates that are much higher than measured by tags deployed on humpback whales (horizontally lunging towards fish). On the other hand, fish-engulfment costs become smaller and more realistic, i.e. similar or lower than the highest active metabolic output of any terrestrial mammals (mass-specific), if engulfment is modified by resorting to smaller maximal gapes (i.e., 50 rather than 80deg) and by keeping the mouth opened over longer durations (i.e., 2-3 time longer than for krill-feeding). Also, applying such revised lunging kinematics over the body size spectrum of humpback and fin whales shows costs decreasing with the smaller bodies and trending to levels characteristic of krill-feeding.

144.2 POWDER, KE*; ALBERTSON, RC; Univ Massachusetts;
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A novel transcriptional regulator, lbh, regulates cranial neural crest development and craniofacial evolution in East African cichlids

East African cichlids exhibit a rapid and extensive adaptive radiation. One major axis of their divergence is trophic specialization, which is reflected in their craniofacial skeleton. We previously identified a quantitative trait locus (QTL) that contributes to the mechanical advantage of closing the lower jaw (i.e. a functional tradeoff of force versus speed). This region includes the genes *bone morphogenetic protein 4 (bmp4)*, expression of which is associated with more robust cichlid jaws and avian beaks, and *limb bud and heart homolog (lbh)*, a poorly characterized transcriptional regulator. In order to further characterize this linkage, we re-sequenced the region in wild-caught cichlid populations. We identified two single nucleotide polymorphisms (SNPs) that are alternatively fixed in cichlids with differing feeding strategies and jaw morphologies. The first is located in a putative craniofacial enhancer for *bmp4*, and may mediate different expression levels of *bmp4* previously identified in cichlids with differing jaw morphologies. The other alternately fixed SNP encodes a non-synonymous change in the largely unknown gene *lbh* that alters protein polarity. We observed *lbh* expression in cranial neural crest (CNC) cells, which give rise to the facial skeleton. Knock-down of Lbh in zebrafish results in aberrant CNC development and discrete facial defects including a severe reduction of the lower jaw precursor. These data suggest that the linked genes *bmp4* and *lbh* may both contribute craniofacial evolution in cichlids, and offer *lbh* as a molecular inroad into the developmental processes that mediate this process.

13.6 POWELL, M/L*; D'ABRAMO, L/R; WATTS, S/A; The Univ. of Alabama at Birmingham, Mississippi State Univ.;
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Effects of Dietary n6 and n3 Fatty Acids on Zebrafish Total Body Composition

In 2003, the WHO identified diet and lifestyle as contributing factors to the growing epidemic of metabolic disease. High fat diets are often cited as a major contributing factor in the progression of these diseases; however, some fats may play a crucial role in reducing the incidences and/or severity of these diseases. In humans, n3 fatty acid components of lipids may slow the progression of some diseases, and conjugated n6 fatty acid components have been shown to increase lean body mass in mice. To achieve maximum health benefits of these fatty acids, an ideal dietary ratio of n6/n3 fatty acids has been suggested. Mice are used extensively to study aspects of human diet and corresponding disease, but zebrafish can serve as an effective, high throughput vertebrate model to study effects of diet on development and progression of many diseases. Using the first open formulation zebrafish diet, recently released by our lab for research applications, we incorporated known quantities of specific lipids for evaluation of weight gain and lipid content. Juvenile zebrafish (28 dpf) were fed identical isocaloric diets that differed only in the ratio of n6/n3 fatty acids (15/1, 3/1, 1/1) for 5 months. The final wet weight of fish fed the 15/1 (n6/n3) diet was significantly greater than that of fish fed the 1/1(n6/n3) diet. However, total percent lipid of female fish fed the 15/1(n6/n3) was significantly lower than that of female fish fed the 1/1(n6/n3) diet. These data suggest that zebrafish exhibit similar trends in body composition in response to dietary lipids as those reported for other vertebrate models and can be used as a model to further investigate the health benefits of these fatty acids. UAB NORC grant (P30DK056336).

20.1 POWERS, D.R.*; TOBALSKE, B.W.; George Fox University, Newberg, OR, University of Montana, Missoula, MT;
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Metabolic Power, Mechanical Efficiency, and Heat Production during Hovering and Forward Flight in Calliope Hummingbirds (Selasphorus calliope)

Flight requires higher power output than other forms of animal locomotion, and the effects flight speed upon power have important implications for the ecology and evolution of different flight styles. We studied the conversion efficiency of metabolic power (MBP) produced during hovering and forward flight in calliope hummingbirds (*Selasphorus calliope*; ~2.5 g) to mechanical power (MEP) production by the pectoralis muscle. Measurements were made in a wind tunnel at speeds ranging from 0-12 m/s. To determine MBP we measured oxygen consumption using negative-pressure, open-flow respirometry. To measure MEP we used stereo particle image velocimetry (PIV). We sampled the wake along planar, parasagittal transects separated by 1 cm, then integrated velocity with respect to area to obtain total kinetic energy flux within one wingbeat. Because mechanical efficiency (MEF) is low we accounted for the balance of MBP, most of which is released as heat, using infrared thermography to calculate heat dissipation from the general body surfaces. MBP exhibited a typical U-shaped curve. MEF for hovering and 10 m/s was ~8%, similar to previously reported values. MEF at 2-8 m/s was only ~4%, this might be an underestimate arising from the complexity of the aerodynamic wake at intermediate flight speeds. Heat dissipation exhibits strong negative correlation with wind speed (R2 range 0.75-0.93) but does not correlate with calculated MEF further highlighting that our estimates of efficiency at intermediate speeds might be underestimated. Funded by NSF IOS-0923606 & IOS-0919799, NASA 10-BIOCLIM10-0094, the Richter Scholar Program (GFU), and FLIR Systems, Inc.

P3.219 POWERS, S.D.*; POWERS, D.R.; LANGLAND, K.M.; FRIESEN, C.R.; MASON, R.T.; George Fox University, Newberg, OR, Oregon State University, Corvallis, OR;
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The Importance of Female Temperature in the Attraction of Courting Males in Red-Sided Garter Snakes (Thamnophis sirtalis parietalis)

The red-sided garter snake (*Thamnophis sirtalis parietalis*) is a well-studied system where females upon emergence from hibernation produce a pheromone found in their skin lipids that indicates their reproductive state. When females emerge from hibernation they typically have low body temperature (T_b) and it is believed that "cold" females are more attractive to courting males. The goal of this study was to determine if T_b plays a role in female attractiveness. We collected virgin (VF) and nonvirgin (NVF) female snakes from a den site in Manitoba, Canada. All females were cooled to ~8°C and individually placed in a courtship arena with 50 male snakes. During the trials we recorded courtship activity and surface temperature (T_s) for both females and males. Courtship and T_s measurement were made using infrared video recordings. All VFs (n = 8) were courted while all NVFs were not (n = 9). We found a positive and significant relationship between T_s and time from start of the trial with both VF (n = 5, F = 74.3, P<0.001) and NVF (n = 5, F = 260.6, P<0.001). Warming rates for NVFs (slope = 1.22) relative to the VFs (slope = 0.64) was significantly greater (F = 18.34, P<0.001) perhaps due to NVFs having more freedom to thermoregulate. Regardless both VFs and NVFs stabilized at T_s~30 °C in 10-15 min. Our data suggest T_s would only serve as an indicator of den emergence for a short time period and does not impact long-term attractiveness of VFs.

146.5 PRADHAN, DS*; SOLOMON-LANE, TK; WILLIS, MC; GROBER, MS; Georgia State Univ.; *dpradhan1@student.gsu.edu*

Rapid neurosteroidal regulation of paternal care

In vertebrates, shifts in profiles of circulating steroid hormones are critical for reproductive success because they regulate fundamental aspects of reproductive life-history/phenotype. Analyses of region-specific expression and activity of steroidogenic enzymes in the brain have confirmed both the presence of locally regulated steroidal signaling and the importance of neurosteroids for regulating behavior. Thus, rapid control of sex-specific reproductive behavior is likely driven by neural rather than gonadal hormones. Here, we demonstrate neuroendocrine regulation of paternal care in a highly social, polygamous marine fish, the bluebanded goby (*Lythrypnus dalli*), by *in vivo* neurochemical manipulation of males in social groups. Parenting was perturbed by modulation of local levels of steroids in the brain via intracerebroventricular injection of a critical enzyme blocker that elevates stress hormones and decreases androgens. Males treated with the drug took longer to enter their nest and had dramatically reduced egg care bouts. Social behaviors, such as agonistic interactions and courtship, remained unaffected. To determine which pathway was involved in inhibiting parenting in our manipulation, we tested two alternate hypotheses. We did not observe a significant reduction in parenting after injection of the glucocorticoid, cortisol. Injection of 11-ketotestosterone, an androgenic product of enzyme synthesis, along with the enzyme inhibitor reversed the negative effects on parenting. Our results show that brain-derived hormones are sufficient to regulate a crucial reproductive behavior, brain androgens directly regulate parenting behavior, and the speed of behavioral effects are consistent with non-genomic mechanisms.

81.2 PRAVIN, S*; KOEHL, MAR; REIDENBACH, MA; University of Virginia, Charlottesville, University of California, Berkeley; *sp8yh@virginia.edu*

Simultaneous sampling of flow and odorants in a turbulent plume can aid tracking behavior by aquatic organisms

Odors are dispersed across aquatic habitats by turbulent water flow as filamentous, intermittent plumes. Many crustaceans take discrete samples of odors by flicking their olfactory antennules. These antennules, in addition to containing chemo-sensors, also contain mechano-sensors that can detect water motion in the surrounding fluid. We examined correlations between fluctuating odorant concentrations and turbulent flow that can provide cues for plume tracking. Laboratory flume experiments utilized a combined planar laser-induced fluorescence (PLIF) and particle image velocimetry (PIV) system to simultaneously measure the flow and odorant concentrations within a turbulent plume. In addition, a numerical model of an odorant release within a boundary layer flow was constructed to simulate the impact of bed geometry and ambient velocity on odorant transport. Results from the laboratory experiments show correlations between high energy eddies and odorants that are actively being stirred, while numerical simulations show that these correlations between flow and odorants change in systematic ways with distance from the source. Detection and use of these correlations by aquatic organisms may enhance tracking efficiency above detection of odorant concentrations or flow alone.

67.2 PRICE, S. A.*; SCHMITZ, L.; ANDERSON, P.S.L.; BOETTIGER, C. L.; WAINWRIGHT, P. C.; University of California, Davis, Keck Science Department, Claremont McKenna, Pitzer and Scripps College,, University of Massachusetts, Amherst,; *saprice@ucdavis.edu*

Comparing disparity between traits using the Ornstein-Uhlenbeck model: a test of functional constraint on the eyes of labrids

On a macroevolutionary scale the comparison of rates of phenotypic evolution between traits within a clade is useful for answering questions about niche conservatism, natural versus sexual selection as well as functional constraints. However, such comparisons present several challenges including the use of comparable standardized units and incorporating differences in phylogenetic signal. Using simulations we illustrate how disparity measured using the Brownian motion rate parameter estimated on an untransformed phylogeny can be confounded by phylogenetic signal. Rates are inflated when phylogenetic signal is weak, as the phylogeny overestimates the covariance among species. As a possible solution we show that calculating disparity using the variance estimated from the Ornstein-Uhlenbeck model can account for differences in phylogenetic signal. With this method we test the hypothesis that the eyes of labrids, a diverse group of reef fish, exhibit less disparity than the fins, teeth and jaws and find that the disparity within the two eye traits is substantially lower. We suggest that this result is due to functional constraints as most potential morphological changes to a fishes eye will ultimately lead to the projection of an under-focused image onto the retina causing loss of function.

P3.21 PRICE, BC*; SHELTON, DS; MARTINS, EP; North Carolina State University, Indiana University-Bloomington; *delsshel@indiana.edu*

Group Size Dependent Cohesion of Zebrafish (Danio rerio) in the Presence of Disturbances

Group cohesion may vary because of different social structures (e.g., dominance hierarchies), responses to environmental factors (e.g., physical barriers, turbulence), or due to the immediate perception of risk (e.g., antipredator vigilance following a disturbance). Here, we tested the relative importance of these three features by measuring the distance between individual zebrafish (*Danio rerio*) in different group sizes, after varying the water current velocities, and manipulating time since disturbance. Across all conditions, we found that groups of four fish were significantly more dispersed than groups of eight fish. These results suggest that social context has a largest and most consistent impact on the spacing of group members. Water flow rates and time after a disruptive event had an important, but less consistent influence on group cohesion. The specific social dynamics that modulate group cohesion in zebrafish, such as spatial alignment, group centrality, aggression, and activity levels are discussed. An investigation of these group and individual characteristics may lead to a better understanding of the behavioral mechanisms that modulate group size dependent spatial distribution of zebrafish.

98.6 PRICE, E. R.*; BRUN, A.; FASULO, V.; KARASOV, W. H.; CAVIEDES-VIDAL, E.; University of Wisconsin-Madison, Universidad Nacional de San Luis; *eprice2@wisc.edu*

Paracellular absorption of nutrients in bats is high during intestinal luminal perfusions

Water-soluble nutrients can be absorbed across enterocytes via protein-mediated transport, or paracellularly through the tight junctions between enterocytes. Previous in vivo measurements of bats that were orally dosed with carbohydrate probes have shown that bats absorb larger proportions of nutrients paracellularly than similarly-sized non-flying mammals. While this could indicate greater paracellular permeability of the intestinal epithelium, it could also be caused by longer retention time or slow gastric evacuation. We sought to determine if bat intestines are particularly permeable to nutrient-sized molecules. We performed in situ intestinal luminal perfusions on *Tadarida brasiliensis* and *Myotis lucifugus*. We cannulated the intestine and recirculated an isosmotic buffer containing 10-75 mM D-glucose, 10-75 mM proline, and two carbohydrate probes that are only absorbed paracellularly, 1 mM L-arabinose, and 1 mM lactulose, and radioisotope tracers for these molecules. Absorption of arabinose (MW 150) was nearly double that of lactulose (MW 342), demonstrating a similar molecular size sieving effect as has been seen previously for various species in vivo. At low molarity proline conditions, paracellular absorption (assessed by arabinose clearance) can account for at least 44% of total proline absorption. At 75 mM proline, paracellular absorption accounts for a majority of proline absorption. These data demonstrate that insectivorous bats rely heavily on paracellular absorption for the uptake of nutrients and confirms the high intestinal permeability suggested by whole-animal studies. Supported by NSF Award 1025886.

P2.42 PRONKO, AJ*; PERLMAN, BM; ASHLEY-ROSS, MA; Wake Forest University; *pronaj9@wfu.edu*

Going out for a bite: how the mangrove rivulus Kryptolebias marmoratus leaves the water to capture terrestrial prey

Mangrove rivulus (*Kryptolebias marmoratus*) is a small fusiform teleost (Cyprinodontiformes) with the ability to locomote on land, leaving their aquatic habitat for moist, terrestrial environments when water conditions are poor, or, as we show here, to capture terrestrial insects. We quantified kinematics of the water-land transition for this seemingly ordinary fish, selecting five specimens from a single population. Fish were individually housed in 2.5 gallon tanks with 25 ppt salinity. Tanks were temperature controlled at 25˚C, with a 12 hour photoperiod. The specimens were conditioned to eat pinhead crickets on one side of their tanks. After two weeks of conditioning, a barrier with an ecologically relevant slope of 15˚ was partially submerged in the middle of each tank, forcing the fish to transition from water to land and back in order to feed. Kinematics during the transition were recorded using Fastec high speed video cameras (125-250 fps). Videos were then analyzed using Didge and ImageJ software programs. Transition behaviors were characterized and analyzed according to their specific type. Body wavelength, amplitude, and frequency were quantified for movements along the substrate, along with initial jump velocity for launching behaviors. *K. marmoratus* use a diverse suite of behaviors to transition from water to land. These behaviors can be categorized as jumps, pounces, and squiggles. Prey are captured terrestrially and brought underwater for consumption. *K. marmoratus*'s suite of behaviors represents a novel solution to non-tetrapodal terrestrial locomotion, which suggests that fishes may have been able to transiently exploit land habitats earlier than the Late Devonian proto-tetrapods.

S10-2.1 PROTAS, M. E.*; TRONTELJ, P.; PATEL, N. H.; Univ. of California, San Francisco, University of Ljubljana, Univ. of California, Berkeley; *ProtasM@vision.ucsf.edu*

Multiple mechanisms of eye reduction within a single population of the cave crustacean, Asellus aquaticus

Cave animals are an amazing group of organisms. Cave dwelling animals can have the following characteristics: reduced eyes, reduced pigmentation, longer life span, decreased metabolic rate, elongated appendages, and enhanced sensory systems. These characteristics can be found in animals as diverse as salamanders, fish, spiders and crustaceans. We investigated the genetic basis of morphological evolution in a particular cave animal, an isopod crustacean, *Asellus aquaticus*. There are both surface and cave forms of *A. aquaticus* that are able to interbreed and produce fertile offspring. We brought these animals to the lab and ultimately set up backcrosses between the cave and surface forms. We generated genetic markers, a subset associated with candidate genes involved in eye, pigment, and appendage development, and genotyped the backcrosses for these markers generating a linkage map. We mapped several regions of the genome responsible for eye size and eye pigmentation traits and found multiple mechanisms responsible for both eye and pigment regression within a single cave population.

32.2 PROVINI, P*; BIEWENER, A A; ABOURACHID, A; Muséum National d'Histoire Naturelle, Paris, Department of Organismic and Evolutionary Biology, Concord Field Station, Harvard University, Cambridge; *provini@mnhn.fr*

The 3D kinematics of the trunk and hindlimbs during take-off and landing in zebra finch (Taeniopygia guttata)

Take-off and landing are crucial components of avian flight but the mechanical aspects of these phases are not well-understood. A previous analysis on the relative contributions of the wings and legs during these two phases has demonstrated the prominent role of the hindlimbs in the propulsion during take-off and deceleration during landing. Moreover, the importance of trunk 3D motion control during differing locomotor behaviors in birds has encouraged us to undertake a kinematic analysis not only of the legs, but also of the trunk during take-off and landing. For that purpose, we used X-ray methods (XROMM) to reconstruct the 3D kinematics of the trunk and the hindlimbs, in zebra finch (*Taeniopygia guttata*). Our data revealed the existence of two phases in both motions: a rapid phase corresponding to parasagittal and linear motions of the trunk and the femur, and a slower phase corresponding to relatively complex motions of the trunk, with pitching motions in a parasagittal plane. Moreover, during the propulsion associated with take-off, and the energy absorbed during landing, distal parts of the legs seem to play the role of a spring-damper unit, with a high extension or flexion at the ankle and knee, respectively. This kinematic analysis highlights the fundamental role of the hindlimbs and the femur/trunk association during take-off and landing. Our results also demonstrate the existence of different functional modules within the bird's skeletal system during these two phases of flight.

P1.9 PRUETT, JA*; VITAL, C; ZÚÑIGA-VEGA , JJ; MARTINS, EP; HEWS, DK; Indiana State University, Terre Haute, USA, Universidad Autónoma de Ciudad Juarez, México, Faculdad de Ciencias,Universidad Nacional Autónoma de México, Indiana University, Bloomington, USA, Inidana State University, Terre Haute, USA; *jpruett1@sycamores.indstate.edu*

Behavioral responses to conspecific chemicals of two Sceloporus species differing in signaling morphology

Lizards communicate through a variety of signal modalities that involve motion, display of color patches, and pheromones. Trade-offs among signal modalities along with variation in trait lability can affect evolution of multimodal signals. Previous work with *Sceloporus* suggests that a species without color patches (white) is more responsive to chemical cues than a species with patches (blue). Here, we further investigate how the loss of blue coloration might have influenced the evolution of chemical signaling in *Sceloporus*. We predicted that behavioral responses to chemical cues of conspecific males would be stronger in *S. siniferus* (white) than in *S. merriami* (blue). We presented swabs with chemical cues and clean swabs (control) to male lizards in the field and recorded chemosensory behaviors, aggressive displays and movement. Male *siniferus* performed more visual displays overall than *merriami*, however, exposure to male cues decreased visual display rates in both species. Rates of chemosensory behaviors overall were low for both species, but *merriami* tended to exhibit more (tongue flick, chin wipe). Exposure to male cues reduced the distance and frequency of movements by *siniferus* but not in *merriami*. These data and our other *Sceloporus* studies suggest that male *merriami* are less likely to exhibit visual displays when presented only with conspecific chemical stimuli compared to when they are presented with visual stimuli. The overall high rates of visual displays by *siniferus* may reflect the importance of motion versus color in certain habitats.

49.1 PRUITT, JN*; RIECHERT, SE; University of Pittsburgh, University of Tennessee; *Agelenopsis@gmail.com*

The differential reproductive success of spider lineages is dictated by their ability to "outrun" their parasitic inquilines

Understanding how the traits and actions of individuals unite to shape the collective behavior, life history, and performance of social groups is a long-standing goal of behavioral ecology. Here we report on the long-term effects of social group composition on colony-level life history and performance in the social spider Anelosimus studiosus (Araneae, Theridiidae). Anelosimus studiosus exhibit a notable behavioral polymorphism where colony members exhibit either an aggressive or docile behavioral type. We created colonies of three starting compositions (2 docile; 1 aggressive 1 docile; 2 aggressive) and tracked colony vitals of these colonies and their descendant colonies over the course of six years. We found that, relative to other phenotypic compositions, docile colonies sequestered inquilines at a faster rate than other compositions, grew more rapidly in size (# females therein), produced more descendant colonies per year, but suffered reduced longevity (i.e., not unlike the constellation of traits that define "r" and "K" life history strategies in solitary organisms). However, performance data on descendant colonies revealed that descendants of docile colonies tend to experience reduced survivorship, because upon the collapse of the parental colony, parasitic inquilines rapidly recruit to descendant colonies and drive their collapse. As a result, lineages founded by docile colonies are eradicated by rapid lineage selection, driven by the relative dispersal abilities of parasitic inquilines and their hosts.

P1.56 PUNGOR, J/R*; ALBERTIN, C/B; KANG, S; RAGSDALE, C/W; Stanford University, University of Chicago; *jpungor@stanford.edu*

Molecular Characterization of the Octopus Visual System

Cephalopods are highly visual animals; they use extensive visual cues in many aspects of their lives, from predator avoidance and prey capture to mating and aggression displays. Cephalopods, like vertebrates, possess a single chamber eye with a lens that focuses onto a retina densely packed with photoreceptors. The visual systems of cephalopods, although evolved to deal with the same challenges as teleosts face, show dramatic anatomical and processing differences from those of their vertebrate counterparts. While a great deal of research has focused on the organization of vertebrate visual systems, little is known about visual processing in cephalopods. For example, neurochemical measurements have documented the presence of a number of different neurotransmitters in the octopus visual system, but study of their localization on the cellular level in the retina or optic lobes has been very limited. Without specific knowledge of the anatomical distributions of these neurotransmitter systems, it is impossible to understand their roles in cephalopod visual processing. In situ hybridizaton (ISH) techniques provide the resolution needed to begin to address these questions. Our aim is to develop ISH protocols appropriate for an emerging model organism in cephalopod neurobiology, *Octopus bimaculoides*. Here we will discuss the methods and findings emerging from this work.

P1.226 PUSCH, E.A.*; NAVARA, K.J.; THOMPSON, J.; Univ. of Georgia; *pusche@uga.edu*

Effects of short-term food restriction on gonadotropin inhibitory hormone (GnIH) receptor mRNA expression the brain and testes of zebra finch (Taeniopygia guttata).

Zebra finches do not follow the seasonal breeding patterns of other passerine species. They are able to breed continuously if conditions are favorable, if food and water is available. This means they are more sensitive to changes in food and water availability. Gonadotropin inhibitory hormone (GnIH) is a recently discovered neuropeptide that controls reproduction by inhibiting gonadotropin release from the pituitary and acting on the gonads in avian species. It has been documented that short-term fasting in zebra finches decreases testosterone levels and increases corticosterone levels in the plasma. In this study we assessed the effects of short term fasting on the testes and brain of adult male zebra finches to determine if GnIH receptor mRNA expression is changed. Male finches were fasted for 10 hours at which time blood, brains, and testes were collected for analysis. Results will be discussed.

41.1 QIAN, F*; GOLDMAN, D/I; Georgia Tech; *qianfeifei1114@gmail.com*

Locomotion on heterogeneous granular substrates

Natural particulate substrates like deserts are often composed of collections of multi-size particles: fine sand, pebble, and boulders. While much is known about locomotion on hard ground and increasingly on homogeneous granular media like fine sand, the principles by which organisms and robots locomote over heterogeneous granular substrates are unexplored. To investigate how particle size and distribution affect speed and stability, we performed laboratory experiments in a legged robot. Our hexapedal robot (15 cm, 150 g) used an open-loop alternating tripod gait and c-shaped rigid plastic limbs (radius 1.5 cm). We filled a trackway (75 cm long, 30 cm wide) with 3 mm glass particles ("sand") and two parallel lines of eight 2.54 cm large glass particles ("boulders") embedded one-quarter within and separated by 10 cm. Without the boulders, for a limb frequency 3 Hz, the robot moved forward at 1.7 BL/s. Forward speed oscillated periodically in a run, and run-to-run variation in standard deviation of speed was 0.50 ± 0.04 BL/s. Locomotion across the boulder field reduced the average speed to 1.2 BL/s. Large fluctuations in speed within a run and across runs were observed (standard deviation 0.69 ± 0.25 BL/s) resulting from a diversity of foot-boulder interaction modes. Of these we identified two important modes: 1) A slipping mode, where a leg contacted and slid near the top of a boulder, causing the robot to pitch, yaw and roll, while the boulder remained still or rotated against the sand. Large fluctuations in speed were observed. 2) A forced intrusion mode, where a leg forced a boulder to penetrate vertically into the sand, yaw was comparable to movement on sand, and instantaneous speed fluctuations were smaller than in mode 1. We conclude that non-trivial interaction effects can lead to complex locomotion dynamics even for a simple locomotor.

P1.47 QUACH, LN; PEREZ, JH; KRAUSE, JS; CHMURA, HE*; WORD, KR; SCHAS, J; RAMENOFSKY, M; WINGFIELD, JC; University of Calfironia, Davis; *jhperez@ucdavis.edu*

Adrenocortical Responses to Stress on the Leading Edge of a Northward Range Expansion in White-crowned Sparrows

Global climate change has resulted in rising temperatures worldwide and an increase in the frequency and intensity of unpredictable events such as storms. These effects of global change have been particularly potent in arctic ecosystems. As a result there have been numerous range shifts, particularly northward. Previous work has shown a pattern of increased responsivity of the Hypothalamo-Pituitary-Adrenocortical axis to acute external stressors in songbird species breeding at the northern limits of their range when compared to more southerly breeding populations. Elevated stress responses may be critical for birds breeding at the northern limits of their range, allowing for rapid response to environmental perturbations at high latitudes. To date this pattern of elevated responsivity to a stressor has been detected in about ten avian species. However, these comparisons all represent large latitudinal gradients in long established populations. In this study we investigated whether this pattern holds on the smaller scale of northern pioneers on the edge of an active range expansion. We present profiles of plasma corticosterone levels in response to a standardized acute stress from free living white-crowned sparrows (Zonotrichia leucophrys gambelii) from four locations across the latitudinal gradient of their range. Samples were taken from birds at the northern extent of their range, on the North Slope of Alaska, Toolik Lake Alaska, Fairbanks Alaska, and Washington State. Here we show that maximal stress levels are higher in Alaska than in Washington State, however, no difference was detected across a 500 mile latitudinal gradient within Alaska.

P3.142 QUIST, A.*; DARAKANANDA, K.; HITCHCOCK, A.; JEONG, J.; CONNOLLY, E.; ROBBINS, A.; ELLERBY, D.; Wellesley College; *dellerby@wellesley.edu*

Don't swim after a large meal, crawl instead.

Soft-bodied organisms drive locomotor movements using antagonistic muscle layers to transmit forces via hydrostatic skeletons. Unconstrained by rigid skeletal elements, this arrangement allows for a high degree of functional flexibility. Modulation of motor outputs from central pattern generators can create distinct movement patterns, e.g. crawling and swimming, using a single muscular hydrostat. Changes in hydrostat volume potentially disrupt these movements through muscle length-tension effects and suppression of motor outputs. This is particularly apparent in organisms that undergo large volume changes, such as sanguivorous leeches where body volume may increase tenfold during feeding. Immobility after feeding increases vulnerability to predation. Swimming is the fastest locomotor mode before feeding, but is disrupted by the volume increase associated with feeding due to changes in body shape and flexibility, and inhibition of the swimming motor pattern. Crawling however is relatively unimpaired. Crawling speed remained at 80% of the pre-feed level immediately after feeding, and after 1 hour there was no detectable loss of performance relative to the pre-feed level. Broad length tension relationships in the antagonistic muscle layers of the body wall allow maintenance of contractile function despite the massive volume increase. In contrast to swimming, crawling motor patterns appear not to be suppressed by activation of body wall stretch receptors after feeding. These factors, coupled with rapid volume reduction through excretion of blood plasma, allow for a remarkable maintenance of mobility despite the mechanical challenges posed by feeding.

P3.5 QUOCK, C/D; San Francisco State University; *cdquock@mindspring.com*

Use of RFID tracking to detect effects of parasitism by Apocephalus borealis on the European honey bee, Apis mellifera

Recently, Radio Frequency (RFID) systems, have been used to track various behavioral aspects of the European honey bee, *Apis mellifera*, and such systems have the potential to yield 24-hour activity patterns of marked foragers (Schneider et al., 2012; Pahl, et al., 2011). We have adapted this technology to study the possible effects of parasitism by the Phorid fly, *Apocephalus borealis*, on the lifespan and behavior of these worker bees. This phenomenon, first discovered on the San Francisco State University campus, was found to be closely correlated with apparent night abandonment by infected bees (Core et al., 2012). Similar patterns of hive abandonment have been associated with other, more enigmatic afflictions of honey bees (Dainat et al., 2012; Tokarz et al., 2011). Thus, understanding the onset of this behavior in this context may have broader applications. The use of such a system to attempt to shed more light on this host-parasite interaction is itself an example of a novel application of this technology.

113.2 RACK, JM; Univ. of Connecticut; *jessica.rack@uconn.edu*
Ambystoma maculatum larvae evolve to recognize local predator cues
In an aquatic environment where visual cues are limited, prey animals often respond to predator-released chemical cues with changes in behavior, morphology, or life history traits. Assuming sufficient additive genetic variation, natural selection should act to improve the prey population's recognition of local predator populations. Across a geographic landscape of varying selection pressures, prey and predator populations could evolve altered recognition systems or cues, respectively. If predators respond to prey evolution, then we might expect a coevolutionary arms race. Alternatively, prey might retain generalized cue recognition systems and predators might differ little in their cue chemistries, creating more predictable predator-prey interactions. I performed an experiment to determine if prey behavior differed in response to local predator chemical cues versus cues from a geographically distant population of the same predator species. Larvae of the spotted salamander, *Ambystoma maculatum*, were presented with predator cues isolated from two species of amphibian predator (marbled salamander larvae, *Ambystoma opacum* and red-spotted newts, *Notophthalmus viridescens*) collected from ponds stratified by distance from a focal population. I found that larval *Ambystoma maculatum* took more time to move in response to cues from local predatory newts, suggesting a recognition and avoidance mechanism based on adaptation to local predators. Rearing condition of the larvae (raised in the presence or absence of predator chemical cues) also affected prey behavior, suggesting that experience is a factor in such interactions. These results provide evidence for higher relative fitness in the prey animal's home environment, and support the hypothesis that prey can evolve to recognize the specific chemical cues released by the local predator population.

P2.124 RADE, CM*; HERNANDEZ, LP; George Washington Univ; *cristinarade@gmail.com*
Pharyngeal jaw apparatus variation in cypriniform fishes
The pharyngeal jaw apparatus (PJA) is a novel feeding structure that distinguishes the morphologically diverse order of fishes, Cypriniformes. While perciform pharyngeal jaws of various fish groups, including cichlids, haemulids, and labrids have been examined, morphological diversity of cypriniform pharyngeal jaws has been mostly overlooked. Considering that the cypriniform PJA consists of significantly hypertrophied ceratobranchials 5 and loss of the upper pharyngeal jaws, a character seen only at the base of this group, it is crucial to investigate its anatomy and the variation therein. Here we describe the musculoskeletal differences characterizing the cypriniform PJA. We examine inter- and intra-familial morphological variation using both cleared and stained specimens and formalin-fixed specimens. Cypriniform clades examined exhibit either patterns of conserved morphology or significant variation at the familial level. Balitoridae and Gyrinocheilidae exhibit minimal intrafamilial variation but have distinct interfamilial differences. Alternatively while Cyprinidae and Cobitidae show common features at the subfamilial level, they show significant variation of the PJA at the familial level. While significant hypertrophy of the pharyngeal jaws characterizes most cypriniform fishes, gyrinocheilids tend to have smaller, more slender pharyngeal jaws and catostomids typically have an intermediate size; this is in strong contrast to the thicker and broader pharyngeal jaws of several of the examined cyprinids. Overall, this comparative study identifies various morphological features, including some that are potentially correlated with tropic niches and diets. Findings here will be help to elucidate the importance of the PJA in relation to cypriniform fishes' trophic diversity and ecological success.

79.2 RADE, CM*; SANFORD, CP; HERNANDEZ, LP; George Washington Univ, Hofstra Univ; *cristinarade@gmail.com*
Using sonomicrometry to compare pharyngeal jaw kinematics in cypriniform fishes
While much of the documented functional diversity in fish feeding systems involves the mechanics of suction feeding and prey capture, the pharyngeal jaw apparatus (PJA) is an understudied element of fish trophic diversity. The PJA is a second set of jaws behind the gill arches that serves to separate organic and inorganic matter, manipulate prey, and process food items. These jaws promote trophic diversity by decoupling feeding and processing events, thus providing an opportunity for different prey types. Cypriniformes is a diverse clade of teleosts characterized by a novel PJA that has significantly hypertrophied ceratobranchials 5 and a loss of the upper pharyngeal jaws, a feature seen only at the base of this group. Here we examine the use of the cypriniform PJA during prey handling in two species by employing sonomicrometry to interpret the kinematics of this novel biomechanical system. Using the positional relationships of five piezoelectric crystals we monitored the movements of the lower pharyngeal jaw in transverse and sagittal planes for goldfish (*Carassius auratus*) and sailfin suckers (*Myxocyprinus asiaticus*) to account for phylogenetic and behavioral differences, with goldfish being a member of Cyprinoidea and sailfins representing the other major clade, Cobitoidea. Goldfish predominantly use the pharyngeal jaws for crushing and grinding, while catostomids presumably use these jaws for sifting purposes. *M. asiaticus* is especially important for understanding functional difference within this group as there is no published functional work on catostomid fishes to date. Statistical analyses reveal that the catostomid generates more chewing cycles per event and less lateral movement in the transverse plane than the cyprinid species.

P1.84 RADER, J.A. *; NEWSOME, S.D. ; CHESSER, R.T.; MARTINEZ DEL RIO, C.; University of Wyoming, National Museum of Natural History, Smithsonian Institution; *jrader@uwyo.edu*
Phenotype-environment correlations in Cinclodes ovenbirds: Linking morphology to isotopic niche
The species in the genus *Cinclodes* (Furnariidae), inhabit coastal and riparian zones from sea level to >4000 m, and some species display seasonal elevational migration. They might represent a good example of an adaptive radiation. We characterized the isotopic niches of 13 species of *Cinclodes*. We found that species occupied distinct hypervolumes of a $\delta^{13}C$, $\delta^{15}N$, $\delta^{18}O$, δD isospace. The $\delta^{13}C$ and $\delta^{15}N$ characterized dietary resource use, whereas the $\delta^{18}O$ and δD axes served as a proxy for altitude. A terrestrial/freshwater habit appears to be ancestral and the most prevalent in the genus. This type of resource use was found in 8 species. The use of tidal marine resources appears to have evolved once and to be found in two species: *C. nigrofumosus*, *C. taczanowskii*. The occupancy of islands with mixed reliance on coastal habitats fertilized by seabirds and intertidal habitats appears to have evolved only once, in *C. antarcticus*. Finally, two species (*C. patagonicus*, *C. oustleti*) make use of both marine and terrestrial resources. These two species also seem to exhibit altitudinal movements. The marine/terrestrial mixed use habit seems to have evolved twice. Morphological diversification was determined by principal components analysis of multiple linear measurements. The genus *Cinclodes* seems to have two primary subclades characterized by relatively large body size, and small body size, respectively. However, the island species, *C. antarcticus*, a member of the small subclade, seems to have evolved unusually large body size. Stable isotopes appear to be a useful tool to characterize the ecological habits of species and their diversification.

31.6 RAGLAND, GJ; University of Notre Dame; *gragland@nd.edu*

Relaxed, but ready: dormancy responses are the opposite of stress responses at the transcriptional level

Dormancy is a metabolically and developmentally supressed state that many organisms use to withstand stressful environments unfavorable for growth and reproduction. As an adaptation to extreme environmental stress, it is unsurprising that dormant life history stages almost universally exhibit enhanced resistance to multiple stressors compared to active, non-dormant stages. However, transcriptomic data show that at the level of global gene expression, the dormant/diapause phenotype is nearly the opposite of a stress response phenotype as illustrated by strong, consistent negative correlations. Here I present these patterns both within and across species and discuss functional explanations and evolutionary implications.

126.5 RAINWATER, E*; FASSBINDER-ORTH, C; Creighton University; *elleciarainwater@creighton.edu*

Experimental inoculation of nestling houses sparrows (Passer domesticus) with Buggy Creek virus

The etiology of arboviral infections in wild nestling birds has been understudied. In this study, captive house sparrow (*Passer domesticus*) nestlings were inoculated with Buggy Creek virus (BCRV). BCRV is an alphavirus that is vectored by the swallow bug (*Oeciacus vicarious*) and amplified by house sparrow nestlings in the wild. Seven-day-old nestlings were inoculated with 3.5 $\log_{10}$ plaque forming units (PFU) of BCRV lineage A (BCRV-A), BCRV lineage B (BCRV-B), or vehicle control, and the infection was monitored for 4 days post inoculation (4 DPI). Peak viremia occurred 1 DPI for both BCRV-A and B groups, with a mean peak virus titer of $4.24 \pm 0.18 \log_{10}$ PFU/ml sera for BCRV-A and $4.29 \pm 0.12 \log_{10}$ PFU/ml serum for BCRV-B. Viremia lasted for 2 DPI for both lineages, and no significant differences in viremia were detected between the two lineages ($P = 0.967$). Cytopathic BCRV was isolated from all lung and cerebral tissues in both BCRV-A and BCRV-B groups 2-4 DPI. Additionally, virus was isolated from the skin, skeletal muscle, heart, kidney, and small intestine for both BCRV-A and BCRV-B groups. Mucosal viral shedding was exhibited in 50% of BCRV-B nestlings and only 17% of BCRV-A nestlings. The impact of alphavirus infection on digestive parameters was also investigated. Digestive efficiency was 11% lower in BCRV-A group compared to the control ($P < 0.016$). Our results suggest that BCRV-A and BCRV-B are both effectively amplified in nestling house sparrows, and the infection results in widespread viral dissemination. Additionally, BCRV-A appears to negatively impact digestion in nestlings, while BCRV-B does not. Reduced digestive capabilities may contribute to the higher virulence that is seen for BCRV-A in wild nestling house sparrows compared to BCRV-B.

106.6 RAMIREZ, D*; OAKLEY, TH; Univ. of California, Santa Barbara; *ramirez@lifesci.ucsb.edu*

Dispersed sensory neurons express opsin in the skin of Octopus bimaculoides

Although we have known for some time that animals can detect light with dispersed, dermal photoreceptor cells and can guide behavior, in most cases we do not know which molecules or dispersed cells actually confer this light sense. This holds true for molluscs, which have well documented photo-behaviors likely mediated by dispersed cells, but very limited data about the cells or molecules involved. In cephalopod molluscs, behavioral evidence of dispersed photoreception is scarce, but there are two brief reports of a direct chromatophore response to light in *Octopus* spp. As for molecular data, r-opsin is expressed in the skin of the cuttlefish *Sepia officinalis*. We have also found five major phototransduction components expressed in the skin of *Octopus bimaculoides*, including r-opsin and G-protein &alpha-q. Further, we found primary sensory neurons (PSNs) expressing opsin in octopus skin using antibodies raised against octopus eye opsin and mouse tubulin. These cells consist of small ciliary bundles emerging from the skin surface connected to cell bodies within the epidermis. They are relatively evenly spaced across the entire surface of the animal, except for a subset of these PSNs. These form lines on the siphon and dorsal head and mantle, and have previously described as mechanoreceptors based on both morphology and electrophysiology. We propose that these opsin-expressing PSNs are octopus dispersed photoreceptor cells and may contribute to a dermal light sense in both octopus and other coleoid cephalopods. Further, ultrastructure studies have identified this same cell type in several other classes of molluscs, including bivalves and gastropods. They may underlie the known dispersed photoreception behaviors in these other taxa, although it remains to be seen whether these other putative molluscan dispersed cells also use opsin-based phototransduction pathway genes.

P1.28 RAMIREZ-OTAROLA, N*; SABAT, P; BOZINOVIC, F; MARTINEZ DEL RIO, C; Univ. de Chile, Santiago, Pont. Univ. Cat. de Chile, Santiago, Univ. of Wyoming, Laramie; *nat.rotarola@gmail.com*

Assessing the isotopic niche of passerine birds: analysis of the carbon and nitrogen isotopic composition of tissues and diet.

We analyzed the carbon and nitrogen isotopic value of the muscle, liver, and crop contents (“diet”) of 132 individuals of 16 species of Chilean birds. The nitrogen content of diet was tightly correlated with the fraction of gut contents represented by insects relative to plant material. The carbon and nitrogen isotopic values of diet, liver, and muscle were all linearly correlated, implying high temporal consistency in the isotopic value of the diet of these birds. However, $\delta^{15}N$ was not significantly related with the percentage of insects in diet. These results cast doubt on the applicability of the use of ^{15}N enrichment to diagnose trophic level in, at least some, terrestrial ecosystems. However, the residuals of the relationship relating the isotopic value of bird tissues with those of their diet were weakly negatively correlated with insect intake. We hypothesize that this negative correlation stems from the higher quality of protein found in insects relative to that of plant materials. Finally, our data corroborated a perplexing and controversial negative relationship between tissue to diet isotopic discrimination and the isotopic value of diet. We suggest that this relationship is an example of the commonly observed regression to the mean effect that plagues many scientific studies.

P2.146 RAMOS, L.S.*; OMONDI, C; FUSE, M; San Francisco State University; *vermilionone@hotmail.com*

Developing a transfusion techique in the tobacco hornworm, Manduca sexta

Holometabolous insects, those that go through complete metamorphosis, have highly regenerative tissues known as imaginal discs which will develop at the appropriate stage into adult structures. It has been found in both holometabolous insects, the fruitfly *Drosophila melanogaster* and the tobacco hornworm *Manduca sexta*, that developmental is delayed when these tissues are damaged via x-ray irradiation. Thus it has been proposed that a signal from the imaginal discs is transmitted to peripheral endocrine tissues, to delay pupation and even adult eclosion. Putative factors have been proposed from genetic analyses in *D. Melanogaster*, but size limitations have made identification in the hemolymph (blood) slow. As a solution to this problem, we suggest the use of *M. sexta* for hemolymph analyses, given its very large size as a larva. We have developed an experimental transfusion protocol, and also assessed direct injection of substances into the hemolymph. We have verified that (i) we can elicit developmental delays via the transfusion of hemolymph from irradiated larve, but that (ii) tissue damage from the injection itself, and (iii) from transfused hemolymph, only affect development minimally. This protocol will be highly useful in quickly and efficiently evaluating hemolymph components that delay development, as well as testing isolated factors that may contribution to developmental delays.

79.5 RAMSAY, J.B.*; WILGA, C.D.; University of Rhode Island; *jasonramsay@my.uri.edu*

Preorbitalis and quadratomandibularis function during feeding in little skates, Leucoraja erinacea

The horizontal preorbitalis (PO) muscle of little skates originates from the cranium and inserts onto the lateral surface of the quadratomandibularis (QM) and the lower jaw. The PO is considered to function as a jaw protractor and also may assist the QM in adducting the jaws. However, manual depression of the hyomandibulae and lower jaw results in anteroventral rotation of the PO with little obvious stretching of the muscle as the jaws protrude. Thus, instead of strictly shortening to actuate jaw protrusion and adduction, the PO may potentially contract isometrically or eccentrically; functioning to stabilize and guide the jaws during protrusion driven by hyomandibular depression during the expansive phase of feeding. Hyomandibulae, upper and lower jaw kinematics, as well as motor activity in the PO and QM, and fascicle strain in the PO and QM were recorded simultaneously with buccal pressure during feeding. During prey capture the PO activates isometrically during the expansive phase and continues into the compressive, while the QM actively shortens during the compressive phase. In contrast, during prey processing the PO and QM are passively lengthened during the expansive phase and actively shorten during the compressive phase. The strain patterns exhibited in the PO of little skates suggests that the PO is functioning as an additional suspensory element during rapid prey capture and an additional jaw adductor during prey processing. The dual function of the PO as a supportive and actuating element may be another critical feature resulting in the increased functional versatility of the feeding apparatus in batoids compared to sharks.

P3.167 RANA, P.V.*; LARSON, N.P.; ABBOTT, E.M.; AZIZI, E.; Univ. of California, Irvine; *ranapv@uci.edu*

How toads minimize torques to stick their landings

The task of landing after a jump requires motor control strategies that allow muscles to effectively dissipate energy and control posture to stabilize the body. Toads are exemplary models for understanding the mechanics and motor control of landing given their ability to land consistently during bouts of hopping. Previous studies in anurans have shown that ground reaction forces (GRF) during landing are significantly higher compared to take-off and can therefore destabilize the body at impact. To “stick” the landing, toads must minimize torques acting about their center of mass (COM) in order to avoid excessive body rotation and provide time for their forelimbs to dissipate mechanical energy. We predict that flexion of the hindlimbs during the aerial phase and in anticipation of impact functions to change the position of the COM and minimize torques during landing. To test this hypothesis we first quantify the location of the COM at hindlimb positions ranging from fully flexed to fully extended in anesthetized Cane toads (*Bufo marinus*). We then quantify ground reaction forces during landing using a three-axis force plate and quantify posture during landing using high-speed video. We use GRF data and the instantaneous position of the COM to calculate peak torques during landing. We find that hindlimb flexion during the aerial phase moves the COM anteriorly and reduces torques at the COM. Therefore, we conclude that toads are actively shifting their center of mass to reduce torque and stabilize the body during landing. Supported by NSF grant 1051691.

P3.146 RANDAZZO, A.B.*; GAMBLE, G.B.; SECOR, S.M.; University of Alabama, Tuscaloosa; *abrandazzo@crimson.ua.edu*

Rapid upregulation of the python’s small intestine

The Burmese python (*Python molurus*) experiences an unprecedented upregulation of intestinal structure and function after feeding. Within days the small intestine has doubled in mass, microvilli have lengthened by 5-fold, and intestinal nutrient uptake and hydrolase activities have increased 5 to 10-fold. These responses are then reversed after digestion has completed. Previously we found that by 6 hours after feeding, the small intestine had already begun to respond with the doubling of microvillus length and slight increases in intestinal enzyme activity and nutrient uptake. A recent transcriptomic study of the python small intestine revealed that at 6 hours postfeeding more than 2000 genes had increased (> 2-fold) their expression. The aim of this study was to characterized changes in intestinal morphology and function of the python’s small intestine prior to 6 hours after feeding. Segments of anterior small intestine were removed serially from pythons at 0, 1, 2, 4, and 6 hours after feeding. From samples we measured enterocyte size, microvillus length, and the activity of the hydrolase aminopeptidase. Across these time points there were significant increases in enterocyte volume, microvillus length, and aminopeptidase activity with increases evident 2 to 4 hours postfeeding. The eventual goal of this project is to determine the extent that the initial postprandial responses of the python small intestine is provided by posttranscriptional mechanisms or stems purely from a genomic response.

P1.52 RANDEL, N*; JéKELY, G; Max Planck Institute for Developmental Biology, Spemannstrasse 35, 72076 Tübingen, Germany; *gaspar.jekely@tuebingen.mpg.de*
Mechanism of negative phototaxis in Platynereis larvae
Phototaxis is widespread among planktonic organisms, and can be found in the larval stages of sponges, cnidarians, protostomes and deuterostomes. The ability of zooplankton to find their preferred water depth depends on varying daily light conditions and developmental stage. Planktonic larvae often undergo a behavioral change, switching from positive phototaxis, characteristic of the post-hatching stages, to negative phototaxis, characteristic of later larval stages before settlement and metamorphosis. The marine annelid Platynereis dumerilii is an excellent laboratory model to study the mechanisms of larval phototaxis. Platynereis has a bentho-pelagic-life cycle with a pelagic larva that shows early positive and late negative phototaxis. The neuronal circuit and mechanism of early larval phototaxis is well understood: the larval eyespots, consisting of a shading pigment cell and a rhabdomeric photoreceptor cell, mediate this response. The eyespot photoreceptor directly innervates the ciliary band (prototroch). The mechanism and neural circuitry underlying negative phototaxis is unknown. To study the mechanism of negative phototaxis in Platynereis larvae we combined behavioral experiments, laser ablation, and transmission electron microscopy. Late Platynereis larvae have six eyes, the two eyespots and four additional dorsal eyes, precursors of the adult eyes. We characterized the role of these eyes in larval phototaxis, using laser ablations. Our electron microscopic reconstructions are beginning to reveal how the larval eyes regulate motor output during phototactic turning.

90.6 RANK, NE*; MARDULYN, PM; ROBERTS, KR; HEIDL, S; SMILEY, JT; DAHLHOFF, EP; Sonoma State University (SSU), University of Brussels, SSU, SSU, White Mountain Research Center, Santa Clara University; *rank@sonoma.edu*
Variation in nuclear and mitochondrial genes important for energy metabolism along a climatic gradient in montane populations of a leaf beetle
Many montane organisms live in fragmented populations that are especially vulnerable to climate change. The ability of small populations to persist depends partly on whether they possess genetic variation in their capacity to respond and adapt physiologically to altered environments. In the Sierra Nevada Mountains of California, the willow leaf beetle *Chrysomela aeneicollis* occurs at high elevations just below tree line (2400-3600 m). Variation at genetic marker loci [5 allozymes, 5 microsatellites, and a 550 bp region of mitochondrial *cytochrome II oxidase* (COII)] shows significant differentiation among montane drainages along a 75 km transect from the King's River in the southwestern Sierra to Rock Creek in the central Sierra. Geographic variation along this transect is much greater for the allozyme *phosphoglucose isomerase* (PGI) than for other nuclear loci. In prior studies, we described functional, physiological, and reproductive differences among PGI genotypes that correspond to differences in frequency over a latitudinal transect. Here we show that PGI variation and environmental variability jointly affected persistence of local populations over the past decade. In addition, we found that latitudinal variation in frequencies of mitochondrial COII haplotypes is concordant to variation in PGI frequencies previously observed. Natural selection may act on COII and PGI. Genetic variability at loci, such as COII and PGI, which are critical to energy metabolism, may contribute to population persistence in the face of rapid environmental change.

34.2 RASTORGUEFF, P.-A.*; CHEVALDONNé, P.; LEJEUSNE, C.; Aix-Marseille Université - UMR CNRS 7263 IMBE, Estación Biológica de Doñana - CSIC; *pierre-alexandre.rastorgueff@imbe.fr*
Unexpected patterns of connectivity and phylogeographic breaks in Mediterranean marine cave mysids
Habitat fragmentation is a major threat to biodiversity by reducing habitat availability and interpopulation connectivity. Submarine caves represent a naturally fragmented habitat allowing to understand how habitat fragmentation affects connectivity. We worked on the Mediterranean brooding cave-dwelling mysids *Hemimysis margalefi* and *Harmelinella mariannae* which disperse only as adults. At the Mediterranean scale, our phylogeographic study based on several mitochondrial and nuclear molecular markers revealed that *H. margalefi* is actually composed of five highly divergent lineages, likely representing as many events of ongoing allopatric speciation. Populations of the different lineages are highly structured genetically mostly according to the general current circulation and the geography of the Mediterranean, habitat fragmentation and poor dispersal abilities. However, some well-known barriers to gene flow appear to have a surprisingly reduced influence on this species. Compared to *H. margalefi*, the little-known *H. mariannae* shows far less structured populations. This is particularly puzzling since this species, considered rare, has a more fragmented habitat. At small geographical scale, the use of microsatellite markers has evidenced differences in the genetic population structuring of *H. margalefi* compared to mitochondrial data. Understanding marine population connectivity in fragmented habitats has proved more complex than previously thought and may benefit from unconventional biological models such as marine cave mysids.

P3.63 RASTORGUEFF, P.-A.*; HARMELIN-VIVIEN, M.; RICHARD, P.; CHEVALDONNé, P.; Aix-Marseille Université - UMR CNRS 7263 IMBE, Aix-Marseille Université - UMR CNRS 7294 MIO, Université de La Rochelle - UMR CNRS 7266 LIENSs; *pierre-alexandre.rastorgueff@imbe.fr*
Feeding strategies and resource partitioning among mysids in oligotrophic marine caves.
The understanding of how large populations of several mysid (Crustacea) species coexist and share resources in oligotrophic underwater marine caves from the northwestern Mediterranean Sea was investigated using carbon and nitrogen stable isotopes. The isotopic signatures indicated food partitioning among the five species of cave-dwelling mysids. *Hemimysis speluncola* feeds mainly on phytoplankton and zooplankton from outside the caves, *Siriella gracilipes* on sedimentary organic matter and zooplankton from the outside, *Harmelinella mariannae* on small cave-dwelling crustaceans and *Hemimysis margalefi* and *Hemimysis lamornae mediterranea* on sedimentary particulate organic matter. Different diets seem to promote mysid coexistence in caves as resource partitioning reduces interspecific competition. However, the analysis of both seston and cave sediments indicates that the quantity and quality of organic matter are strongly reduced in caves compared to the outside. Therefore some mysid species have adapted to finding their food in another environment. Some species are indeed documented to migrate outside of caves at night, where phytoplankton and zooplankton are available. These outside-inside movements make cave-dwelling mysids important drivers in the organic matter transfer from the open sea to different locations inside caves. The organic matter from the open sea accumulated by mysids is then made available to other cave-dwellers by fecal pellet production and predation by cave-dwelling teleost fishes, decapod crustaceans or even carnivorous sponges.

64.2 RAVI, S*; CRALL, J; COMBES, S; Harvard University; *sravi@fas.harvard.edu*

On the flight of foraging bumblebees in the near-wake of objects

The high energy demands of a growing hive require bees to forage relentlessly, even under unfavorable weather conditions such as cool temperatures, precipitation or high winds. Bees forage in the complex environments surrounding flowering plants, bushes and trees, and the flow structures that they encounter on days with mild or strong winds can be vastly different from those encountered on calm days. Vortices shed from structures in the surrounding environment (trees, flowers, branches, etc.) can vary dramatically in size, strength and orientation, and these flow structures may influence the flight trajectories of foraging bees. Efficient flight trajectories, effective control strategies, and precise landings on nectar sources are vital to maximizing foraging success. To shed light on the interaction between bees and the wakes generated by objects in their environment, freely flying bumblebees (Bombus impatiens) were filmed with high speed cameras as they flew upstream in a wind tunnel at a range of freestream velocities, towards artificial flowers mounted on cylinders of varying size and orientation. Measurements of bumblebee approach trajectories were augmented with smoke flow visualization and high speed anemometry to obtain qualitative and quantitative insight into the flow structure in the vicinity of the cylinders. We found that bumblebees do employ approach patterns that depend on the geometric properties of the upstream object and its associated flow structures. This suggests that certain types of plants or particular habitats may be more challenging and/or costly for bees to forage in under adverse weather conditions.

39.4 RAY, R.; HENNINGSSON, P.; NAKATA, T.; BOMPHREY, R.J.*; CRUK London Research Institute, United Kingdom, University of Oxford, United Kingdom; *richard.bomphrey@zoo.ox.ac.uk*

Wing shape characteristics exaggerated by RNA interference modulate aerobatic performance in fruit flies

The diversity of insect wing morphology seen in nature reflects the time-integrated sum of evolutionary pressures. Extant designs represent a compromise of ecological factors including – but not necessarily dominated by – aerodynamic performance characteristics. Correlating wing design with flight performance usually involves crossing species boundaries and can, therefore, be confounded by phylogenetic history. Since biomechanical data sets can be technically challenging and time-consuming to obtain, implementing the comparative method is often unfeasible. One approach to this problem lies in the development of a standardized procedure for a single species that affords either discrete or continuous variation of morphological parameters that are expected, from aerodynamic theory, to play important roles in aerobatic capabilities. Aerial prowess may be crucial to individual fitness and has certainly been instrumental in the success of the insects as a class. Thus, the ability to modify experimentally wing shape alone is a powerful tool with which to investigate the underlying mechanisms of functional morphology. Here we use RNA interference to down-regulate the expression of a gene that determines wing shape in fruit flies (*Drosophila melanogaster*). The resulting phenotypes differ markedly in wing tip curvature and aspect ratio. We used stereo photogrammetry to acquire three-dimensional free flight trajectories from the range of phenotypes, calculated flight performance metrics, and found them to be significantly correlated with the modified wing morphology.

P2.121 READER, L*; CARRIER, D; GOLLER, F; University of Utah; *L.Reader@utah.edu*

Flexural stiffness of woodpecker tails with respect to foraging ecology

The woodpeckers (Picidae: Picinae) exhibit a unique locomotor style: climbing vertically upwards on tree trunks while supported by a stiff tail. Members within the group, however, exhibit varying degrees of dependence on this strategy. Tail support is also critical to the birds' ability to hammer into trees when excavating nests or foraging. Accordingly, we expected that the stiffness of tail feathers would correlate with foraging style – and that tails would be stiffest in species with: 1) a high degree of dependence on hammering, and/or 2) a high frequency of tail propping during vertical climbing. Some species forage on trunks infrequently, but are adept at hammering hard food items that make up their winter diets (i.e. Lewis' woodpecker). Others drill less forcefully, but remain on trunks constantly to forage (i.e. sapsuckers).We examined whole-tail flexural stiffness of several genera along this spectrum. We found that tails of woodpeckers most dependent on trunk foraging and/or anvil-style hammering have higher flexural stiffness than those of ground foraging woodpeckers like flickers. Ground foragers - which still excavate nest cavities - have higher stiffness values than robins, which served as the outgroup. Additionally, flexural stiffness changes along the feather shaft; tails are more rigid near the base than the tip. This difference is most pronounced in trunk foragers/hammerers, indicating a greater need for a stiff lever arm and a flexible point of contact on the tree.

S8-1.2 REDMOND, NE*; MORROW, CC; THACKER, RW; DIAZ, MC; BOURY-ESNUALT, N; CáRDENAS, P; HAJDU, E; LôBO-HAJDU, G; PICTON, BE; COLLINS, AG; NMNH, Smithsonian Institution , Queen's University, Belfast, Northern Ireland, University of Alabama at Birmingham, Museo Marino de Margarita, Venezuela, Université d'Aix-Marseille, France, Uppsala University, Sweden, Museu Nacional/Universidade Federal do Rio de Janeiro, Brazil, Universidade do Estado do Rio de Janeiro, Brazil, National Museums Northern Ireland, UK; *redmondn@si.edu*

New 18S rDNA Sequence Data Suggest Exciting New Hypotheses for Internal Relationships of Demospongiae (Phylum Porifera).

The systematics of sponges (Porifera) is extremely difficult to decipher and constantly evolving. Here we present some exciting results on the phylogenetic relationships within Demospongiae based on 18S rRNA data. We add over 420 new nearly complete demosponge 18S sequences to approximately 180 existing sequences from GenBank. Our dataset includes over 35 genera that had not been included in molecular phylogenies to date, shedding new light on their familial affinities. We present several new hypotheses suggesting further revision and refinement of the emerging, more consensus-based, systematics of demosponges. Among numerous results are the following hypotheses: 1) within Myxospongia Chondrosia is sister to a monophyletic Verongida making the order Chondrosida paraphyletic; 2) within Keratosa, Dendroceratida is weakly supported as monophyletic, while Dictyoceratida has high support and is split into two highly supported clades, Spongiidae + Irciniidae + most Thorectidae and Dysideidae + remaining Thorectidae; 3) numerous lineages within Haploscleromorpha have undergone simplification of skeletal structure; 4) within Democlavia (=Heteroscleromorpha), nearly all of the independently derived clades of Morrow et al. 2012 are valid; and 5) freshwater Spongillida and "lithistid" Vetulinidae are sister groups with a close relationship to Scopalinidae.

90.5 REED, W. L.*; CLARK, M. E.; North Dakota State University, Fargo; *wendy.reed@ndsu.edu*
Seasonal maternal effects on post-hatching growth and development in Franklin's gull
Theoretical predictions and empirical evidence suggest that parental investments in offspring decrease across the breeding season. However, it is not well documented how offspring fitness responds to variation in seasonal timing of reproduction. Our hypothesis is that offspring respond to cues of season and adjust their phenotypes to maximize their fitness based on conditions at hatching. We evaluated the impact of seasonal changes in parental investment on offspring growth and development in common garden experiments with Franklin's gull (*Leucophaeus pipixcan*), a long distance migrant. We previously documented that Franklin gull embryos are able to integrate cues of season from egg investments and photoperiod and can adjust growth and development during embryonic development. In this experiment we evaluated the impact of season and photoperiod during embryonic development on post-hatching growth and development. Freshly laid eggs were collected, incubated under photoperiods similar to early and late season, and chicks were reared in a common environment. The effects of photoperiod on development appear to be limited to embryonic development, but the maternal effects of season extend through the nestling period. Late season gull chicks grow faster, reach maximal growth rates at earlier ages, and reach lower peak masses than early season gull chicks. Early and late season chicks ultimately achieve similar asymptotic or final masses, which suggests that growth in late season chicks can compensate for a poor start.

120.3 REFT, AJ*; DALY, M; Ohio State University; *ajreft@gmail.com*
Small and mighty: the phylogenetic significance of mastigophore nematocysts in sea anemones
An account of the size, distribution, and morphotypes of microscopic stinging capsules called nematocysts is historically included in species descriptions of sea anemones (Cnidaria: Anthozoa: Actiniaria). Differences in the observed size ranges of capsules may justify the separation of species, and the occurrence of particular morphotypes justifies higher-level taxonomic distinctions. Nonetheless, the identity of some types of nematocysts remains obscure, and their phylogenetic significance remains untested. Here we use scanning and transmission electron microscopy, light microscopy, and shape analysis to evaluate the similarities among mastigophores, the most common type of nematocyst in sea anemones. We recognize several new types of mastigophores, and find that many of these occur uniquely in particular lineages or tissue types.

134.2 REICHARD, D.G.*; RICE, R.J.; SCHULTZ, E.M.; KETTERSON, E.D.; Indiana Univ., Bloomington, Univ. of California, Davis; *dgreicha@indiana.edu*
Whispers of love and war? Inferring the function of low-amplitude song in a songbird
Males of many species produce high amplitude long-range songs during the breeding season that often serve a dual function in attracting mates and repelling rivals. In some species, males also produce low-amplitude (whispered) songs during close-proximity interactions that can precede a physical confrontation between males or be paired with visual courtship displays to females. We investigated the function of these songs in the dark-eyed junco (*Junco hyemalis*), a species of songbird with two distinct low-amplitude songs: (1) soft, long-range song, which does not differ structurally from loud long-range song, and (2) short-range song, which is substantially divergent in structure from long-range song. We presented free-living, male juncos with a live, caged male or female conspecific and quantified the number and type of songs produced to each sex. We also performed a series of playback experiments that tested whether male territorial response differed between high- and low-amplitude songs and whether male response differed according to the fertility status of his mate. Males produced soft and loud long-range song to both male and female conspecifics, but directed short-range song only to females. When confronted with playback of these song types in the absence of a visual stimulus, males responded significantly more aggressively to short-range song than long-range song but did not differ in their response to loud or soft long-range song. When their mates were fertile, males elevated their aggressive response to short-range song but not soft long-range song. Considered together, these results suggest that soft and loud long-range song may serve a similar dual function, while short-range song is a female-directed signal important in courtship.

P1.119 REIDER, M*; CONNAUGHTON, VP; American University; *mreider888@gmail.com*
Effects of rearing temperature and thyroid hormone inhibitor Methimazole (MMI) on eye development and general morphology in zebrafish
Effects of rearing temperature and thyroid hormone inhibitor Methimazole (MMI) on eye development and general morphology in zebrafish Reider, M and Connaughton VP. mr3039a@american.edu. Biology. American University. Zebrafish development is a complex process that has been shown to be highly dependent on thyroid hormones (THs), an endocrine system that is highly conserved from fish to humans. MMI, the thyroid inhibitor used in this study, is a common medication used to treat hyperthyroidism in humans, and is also frequently used in animal research. The purpose of this study was to examine the effects of TH deprivation on larval development. We analyzed MMI and rearing temperature effects on various aspects of zebrafish growth: eye size, inter-eye distance, body length, and spinal curvature. Embryos were sampled hourly from 60-72 hpf, a critical time in thyroid development. Results indicate a significant temperature effect for all growth parameters examined ($p < 0.01$). Maximal inhibitory effects of MMI were found between 66-68hpf for the 31oC group and at 64-66hpf for the 28oC group for 3 of the 4 parameters tested. Interestingly, following each inhibitory peak, measurements recovered and were similar to control values, indicating feedback mechanisms may be established as early as 64hpf. Because MMI inhibits endogenous TH synthesis only, sensitivity to this chemical is presumably indicative of both a functional embryonic TH system and a need for THs in overall zebrafish growth. Additionally, significant temperature effects supports rearing temperature as a critical factor in development studies.

42.5 REISER, PJ*; BICER, S; Ohio State University; *reiser.17@osu.edu*

Cardiac, Slow and Fast Troponin-T Isoform Expression Patterns in Dog and Rat Extraocular Muscles

Mammalian extraocular muscles (EOMs) consist of two distinct layers. Global layer fibers insert directly onto the eyeball and orbital layer fibers insert onto an outer connective tissue complex. Orbital fibers appear to modulate the force vector associated with EOM contractions. EOMs express a large number of myosin heavy and light chain isoforms and this diversity is a major contributor to the broad range of eye rotation velocities. We previously reported (Reiser and Bicer, 2011 Annual Meeting of the Biophysical Society) an unusual isoform expression pattern of the thin filament protein, tropomyosin (Tm), in the orbital layer. Specifically, fast orbital fibers express all three isoforms of Tm (α, β and γ), whereas fast and slow global and limb muscle fibers consistently express two Tm isoforms, α and β or γ and β, respectively. Given the critical dependence of interactions between Tm and troponin-T (TnT) during muscle activation, the objectives of this study were to identify TnT isoforms in fast and slow fibers in the global and orbital layers of dog and rat extraocular muscles and to quantitate their relative amounts in homogenates of both layers. SDS-PAGE and immunoblotting results indicate that fast global and orbital fibers express only fast isoforms of TnT, but the relative amounts of the individual isoforms are different from those in limb skeletal muscles. Slow fibers in both layers express slow TnT isoforms and the relative amounts also differ from those in limb slow fibers. Unexpectedly, cardiac TnT isoforms were detected in slow orbital fibers. These results further distinguish extraocular muscle fibers from limb muscle fibers and suggest that unique calcium-activation properties, especially among orbital fibers, subserve EOM contractions that drive oculomotor functions.

S7-1.2 REITZEL, A.M.*; TARRANT, A.M.; Univ. of North Carolina, Charlotte, Woods Hole Oceanographic Inst.; *areitzel@whoi.edu*

Circadian clock of the starlet sea anemone Nematostella vectensis: a conserved network and missing links

The molecular components of the circadian clocks of mammals and diverse insects have been well-characterized, revealing that many of the core clock genes are conserved in these two disparate animal groups. This deep conservation suggests that this molecular clock dates back to at least the ancestor of deuterostomes and protostomes (Bilateria). The origin of these clock components and their molecular interactions earlier in animal evolution is unknown but represents a tremendous opportunity for studying the emergence of deeply conserved gene networks in animal behavior and physiology. Comparative genomic analyses support a hypothesis that the genes composing the circadian clock defined in bilaterians arose just prior to the cnidarian-bilaterian ancestor. Recent studies, using reef-building corals, and especially the sea anemone *Nematostella vectensis*, have provided considerable insight into circadian regulation within cnidarians. Several lines of evidence that we will present, including computational biology, gene expression profiling, co-immunoprecipitation, and reporter assays, suggest that the cnidarian clock shares many conserved components of the circadian clock with bilaterians. Investigation into conserved and novel mechanisms of the circadian clocks from cnidarians and other early-diverging animal groups will elucidate the antiquity of this gene regulatory network and provide insight into regulation of reproduction, physiology, and development - processes that are frequently correlated with daily oscillations in environmental cues.

P1.216 RENDON, N.M.*; DEMAS, G.E.; Indiana University, Bloomington; *nrendon@indiana.edu*

Timing Matters: Exogenous Melatonin Mimics Short-Day Increases in Aggression in Female Siberian Hamsters (Phodopus sungorus)

Among the suite of seasonal adaptations displayed by temperate rodents, males and females of some species demonstrate increased territorial aggression in short compared with long day lengths despite its inverse relationship with gonadal steroids. The precise physiological mechanisms mediating such seasonal fluctuations in female aggression, however, remain mostly unknown. The goal of the present study was to determine if melatonin, the major biochemical cue signaling day length, regulates seasonal changes in aggression. To test this, female Siberian hamsters were housed in either long or short days and given daily injections of melatonin (15 µg/day in 0.1 ml saline) or vehicle (0.1ml saline) for 10 weeks. Injections were precisely administered 2 or 8 hours before their entrained night period for 10 weeks to mimic short-day-like and non-short-day-like patterns of melatonin, respectively. Levels of aggression were then determined using the resident-intruder paradigm, and sex steroid (i.e., testosterone and estradiol) levels were quantified following the aggressive interactions. Short-day responsive animals displayed gonadal regression and were significantly more aggressive compared to long-day, and short-day nonresponsive animals that remained reproductively active. Long-day hamsters receiving timed, but not mis-timed melatonin, displayed elevated aggression comparable to short-day animals. These results confirm previous findings of short-day aggression in female hamsters and suggest that environmentally relevant patterns of melatonin regulate these behavioral responses.

11.1 RENN, S.C.P.; Reed College, Portland; *renns@reed.edu*

Genetic accommodation and behavioral evolution: insights from genomic studies

We know that gene expression level, a first order phenotype, underlies much behavioral variation. Using a genomic approach we can ask “how many and which genes show expression level variation related to plastic behaviors?” and “how many and which genes show expression level variation related to evolved changes in behavior?”. Our model system includes two closely related species of African cichlid fishes. *Jullidocromis transcriptus*, exhibits “conventional” sex-biases in behavior such that the larger male provides territory defense while the smaller female provides nest care whereas *J. marlieri* naturally pair in the reverse size ratio, and exhibits a reversal of behavioral roles. In both species, there is plasticity, such that behavioral patterns can be experimentally manipulated by controlling the relative size of the male and female in the pair. By examining gene expression in this system and borrowing terminology from the field of phenotypic plasticity, we characterize changes in gene expression level according to the concept of a norm of reaction and describe the various patterns of gene regulation evolution that accompany the evolution of behavioral plasticity. It is interesting to see the extent to which norms of reaction for evolved gene expression parallel the norms of reaction for the behavioral phenotypes they orchestrate.

65.2 RENSEL, M.A.*; KOSARUSSAVADI, S.; SCHLINGER, B.A.; Univ. of California, Los Angeles; *mrensel@ucla.edu*

Real-time measurement of hippocampal corticosterone in a songbird

Traditional models of steroid hormone action assume release from distinct endocrine glands into the bloodstream. However, recent studies indicate that tissues such as the brain are capable of synthesizing some steroids de novo, providing a means of local regulation independent of the periphery. The steroid hormone corticosterone (CORT) is produced in the adrenal glands and potentially within the brain, and is an important mediator of physiological and behavioral responses to stress in addition to numerous other functions. Most studies of CORT focus on measurement of circulating hormone levels as a proxy for levels at target tissues, but less is known about the actual amounts of hormone that reach these targets. The goals of the current study were to 1) validate the real-time measurement of CORT in brain tissue using in-vivo microdialysis in a songbird, the zebra finch, 2) determine whether the circadian pattern of CORT commonly found in the bloodstream is present in the hippocampus, an important site for negative feedback of the hypothalamic-pituitary-adrenal axis, and 3) assess whether hippocampal CORT levels are elevated in a matter similar to that seen in the bloodstream in response to a standard handling stress paradigm. We reliably measured CORT in the hippocampus of awake zebra finches. Baseline levels over the course of 24 hours were cyclical, with significantly depressed levels during the night, a time when levels in the bloodstream are also low. Future studies will examine endogenous fluctuations in CORT that may occur during cognitive tasks such as the formation and recall of spatial memory.

S7-2.4 REPPERT, SM; UMass Medical School, Worcester; *Steven.Reppert@umassmed.edu*

The monarch butterfly reveals the prototype ancestral TTFL clock of insects: a focus on cryptochromes

In *Drosophila* and mammals, the classic clock mechanism is comprised of a core negative transcriptional/translational feedback loop (TTFL), which drives self-sustaining rhythms of essential clock components. The monarch butterfly (*Danaus plexippus*) core feedback loop possesses all the critical clock genes found in *Drosophila— clock* (*clk*), *cycle* (*cyc*), *period* (*per*), *timeless* (*tim*), and type-1 *cryptochrome* (designated *cry1*) —but differs in that it also possesses a type-2 vertebrate-like *cry* (*cry2*), which encodes the main transcriptional repressor in the monarch clock, a function fulfilled by *per* in *Drosophila*, which does not possess *cry2*. The discovery of type-2 vertebrate-like CRYs in insects, derived from the discovery of CRY2 in monarchs, has profoundly altered our view of how circadian clocks of non-drosophilid insects work. To further our understanding of animal clock evolution, we reinvestigated the existence of type-1 and type-2 CRYs in all arthropods in which a draft genome has been published. All possess a type-2 CRY, except for all *Drosophila* species, which only possess the light-sensitive type-1 CRY. This supports the existence of both CRY types at the base of arthropod evolution. In addition, type-1 CRY and TIM appear to have been lost prior to the radiation of the hymenopterans, suggesting that the Hymenoptera have evolved different mechanism(s) for photic entrainment. Perhaps the TIMELESS paralog, TIMEOUT, which has some influence on the light input pathway in *Drosophila*, is the key, as it is expressed in all available insect genomes.

P1.200 REYNAGA, CM*; FERRY, LA; CLARK, AJ; Univ. of California, Santa Cruz, Arizona State Univ., College of Charleston; *cmreynag@ucsc.edu*

A comparative study of body shape and swimming kinematics in pholid and stichaeid fishes

Body shape may provide a potential explanation for the variation in swimming kinematics across fish groups. The anguilliform body plan is one extreme body shape that strongly influences swimming behavior. Anguilliform teleosts are phylogenetically and morphologically diverse, especially with respect to their 2nd major body axis (body depth/width). We examined the effects of second major body axis on the swimming kinematics in two teleost families with eel-like bodies: the Pholidae and Stichaeidae. In four species of pholids (*Apodichthys purpureus, Pholis laeta, Pholis ornata*) and three species of stichaeids (*Anoplarchus purpurescens, Xiphister muscosus, Xiphister atropurpureus, Lumpenus sagitta*), we recorded standard length, and the body widths and body depths at 10% standard length increments. Second major axis was defined as the ratio between body depth and width. As this ratio changed with length along the body, a single unifying metric, the "body shape slope" was used to characterize body shape across individuals; this is the slope of the increasing ratio of body depth to width along the caudal region. Forward swimming speed, caudal fin beat frequency, body wavelength frequency, and maximum amplitude were examined from high-speed video recordings at steady swimming speeds ranging from 13.5 – 78.0 mm/s. Pholids, with greater body depths, are morphologically distinct from stichaeids, which have greater body widths. Although pholids and stichaeids varied in body plans, body shape and second major axis were not strong predictors of wave frequencies, maximum body wave amplitudes, and caudal fin beat frequencies relative to standard lengths. The results demonstrate the complexity between body shape and locomotor performance within the body plan of the two teleost families.

P1.104 REYNOLDS, JA*; POELCHAU, M; ARMBRUSTER, P; DENLINGER, DL; Ohio State University, Georgetown University; *reynolds.473@osu.edu*

Transcriptional changes in key metabolic enzymes contribute to metabolic restructuring during diapause in the mosquito, Aedes albopictus.

The Asian tiger mosquito, *Aedes albopictus*, is one of the most invasive species on the planet, and its range has expanded dramatically during the last 20 years. One key to the success of this species is its ability to enter diapause, an endogenously controlled form of dormancy characterized by developmental arrest and metabolic restructuring (i.e. coordinated downregulation of energy production and utilization, and upregulation of processes that enhance stress resistance). To improve our understanding of the molecular regulation of the metabolic restructuring that occurs during embryonic diapause in *Ae. albopictus*, we used qRT-PCR to assess transcriptional changes of genes encoding key enzymes involved in the metabolism of lipids, which are at least 30% more abundant in diapause embryos compared to non-diapause embryos. Elevated expression of *lipid storage droplet protein 2* likely contributes to lipid conservation during diapause as does downregulation *lipase 2, lipase 3, lipase 4, acyl-CoA dehydrogenase 4*, and *isovaleryl-CoA dehydrogenase*, which are genes with known roles in lipid catabolism. Two genes involved in fatty acid synthesis and modification, *Δ(9)-desaturase*, and *fatty acyl-CoA elongase*, were both up-regulated in diapausing pharate larvae, suggesting roles for their gene products in generating saturated fatty acids to enhance membrane fluidity at low temperatures and generating precursors to the surface hydrocarbons needed to resist desiccation, respectively. Taken together, our results provide new insights into the molecular pathways affecting lipid metabolism during diapause in *Ae. albopictus*.

P1.50 REYNOLDS, JA*; DENLINGER , DL; Ohio State University; *reynolds.473@osu.edu*

Do epigenetic mechanisms regulate diapause and the maternal block of diapause in the flesh fly, Sarcophaga bullata?

Diapause, an alternative developmental pathway that provides a means to escape from predictable periods of harsh environmental conditions, is maternally regulated in many insects. Although non-genetic, maternal regulation of diapause is common, the molecular basis of these maternal effects are unknown. In the flesh fly, *Sarcophaga bullata*, the potential to enter diapause is blocked if the mother experienced diapause when she was a pupa. We tested the hypothesis that histone modifications and RNA-interference (RNAi), two types of epigenetic mechanisms that can alter phenotype without changing the DNA sequence, regulate diapause and the maternal block of pupal diapause in *S. bullata*. We used quantitative real-time PCR (qRT-PCR) to assess mRNA expression of 15 epigenetics-related genes. In photosensitive 1st instar larvae, the stage when diapause can be induced in this species, 7 epigenetics related genes, *heterochromatin protein 1*, *su(var)3-9*, *su(var)3-3*, *piwi*, *spindle*, *histone deacetylase 1*, and *argonaute 2* are upregulated in larvae exposed to diapause-inducing conditions compared to larvae reared in diapause-averting conditions. Thus we predict these genes have a role in diapause initiation. We also predict that *argonaute 1*, which encodes an RNAi pathway component that is upregulated 2-fold in diapause pupae compared to non-diapause pupae, has a role in diapause maintenance. In addition, *piwi*, *histone demethylase 4*, and *dicer1*, are likely involved in the maternal block of diapause because mRNA expression of these genes is upregulated in pupal progeny of females with a diapause history compared to females with a non-diapause history. Taken together, our results reveal major differences in transcript abundance of several epigenetics-related genes and provide evidence that epigenetic mechanisms regulate diapause and the maternal block of diapause in *S. bullata*.

16.2 REYNOLDS, L. A.*; GIBBS, A. G.; University of Nevada, Las Vegas; *reyno172@unlv.nevada.edu*

20-hydroxyecdysone (20E) Signaling Delay in Starvation Resistant Drosophila

We selected for adult starvation resistance in replicated outbred populations of *Drosophila melanogaster*. These populations accumulate greater lipid stores as larvae that they then use to survive adult starvation. Lipids are accumulated during the 3rd instar larval feeding period, which is ~24 hr longer in starvation-selected populations than controls; the rate of lipid accumulation during larval feeding is the same between starvation-selected populations and controls. To understand how the developmental delay is achieved we studied timing of gene expression during the 3rd instar. Genes associated with the 20-hydroxyecdysone (20E) pulse that results in puparium formation had delayed expression times. We rescued delayed larval development by feeding 20E to 3rd instar larvae, decreasing adult lipid stores, and further supporting a change in the timing of the 20E titer. We conclude that selection for adult starvation resistance has resulted in physiological changes in larvae that are mediated by 20E signaling. Supported by NSF award IOS-0719551 and NIH award 1R15GM100395.

S11-2.2 RHEN, Turk*; SCHROEDER, Anthony; FAGERLIE, Ruby; LEGGE, Heath; WESSMAN, Laurel; HEIMLER, Jon; BONAPACE-POTVIN, Michelle; ZHANG, Kurt; University of North Dakota; *turk.rhen@email.und.edu*

Genetics, Genomics, and the Evolution of Temperature-dependent Sex Determination in Reptiles

Temperature-dependent sex determination (TSD) is found in some fish and amphibians and many reptiles. Yet, the gene(s) that transduces temperature into a signal for ovary versus testis development is not known in any species. We are using genomic and genetic approaches to dissect the molecular basis for TSD in the snapping turtle, *Chelydra serpentina*. We used “next generation” sequencing to characterize the transcriptome in gonads from embryos incubated under male and female thermal regimes. We used the 454 system to sequence two normalized libraries, producing 2.8 million reads (1.4 million/temp) with average read length of 350 bp. We assembled and annotated these sequences. In a second study, we used the Illumina platform to sequence 20 RNA samples (2 temps x 5 days x 2 biological replicates). This study produced 156.4 million reads (100 bases/read) for a total of more than 15 trillion bp of cDNA sequence. We used DEseq within the R statistical package to analyze transcript abundance (i.e., reads/contig). We identified numerous differentially expressed transcripts during the temperature sensitive period of sex determination: 302 genes on day 1, 145 genes on day 2, 247 genes on day 3, 630 genes on day 4, and 1071 genes on day 5. We used quantitative PCR to verify differential expression of candidate genes. We are also identifying polymorphisms in candidate genes. These polymorphisms will be used in allele specific expression assays in embryonic gonads and genetic association studies in hatchlings from a temperature that produces mixed sex ratios. Here we report results of our transcriptome analyses and describe results of structural equation modeling of the gene network underlying TSD. We discuss TSD within the context of the reproductive biology and ecology of the snapping turtle.

S2-2.1 RICHARDS, CL*; BORUTA, Martyna; BOSSDORF, Oliver; COON, Courtney AC; FOUST, Christy M; HUGHES, A Randall; KILVITIS, Holly J; LIEBL, Andrea L; NICOTRA, Adrienne B; PIGLIUCCI, Massimo; ROBERTSON, Marta H; SCHREY, Aaron W; Univ. of South Florida, Univ. of Bern, Florida State Univ., Australian National Univ., City Univ. of New York, Armstrong Atlantic State Univ.; *clr@usf.edu*

Epigenetic mechanisms of phenotypic plasticity

Our understanding of the translation of genotype to phenotype is still in its infancy, but the ability of an organism to express plasticity in a given trait must be mediated at the molecular level. Epigenetic mechanisms, such as DNA methylation, can result in different phenotypes from the same genotype and therefore fit a classic definition of phenotypic plasticity. However, demonstrating a role of molecular epigenetics in phenotypic plasticity is difficult, especially in natural populations. We present conceptual issues related to measuring phenotypic plasticity and discuss designs that have been used to explore phenotypic plasticity at different levels of organization from the genotype to the species level. Further, we explore the difficulties of linking plasticity and epigenetic effects by presenting data from several plant and animal systems. Our data suggest that differential DNA methylation can contribute to an organism's ability to elicit a variable phenotype. However, deciphering the relationship between phenotypic plasticity and epigenetic variation will require manipulative studies that isolate specific epigenetic changes and their phenotypic effects.

P3.196 RICHARDS, C.T.*; RIVERA, A.R.V.; CHOUDHURY, U.; Harvard University; *richards@fas.harvard.edu*

Modeling the benefits and detriments of tendon elastic recoil

Elastic energy stored in spring-like tendons is known to reduce locomotion cost or to enhance limb power output. Hence, many physiologists assume that elastic structures are beneficial. Yet, their implications are unknown across locomotor tasks. Using a simplified frog limb model, we examined whether a limb that is ‘well tuned’ for jumping also functions well during swimming (or, reciprocally, if a swimming-tuned limb enhances jumping). We characterized which intrinsic properties (muscle activation kinetics, Vmax, tendon stiffness) confer long distance jumping. We then determined whether those jumping ‘specializations’ enhance or impede swimming ability compared to a limb lacking a spring-like tendon. Two non-dimensional parameters were used: *drag multiplier* vs. *mass multiplier* representing drag loads during swimming versus inertial loads during jumping. Simulation data predicted that activation kinetics were nearly irrelevant for inertial loads, as long as full activation occurred within the first 20 ms. However, the shape of the activation waveform grew important as fluid drag increased, requiring an increasingly delayed onset of deactivation in order to maintain power output. Additionally, when *drag multiplier*/*mass multiplier* ratio was high (e.g. swimming with large webbed feet and compliant tendon) the tendon greatly attenuated muscle power transmission.

S2-1.4 RICHARDS, Eric J*; HENKHAUS, Natalie; ANAND, Ila S.; Boyce Thompson Institute for Plant Research, Cornell University; *ejr77@cornell.edu*

Natural Epigenetic Variation in Arabidopsis

The accumulating evidence documenting the prevalence of stable inherited epigenetic alleles, which can be transmitted from one organismal generation to the next independent of strict control by genetic variation, forces a re-examination of the role that epigenetic variation might play in a ecological and evolutionary context. In a survey for natural variation in transcriptional activity and cytosine methylation, we undercovered epigenetic variation in the *Sadhu* retroposon family in the flowering plant, *Arabidopsis thaliana*. I will present an update on our work charting the genetic behavior of *Sadhu* element epigenetic alleles, as well as an investigation of the impact that this epigenetic variation exerts at both the genomic and phenotypic level.

P2.132 RICHARDSON, J.R.*; LARGHI, N.P.; DEBAN, S.M.; Univ. of South Florida, Tampa; *jcricha3@mail.usf.edu*

Does the unique desmognathine jaw morphology enhance bite force?

Analysis of bite force in vertebrates provides insight into the performance of functions such as anti-predator defenses and prey capture and processing. Desmognathine salamanders have been observed consuming crustaceans and other salamanders, prey items which require powerful jaws for subduing and crushing. The robust jaw and skull morphology and unique jaw mechanics of desmognathines, in which the cranium is pulled ventrally while the mandible is locked in place, have led investigators to hypothesize that these salamanders can produce higher bite forces than comparatively sized salamanders. *Desmognathus quadramaculatus* is an ideal species in which to test this hypothesis because of its large size (70-120 mm SVL) and willingness to bite. *In vivo* voluntary bite force was measured during feeding bites using a custom-built piezoelectric bite meter, in both *D. quadramaculatus* and in the comparably sized *Pseudotriton ruber*, another salamander-feeder with a more generalized jaw morphology. *D. quadramaculatus* was found to generate static forces over ten times greater than *Pseudotriton ruber* (8.49 vs 0.59 N on average). Comparison to published bite forces suggests that neither *D. quadramaculatus* nor *Pseudotriton ruber* exerts bite forces that are significantly different than other comparably sized vertebrates. The divergent jaw mechanics of *Desmognathus* may enable bite force to be maintained with reduced levator muscle mass, rather than increasing bite force, per se.

137.5 RICHMAN, S.E.*; MCWILLIAMS, S.R.; LEAFLOOR, J.O.; KARASOV, W.H.; University of Rhode Island, Environment Canada, Winnipeg, MB, University of Wisconsin-Madison ; *cruciger7@gmail.com*

Growing Fast and Dying Young: Influence of Forage Quality on Growth and Survival of Arctic Avian Herbivores

Keystone herbivores such as geese in Arctic ecosystems are highly sensitive to reduced quantity and quality of available forage like that caused by overgrazing. To determine the effects of diet quality on growth and survival of sympatric goose populations, we raised 100 Canada and 100 Snow goose goslings on grass-based diets that included a factorial combination of three levels of protein (10, 14 and 20%) and two levels of neutral detergent fiber (30 and 45%), but similar energy content (~18 kJ/g). Survival of Snow but not Canada goslings was significantly affected by both dietary protein and fiber content. Goslings fed the low protein diets had ~40-65% lighter body mass and reduced structural growth compared to goslings raised on the higher protein diets. The effects of dietary fiber were more extreme for Snow compared to Canada gosling in part because Canadas increased food intake (corrected for body size) by ~100% while Snows increased food intake by only 15% when fed the high-fiber diets. Apparent Metabolizable Energy was similar between species, but lower for diets with high fiber content. Canada goslings had larger gizzard mass and small intestine length than Snow goslings in response to increased fiber content. These results indicate that Snow gosling had higher protein requirements than Canadas, and that there were interspecific differences in compensatory growth that were explained by their digestive physiology. Although phenotypic flexibility in gosling growth and digestive system allows geese to respond successfully to habitat change, there appears to be a lower limit to the quality of forage eaten (<10% protein and high fiber) that is to a degree species-specific.

104.1 RICHTER, M.M.*; LEE, T.N.; TOIEN, O; BARNES, B.M.; BUCK, C.L.; Univ. of Alaska, Fairbanks, Univ. of Alaska, Anchorage; *mmrichter@alaska.edu*
Hibernation at Extremes: How low can you go?
During hibernation, soil temperatures adjacent to hibernacula (Ta) average a low of -15.8&degC and can drop as low as -23.4&degC. Thus, unlike many hibernators, AGS must remain continuously thermogenic during hibernation to defend the gradient between core body temperature (Tb) and Ta. Here we determined the lowest ambient temperature at which AGS will remain torpid. First, we progressively decreased Ta at 2&degC increments from 2&degC to -20&degC, measuring metabolic rate (MR) during steady state torpor at each Ta and arousing animals between trials. We found MR increased from 0.01mlO2/g*hr at 2&degC to 0.29mlO2/g*hr at -20&degC. We also held AGS in steady state torpor at 2&degC, 0&degC, -10&degC, -20&degC and then decreased Ta in 2&degC increments until animals failed to hibernate. Similar to our first findings, MR steadily increased until it reached a maximum of 0.36ml O2/g*hr at -26&degC. Lastly, we held animals in steady state torpor at -20&degC and within a bout of torpor decreased Ta at 0.2&degC/30min. Decreasing Ta within a torpor bout continued until the animal spontaneously aroused or no longer increased MR despite decreasing Ta. We found animals spontaneously aroused at Ta’s between -23.1&degC to -29.8&degC , with an average of -26.0&degC ± 2.7&degC. Our results show that AGS are able to remain in steady state torpor at Ta as low as -26&degC , guarding a temperature gradient of 23&degC between their core body temperature and the ambient environment.

148.4 RICHTER, J.P.*; RUMPLE, C.R.; QUIGLEY, A.P.; RANSLOW, A.N.; NEUBERGER, T.; RYAN, T.M.; STECKO, T.D.; PANG, B.; VAN VALKENBURGH, B.; CRAVEN, B.A.; Penn State University, University of California, Los Angeles; *jpr244@psu.edu*
Comparative Anatomy and Functional Morphology of the Mammalian Nasal Cavity
The mammalian nasal cavity is a complex anatomical structure, having many functional roles. The convoluted nasal airway labyrinth provides a tortuous airflow path and a large surface area for respiratory air conditioning, filtering of inspired contaminants, and olfaction. Due to the small and contorted structure of the nasal turbinals (or turbinates), the anatomy and function of the nasal cavity remains poorly understood in most mammals. However, recent advances in medical imaging, image processing methods, and three-dimensional anatomical reconstruction techniques are now permitting comparative studies of nasal anatomy and function across species. In this study, we present high-resolution magnetic resonance imaging (MRI) and computed tomography (CT) scans of the nasal cavity in different mammalian species that include terrestrial and semi-aquatic carnivorans (coyote, bobcat, sea otter), ungulates (white-tailed deer), and rodents (gray squirrel). Using these data we compare the nasal anatomy, based on the MRI and CT scans and three-dimensional anatomical reconstructions. The functional implications regarding respiration and olfaction are then presented, based on non-dimensional analyses that incorporate airway morphometry data (e.g., airway diameter, perimeter, cross-sectional area, surface area, volume) extracted from the anatomical reconstructions. These analyses are used to quantitatively assess and predict functional nasal airway performance. Supported by NSF grants IOS-1120375 (to BAC), NSF IOB-0517748 (to BVV), and NSF IOS-1119768 (to BVV).

129.2 RICO-GUEVARA, A.*; RUBEGA, M.A.; Univ. of Connecticut; *a.rico@uconn.edu*
Tongue loading and intraoral transport of nectar in hummingbirds
Hummingbirds have remarkably high metabolic rates, amazing speed and aerodynamic control, and they are classic examples of coevolution with flowering plants. All of these facts are related to a single reality: they have evolved to efficiently find and rapidly consume small, scattered nectar pools. We describe here the biomechanics of every step of fluid capture and transport, including the processes by which the nectar is loaded onto and fills the tongue, offloaded inside the bill and transported to the throat. We filmed (high-speed videos up to 1000 fps) 20 species of hummingbirds in localities throughout the Americas. We coupled high-speed cameras to a dissecting microscope to film how the whole tongues of four recently deceased specimens filled with nectar at the tongue-nectar interface. Instead of the capillary filling long thought to be responsible for loading the tongue, we found a surprising mechanism of elastic expansion of the tongue that accounts for its complete filling with nectar. To further understand the feeding process, we used MicroXCT scans to create three-dimensional reconstructions of bills and tongues at a scale that allows measurement of internal volumes and hence calculation of nectar flow rates. Lastly, to elucidate fluid transport inside the bill, we used illumination techniques that allowed us to film nectar flow through the whole beak of live hummingbirds. We were able to visualize nectar flow through the keratin, to track nectar menisci, and to follow bubble formation. We found that hummingbirds exploit hydrostatic pressure to move fluid inside the bill and we describe an unexpected role of the tongue base in nectar transport. These combined data help us understand how their ability to efficiently extract all of the nectar from flowers affects hummingbird ecology and evolution.

119.5 RIDDELL, EA*; SEARS, MW; Clemson University; *eriddel@g.clemson.edu*
Extending thermal games of predator-prey interactions in a spatially-explicit context
For many organisms, biotic interactions are mediated by abiotic features of the environment. Interactions amongst predators and their prey are no exception. For prey, behaviors are the result of balancing trade-offs between the risks of mortality associated with detection by predators and the energetic costs associated with movement while foraging and thermoregulating. In response, predators must adapt to changes in the behavior of prey while also balancing energetic requirements. To date, models of thermally-mediated predator-prey interactions have predicted the extent to which prey specialize on thermal resources in response to predator lethality. However, these predictions have not considered costs associated with movement amongst thermal patches, nor have they considered constraints on movement amongst patches imposed by thermal conditions. Here, we extend these models to include spatially explicit constraints on movement as mediated by thermal features of the environment. The results of these models suggest that the configuration of patches in the environment drives the behavioral decisions in predator-prey interactions. Configurations of habitat that concentrate prey detection tend to favor generalization of the thermal preferences of prey; whereas configurations that reduce prey detection tend to favor specialization.

148.1 RIEDE, T*; GOLLER, F; University of Utah, Salt Lake City; *t.riede@utah.edu*
Complexity of the labial lamina propria increases with increasing range of fundamental frequency in songbird song
The mechanical properties of connective tissue are determined by the morphology of its extracellular matrix. These properties are especially pivotal in sound generating organs where soft connective tissue, is set into flow-induced oscillations , and differences in the morphology of the connective tissue must contribute to vocal differences. In the vocal organ of songbirds (syrinx) labia are the main sound generating tissues. When air is pushed through the syrinx, two pairs of labia are set into oscillation, and these flow-induced tissue oscillations are the basic mechanism for converting aerodynamic energy into acoustic energy. However, during sound production the connective tissue of the labia is exposed to mechanical stresses, and their morphology determines how they respond to stresses such as tensile, shear, and collision stress. Most importantly, these forces contribute to how fast the labia oscillate. We investigated the relationship between morphological features of the labia and fundamental frequency (F0) features in the vocal repertoires of eight songbird species. Species differed in the layered structure of the labia and the degree of labial asymmetry between the left and right syrinx. These differences in species-specific syringeal anatomy explain a significant portion of the variation of the size of a song's F0 range of these species. The relation between F0 range and the number of layers indicates a vocal-repertoire-dependent morphological feature that is independent of body size.

P2.183 RIEDE, T; University of Utah, Salt Lake City; *t.riede@utah.edu*
New insights into laryngeal motor patterns generating rat ultrasound vocalizations
Rodents produce highly variable ultrasound whistles as communication signals unlike many other mammals, who employ flow-induced vocal fold oscillations to produce sound. The function of the laryngeal valve in controlling fundamental frequency features of the whistle sounds across different call types was investigated by recording laryngeal muscle electromyographic activity, subglottal pressure and vocal sound output in awake and spontaneously behaving rats. Subglottal pressure patterns explain only a small amount of the fundamental frequency variations across the rat's vocal repertoire. However, laryngeal muscle activities are highly stereotypic and call type specific. The ultrasound whistle's fundamental frequency contour therefore provides insight into the neurophysiological control of the larynx. The data allow also a refinement of a model explaining the rodent whistle mechanism, including a focus on laryngeal and pharyngeal anatomical structures and an explanation of variables affecting fundamental frequency, call duration and sound amplitude.

P2.17 RIGGS, C.L.*; PODRABSKY, J.E.; Portland State University; *riggsclaire@gmail.com*
The role of microRNA in extreme anoxia tolerance of annual killifish embryos
Investigating the physiological mechanisms of anoxia tolerance and ischemic preconditioning in vertebrates strengthens our understanding and application of anoxia survival strategies. Most anoxia research has focused on mammals, an anoxia intolerant group, with limited studies of anoxia tolerant vertebrates. This study examines the role of microRNA expression associated with anoxia tolerance of *Austrofundulus limnaeus* embryos, a highly anoxia tolerant vertebrate. Embryos of *A. limnaeus* appear to share many characteristics with anoxia intolerant species in their response to anoxia, yet they are able to survive for months in the complete absence of oxygen. Thus, it is likely that this species has evolved novel mechanisms to support anoxia tolerance. Several recent studies indicate a potential role for microRNA in metabolic depression during anoxia tolerance, through gene silencing. We hypothesize that changes in miRNA expression during exposure to and recovery from anoxia may identify molecular pathways that are central to supporting survival of anoxia in *A. limnaeus* embryos. miRNA levels were profiled in anoxia treated *A. limnaeus* embryos sampled prior to and following a 24-hour anoxic exposure. These data will provide the first detailed study of miRNA expression during exposure to anoxia, and will hopefully lead to a better understanding of the molecular pathways that support anoxia tolerance in vertebrates.

P2.163 RILEY, L.A.*; WALKER, R.A.; DEAROLF, J.L.; Hendrix College, Conway, AR; *rileyla@hendrix.edu*
The effect of prenatal steroids on the fatigue resistance of the fetal guinea pig diaphragm
The application of glucocorticoid steroids to women at risk of premature birth has increased the viability of their infants, but little is known about the effects of these steroids on the development of breathing muscles. We hypothesize that the administration of betamethasone, a glucocorticoid, during muscle fiber differentiation will increase the fatigue resistance of the diaphragm in fetal guinea pigs. To test this hypothesis, we removed diaphragms from fetal guinea pigs that were treated with two injections per week of betamethasone (0.5 mg/kg) or sterile water. These injections occurred twenty-four hours apart at 65%, 75%, and 85% gestation. We then measured the contractile abilities of the fetal diaphragms using a standard two-minute fatigue test and a tetanic force fatigue test. Results from the two-minute fatigue test demonstrated that exposure to prenatal steroids does not lead to a significant difference between the fatigue resistance of control and treated fetal diaphragms, while preliminary tetanic fatigue data showed that control diaphragms are slightly more fatigue resistant than treated diaphragms. However, when analyzing the contractile response of the diaphragm, we realized that no diaphragm (treated or control) reached tetanus during the standard two-minute fatigue test, which led to changes in our fatigue test protocol: the duration of the stimulation trains was extended and the time between trains was reduced. Using the revised fatigue test, results that support our hypothesis would indicate that a multi-course exposure to betamethasone leads to a more fatigue-resistant diaphragm. Therefore, treated premature infants may better sustain ventilation during times of stress than untreated infants.

P3.6 RILEY, M.E.*; GRIFFEN, B.D.; University of South Carolina; *rileyme3@email.sc.edu*

You are what you eat: Effect of diet on physiological and reproductive condition in the mangrove tree crab Aratus pisonii

The mangrove tree crab *Aratus pisonii* is a major consumer of fresh mangrove tissue in neotropical mangrove systems, providing a key link between primary production and the detrital food web. Literature documenting their trophic behavior has often reported the species as being primarily herbivorous. However, recent field observations and gut content analyses have revealed that the diet choices of *A. pisonii* are more accurately described as omnivorous. In order to investigate the implications of *A. pisonii*'s omnivorous trophic behavior for physiological condition and reproductive output, we performed a controlled diet experiment varying both the type (proportion of plant and animal material) and amount of food offered to crabs in a long-term laboratory setting. In conjunction with field collections that provide snapshots of *A. pisonii*'s natural diet choices, physiological condition, and reproductive patterns, this study provides insight into the effect of individual diet choices on the overall physiological and reproductive condition of a key consumer in neotropical mangrove systems.

54.1 RIPPE, J.*; STOCKING, J.; REIDENBACH, M.; University of Virginia, Charlottesville; *jpr6mg@virginia.edu*

Coral-macroalgae dominance shift may impact flow-mediated recovery from bleaching

In the last decade, coral bleaching has emerged as one of the most pressing issues facing tropical coral reef ecosystems, a process that frequently results in a community dominance shift on the reef from a coral- to macroalgae-dominated system. Recent studies have shown that increased water flow enhances recovery from bleaching by reducing the boundary layer thickness and increasing mass flux between the coral and water column. We characterized the water flow profile and oxygen concentration immediately over the surface of both a healthy, coral-dominated and a bleached, algal-dominated specimen of *Siderastrea siderea*, by utilizing a Nortek Vectrino II velocimeter, particle image velocimetry, and an oxygen microelectrode. We coupled this to photosynthetic yield of the coral using in-situ pulse amplitude-modulated fluorometry. With this experimental setup, we quantified a significant effect on momentum boundary layer thickness over the coral due to macroalgal presence, which influenced oxygen flux at the coral surface-water interface and altered photosynthetic activity compared to healthy coral. As bleaching is often attributed to photorespiration and oxidative stress on the coral host, these results will likely have implications for recovery potential from a bleaching event.

43.2 RIVERA, A.R.V.*; CHOUDHURY, U.; RICHARDS, C.T.; Rowland Institute at Harvard; *angelarivera@fas.harvard.edu*

Tendon function during swimming: does compliance enhance performance?

Tendons can enhance performance by storing elastic energy produced by the muscle, then releasing it rapidly during recoil, assisting the muscle to accelerate the load. Under certain conditions, tendon dynamics cause 'power amplification', where peak muscle-tendon (MT) power exceeds the theoretical limits of contractile element (CE) power. While power amplification is likely in jumping, its role during swimming is less known. Recent models of MT dynamics during hydrodynamic loading suggest that multiple morphological configurations may maximize MT power, sometimes causing power amplification. However, as this work was performed in still water, it is unclear whether compliant tendons enhance or reduce swimming speed. To address this, we used a forward translating bio-robotic foot actuated by motors simulating *Xenopus laevis* muscle dynamics. We simulated muscle contractions with and without translation at tendon stiffness values ranging from 750 to 30,000 N/m allowing us to relate MT and whole body swimming performance. While peak CE power was similar with and without translation, and across stiffness levels, peak MT power increased with decreasing stiffness with translation, but not in still water. Differences in peak MT power with and without translation stem from timing differences in tendon recoil (starting earlier and lasting ~2x as long without translation). Among translational cases, we observed power amplification for all but the stiffest tendon; for example, in the most compliant case, peak MT power was ~33% greater than the limit for muscle alone. However, there was no enhancement of either swimming speed or muscle work as compliance increased. Hence, it remains unclear whether tendon compliance is beneficial for swimming performance.

S10-2.4 RIVERA, Ajna S*; SAJUTHI, Andrea; CARILLO-ZAZUETA, Brenna; LAMPEH, Rebecca; SPEISER, Dan; HU, Brianna; Univ. of the Pacific, Univ. of Kansas Natural History Museum, Univ. of California, Santa Barbara; *arivera@pacific.edu*

Gene expression differences underlying sexual dimorphism in ostracod eyes: Insights from transcriptomics

The genetics of convergent evolution and switchback evolution is largely unknown. The assumption is that latent gene regulatory networks are redeployed to recreate an ancestral tissue or cell-type. However, the specifics of this are unknown, for example: At what level is the pathway suppressed? How was the network maintained over the evolutionary history of the group? Is the same redeployment strategy used in convergently evolved species? To begin to answer these types of questions we are using transcriptomics, comparative gene expression analysis, and developmental biology to examine a likely case of switchback evolution – the lateral compound eyes in myodocopid ostracods. Our study species, Euphilomedes carcharodonta and E. morini, are of particular interest in that they exhibit dramatic sexual dimorphism of eye morphology. Males have large compound lateral eyes while females have only a tiny rudimentary eye lacking ommatidia. In this way females may represent the ancestral case with eye development suppressed throughout their development while males escape this suppression. Here, we examined the transcriptomes of both embryos and developing male eyes and found 11 of 82 developmental eye genes. After confirming the identity of these genes via phylogenetic methods, we compared gene expression in developing males and females via qPCR and in situ hybridization. We found phototransduction and eye differentiation genes expressed in both male and female eyes, but eye differentiation genes were typically lower in developing female eyes while phototransduction genes showed similar expression levels.

105.1 RIVERS, TJ*; LIVERMORE, JC; PERREAULT, TR; Bowdoin College; *trivers@bowdoin.edu*

Luminescence reduces mortality of the scale worm Harmothoe imbricata when attacked by crustacean predators.

The luminescent scale worm *Harmothoe imbricata* is found in abundance in the intertidal and subtidal habitats of coastal Maine. Luminescence occurs in the elytra (scales), which emit light when both attached and detached from the body. Worms can also exhibit whole-segment autotomization, with the posterior half luminescing and the anterior half staying dark, presumably to escape and regenerate the lost segments. Although the luminescence has long been postulated to provide an increase in survivability upon predation attempts, the role luminescence plays on survivorship has yet to be quantified. Using low-light CCD cameras with infra-red (IR) illumination, a night vision device with an IR barrier filter, and a photomultiplier, we recorded the interactions of dark-adapted *H. imbricata* with crustacean predators having different visual capabilities. The eyes of green crabs (*Carcinus maenas*) and American lobsters (*Homerus sanguineus*) were painted with a matte-black or clear polish, or left unpainted. We found *H. imbricata* were 15% more likely to escape after the first attack eliciting luminescence with visually unimpaired predators than with blind predators. Upon multiple attacks by the same predator, the trend increased, with worms escaping 25% more from predators able to see the luminescent displays than from blind predators. These data indicate that the luminescent behavior of the worms does play a role in escaping predation. In order to further determine the role of light for defense, we will discuss how computer-controlled LED displays mimicking scale worm displays affected predator behavior in the absence of any other sensory modality.

P2.35 RIVEST, E.B.*; CHEN, C.-S.; FAN, T.-Y.; LI, H.-H.; EDMUNDS, P.J.; HOFMANN, G.E.; Univ. of California, Santa Barbara (UCSB), National Museum of Marine Biology and Aquarium (NMMBA), NMMBA, NMMBA, California State Univ. Northridge, UCSB; *emily.rivest@lifesci.ucsb.edu*

Energetic consequences of ocean acidification and warming for coral larvae

In a rapidly changing ocean, understanding how larval dispersal and recruitment will be affected is crucial for the management of adult populations. An investigation of the condition of larvae – their physiological tolerances and capacities – may highlight or reveal mechanisms behind the impact of anthropogenic ocean change on larval dispersal. Towards this end, in this study, we assessed the energetics of larvae of tropical scleractinian coral *Pocillopora damicornis* in response to conditions of ocean acidity and warming during their dispersal, using lipid consumption as an index. Larvae were incubated for 24 hours in seawater containing combinations of CO_2 concentration (450 and 950 µatm) and temperature (27.5 and 30.5°C). An autonomous, modified Honeywell DuraFET® provided a continuous time series of pH on the natal fringing reef throughout the experimental time period. In June/July 2012, pH values averaged 7.968 ± 0.13. Time series of temperature, salinity, and tidal height were also collected. Protein-standardized levels of wax esters changed in response to CO_2 treatments, while those of triacylglycerol were more sensitive to changes in temperature. Changes in additional lipid classes were more variable. Under day-long exposures to seawater with almost twice the acidity of the present fringing reef environment, *P. damicornis* larvae consume lipids to satisfy additional energy demands; however, these rates vary across the larval release period. As a result, portions of each cohort may deplete their lipid reserves quickly in a future ocean scenario, affecting their dispersal range and their potential for completing settlement and metamorphosis.

P3.32 ROARK, AM*; THORN, HA; Furman University, Greenville, SC and Hood College, Frederick, MD, Hood College, Frederick, MD; *alison.roark@furman.edu*

Reproductive effects of 17 beta-estradiol, bisphenol A, and tributyltin in Aiptasia pallida

The potential for adverse effects of endocrine-disrupting chemicals on cnidarians is unknown. In our study, adult sea anemones (*Aiptasia pallida*) were subjected to three endocrine-active chemicals that are found in the marine environment. The 21-day exposure trial included treatments of 17 beta-estradiol, bisphenol A (BPA), and tributyltin (TBT) at concentrations found in the coastal marine environment and at concentrations 25X those found in this environment. We quantified the effects of these chemicals on reproductive endpoints including the number of adults producing offspring (lacerates) asexually, the number of lacerates produced, and lacerate development rate. We also quantified the density of algal symbionts in anemones. Our results provide insights into the effects of environmental endocrine disruptors in invertebrates.

119.1 ROBBINS, TR*; FREIDENFELDS, NA; LANGKILDE, T; Penn State; *robbins.travis@gmail.com*

Native predator eats invasive toxic prey: evidence for increased incidence of consumption rather than aversion-learning

Contemporary adaptation of native prey species to invasive predators has been relatively well documented, but that of native predators to invasive prey has received less attention. Because the level of impact an invasive species will have on its predators versus its prey will determine changes in community trophic structure, it is important to understand how native predators respond to novel prey. Here we examine the response of native fence lizards to the invasion of red imported fire ants, a novel toxic prey. Examining invaded and uninvaded lizard populations, we tested whether or not aversion-learning occurs in juvenile fence lizards over successive feedings (within lifetime), how previous fire ant exposure may affect avoidance behavior (over generations), and whether population differences are consistent when prey choice exists. We also examine rates of phenotypic divergence in traits associated with the native species as both predator and prey. Aversion-learning did not occur in either population. Instead, the incidence of fire ant consumption increased over both successive feedings and generations. Lizards from the fire ant invaded population had a higher propensity to eat fire ants than fire ant-naïve lizards, even when given a choice between prey items. We found greater phenotypic divergence in traits associated with the native species as predator on, versus as prey to, fire ants. Although the strategy of eating these novel toxic prey can impose survival costs in the short term, over the longer-term, eating fire ants may cost little or even benefit survivors.

P1.51 ROBBINS, T; SCHREY, A*; RICHARDS, C; LANGKILDE, T; Penn. State U., Armstrong Atlantic State U., U. South Florida; *aaron.schrey@armstrong.edu*

Fire ant invasion status accounts for variation in DNA methylation of lizard populations

Red imported fire ants (*Solenopsis invicta*) have invaded half the native range of the eastern fence lizard (*Sceloporus undulatus*). Fire ants act as both predator of and prey for S. undulatus; hence the selective landscape is changed in both trophic directions. Fence lizards within invaded sites are more physiologically stressed, and have altered their behavior and morphology in response to these novel selective pressures. Variation in DNA methylation can be stably transmitted across generations and be active in stress-responses; therefore, may provide the short-term adaptive mechanism for some of the observed changes following invasion. We tested for variation in DNA methylation of S. undulatus from invaded versus uninvaded populations (n = 10 from each), and compared patterns across tissue types (blood versus toe-clip) using MS-AFLP. DNA methylation varied among individuals; every individual had a unique epigenotype, and there was similar diversity among populations. DNA methylation varied significantly between invaded and uninvaded populations; two loci had higher methylation in invaded populations, and one had higher methylation in uninvaded populations. Further research manipulating fire ant exposure will clarify whether these epigenetic differences are being driven by this invader, and shed light on the potential role an epigenetic mechanism may play in driving co-varying phenotypic change.

70.2 ROBERTS, JA*; KOOIJMAN, SALM; COULSON, GC; MUNN, AJ; KEARNEY, MR; Univ. of Melbourne, Australia, Vrije Univ., Amsterdam, Univ. of Wollongong, Australia; *j.ridenour@pgrad.unimelb.edu.au*

Using biophysics and Dynamic Energy Budget theory to investigate how a large mammal responds to varying environmental conditions

Multiple factors affect where species can survive and persist across the landscape. Climate limits a species' range and abundance directly – via physiology, activity constraints, and mortality in extreme events – and indirectly, by affecting food availability. We have developed and linked two mechanistic and individual-based models to investigate how populations of red kangaroos (*Macropus rufus*) respond to varying climate and nutritional conditions. Biophysical models are a powerful tool for predicting an animal's metabolic and water requirements based on how their physiology, behavior, and morphology interact with microclimate conditions. However, biophysical models do not fully capture what energy (and water) is available and how this energy is allocated to different metabolic purposes. Such insight can be granted by metabolic theory, such as the Dynamic Energy Budget (DEB) theory, which considers how animals allocate energy (and mass and nutrients) to maintenance, development, growth, and reproduction throughout the animal's lifespan. We used the output from a biophysical model (NicheMapper) to calculate maintenance requirements of red kangaroos for a DEB model, and coupled the models with estimated food availability, based on spatial and temporal data on pasture growth. We found that the northern range boundary of the red kangaroo is limited by heat tolerance, which constrains foraging time. We also show how body condition and temporal changes in food availability interact with climate to affect reproductive output. Such a fully mechanistic approach is a novel and powerful tool for investigating how range limits and population vital rates are affected by varying nutritional and climatic environments.

P3.64 ROBERTS, S.N.*; GALLOWAY, A.W.E.; DETHIER, M.N.; DUGGINS, D.O.; University of Colorado, Boulder, University of Washington, Friday Harbor Labs; *spencer.roberts@colorado.edu*

A comparison of laboratory algal feeding rates with in situ capture of drift algae by the red urchin (Strongylocentrotus franciscanus)

The red sea urchin (*Strongylocentrotus franciscanus*) is a common subtidal herbivore throughout the northeast Pacific. In the San Juan Archipelago (SJA), Washington, red urchins are subject to little predation pressure and are generally exposed and sedentary. Recent research has shown that detached drift algae are common and abundant at all subtidal depths surveyed (>150 m) in the SJA. Here, we investigated whether red urchin feeding rates observed in the laboratory were consistent with field observations of drift capture. Feeding rates were quantified for captive red urchins; from most to least rapidly consumed (grams per hour), these were: *Nereocystis luetkeana, Mazzaella splendens, Saccharina sp., Agarum fimbriatum, and Ulva sp.* In the field using SCUBA, we repeatedly collected all algae captured by urchins at one-day and six-day intervals within a 25 m^2 permanent transect at a depth of 18 m. We identified, blotted, and massed the 'stolen' algae to compare taxonomic composition and mass captured over different time frames, assuming that drift held after a longer time period would more closely reflect urchin preference. Results indicate that at least at this site, availability of particular algae is more important in determining overall drift capture rates than is urchin preference. However, captured *Agarum* constituted a smaller proportion of total algal mass when urchins were given six days to collect drift, indicating that they are likely discarding this alga. This result is consistent with current and previous lab preference studies and suggests that the large quantity of *Agarum* drift into deep water is a low-quality subsidy, at least for urchins.

P1.133 ROBERTS, K.T.*; HEIDL, S.J.; DAHLHOFF, E.P.; SMILEY, J.T.; RANK, N.E.; Sonoma State University, Santa Clara University, White Mountain Research Center; *roberkev@sonoma.edu*

Effects of environmental and genetic variation on survival and development of a montane insect in the presence of natural enemies

Natural populations are confronted with unpredictable abiotic challenges and natural enemies, but interactions between genes, temperature and predation are poorly understood. Sierra Nevada populations of the leaf beetle *Chrysomela aeneicollis* distributed along latitudinal and elevation gradients are polymorphic at the glycolytic enzyme locus *phosphoglucose isomerase (pgi)* and mitochondrial gene *cytochrome oxidase II (COII)*; latitudinal variation at *pgi* and *COII* are concordant. Prior studies have shown that effects of temperature on larval survival, development and locomotion differ among *pgi* genotypes; the most important enemies are specialist predators. Here, we relate genetic and environmental variation to larval survival and development in the presence and absence of natural enemies. Adult beetles were collected from genetically and environmentally intermediate localities and transplanted to high, mid and low elevation sites in three drainages to produce offspring there. Offspring were either exposed to predation or enemies were excluded. Survival and development of offspring was recorded from oviposition to pupation. Development rate was faster at warmer, low elevation sites but natural enemy pressure was lower at high elevation. Maternal *pgi* and *COII* genotype jointly affected development rate and survival of offspring in the presence of enemies. Predation was higher at low elevation and mortality was higher at high elevation in the enemy exclusion treatment. Genotypes from southern populations tended to develop faster and survive better than those from northern populations. We discuss these findings in relation to earlier studies of the adaptive significance of *pgi*.

P1.48 ROBERTSON, MH*; RICHARDS, CL; HUGHES, AR; Univ. of South Florida; *mhr@mail.usf.edu*

Genotypic and Epigenetic Response to Community Structure in Spartina alterniflora

Community structure critically impacts species fitness via mechanisms such as competition and cooperation. The success of organisms in a community is influenced by genotypic diversity of the species present and of the community as a whole. Genotype is typically thought of as the primary determinant of phenotype, where environmental pressures (i.e. natural selection) influence which genotypes increase in the population. However, a growing body of evidence suggests that phenotype may also be influenced by epigenetic modulation of gene *expression* in response to environmental stimuli (e.g. via DNA methylation). Furthermore, biotic interactions have an impact on epigenetic variation and epigenetic variation can influence species interactions. Few studies have examined epigenetic responses in natural populations, and the importance of epigenetic variation in natural populations remains largely unknown. In this study, five genotypes of *Spartina alterniflora* were grown in a natural environment in monoculture and polyculture. We found differences in density and height in three of the five genotypes depending on the genotypic diversity of the experimental population. We also tested for an effect of genotypic diversity on DNA methylation patterns in these genotypes using methylation-sensitive AFLP markers. Differences in the methylation pattern among genotypes and environments suggest a differential ability for genotypes to respond epigenetically to community structure, and potential for natural selection to act on that variation.

P1.91 ROBINSON, A P*; LABONTE, D; MUIR, M J; FEDERLE, W; University of Cambridge; *ar433@cam.ac.uk*

Slippery when wet: the roles of ridge morphology and surface energy in the pitcher plant trapping zone

Nepenthes pitcher plants employ the peristome, a specialised, microstructured surface at the pitcher rim as a prey capture device which becomes slippery when wet. The peristome's wettability appears to be aided by radial ridge structures that have two different length scales: first-order ridges on the 100µm length scale, superimposed on which are ca. 10 second-order ridges on the 10µm length scale. In order to study the function of the first- and second-order ridges, we measured single-pad friction forces of Nauphoeta cinerea cockroaches on dry and wetted peristome replicas and artificial surfaces patterned with ridges of each single length scale. Replicas were produced in transparent epoxy using silicone moulds of Nepenthes maxima peristomes; artificial ridge structures were made from the same material after taking moulds of ridge substrates fabricated by photolithography. Friction forces were found to be significantly lower on wetted substrates in all cases; however, the effect was approximately three times stronger for surfaces where the second-order ridges were present. Dynamic contact angle measurements were performed on peristome specimens with both water and diiodomethane. Whilst both fluids rapidly wetted the peristome in the direction parallel to the ridges, movement of fluid was limited across the first-order ridges by high apparent contact angles (around 90º for water and 120º for diiodomethane). We therefore propose that first-order ridges act to confine the fluid wetting to channels running into the pitcher, facilitating prey capture, whilst the second-order ridges are essential to stabilise the water films on which insects aquaplane. By varying the surface energy of peristome replicas and smooth epoxy substrates, we demonstrate that the peristome's ridge topography facilitates full wetting even for moderately hydrophilic materials.

P3.82 ROBINSON, C.D.*; SANGER, T.J.; BATTLES, A.C.; JOHNSON, M.A.; Trinity University, San Antonio, TX, Harvard University, Cambridge, MA; *crobins3@trinity.edu*

Sexual dimorphisms in behavior in two long-snouted Anolis lizard species

Sexual dimorphisms can evolve as the result of sexual selection or because of natural selection that enhances ecological differences between the sexes. In this study, we examined the behavior and ecology of two species of *Anolis* lizards, *A. maynardi* in Cayman Brac, and *A. brunneus* in Crooked Island, Bahamas, to assess factors that may influence the evolution of their remarkably long male snouts. These long snouts could have evolved via female choice, if females exhibit some preferences for longer male snouts, or through male-male competition, if longer snouts result in social dominance. Alternatively, sexual dimorphism in snout length may have evolved if the sexes utilize different habitats in which different prey capture techniques depend on the shape of the snout. Using behavioral arena trials to assess the hypotheses of sexual selection, we found that *A. maynardi* males with shorter snouts were somewhat more likely to be dominant over longer-snouted males, but females tended to prefer to associate with males with longer snouts. Conversely, in *A. brunneus*, male dominance was not associated with snout length, and females tended to associate with the shorter-snouted males. Thus, the evidence for snout length evolving via sexual selection is weak. Further, field data showed that males and females of both species utilize very similar microhabitats, as measured by perch height and diameter. However, in both species, females performed active foraging for insect prey more frequently than males, who relied more on a sit-and-wait foraging strategy. Together, these data suggest that foraging differences between the sexes may be a more likely explanation for the evolution of sexually-dimorphic snout length than sexual selection.

S1-3.3 ROBINSON, H.E.*; KOEHL, M.A.R.; Univ. of California, Berkeley; *erobinson@berkeley.edu*

Sessile predators and motile prey: the effects of turbulence and wavy flow on benthic predator-prey interactions

Suspension feeders are important components of bottom-dwelling marine communities. Passive suspension feeders that do not generate feeding currents are dependent on surrounding flow to deliver particles and small organisms suspended in the water column. In coastal habitats, turbulence and waves affect food availability, encounter rates, and prey capture by sessile, suspension-feeding sea anemones. The zooplankton prey that anemones ingest, such as veliger larvae, barnacle nauplii, and copepods, exhibit differences in swimming behavior and escape capabilities. To address how the fluid environment and prey behavior shape predator-prey interactions, we used *in situ* flow measurements taken above beds of the aggregating sea anemone, *Anthopleura elegantissima*, to recreate realistic flow characteristics in a laboratory flume. Zooplankton swimming behavior and suspension feeding by sea anemones were observed in still water and in turbulent, wavy flow. During predator-prey interactions, encounter rates and capture success by anemones were compared to determine the impact of physical and behavioral effects on suspension feeding.

P2.86 ROCK, K.; BRADSHAW, E*; MAYER, M; SKEELS, M; SCHREIBER, A; St. Lawrence University; *aschreiber@stlawu.edu*

Maternal transfer of mercury and its redistribution in tissues of metamorphosing Xenopus laevis tadpoles

Mercury (Hg) from industrial pollution is converted into its toxic organic form, methylmercury (MeHg), which bioaccumulates in aquatic wildlife. MeHg binds to cellular protein, and its sub-lethal effects include neurotoxicity, endocrine disruption, and immune suppression. Total Hg concentrations from amphibians living in Hg-rich wetland environments vary between 0.04 and 1.6 ug/gram tissue. Few laboratory studies using amphibian models have addressed dietary Hg uptake and distribution among different life history stages. After feeding adult females swordfish fillets (0.1 ug Hg/g fillet) for one month, total Hg levels increased from less than 0.01 to 2.5 ug/g in liver, and increased to 0.5 ug/g in ovaries. Interestingly, concentrations of total Hg in tadpole progeny (7d) of swordfish-fed females was 50-fold higher (0.5ug/g) compared with controls, suggesting that Hg is maternally transferred. To study how Hg distribution changes during metamorphosis, Nieuwkoop-Faber (NF) stage 54 tadpoles were raised for 30d on a diet of powdered swordfish, resulting in a 200-300 fold increase in total Hg by NF 57, with tail Hg (2.8 ug/g) significantly higher compared with body levels (1.9 ug/g). Interestingly, following metamorphosis the concentration of Hg increased abruptly by a further 2-3 fold (limb and body Hg levels were 6 and 4 ug/g, respectively), even though the tadpoles were not fed during this period. We attribute the abrupt rise in body Hg to transference of Hg from resorbing and condensing organs, such as the tail, gill, and gut, to proliferating organs like the brain and limbs. Therefore, metamorphosis may represent a critical period when tadpoles living in environments containing elevated Hg are particularly susceptible to its toxic effects.

55.5 RODNICK, KEN; Idaho State University; *rodnkenn@isu.edu*

Does glucose metabolism limit rainbow cardiac performance in rainbow trout at high temperatures?

Fundamental questions remain regarding the limits and regulation of cardiac function in fish challenged with elevated water temperature. While the use of glucose for energy metabolism - especially during hypoxia - is well established in the fish heart, it is unclear how increased metabolic needs of cardiomyocytes are supported. Our recent work suggests that increases in cardiac output to meet the fish's overall metabolic demands at high temperatures are met primarily through an increase in heart rate, because tachycardia is an unavoidable physiological response. For quiescent rainbow trout, an acute increase in water temperature to near lethal values (from 14 to 24°C at 2°C h^{-1}) raised heart rate in a linear fashion (from 60 beats min^{-1} to 125 beats min^{-1}, Q_{10}= 2.1). However, in isolated, electrically-stimulated ventricle strips, the presence of exogenous glucose did not support or improve contractile function at elevated temperatures or heart rates. An increase in temperature from 14 to 24°C also did not affect the uptake (transmembrane transport and intracellular phosphorylation) of 2-deoxyglucose (Q_{10} = 1.1-1.2) by quiescent ventricle strips, providing evidence for a lack of thermal sensitivity over this range and a limited ability to support increased energy metabolism. We also explored the possibility that endogenous glycogen and glycogenolysis play significant roles in supporting contracting cardiomyocytes. In contrast to the uptake of extracellular glucose, the thermal sensitivities of ventricular glycogen phosphorylase (Q_{10} = 1.9-2.2) and acid alpha glucosidase (Q_{10} = 1.8) between 14 and 24°C suggest greater enzymatic capacities to increase intracellular glucose metabolism and an important function of glycogen for cardiac energy production in rainbow trout at elevated temperatures.

P1.129 RODRIGUEZ, A.M.*; HAWKINS, M.B.; STOCK, D.W.; Univ. of Colorado, Boulder, Harvard University, Cambridge, MA; *alexandra.rodriguez@Colorado.edu*

The zebrafish as a model for the evolution and development of breeding tubercles in fishes

Breeding tubercles are multicellular, keratinized epidermal projections thought to serve a variety of functions in fishes, including facilitating contact between individuals during spawning, as well as defending nests or territories. They are found in members of four relatively distantly-related orders of fishes, suggesting multiple independent origins. In addition, they frequently differ in size, number, and location among even closely-related species. The development of breeding tubercles has been little studied, and despite their presence in the zebrafish (*Danio rerio*), they have received virtually no mention in this model system. We have begun characterizing the distribution and development of breeding tubercles in the zebrafish with the goal of identifying the developmental genetic mechanisms involved in their origin and diversification. We found tubercles to be present on pectoral fin rays of males, but not females. Both sexes exhibited tubercles on fleshy pads at the tip of the lower jaw and in rows along each ramus. Additional tubercles on the lower jaw, dorsal surface of the head, and operculum exhibited sexual dimorphism that appeared to differ among strains. The first tubercles to appear during development were in the location of the lower jaw pads before the latter were apparent. In the zebrafish and other members of the genus *Danio*, these pads are supported by a projection from the dentary bone; we found that this projection appears at virtually the same time as the overlying tubercles. Finally, we have begun examining breeding tubercles in adult-viable mutants and have found to date that ectodysplasin signaling is necessary for their development.

62.4 ROGNSTAD, R.L.*; WETHEY, D.S.; HILBISH, T.J.; Univ. of South Carolina, Columbia; *rlrognstad@gmail.com*

The effects of rare events on climate-driven range expansion/contraction in marine communities

Species' distributions are frequently determined by temperature and thus species' range limits experience expansions and contractions as climate changes. Shifts in range limits are not always linear and rare climatic events can potentially counteract or exacerbate the effects of climate change on species' distributions. Temperature affects range limits via multiple mechanisms, both direct, such as heat-induced mortality, and indirect, such as reducing growth or inhibiting reproduction. We assessed the effects of recent extraordinarily cold winters on the southern range limit of the arctic acorn barnacle, *Semibalanus balanoides*, in Southwestern England. Additionally, we examined the historical frequency of such events to determine whether rare cold events could be responsible for observed historical and contemporary oscillations in the density and southern range limit of *S. balanoides*. We found that recent cold winters have led to a range expansion of *S. balanoides*, likely because temperatures are now meeting the critical temperature for reproduction of this species. However, the frequency of such cold winters, which are necessary for *S. balanoides* persistence in the area, has declined over the past thirty years. If repeated cold events occur within the lifespan of *S. balanoides*, there is potential for a storage effect and the species could persist in an area, even when faced with unsuitable years caused by warming. We also investigate the interplay between cold winters, which promote reproduction, and cold summers, which reduce mortality. This study demonstrates the importance of considering the role of rare events in controlling species' distributions, particularly when they oppose the overall trend of climate change.

32.3 ROLIAN, C*; DOWHANIK, A; KRUEGER, C; HALLGRIMSSON, B; University of Calgary; *cprolian@ucalgary.ca*

Observing skeletal evolution in real time: preliminary results from an artificial selection experiment in laboratory mice.

Vertebrates show tremendous diversity in the morphology of the postcranial skeleton. This diversity is the long-term result of evolutionary forces acting on population-level skeletal variation. However, this variation is not random or uniformly distributed across traits. Instead, the direction and magnitude of phenotypic variation across the skeleton is patterned by normal processes of organismal development, in turn affecting the evolvability of individual traits. Here, we report on the first few generations of an artificial selection experiment targeting increases in tibia length in the mouse. The experiment is designed to observe skeletal evolution in real time, and to document how the structure of (co)variation across the skeleton affects the evolvability of individual skeletal traits. The experiment comprises two Selected lines and one Control line of CD1 mice, each set up into 14 families. In the Selected lines, mice are tagged and x-rayed, and littermates with the longest tibiae relative to body mass are chosen as breeders for the following generation, and out-bred to top-ranked individuals from other litters. Control mice are paired randomly. After six generations, tibia length has increased 7.3% in Selected vs. Control mice, while the change in body mass is not significant. Other limb bones have increased significantly in length, though not to the same extent, leading to significant changes in limb proportions. These early results show that despite strong phenotypic covariation with other limb bones and overall body mass, targeted selection on a single quantitative skeletal trait can produce relatively independent evolutionary change in individual skeletal traits.

P3.121 ROMAN, M. R.*; BURNETT, K. G.; BURNETT, L. E.; College of Charleston; *mdr8306@uncw.edu*

THE EFFECT OF THE PATHOGENIC BACTERIUM VIBRIO CAMPBELLII ON FATIGUE IN THE ATLANTIC BLUE CRAB, CALLINECTES SAPIDUS, DURING SUSTAINED EXERCISE

The Atlantic blue crab, *Callinectes sapidus*, is a highly mobile crustacean that must locomote daily to perform various activities, such as finding food, finding mates, avoiding predation, and migrating. The ability of a blue crab to become and remain active, while resisting fatigue, may be necessary for survival. In this study, we tested the effects of a bacterial injection of *Vibrio campbellii* (2.5×10^4 *Vibrio* g^{-1} crab) on fatigue in the Atlantic blue crab during sustained exercise. Fatigue was induced by having a crab walk on an underwater treadmill and was quantified as a percent decrease in grip force that a crab could exert when pulling on an underwater mesh net. The holding behavior on the net mimicked the mate guarding behavior of a male crab during copulation with a female. A crab was considered fatigued when it pulled with a force of less than 67% of a pre-exercise pull force value. On average, control crabs injected with saline became fatigued in 5.6 h (±0.31 s.e.m.), while those injected with *Vibrio* became fatigued in 3.5 h (±0.21 s.e.m.). *Vibrio*-injected crabs exhibited a quicker increase in the number of fatigue-indicating behaviors (180° turns or stops) over time and had overall lower pull force values than saline injected crabs. These results indicate that bacteria compromise the ability of a blue crab to become and remain active (supported by NSF Awards IOS-1147008 and DBI-1062990 to LEB and KGB).

P2.16 ROMNEY, AMIE*; PODRABSKY, JASON; Portland State University; *arom2@pdx.edu*

MicroRNA regulation of alternative phenotypic development of the annual killifish, Austrofundulus limnaeus

The annual killifish, *Austrofundulus limnaeus*, is capable of severe metabolic depression during embryonic development as a facultative phenotype termed diapause. However, a small percentage of genetically related individuals do not enter diapause but instead, "escape" and continue to develop until hatching. Entrance into diapause appears to be regulated by maternal effects and environmental cues experienced by the embryos. We hypothesize that regulation of gene expression underlying these alternate phenotypes is epigenetically controlled through expression of diapause-specific microRNAs. We have investigated the expression of small noncoding RNAs, including microRNAs, during development from fertilization until the 24-somite stage in embryos developing on both diapause and escape trajectories. We also profiled expression of small noncoding RNAs in fertilized embryos collected from females known to produce a high proportion of diapausing and escape embryos. We hope to identify diapause- and escape-specific noncoding RNAs, and use these to identify possible gene regulatory pathways that control entrance into diapause and that may underlie the high tolerance of environmental stress exhibited by diapausing embryos. The patterns of expression of such RNAs will provide an extensive view of their role in tissue phenotype determination and plasticity in this species between the two developmental trajectories. The results of this study will likely have far-reaching implications for the regulation of development within an emerging model vertebrate, as well as for the evolution of vertebrate development.

17.2 ROS, I.G.*; BIEWENER, A.A.; Harvard University; *ivo.ros@gmail.com*

Potential control inputs for aerial turning in the pigeon

To investigate the role of head stabilization in flight control of aerial turning, we analyzed 3D head and body orientations during 90°, level turns in pigeons. Assuming the eyes maintain a fixed orientation within the head, the velocity and orientation of the head can be used to approximate the visual feedback. Specifically, the position of the focus of expansion (FOE) of a visual flow field on the retina can be approximated by the degree of head side slip (the offset between the head-fixed gaze and head bearing). During low speed aerial turns, all four pigeons displayed periods of head stabilization alternated with brief repositioning movements (saccades). Translational head saccades consisted of periodic fore-aft speed fluctuations of ~1 m/s for flight speeds of 3-4 m/s. Rotational head saccades occurred near the downstroke-upstroke transition, immediately following peaks in translational head speed. Rotational saccades were of fixed duration (17±3% of wingbeat-cycle period), but of varying magnitude (5-30°) and speed (400-1200 °/s). Rotational head saccades were directed away from the flight direction and into the turn. The degree of head side-slip immediately after a saccade predicted the change in flight trajectory during the subsequent wingbeat-cycle and the body rotation component underlying those flight trajectory changes. Additionally, when the head was not measurably side-slipping, the degree of neck bending or twisting predicted body rotations that re-acquired the forward flight orientation of the body, without substantially affecting flight trajectory. These correlative results indicate that in slow turning flight pigeons use visual information to control flight trajectory, complemented by head deviations relative to their body to control body orientation. (NSF IOS-0744056 & ONR N0014-10-1-0951)

82.3 ROSARIO, M.V.*; DUMONT, E.R.; PATEK, S.N.; UMass, Amherst; *mrosario@bio.umass.edu*

Shrimp springs: how shape affects strength in energy storage

Elastic systems are widespread in nature and vary in morphology across taxonomic groups. A key question in elastic systems is how shape influences strength, thereby affecting how much energy can be stored before failure. To address this question, we analyzed the spring system in the striking appendages of mantis shrimp (Stomatopoda). The fastest-striking mantis shrimp smash prey by using their springs to generate strikes exceeding 24 ms^{-1}. Shrimp that spear are less dependent on elastic energy and strike at slower speeds. First, we asked if cross-sectional shape of smasher appendages results in higher strength. Second, we tested how the location of the saddle (a major spring component) and its removal influence energy distribution in spearers and smashers. Shape factor analysis was used to analyze the effect of cross-sectional shape on bending strength. We also used finite element analysis and manipulations *in silico* to assess the effect of spring location and removal on strain energy density throughout the appendage. We found that smasher appendages achieve equivalent bending strengths as spearers while using less than 1/5 of the material. Removal of the saddle increases energy storage while variation in its position can decrease energy storage. We also found functional differences between smashers and spearers in the non-spring components of the appendages; the smasher configuration uniquely reduces energy in other regions of the appendage. These results suggest that species with higher dependence on fast, spring-loaded movements (i.e., smashers) may have cross-sectional shapes that increase spring strength, and that variation in the configuration of spring components affects the energy in regions other than the spring during spring compression.

P2.102 ROSCOW, R. F.*; CRUZ, A.; Univ. of Colorado, Boulder; *robroscow@snet.net*

Brood Parasitism and Variation in Early Growth Rates of African Rift Lake Cichlids

The cichlid fishes of the Rift lakes of equatorial east Africa represent a model of rapid speciation due to geographic and other reproductive isolating mechanisms. A paramount trait among these species is the common strategy of mouthbrooding, the practice of incubating eggs within the mouth. Within Lake Tanganyika, a catfish species, *Synodontis multipunctatus*, has evolved to take advantage of mouthbrooding in cichlids. By mixing their eggs with the eggs of a cichlid host, *S. multipunctatus* tricks the cichlid into caring for the parasitic young to the detriment of the cichlid larvae. This study investigates traits associated with ontogeny (timing of individual development), specifically early growth rates and whether the presence of *S. multipunctatus* affects growth and development of host cichlid larvae compared to species not exposed to parasitism. Four fish species from the Rift lakes, representing all three lakes, were observed in aquaria during the initial three weeks of life, to establish notochord (embryonic spinal structure) growth rates and early ontogeny. The data collected for each of the four species showed that of the spread of growth attained by individuals for each day observed, the *Ctenochromis horei* from Lake Tanganyika showed the greatest spread around the mean, as well as the greatest mean standard length attained for each day. Observation of the actual growth profiles for all of the species clutches showed *C. horei* displayed the most variability in growth rate, due to the large variability in notochord growth observed day to day. Overall, the data supports the hypothesis of *C. horei* experiencing selection different from the observed cichlids of Lake Malawi and Victoria due to the presence of the brood parasitic *S. multipunctatus*.

51.1 ROSE, C.S.; James Madison University, Harrisonburg, Va; *rosecs@jmu.edu*

The Cellular Basis of Cartilage Growth and Shape Change in Frogs

Unlike bone, skeleton that is comprised entirely of cartilage grows and changes shape as a result of cell behaviors inside the tissue as well as on its surface. The pharyngeal arch skeleton of the frog Xenopus laevis offers an excellent model for studying how cartilage growth and shape change are controlled at the cell level because the three ventral elements (Meckel's cartilage or MC, ceratohyal or CH, and branchial arch cartilages or BA) are not replaced by bone and their cell behaviors are not localized to specific regions, yet they grow isometrically at tadpole stages and undergo diverse shape changes at metamorphosis. MC lengthens and increases its curvature, CH transforms from a broad plate into a narrow cylinder, and BA is resorbed. Our goal is to understand how these growth and shape changes are accomplished at the level of cell division, enlargement, shape change, matrix secretion, and death. We used BrdU to label dividing cells, DAPI to stain dying cells, and Cell Profiler to quantify cell size, shape and orientation in frontal and transverse sections through MC and CH at early, mid and late tadpole and metamorphic stages. BrdU pulse labeling was used to estimate the duration of chondrocyte cell cycles at mid and late tadpole stages. MC and CH have different ontogenetic profiles of cell division, death, size, shape and matrix secretion. However, with the exception of cell death in CH, no cartilage exhibits a dramatic change in frequency or spatial pattern of any behavior going from growth to shape change. Most cells that complete S phase do not complete mitosis, and only a small percentage complete a second mitosis. These data will be used to generate rules of cell behavior for cartilage growth and shape change and to test multiple models for their developmental regulation.

93.1 ROSEN, O.*; MANOR, R.; WEIL, S.; SAGI, A.; Ben Gurion University of the Negev; *roseno@post.bgu.ac.il*

A newly identified IGFBP in crayfish: another piece in the insulin-like androgenic hormone's puzzle?

In malacosracan crustaceans, male sexual differentiation is known to be induced and also maintained by a secreted insulin-like androgenic gland hormone (IAG). The involvement of this peculiar insulin-like factor was thoroughly examined using RNAi in decapods in which silencing several IAG orthologs induced dramatic phenotypic changes ranging from de-masculinization to even male sex-reversal into fully functional female. As of this moment, binding proteins modulating this hormone's signal (e.g., receptor, carrier etc.) were not documented in *Crustacea*. In the screening process of an AG cDNA library of the red claw crayfish, *Cherax quadricarinatus*, an EST encompassing a deduced insulin binding domain was identified. This transcript was found to be expressed in all examined tissues using RT-PCR. Upon full sequencing and bioinformatic analysis, it was found to encode an insulin-like growth factor binding protein (IGFBP) in this crayfish (Cq-IGFBP). Specifically, this deduced protein demonstrates structural homology to the seventh member of the IGFBP family (IGFBP-7). In many cases, members of this family were found to inhibit the action of their IGF-like ligand activity, possibly by their extreme specificity and selective binding which exceeds those of the corresponding insulin-like receptors by more the one/two orders of magnitude. Characterizing the potential link between the crayfish insulin-like androgenic hormone and the newly identified Cq-IGFBP was attempted both by RNAi and protein-protein interaction assays.

57.2 ROSIER, R. L.*; LANGKILDE, T.; Pennsylvania State University; *rlr265@psu.edu*

Potential competitors drive boldness variation in the absence of predation

Risk-taking behavior, or boldness, has often been correlated with body size or condition. Research suggests that variation in boldness behavior, and consequently the boldness-body size correlation, is driven by the cost of predation. Competition can also be an important selective force, however, and can at times play a greater role than predation pressure in structuring communities. Social tolerance has been linked with boldness behavior, suggesting that this trait may be influenced by the presence of would-be competitors, even in the absence of predation risk. We tested for an effect of competitor presence on boldness variation through early development by raising sibling Eastern Fence Lizards (*Sceloporus undulatus*) under different social conditions. Within a clutch, four siblings were housed together in a single enclosure and four siblings were each housed separately. All hatchlings were tested for boldness behavior in open field trials at 8 days and 8 weeks of age. At 8 days of age, hatchlings from the two housing treatments did not differ in boldness behavior. However, by 8 weeks of age, hatchlings that were housed with potential competitors were bolder on average than were siblings that had been raised individually. Additionally, boldness positively correlated with body size at 8 weeks of age only for lizards raised with conspecifics. Bolder juveniles may have a competitive edge, increasing their access to food resources for growth, whereas there may be no benefit to boldness behavior in the absence of competitors. This study indicates that the presence of potential competitors may drive boldness variation independently of predation.

P3.120 ROSS, A.E.*; ROCK, R.P.; FOLTZ, S.L.; MOORE, I.T.; Virginia Tech; *allenr15@vt.edu*

Body condition and heterophil to lymphocyte ratios in urban and rural song sparrow (Melospiza melodia) populations

The environment an organism inhabits may directly or indirectly influence the pressures placed on that organism's immune system, as well as the amount of energy the organism is able to allocate toward immune activity. Previous studies have shown that the immune activity and body condition of urban birds may differ from those of their non-urban counterparts. Our study was conducted to see whether heterophil to lymphocyte ratio (H/L) and body condition are correlated with urbanization in populations of song sparrows *(Melospiza melodia)* in southwestern Virginia. Song sparrows are abundant in both rural and urban environments and our previous studies have suggested that glucocorticoid levels are sometimes higher in urban environments. We chose to investigate H/L and body fat score because they are additional organismal-level assessments of general physiological stress. We collected blood samples from 41 free-living males from 3 rural and 3 urban sites. Our data show that urban birds have significantly lower H/L ratios than rural birds. While there was no difference in fat scores between urban and rural birds, there was a trend toward a negative correlation between fat scores and H/L. These results appear to contradict our previous work suggesting that urban habitats are more stressful and may mean that measures such as these are context-dependent and variable.

61.4 ROSS, C.F.*; HERREL, A.; PORRO, L.B.; EVANS, S.E.; FAGAN, M.J.; MURRAY, K.D.; University of Chicago, C.N.R.S/M.N.H.N. , University College London, University of Hull; *rossc@uchicago.edu*

Cranial bone strain in the teiid lizard Tupinambis merianae and the diversity of optimality criteria in vertebrate skulls

In vivo bone strain data provide the most direct evidence of patterns of strain in the skull during feeding and have provided important insights into skull design in mammals and *Alligator*. These data suggest that bone strain magnitudes in the calvaria and upper face of mammals are absolutely low, and low compared with strain magnitudes elsewhere in the skull. This suggests that the calvaria and upper face are not optimized for resisting feeding forces—where optimality is defined as maximum strength with minimum material—because they are optimized for other functions, including protection of the brain and eyes. Here we present in vivo bone strain data recorded from the cranium of the teiid lizard, *Tupinambis merianae* during transducer biting and feeding. *Tupinambis* experiences very high strain magnitudes in the frontal and parietal bones during feeding, much higher than those recorded at comparable sites in mammals. These results suggest that the cranium of *Tupinambis*, like those of *Alligator* and *Sphenodon*, is more optimized for resisting feeding forces than is the cranium of mammals. During feeding the snout of *Tupinambis* is bent, sheared and twisted, depending on bite point and behavior, emphasizing the importance of recording strain data across a wide range of natural behaviors. In contrast, the deformation regime in the parietal bone is relatively constant across behaviors. This suggests that the "mesokinetic hinge" between frontal and parietal bones absorbs strain energy associated with forces acting on the snout of *Tupinambis* during feeding.

P3.51 ROSSITTO, JJ*; BURGGREN, WW; University of North Texas; *josierossitto@my.unt.edu*

Cardiac and Renal Developmental Windows for Atenolol Exposure in Embryos of the Chicken Gallus domesticus

Embryonic development of the cardiovascular and renal organs is usually independently explored. Yet, these organs operate as a highly interactive system in the adult. We studied the ontogeny of these interactions by altering heart rate and blood pressure with Atenolol, a β1-cardioselective blocker, to determine effects on organ mass and renal microstructure in day 18 chicken embryos. Embryos were chronically dosed with Atenolol during the mesonephric stage (E7-E9), mesonephric-metanephric stage (E11-E13), or metanephric stage (E15-E17). Body masses of all Atenolol-treated groups were significantly smaller than the control group ($p<0.01$) and body mass of the mesonephric group (16.34 ± 0.656 g) was the smallest. Heart mass of the mesonephric group (130.0 ± 5.31 mg) was significantly larger than all other groups ($p<0.01$). Kidney masses of the mesonephric and metanephric groups were significantly larger than the remaining groups with the mesonephric group showing the largest kidney mass (149.5 ± 6.75 mg, $p<0.0001$). Nephron number was significantly reduced ($p=0.002$) by Atenolol in the mesonephric group. Glomerular areas of the mesonephric and metanephric groups were significantly larger than the control group ($p<0.001$). Surprisingly, day 15 embryos showed a transient increase in mean arterial pressure (MAP) with all but the highest dose (12.0 µg Atenolol/mg of embryonic mass) tested, where MAP actually began to decrease as expected. All doses significantly decreased heart rate. Collectively, these data suggest a day 7-9 critical window of Atenolol sensitivity for cardiovascular and renal development.

136.5 ROUSE, GW*; WILSON, NG; VRIJENHOEK, RC; Scripps Institution of Oceanography, Australian Museum, Monterey Bay Aquarium and Research Institute; *grouse@ucsd.edu*

First Xenoturbella spp. (Xenoturbellida) from the Pacific

Xenoturbella is an enigmatic bilaterian taxon of animals that currently contains two nominal species, *Xenoturbella bocki* Westblad 1949 and *Xenoturbella westbladi* Israelsson 1999, both from shallow waters off the Swedish west coast and reaching about 3 cm in length. Evidence from mitochondrial cytochrome C oxidase I sequences suggest that these two in fact represent a single species, *Xenoturbella bocki*. Following initial placement as close to acoel flatworms, the position of *Xenoturbella* amongst Metazoa has varied considerably. They have been considered to be derived molluscs, deuterostomes, or with acoels as basal bilaterian animals. The most recent study places *Xenoturbella* and Acoelomorpha as a clade that is sister to Ambulacraria (Hemichordata and Echinodermata) among the deuterostomes. Here we report the discovery, via Remote Operated Vehicles, of three new species of *Xenoturbella* from deep waters of the eastern Pacific Ocean. One species is closely related to *Xenoturbella bocki* and is of a similar size, and was found near a whalefall at 600 m depth in Monterey Canyon (California). The second species is much larger (~10 cm), and was found in a vesicomyid clam field at ~3000 m depth in Monterey Canyon. This species was also found at 2000 m. in the Guaymas Basin (Gulf of California, Mexico). The third species, also large, was also found in the Guaymas Basin at 2000 m. Evidence from live observations, morphology and molecular sequence analyses are presented. It is likely that this dramatic expansion in the known diversity of *Xenoturbella* will provide further data to stabilize their systematic placement within Metazoa.

105.6 ROWE, A.*; XIAO, Y.; ROWE, M.; CUMMINS, T.; ZAKON, H.; The Univ. of Texas at Austin, Indiana Univ. School of Medicine, Sam Houston State Univ.; *ahrowe@utexas.edu*

No pain, big gain: coevolution between bark scorpion pain-inducing toxins and grasshopper mouse nociceptors

Traits that mediate interactions between predator and prey rely on fast, specialized sensory inputs. Ion channels expressed in excitable membranes are critical for encoding information about and producing responses to sensory stimuli. Given their critical role, it is not surprising that some animals have evolved toxins that bind ion channels and disrupt their activity. Disruption of channel activity may impose strong selection on the receiver, driving the evolution of counter adaptations. Arizona Bark scorpions [(AZB) (*Centruroides sculpturatus*)] produce toxins that selectively bind sodium- (Na^+) ion channels expressed in pain-pathway neurons (nociceptors), inducing intense pain in sensitive mammals. Southern grasshopper mice [(SG) (*Onychomys torridus*)] attack and consume these toxic scorpions. Natural stings and paw-licking assays showed that SG mice respond only briefly to venom, suggesting they have evolved insensitivity to pain-inducing toxins. Recordings of Na^+ current from ion channels expressed in SG mice nociceptors revealed a novel mechanism where a component of AZB scorpion venom is co-opted by these Na^+ channels – to block the very pain signals that the toxins are generating. Cloning and sequencing of genes that encode nociceptor-expressed Na^+ channels from grasshopper mice revealed structural modifications in the channel that are positioned to co-opt toxin activity. Current work is focused on using site-directed mutagenesis, an expression system and electrophysiology to determine if structural modifications of grasshopper mice Na^+ channels produce functional changes in nociceptors that explain insensitivity to bark scorpion pain-inducing toxins.

140.6 ROWELL, TR*; SEALE, LA; SEALE, AP; BANUELOS, GS; GRAU, EG; RILEY, LG; Fresno State Univ., Univ. of Hawaii, USDA-ARS; *temperance15@mail.fresnostate.edu*

Effects of Selenium-enriched meal on growth performance, endocrine control of growth and selenoprotein expression in tilapia (Oreochromis mossambicus)

Selenium (Se) is a naturally occurring essential trace element required for normal nutrition and health in animals. It has been shown to aid in the function of a healthy immune system as well as an antioxidant during cellular stress in tissues. Organic Se has been shown to prevent cardiomyopathies and improve antioxidative status as a nutritional supplement. Studies with Se supplemented diets in some fish species have shown increased growth with decreasing mortality and improved antioxidative status. However, the effects of Se supplementation on growth and metabolism in tilapia have yet to be investigated. Tilapia were offered varying doses of an organic Se-enriched or a control diet for 12 weeks. Tilapia fed Se-enriched diets exhibited decreased growth compared to the control group after 12 weeks. However, there was no difference in liver mRNA levels of two important proteins (IGF-1 and GHR-2) of the growth axis across treatment groups. Liver mRNA levels of the antioxidative enzyme (glutathione peroxidase) and selenoprotein (SelS) were decreased across treatments compared to the control. At this point it is not known if Se supplementation affected circulating levels of these proteins. There was also an increase in the concentration of Se in the liver of the Se-enriched treatment. Further speciation confirmed the Se present in the liver was predominantly selenomethionine, which is also the highest form of Se available in the supplemented diets. Currently, these data suggest that the dose and/or length of Se supplementation used in this study inhibits growth and down-regulates the activity of important selenoproteins in tilapia.

82.5 RUBENSON, J.*; SANGHVI, H.; CROMIE, M.J.; EASTON, K.; MARSH, R.L.; DELP, S.L.; Univ. of W. Australia, Linkoping Univ., Stanford Univ., Northeastern Univ., Stanford Univ.; *Jonas.Rubenson@uwa.edu.au*

Influence of tendon compliance and activation level on fibre operating lengths of skeletal muscle

The region over which skeletal muscles operate on their force-length (F-L) curve is fundamental to the mechanics of movement. Function at the plateau region of the F-L curve may be regarded as favourable since force capacity is optimized. The activation level (ACT) of a muscle will, to a large extent, dictate its force output and in turn will affect tendon stretch and muscle fibre lengths. It remains possible that muscle-tendon units with high tendon compliance have a restricted range of ACT over which optimal fibre lengths can be achieved compared to muscles with low tendon compliance. To test this question we developed a three-dimensional (3D) musculoskeletal model of the guinea fowl hind limb that included 3D bone geometry, muscle-tendon paths and wrapping surfaces, and muscle-tendon architecture properties including muscle PCSA, optimal fibre lengths and tendon stiffness. We simulated the region of the F-L curve occupied by the lower-limb muscles under 4 ACT conditions: 1) 100% ACT (maximal), 2) 50% ACT, 3) 25% ACT and 4) 0% ACT (passive). We found that muscle-tendon units with low tendon compliance (hip muscles) have a length operating range that is largely insensitive to ACT. On the other hand, muscles with high tendon compliance (lower limb muscles with long external tendons) have a length operating range that is highly sensitive to ACT. Interestingly, certain muscles (gastrocnemius) operate across the plateau region of the F-L curve at high ACT whereas other muscles (digital flexors) do so at low ACT. The interaction between tendon compliance, ACT and muscle lengths sheds new light on muscle recruitment and function during movement tasks. This interaction is particularly important in animals with high tendon compliance (e.g. cursorial species).

74.5 RUPERT, J.E.*; MOREIRA, A.S.; BUTCHER, M.T.; Youngstown State University, Univ. of Costa Rica, San Jose; *jerupert@student.ysu.edu*

Analysis of myosin heavy chain (MHC) isoforms in the prehensile tails of didelphid marsupials: functional differences in arboreal versus terrestrial opossums

Little is understood about the structure and function of prehensile tails. Prehensile tails are defined as those having the ability to grasp objects and may commonly be used as an additional appendage during locomotor maneuvers. Didelphid marsupials are an excellent model to relate MHC isoform fiber type with function of caudal muscles as all opossums have a prehensile tail and, the function of the tail varies widely between terrestrial and arboreal forms. To expand on our previous study in the Virginia opossum, MHC isoforms will be determined in the tails of the terrestrial *Monodelphis domestica* and the arboreal *Caluromys derbianus* using a combination of gel electrophoresis and immunohistochemistry analyses to determine the composition of MHC isoforms expressed in the primary tail flexor muscle of each species. Preliminary results from mature *M. domestica* indicate the predominant expression of three MHC isoforms (1, 2A, 2X), and a relatively broad distribution of fast, oxidative hybrid fibers similar to what was previously observed in the terrestrial Virginia opossum. With the complete findings of this study we will be able to answer the following questions: 1. Is there differential expression of MHC isoforms in the prehensile tails of arboreal and terrestrial opossums and how does isoform expression relate to their locomotor habits, and 2. Does MHC isoform composition in caudal musculature change during maturation from adolescence to maturity in opossums? Supported by URC #02-12.

32.6 RUPP, M.F.*; HULSEY, C.D.; University of Tennessee Knoxville; *mrupp@utk.edu*

Evolution and Kinematics of Pectoral Fins in Malawi Cichlids

In adaptive radiations such as Malawi cichlids there is a high degree of variation in the way pectoral fins are used in locomotion during feeding and other routine activities. To try and better understand the factors behind the evolution of pectoral fin musculature we tested for differences in the pectoral fin morphology between groups of species, calculated rates of pectoral fin muscle evolution, and explored differences in locomotion during feeding via high speed video. Using this data and known phylogenetic relationships between the species, we were able to compare rates and patterns of macroevolution in cichlid pectoral fins.

P3.220 RUSCH, T. W. *; SEARS, M. W.; ANGILLETTA, M. J.; Arizona State University, Clemson University; *trusch@asu.edu*

Competition for thermal resources between males in complex landscapes

When resources become concentrated in space, dominant members of a species can prevent subordinate members from accessing those resources. We studied the way that male lizards (*Sceloporus jarrovi) competed for thermal resources in simple and complex environments. First, we measured thermoregulatory performance in small laboratory arenas with a single heat source. Under these conditions, lizards thermoregulated more accurately in isolation than they did in the presence of a larger lizard. Then, we measured thermoregulatory performance in large outdoor arenas with either a clumped or patchy distribution of shade. Each pair of lizards experienced both treatments in random order. We predicted that lizards would compete less intensely in patchy arenas than they would in clumped arenas. We will report the effect of these thermal landscapes on the accuracies of thermoregulation and levels of plasma corticosterone.*

23.2 RYAN, C.P.*; DAWSON, A.S.; SHARP, P.J.; WILLIAMS, T.D.; Simon Fraser University, Canada, Centre for Ecology and Hydrology, Edinburgh, U.K., The Roslin Institute, University of Edinburgh, U.K. , Simon Fraser University; *calen_ryan@sfu.ca*

Hormone-trait relationships for experimentally enlarged clutches continue to challenge the prolactin-based model for clutch-size determination

Clutch-size is a chief predictor of avian lifetime reproductive success, with fitness ramifications for both females and their offspring. While adaptive variability in clutch-size in response to predation, seasonality, or condition-dependant cues has theoretical and empirical support, remarkably little is known about the proximate mechanisms that enable both plasticity and repeatability in this trait. The only formal mechanistic hypothesis for clutch-size determination in birds predicts an anti-gonadal effect of Prolactin, a peptide hormone commonly associated with incubation and chick rearing. Now over 20 years old, this model has become widely accepted despite a scarcity of experimental support. Correlational findings from captive-breeding zebra finches (*Taeniopygia guttata*) in our lab do not substantiate a relationship between prolactin and clutch-size. In a follow-up experiment, we accompanied egg removal with sequential blood sampling in an attempt to further investigate any hormone-trait relationships. Egg removal significantly increased clutch-size (from ~6 to 15 eggs, on average), exposing latent phenotypic plasticity, and was associated with changes in circulating prolactin levels. Still, the nature of this relationship was not consistent with a role for either absolute threshold or rate of prolactin increase accompanying the cessation of laying. These findings continue to challenge the applicability of the only mechanistic model available to explain a key fitness trait in birds.

P1.172 RYAN, JF*; BøRVE, A; HEJNOL, A; Sars International Centre for Marine Molecular Biology; *joseph.ryan@sars.uib.no*

Are acoelomorphs deuterostomes? Evidence from the genome of nemertodermatid Meara stichopi (Acoelomorpha)

Despite great strides in the areas of phylogenomics and phylogenetics, the early history of the Bilateria – especially the position of acoelomorphs to the rest of animals – remains ambiguous. Experimental data from these animals holds the promise of helping to elucidate the evolutionary origin of a range of characters specific to the Bilateria including central nervous system, a through gut (mouth and anus), and mesoderm. However, the ambiguity surrounding the phylogenetic position of the Acoelomorpha makes it difficult to confidently interpret this data. Most molecular-based studies place them as sister to the rest of Bilateria (Nephrozoa), a key phylogenetic position for deducing evolutionary events that occurred in the stem of the Bilateria. However, a recent study places them within the Deuterostomia in a clade with hemichordates and echinoderms. We have sequenced, assembled, and annotated the ~250 megabase genome of the nemertodermatid *Meara stichopi*. We have performed phylogenomic analyses on large EST datasets that maximize taxon sampling, as well as datasets that minimize missing data by only including data from sequenced genomes. Early results from these analyses suggest that the acoelomorphs branched sister to the Nephrozoa. Our results, provide a starting point from which experimental data on *Meara stichopi* and other acoelomorphs can be interpreted and suggest that many important developmental 'toolkit' components arose after a number of complex morphological features including centralized nervous system and through gut.

59.4 RYAN, J.F.; PANG, K.; SCHNITZLER, C.E.; KOCH, B.J.; NGUYEN, A.-D.; MORELAND, R.T.; MULLIKIN, J.C.; WOLFSBERG, T.G.; MARTINDALE, M.Q.; BAXEVANIS, A.D.*; NHGRI/NIH and Sars Intl. Centre for Marine Mol. Biol., Kewalo Marine Lab, Univ. Hawaii, Natl. Human Genome Res. Inst., NIH, Natl. Human Genome Res. Inst., NIH; *andy@mail.nih.gov*

The Genome of the Ctenophore, Mnemiopsis leidyi: Insights into the Genetics of Innovation and the Evolution of Multicellularity

Until recently, only three of the four non-bilaterian metazoan lineages had at least one species whose genome had been sequenced. Ctenophora (the comb jellies) remained as the last non-bilaterian animal phylum without a sequenced genome, and its phylogenetic position remained uncertain. To better-understand the molecular innovations that drove the outbreak of diversity and increasing complexity in the early evolution of animals, we sequenced, assembled, annotated, and performed a preliminary analysis of the 150-megabase genome of the ctenophore, *Mnemiopsis*. The availability of these high-quality, genome-scale data has enabled us to answer several important questions regarding phylogenetic diversity and the evolution of proteins that play a fundamental role in metazoan development. While many components of key protein families and regulatory pathways are present in *Mnemiopsis*, there are notable absences; for example, there are no discernible microRNAs in *Mnemiopsis*, and elements of the microprocessor complex are altogether missing. Continued analysis of the gene content of the earliest metazoan groups is helping to define which components were required for the origin of morphological complexity, and these data have provided a stronger foundation for resolving the question of the phylogenetic position of this phylum.

32.4 RYERSON, WG*; SCHWENK, K; Univ. of Connecticut; *william.ryerson@uconn.edu*

The medium matters: tongue-flicking mechanics in air and water in the water snake (Nerodia sipedon)

Snakes use oscillatory tongue-flicking to sample the environment for odor molecules. In air, the oscillations set up two pairs of vortices and regions of high velocity air flow. This pattern of air movement maximizes the rate of molecular mass transfer onto the tongue tips through convection, diffusion and sorption. Water snakes tongue-flick in water as well as in air, leading us to wonder if the same patterns would be observed in the more viscous fluid. We used high speed video analysis and particle image velocimetry (PIV) in air and water to examine differences between environments in the kinematics of tongue-flicking and the patterns of air/water flow it generates around the tongue tips. In water, both the kinematics and fluid dynamics are strikingly different from air-flicks. The velocity and duration of individual oscillations is reduced, as is the number of oscillations within a tongue-flick bout. In water the tines are not kept rigid as they are during air-flicking; instead they bend in a continuous curve along with the body of the tongue and water appears to flow along the tines rather than across them. Vortex formation is similar in both environments, but the reduced number of oscillations and decrease in velocity results in the formation of only a single pair of counter-rotating vortices before the tongue is retracted. It appears that the greater viscosity of water constrains the mechanics of tongue-flicking and that water snakes are unable to exploit the fluid dynamic mechanism used in air-flicking to maximize chemical collection. It is possible that slower and shorter bouts of tongue-flicking help to prevent the dissolution of the salivary fluid covering the tongue tips---the material that physically collects odor molecules during oscillatory tongue-flicking, which trades-off with the efficiency of mass transfer.

81.6 RYGG, A.D.*; COX, J.P.L.; ABEL, R.; WEBB, A.G.; SMITH, N.B.; CRAVEN, B.A.; The Pennsylvania State University, University of Bath, Natural History Museum, London, Leiden University Medical Center; *adr5023@psu.edu*

The Hydrodynamics of Olfaction in the Hammerhead Shark (Sphyrna tudes)

The hammerhead shark is widely known for its unique head morphology, which is thought to facilitate enhanced olfactory performance. The nasal chambers, located at the distal ends of the cephalofoil, contain numerous lamellae that increase the surface area for olfaction. Functionally, for the hammerhead to detect chemical stimuli, water-borne odors must reach the sensory epithelium that lines these lamellae. Thus, odorant transport from the external aquatic environment to the sensory epithelium is the first critical step in olfaction. Here we investigate the hydrodynamics of olfaction in the hammerhead shark based on an anatomically-accurate, three-dimensional reconstruction of the head and nasal chamber of *Sphyrna tudes* from high-resolution computed tomographic (CT) and magnetic resonance imaging (MRI) scans of a cadaver specimen. Using this reconstructed model, high-fidelity computational fluid dynamics (CFD) simulations are used to elucidate the external and internal hydrodynamics of olfaction during swimming. Computed external flow patterns reveal the occurrence of flow phenomena that results in high and low pressures at the incurrent and excurrent nostrils, respectively, which induces flow through the nasal chamber. Internal hydrodynamic flow patterns within the nasal chamber are also revealed and the implications regarding olfaction are discussed. Finally, we consider the effect of swimming speed on the hydrodynamics of olfaction, where we show the functional trade-offs of fast- versus slow-speed swimming.

P2.75 SAJUTHI, A*; CARRILLO-ZAZUETA, B/B; HU, B; LIN, C; SPEISER, D; OAKLEY, T; RIVERA, A; University of the Pacific, University of California, Santa Barbara;
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A putative gene regulatory network for eye development differs in male and female Euphilomedes carcharodonta (Crustacea; Ostracoda; Myodocopida).

Sarsielloidea is a superfamily of ostracods that demonstrates high diversity of eye types and habitat. Some groups of sarsielloid ostracods show sexual dimorphism in their eye phenotype, in which males have an image forming lateral eye similar to those of other pancrustaceans (Hexapoda+Crustacea), while females do not. Sarsielloids have a single-chromosome sex determination system (XX/XO), suggesting that the dimorphism is due to gene expression differences, rather than genotypic differences. In typical arthropod eye development, there are three stages of development - specification, patterning, and differentiation, culminating in phototransduction. At each stage, there are certain genes that are required to execute and complete development at that stage. We looked at the differences in expression of these genes, as elucidated in Drosophila and other arthropods, during the development of *Euphilomedes carcharodonta* males and females by generating and using gene-expression data from high-throughput sequencing, qPCR, and in situ hybridization. Understanding the differences in a dimorphic species gives clues as to how similar genomes can give rise to multiple phenotypes. These data also gives us a basis for studying the genetic basis of convergent evolution. We will be able to compare male and female gene expression patterns for convergently dimorphic species as well as non-dimorphic species at various stages of development to create a clear picture of the genetic underpinnings of the evolution of dimorphism.

58.5 SALCEDO, N. J.; College of Charleston, Charleston;
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Monotypic genera: two unique armored catfish species (Siluriformes: Loricariidae), with naked snouts.

Although the external morphology of a new species of armored catfish suggested it could be closely related to the genus *Chaetostoma*, the lack of nuchal plate and dorsal spinelet suggested it could be closely related to *Lithogenes* or *Hemipsilichthys*; and the narrow anterior process of its basipterygia suggested it could be closely related to *Ancistrus*. To determine the taxonomy of the new species based on phylogetic relationships, the new species and *Lipoterichthys carrioni* (a monotypic genus considered a synonym of *Chaetostoma*) were included in a published matrix of morphological traits (153 taxa and 215 characters). The results of the phylogenetic analysis retrieved 16123 most parsimonious trees (length 1558; CI=0.18; RI=0.76). The new species was retrieved as sister to *Lipopterichthys carrioni*, this relationship is supported by nine unambiguously changing characters. Furthermore, the new species and *Lipopterichthys carrioni* exhibit 11 and 18 unambiguosly changing characters, respectively, but all these characters are homoplasies (CI<0.5). The decision was to describe the new species in a new genus, based on the unique morphology of its evertible cheek odontodes and on its intermediate characters, such as: a slightly projected anguloarticular, and narrow lateral anterior process of the basipterygia, almost in contact with the medial anterior process of the basipterygia.

P1.158 SALZBERG, R*; ZUZOW, M; TOMANEK, L; California Polytechnic State University, San Luis Obispo;
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Proteomic changes in the mantle tissue of the mussel congeners Mytilus galloprovincialis and M. trossulus in response to acute heat stress

The heat-sensitive blue mussel, *Mytilus trossulus*, is native to the Pacific Coast of North America. Its congener, the more heat-tolerant Mediterranean blue mussel, *Mytilus galloprovincialis*, has invaded and displaced *M. trossulus* from the southern part of its distribution range in California. This is hypothesized to be in part due to increases in temperatures related to climate change, giving the invasive species a competitive advantage. In order to identify interspecific differences in thermal tolerance, we conducted a proteomic analysis of mantle tissue in response to acute heat stress. Mussels were acclimated to 13°C for four weeks and exposed to acute heat stress (13°C control, 24°C, 28°C and 32°C) for 1 h and returned to 13°C to recover for 24 h. Proteins from mantle tissue were separated through two-dimensional gel electrophoresis (2D GE). We are currently identifying the proteins using 2D gel image analysis software and tandem mass spectrometry. Previous proteomic analyses of gill tissue from the same experiment indicated that reactive oxygen species (ROS)-producing pathways associated with NADH production and oxidation were down-regulated, while ROS-scavenging NADPH producing pathways were up-regulated during extreme heat stress. In parallel, the more heat-sensitive native *M. trossulus* showed a decrease in the abundance of oxidative stress protein at 32°C. In contrast, the more heat-tolerant *M. galloprovincialis* showed increasing abundances of fewer oxidative stress proteins, indicating a possible role for heat-induced ROS production in setting thermal tolerance limits. We are currently testing if similar proteomic changes occur in other tissues, specifically mantle.

P2.13 SAMARAJEEWA, DA*; HARDER, A; TONER, M; CHAKRABORTY, N; MENZE, MA; Eastern Illinois University, Harvard University, University of Michigan at Dearborn;
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Ice Nucleation Protein Reduces Cryogenic Injury in Eukaryotic Cells

The bacterium *Pseudomonas syringae* synthesizes under certain conditions an extracellular ice nucleating protein (INP) protein (Swiss-Prot: O30611) capable of promoting ice-formation of supercooled water. INPs serve as organization platforms in the orderly formation of water molecules during freezing. Intracellular ice formation at supercooled conditions (below the freezing temperature of ice) is considered to be lethal in eukaryotic cells. However, we hypothesized that slow and regulated intracellular ice formation at higher temperatures (without significant supercooling) will be less injurious to the cells. We transgenically expressed part of the highly repetitive central domain of the protein O30611, composed of 530 amino acids (*Ps*INP), in *Escherichia coli* and purified the protein by affinity chromatography. Addition of purified *Ps*INP to buffer solutions at 0.075 mg/ml substantially raised the ice nucleation temperature to 4.1 ºC. *Ps*INP was then expressed in cells derived from *Spodoptera frugiperda* (Sf-21) or hepatocellular carcinoma (HepG2). After freezing at 1 ºC min^{-1}, *Ps*INP expressing Sf-21 cells showed an increase in membrane integrity compared to control cells (60.1 ± 3.3% control vs. 71.6 ± 3.4% Sf-21-*Ps*INP; n = 6; ±SE). Standard cryomicroscopy demonstrated that HepG2 cells expressing a green fluorescent protein labeled variant of *Ps*INP (HepG2-*Ps*INP-GFP) showed intracellular ice-formation at higher temperature than control cells (ΔT = 17.63 ± 1.16 ºC; n = 3; ±SE), and maintained membrane integrity following freezing and thawing. Our results suggest that induction of orderly intracellular ice formation can reduce cell injury during freezing.

66.2 SAMSON, J.E.*; MOONEY, T.A.; GUSSEKLOO, S.W.S.; HANLON, R.T.; Woods Hole Oceanographic Institution and Wageningen University , Woods Hole Oceanographic Institution, Wageningen University, Marine Biological Laboratory, Woods Hole, MA; *jsamson@whoi.edu*

Behavioral responses to sound stimuli in cuttlefish (Sepia officinalis)

Sound is an important sensory cue for many marine animals that use acoustics for mate attraction, habitat identification and predator avoidance. Cephalopod sound detection abilities were suggested over a century ago and have been a subject of debate since. Yet there are few data addressing potential behavioral responses of cephalopods to sound, their sensitivity range, or whether sound plays a functional ecological role. This study examined the behavioral responses of 12 cuttlefish (*Sepia officinalis*) to tone pips ranging from 80 – 1000 Hz and intensities of 110 – 165 dB re 1 µPa. The most dramatic responses (jetting and inking) were observed for sounds between 100 and 200 Hz and at 300 Hz (juveniles only), all at intensities above 140 dB re 1 µPa. Subtle skin patterning changes and fin movements were observed at all frequencies and intensities. Similarly to vertebrates, cephalopods showed a decrease in reaction latency when the sound intensity increased, suggesting an energy-based detector. Potential habituation to sound stimuli was examined using repeated (n=45) presentations at 200 Hz and two sound intensities. A decrease in response intensity was observed, especially in younger animals, supporting behavioral adaptation and some habituation. However, response extinction was not reached. The gradation in behavioral responses, habituation and reaction times to acoustic stimuli have not yet been described for marine invertebrates and strongly suggest a functional use to sound detection in cuttlefish and other cephalopods.

113.3 SAMUNI-BLANK, M*; IZHAKI, I; DEARING, MD; KARASOV, WH; GERCHMAN, Y; KOHL, K; LYMBERAKIS, P; KURNATH , P; ARAD, Z; Technion, Haifa, Univ. of Haifa, Haifa, Univ. of Utah, Salt Lake City, Univ. of Wisconsin, Madison, Haifa Univ. in Oranim, Tivon, Univ. of Utah, Salt Lake City, Natural History Museum of Crete, Crete; *michal.samuni@gmail.com*

Divergent Behavioral Strategies in Three Congeneric Rodents for Dealing with Fruit Toxins

Fleshy, ripe fruits facilitate seed dispersal by attracting animals that consume the fruits and disperse the seeds. However, many fruits contain secondary compounds (FSCs) that deter potential consumers. Previous studies have demonstrated class-dependent deterrence where frugivorous birds were not affected by the FSCs while granivorous rodents were deterred by them. Here we show divergent behavioral strategies for dealing with FSCs within a single genus of rodents. In a series of field observations, controlled feeding trials and biochemical analysis we investigated the fruit eating strategies of three congeneric rodents for *Ochradenus baccatus*, a desert plant with unique compartmentalization of FSCs. The fruit pulp has high concentrations of glucosinolates (GSLs) that are hydrolyzed into active toxic compounds upon contact with myrosinase released from the seeds crushed during consumption. We found that the granivorous rodents, *Acomys cahirinus* and *A. minous*, circumvent the activation of the GSLs by, respectively, orally expelling vital seeds or by making a hole in the pulp and consuming only the seeds. In contrast, *A. russatus* activates GSLs by consuming the whole fruit. We propose that *A. russatus* possesses physiological adaptations to cope with the toxic compounds generated from the GSLs-myrosinase system whereas *A. cahirinus* and *A. minous* exhibit behavioral adaptations (seed or pulp spitting) to avoid the activation of these toxins. These findings demonstrate the extreme ecological/evolutionary lability of this plant-animal symbiosis to shift from predation to mutualism.

P1.22 SAMUNI-BLANK, M*; WEINSTEIN , A; Technion-Israel Institute of Technology, Haifa, Insectour blog, insectour.blogspot.com; *michal.samuni@gmail.com*

Species Richness in Our Urban Backyard

Urban ecosystems are subject to intensive development, population growth and thus loss of biodiversity. Therefore, achievement of a sustainable solution in order to maintain biodiversity is crucial. In addition, extensive knowledge about species richness under human pressure can contribute to conservation decisions. The main role of this project is to explore the species richness that surrounds us in our urban backyard. The yard is 0.25 acres of an old farm located on the northern fringe of Binyamina (32°31’ N, 34°56’ E), a rural settlement in Israel. The area receives ~600 mm rainfall annually. The dominant vegetation is semi-natural dwarf-shrubland. The yard was under minimal human intervention (e.g. minimal gardening and no pesticides). Over a period of 2.5 years, we have performed series of species richness surveys: twice a month, three days at a time, using light-traps and flashlights during night time. Individuals from each species were documented using macro photography. In order to identify the species we used professional field guides and consulted with specialist taxonomists. We documented 2 species of amphibians out of 7 species known in Israel; 7 reptilian species and 23 avian species. We found 414 insect species representing 16 different orders out of 30 known in the world, 67 spider species representing 23 different families out of ~50 known in Israel and 12 species of butterflies representing 6 families out of 7 known in Israel. The yard successfully supports species richness although no resources were invested in it. Our results illustrate the potential in private yards in the urban environment as a retaining unit for habitats under ongoing human pressure. We recommend applying this model of species richness survey as an educational tool that raises the awareness of the general public to the richness of organisms that can be found in their own backyards.

76.6 SANDBERG, JS; DABRUZZI , TF; BENNETT, WA*; University of West Florida; *wbennett@uwf.edu*

Ontogenetic shifts in oxygen uptake of Common Mudskipper (Periophthalmus kalolo) and its role in microhabitat selection

The Common Mudskipper, *Periophthalmus kalolo*, is a tropical, amphibious fish capable of utilizing both air and water as a respiratory medium. Although little is known about their early life history, smaller juveniles are thought to be more dependent on tidepools than adults. We quantified oxygen uptake in water and air of fish between 1.0 and 10.3 cm standard length to identify ontogenetic shifts in aquatic and aerial oxygen extraction ability. Mudskippers smaller than 4.0 cm in standard length exhibited aquatic mass-independent metabolic rates nearly twice those measured for larger fish (approximately 0.46 and 0.26 mg $g^{-0.8}$ h^{-1}, respectively). Aerial mass-independent oxygen uptake in juvenile mudskipper < 2.0 cm in length was ten times greater than values estimated for larger fish (3.80 and approximately 0.34 mg $g^{-0.8}$ h^{-1}, respectively). Furthermore, water:air metabolic rate ratios showed that emerged mudskippers < 2.0 cm in length consumed seven and one-half times more oxygen than when submerged. Our results suggest that tidepool dependence of small common mudskippers is not related to oxygen extraction limitations in air, but is more likely linked to attributes such as marked increases in metabolic rate, predation, desiccation or the need to enter pools to excrete ammonia.

P1.183 SANDERLIN, A.G.*; ROSE, E.K.; YEOH, A.J.; GILLEN, C.M.; ITAGAKI, H.; Kenyon College; *itagaki@kenyon.edu*

Immunocytochemical localization of the amino acid co-transporter KAAT1 and neuromodulators in the midgut of larval Manduca sexta.

As part of our continuing investigations into the midgut of larval *Manduca sexta*, we have been investigating the expression of different midgut genes, including the potassium amino acid co-transport protein (KAAT1), using qPCR (Yeoh, *et al.*, 2012). More recently, we have developed several antibodies to KAAT1 with the goal of localizing and quantifying this important transport protein in the midgut. Initial studies using immunocytochemistry show localization primarily in the luminal surface of the midgut cells in the later instars, as expected. We are now in the process of looking across the instars and across different regions of the midgut to see if there are differences in KAAT1 expression over development. In parallel, we have been looking at the expression of several neuromodulators (SCPb, serotonin, FMRFamide, allatropin) in the midguts of *Manduca* of different instars to ascertain their distribution across different regions and across development. (Supported by NSF-UBM #0827208)

33.4 SANDERS, S.M.*; SHCHEGLOVITOVA, M; CARTWRIGHT, P; University of Kansas; *s743s088@ku.edu*

Nonparametric bootstrapping of RNASeq data in polymorphic polyps of Hydractinia symbiolongicarpus

One of the most common utilities of RNASeq data is comparative gene expression between different tissues or individuals. These differences in expression data can be correlated to differences in environmental effects, morphology, and developmental stages. A colony of *Hydractinia symbiolongicarpus* comprises genetically identical yet morphologically distinct and functionally specialized polyp types. In order to identify differential expression patterns in these different polyp types, RNASeq libraries were constructed from feeding (gastrozooids), reproductive (gonozooids), and defensive (dactylozooids) polyps for Illumina sequencing. A hybrid transcriptome was assembled on the pooled Illumina reads. The raw reads of the individual libraries were then mapped back to the hybrid transcriptome to obtain expression counts of transcripts from different polyp types. Current differential expression packages measure statistical significance of differential expression by obtaining point estimates from expression data for known distributions (Poisson, Negative Binomial, etc.). With few or no technical replicates (extraction, library construction or sequencing) these methods have little power to discover significant results. In the absence of technical replicates, we used a nonparametric bootstrapping algorithm to assess confidence in potential differentially expressed transcripts. The bootstrapping algorithm simulates data under a binomial sampling distribution where the probability of sampling an individual transcript is equal to the number of times that transcript was found in the library. Confidence intervals on expression counts were taken for each transcript in each library to discern significant differential abundance. Here we report differentially expressed genes in different polyps types and the utility of applying nonparametric bootstrap methods to RNASeq data.

P2.78 SANFORD, R. S.*; KOHN, A.B.; SWALLA, B. J.; MOROR, L.L.; University of Florida, University of Florida, Whitney lab, University of Washington, Friday Harbor Labs, University of Florida, Whtiney lab; *rachelsusansanford@gmail.com*

Identification of the LIM Homeobox gene family in the ctenophore Pleurobrachia bachei.

The LIM homeobox (Lhx) gene family is important for cell-fate specification in animals. In bilaterians and cnidarians there are six subfamilies of *Lhx* genes, *Lhx1/5*, *Lhx2/9*, *Lhx3/4*, *Lhx6/8*, *Islet*, and *Lmx*, which play a critical role in the development of the nervous system. In a search for genes controlling neural specification in early animals, we first screened the sequenced genome of *Pleurobrachia bachei* for the presence of *Lhx-like* gene homologs. From about 20,000 *Pleurobrachia* gene models, we identified four *Lhx-like* genes initially classified as *Lhx1/5*, *Lhx3/4*, *Islet* and *Lmx* but *Lhx2/9* and *Lhx6/8* were absent. This 4-gene *Lhx-like* complement is similar to another recently sequenced ctenophore *Mnemiopsis leidyi* while the sponge *Amphimedon* has only 3 suggesting that both sponges and ctenophores are among the most basally branched metazoan lineages. Our preliminary data (RT-PCR and *in situ* hybridization) suggest that in *Pleurobrachia* LIMs are predominantly expressed in embryonic stages with no detectable expression in adults supporting a hypothesis that even in ctenophores *Lhx-like* gene families can contribute to cell-fate specification. However, we were unable to confirm neuron-specific expression of *Lhx-like* genes in *Pleurobrachia* and further research is needed to understand the genomic bases of neurogenesis in ctenophores – the enigmatic early animal lineage with well-developed neural organization and a complex behavioral repertoire.

S9-1.5 SANFORD, Eric*; GAYLORD, Brian; Bodega Marine Laboratory, University of California Davis; *edsanford@ucdavis.edu*

Interactive effects of ocean acidification and predation on coastal molluscs

In an era of accelerating global change, organisms are increasingly faced with multiple stressors, both physical and biological. However, these impacts are usually considered independently, and thus the influences of physical stress on the outcome of species interactions are poorly understood. For example, ocean acidification can reduce shell thickness and/or strength in calcifying marine organisms, such as oysters, mussels, and snails. Organisms that allocate increased energy to maintaining normal shell properties under acidified conditions may experience trade-offs, such as reduced shell area and/or tissue mass. Each of these responses may in turn influence susceptibility to predation, through effects on prey defenses, energetic content, and predator handling time. We have begun to explore these issues in recent laboratory experiments. Olympia oysters (*Ostrea lurida*) raised under elevated pCO_2 were drilled by invasive snails at a 20% higher rate than control oysters. High-CO_2 oysters did not produce thinner shells, but were smaller than control oysters, presumably leading to the increased per capita effects of predators. In a separate experiment, larval mussels (*Mytilus californianus*) raised under elevated pCO_2 produced shells that were thinner and more easily crushed than under control conditions. However, in this experiment, the strongest response to high pCO_2 was a 33% reduction in tissue mass. These and other studies suggest that marine calcifiers exposed to the physiological stress of ocean acidification can display complex and sometimes divergent patterns of energy allocation to shell defenses and growth. These strategies can in turn influence susceptibility to predation, with unexplored consequences for the population dynamics of coastal molluscs.

142.1 SANTANA, SE*; LYNCH ALFARO, J; NOONAN, A; ALFARO, ME; University of Washington, University of California Los Angeles; *ssantana@uw.edu*

Social life and ecology help sculpt Old World primate faces

Old World primates exhibit almost every possible hue in the spectrum of mammalian coloration, and these colors are often combined to form very complex facial patterns such as those seen in mandrills, guenons and mangabeys. Animal coloration is thought to experience selective pressures related to intra- and interspecific communication, physiology and ecology, but it remains unclear how facial patterns and coloration across Old World primates have been shaped by these factors. We use a phylogenetic comparative approach to explore the relationship among facial traits, sociality and ecology within three major radiations of Old World primates (Cercopithecidae, Hylobatidae and Hominidae). Consistent with the hypothesis that facial patterns function in intra and interspecific communication, we find that species living in larger groups and in higher degrees of sympatry with congeners have evolved more complex patterns of facial coloration, and there have been changes in the rate of facial pattern evolution in some of these clades. Along with social factors, the evolution of facial colors is also strongly linked to ecological features. Species living in tropical, more densely forested and humid habitats have evolved darker faces, but this trend is only observed within the African clades. Along with similar results previously found for New World primates, this study highlights the interplay between behavioral and ecological factors in shaping the diversity of primate faces.

39.3 SANTHANAKRISHNAN, A.*; MILLER, L.A.; LOWE, A.; ROBINSON, A.; HEDRICK, T.L.; Georgia Institute of Technology, Univ. of North Carolina, Chapel Hill, California Institute of Technology; *arvind7@gatech.edu*

Clap and Fling in Tiny Insect Flight: Role of the Porous Flow Introduced by Bristled Wings

In contrast to the flapping flight of insects of length scales ranging from the fruit fly to the hawk moth, the aerodynamics of flight in insects such as thrips that are 1 mm or less in length is not as well understood. These smallest insects typically fly at Reynolds numbers (Re) of 10 or lower and are of ecological and agricultural importance. Flight aerodynamics change at Re in the range of 5-10 due to increased viscous forces, and the ratio of lift to drag forces decreases significantly. Nevertheless, these insects are capable of traveling long distances. A detailed study of the relevant aerodynamics is thus necessary to connect their locomotion to the observed ecological behavior and dispersal mechanics. These tiny insects have been proposed to augment lift through adaptations in flight kinematics, wing flexibility and wing morphology. With reference to flight kinematics, thrips and other tiny insects clap their wings at the end of each upstroke and fling them apart at the beginning of each downstroke. These insects also have highly bristled wing surfaces as opposed to solid wings. We explore the role of bristled wings by modeling them as porous structures. 2D numerical fluid-structure interaction simulations are then used to quantify aerodynamic forces generated during porous-wing clap and fling. The input parameters for the simulations are obtained from high-speed video recordings of actual insects. An idealized form of the ‘clap and fling’ motion of two wings immersed in fluid is then considered. The effect of having bristles on the flow field is examined and compared to that of an equivalent solid wing.

58.2 SANTINI, F.*; CARNEVALE, G.; SORENSON, L.; ALFARO, M.E.; Univ. di Torino, Torino, Univ. of California, Los Angeles, Univ. of California, Los Angeles; *francesco.santini@alumni.utoronto.ca*

Testing adaptive radiation scenarios in marine fishes by combining phylogenomic and paleobiological data

Adaptive radiation scenarios have been invoked to explain the diversity of some of the best studied groups of organisms (e.g., Rift lake cichlids, Hawaiian Silversword Alliance, passerine birds). Under the most traditional adaptive radiation model numerous lineages start diverging within a brief period of time from an ancestral adaptive type, with each new lineage filling an available ecological niche; subsequently this rapid initial morphological evolution is replaced by relative stasis due to most available niches having already been filled. A number of recent studies, based on molecular phylogenies, questioned the generality of this model and found little evidence of an early burst of morphological diversification in most studies. For most of these clades, however, it is not known if inclusion of the paleodiversity would have modified the results. In this talk we will compare the results of our study of several major groups of marine teleosts, such as tetraodontiforms (puffers, triggerfishes and allies), acanthuroids (surgeonfishes, luvar) and scombroids (tunas, snake mackerels and allies). All of these groups possess a rich fossil record, which to date has rarely been used in evolutionary studies. We will show how the results based on extant taxa and those based on extant plus extinct species differ, and how inclusion of fossil data can alter the conclusion of studies based on molecular phylogenies.

26.5 SAPIR, N*; ROTICS, S.; KAATZ, M.; DAVIDSON, S.; ZURELL, D.; EGGERS, U.; JELTSCH, F.; NATHAN, R.; WIKELSKI, M.; Max Planck Institute for Ornithology, Germany, The Hebrew University of Jerusalem, Israel, University of Potsdam, Germany; *nir.sapir@mail.huji.ac.il*

Multi-year tracking of White storks (Ciconia ciconia): how the environment shapes the movement and behavior of a soaring-gliding inter-continental migrant

Understanding the ways in which environmental factors influence evolutionary fitness is of foremost importance for addressing both basic and applied issues, especially under current and expected scenarios of global change. We used satellite-tracking data to study bird response to stochastic environmental events and to test if these incidents carry over to following seasons throughout the birds’ annual routine. Twenty six birds were followed continuously for 1.5 – 8 years after being equipped with satellite transmitters. Tracking data were processed using MoveBank (www.movebank.org). We examine (1) whether departure for migration and en route staging depends on wind support and hindrance, respectively; (2) if bird cross-country flight speed is affected by wind support and soaring conditions; (3) whether droughts modulate over-winter habitat selection and, migration timing, staging and arrival time to breeding grounds; Environmental data to test these questions include remotely sensed tropical rain and vegetation productivity data, as well as observation-based atmospheric model products. Combining annotated and highly detailed environmental data with bird movement, behavior and breeding information enables better understanding of the causes, mechanisms, and consequences of white stork migration.

60.4 SAVOCA, M.S.*; NEVITT, G.A.; Univ. of California, Davis; *msavoca13@gmail.com*

Tritrophic interactions involving a global climate regulator mediate foraging in marine top predators: Evidence from a 50-year seabird dietary database in the Southern Ocean

Dimethyl sulfide (DMS) has been studied intensively in the context of global climate regulation, and has also been implicated as a key signal molecule in foraging cascades. It has been suggested that seabirds and other marine predators use DMS released by depredated phytoplankton as a foraging cue to locate zooplankton prey. However, the dietary links between DMS attraction and trophic foraging level have never been explicitly demonstrated. We conducted a meta-analysis to explore the hypothesis that DMS mediates a tritrophic interaction in a marine system. We focused on 18 species of Antarctic and sub-Antarctic procellariiform seabirds for which experimental data on chemical attraction were available. If DMS is an infochemical facilitating a tritrophic cascade, we predicted that the diets of DMS-tracking species would contain significantly higher proportions of primary consumers (e.g. crustacea) than other food types (cephalopods and fish). Our results supported this prediction (proportion crustacea: 0.814 ± 0.039, proportion cephalopod: 0.065 ± 0.019, proportion fish: 0.108 ± 0.024; $F_{5,274}=42.67$, $P<0.001$). We further explored this hypothesis by examining the diets of species responsive to 3-methyl pyrazine, a scented compound associated with the next highest trophic level, depredated crustacea. These analyses were consistent in showing essentially the opposite relationship: the diets of non pyrazine-tracking species were significantly more reliant on primary consumers than other food types (proportion crustacea: 0.564 ± 0.053, proportion cephalopod: 0.235 ± 0.042, proportion fish: 0.195 ± 0.034; $F_{5,274}=17.18$, $P<0.001$). Together, this provides strong evidence that DMS, a globally important climate regulator, also functions in ecological contexts to facilitate a tritrophic interaction in the pelagic marine environment.

P3.94 SCHACHNER, ER*; LYSON, TR; FARMER, CG; University of Utah, Smithsonian Institution; *eschachner@gmail.com*

Pulmonary anatomy and the evolution of turtles

A fundamental question in evolutionary morphology is the origin of the structural diversity in the amniote lung. A second, and equally as contentious question within biology is the phylogenetic position of turtles. Recent studies have placed turtles outside of Diapsida based upon paleontological characters; however, several recent molecular-based analyses place them as a sister group to archosaurs. Pulmonary anatomy has long been used as a phylogenetic character for many vertebrates (e.g., varanids, chamaeleonids, anguimorph lizards, and rodents), yet there remains to be any detailed investigation into the pulmonary anatomy of turtles with the aim of contributing to the phylogenetic debate. The anatomy of the primary, secondary, and tertiary pulmonary bronchi of multiple genera of turtles were visualized as 3D surface models using computed tomography (CT). This method provides a novel way to analyze the respiratory system *in situ*, which will further elucidate the unusual morphology of turtle lungs as well as contribute to the discussion on the evolution of Testudines.

P2.110 SCHMIDT, A.*; BIKNEVICIUS, A. R.; Ohio University, Heritage College of Osteopathic Medicine; *schmidta@ohio.edu*

The unsteadiness of steady locomotion.

The crouched posture of small- to medium-sized mammals is considered to be advantageous for locomotion on substrates with irregularities where rapid adjustments in the degree of limb flexion and limb function are required. If highly flexible locomotor performance is a hallmark of small- to medium-sized quadrupeal mammals, then evidence of this flexibility may be evident in their locomotor behavior even on substrates without irregularities. To test this, we evaluated a suite kinematic and kinetic locomotor parameters for six rats (Rattus norvegicus) running at their maximum voluntary speed using two high-speed cameras placed lateral to a terrestrial substrate with two integrated force plates. Only trials in which the rats trotted for at least 2 consecutive and complete strides (i.e., four double-support phases) within a small speed range (± 10% of mean velocity) were analyzed. The results of this study show that rats adjusted locomotor speed frequently when running along the trackway, and transient shifts in ground reaction peak forces and impulses follow an irregular pattern. We conclude that this is evidence of a highly flexible locomotor system in rats and is suggestive that “steady-speed” and “steady-state” locomotion may be less relevant to small- to medium-sized mammals that customarily switch between accelerating and decelerating steps during their intermittent locomotion and as they cross uneven substrates.

P3.189 SCHMIDT, M.; Friedrich Schiller University, Jena, Germany; *schmidt.manuela@uni-jena.de*

Whole-body mechanics of arboreal locomotion in primates: integrating gait parameters, limb compliance and weight distribution.

The diversity of locomotor parameters in quadruped primates offers the potential to explore how variations in footfall sequence, limb compliance, and limb forces influence the efficiency of energy recovery from fluctuations in gravitational potential (EP) and kinetic energy (EK). By comparing four species of small, arboreal primates, this study examines whether the principles of arboreal quadruped walking are compatible with principles that are involved in mechanical energy-saving mechanisms. It turns out that variations in footfall sequence largely determine the phase relationships between fluctuations in EP and EK, but only affect the efficiency of energy recovery to a minor degree. The amplitudes of change in EP and EK differ considerably, however, making the level of energy recovery very low, in the range of zero to 20%. Differences among the species are explained by differences in limb stiffness and in weight distribution between the fore- and hindlimbs. In pygmy lorises, limb stiffness is high, thus generating significant changes in EP. Lorises thus recover a considerable amount of energy from vertical oscillations of the centre of mass. Cotton-top tamarins and squirrel monkeys largely avoid these vertical oscillations and confirm the prediction that compliant limb kinematics distribute limb forces more evenly throughout the stride cycle. Amplitudes of change in EP only account for 1% of changes in EK in these species. Mouse lemurs resemble other small mammals such as opossums in their locomotor mechanics and therefore likely represent a condition close to that assumed for the last common ancestor of primates.

140.5 SCHMIDT, K.L.*; MACDOUGALL-SHACKLETON, E.A.; MACDOUGALL-SHACKLETON, S.A.; Western University, London, ON; *kschmi5@uwo.ca*

The Long-term Effects of Early-Life Stress on Metabolic Rates, Body Composition, and Body Size in Song Sparrows

Variation in the pre- and postnatal environments can have long-term effects on adult phenotype. In particular, exposure to stressors during development can lead to long-term changes in physiology. These changes may predispose individuals to disease, especially disorders involving energy metabolism. In addition, by permanently altering metabolic rates and energy requirements, such effects could have important fitness consequences. We determined the effects of early-life food restriction and corticosterone (CORT) treatment on adult metabolic rates, body composition (assessed via quantitative magnetic resonance), and body size in song sparrows (Melospiza melodia). Nestlings were hand-raised in captivity from 3 days of age (d3) and exposed to treatments (ad libitum food, food restriction, or CORT-treatment) from d7- d60. Both experimental treatments had sex-specific effects on standard metabolic rates (SMR). Females exposed to food restriction or CORT treatment during development had higher SMRs in adulthood than control females, but neither stressor affected SMR in males. There were no effects of either treatment on adult body composition (lean or fat mass) or peak metabolic rates. Although both experimental treatments affected nestling growth there was no long-term effect of either treatment on adult body size. In addition, despite the fact that birds were raised in captivity from an early age (d3), their adult mass was positively related to the mass of their genetic father. This suggests that body size may be a canalized trait in this species. Our results also suggest that early-life stress may have sex-specific programming effects on metabolic rates and energy expenditure in song sparrows.

133.4 SCHMITZ, L*; MOTANI, R; OUFIERO, CE; MARTIN, CH; MCGEE, MD; GAMARRA, AR; LEE, JJ; WAINWRIGHT, PC; Claremont McKenna, Pitzer, and Scripps Colleges, Univ. of California, Davis; *lschmitz@kecksci.claremont.edu*

Allometry indicates giant eyes of Giant Squid are not exceptional

The eyes of giant and colossal squid are among the largest eyes in the history of life, yet it is poorly understood how their eye size compares to that of squid and other aquatic organisms when scaling effects are considered. We performed a large-scale comparative study that included 88 squid species and 237 species of acanthomorph fish. While squid have larger eyes than most acanthomorphs, a comparison of relative eye size among squid suggests that giant and colossal squid do not have unusually large eyes. It is probable that the giant eyes of giant squid result from a phylogenetically conserved developmental pattern manifested in very large animals. It was recently proposed that sperm whale predation is the main driver of eye size evolution in giant squid, based on an optical model that suggested optimal performance in detecting large luminous visual targets such as whales in the deep sea. We revised the constants used in the model and conclude that large eyes perform equally well in detecting point targets and large luminous targets in the deep sea. Whatever the cause of large eyes, they appear to have several advantages for vision in the reduced light of the deep mesopelagic zone.

106.2 SCHNITZLER, CE*; PANG, K; POWERS, ML; REITZEL, AM; RYAN, JF; SIMMONS, D; TADA, T; YOKOYAMA, S; HADDOCK, SHD; MARTINDALE, MQ; BAXEVANIS, AD; NHGRI/NIH, Sars International Centre for Marine Molecular Biology, Monterey Bay Aquarium Research Institute, Woods Hole Oceanographic Institution, Kewalo Marine Laboratory/Univ. of Hawaii, Emory University, Monterey Bay Aquarium Research Institute; *christine.schnitzler@nih.gov*

Ctenophore photocytes express a light-sensing opsin as well as bioluminescent photoproteins during development

The recent completion of a draft genome assembly of the ctenophore *Mnemiopsis leidyi*, a representative of the earliest branch of animals that emit light, has provided an excellent opportunity to examine the genome of an organism that uses photoproteins for bioluminescence. Interestingly, we found that photoprotein transcripts are co-expressed with two putative opsin genes in developing photocytes. Opsin expression was also found in four small groups of neural cells in the floor of the apical sensory organ that coincides with structures described as ciliated lamellate bodies; these structures were suggested to be photoreceptors over 130 years ago. We present evidence that one of the opsin genes functions *in vitro*, absorbing light at wavelengths that overlap with peak photoprotein light emission. We also present genomic evidence of a complete ciliary phototransduction cascade in *Mnemiopsis*. These findings led us to hypothesize a novel dual role for ctenophore photocytes in both bioluminescence and opsin-mediated phototransduction. This work provides a foundation for further studies aimed at determining how the bioluminescence cascade operates in *Mnemiopsis*, as well as whether opsin and other phototransduction pathway genes play a role in either promoting or inhibiting luminescence production under different environmental conditions.

P2.61 SCHOENLE, L. A.*; CHRISTOPHERSON, G. L.; Virginia Tech, University of Arizona; *schoenle@vt.edu*

Wildfire's Wild Survivors: How Bird Populations are Affected by a Changing Habitat

Historically, wildfires in southern Arizona occurred frequently, were widespread, and of low intensity. After 100 years of fire suppression, we are observing high intensity wildfires that sterilize the soil and burn the forest crown. The change in wildfire regime appears to affect the montane bird species that evolved under historic conditions. These birds may be a useful indicator of ecosystem health due to their intermediate trophic level and ability to leave an undesirable area. We examined the relationship between burn severity (unburned, low, moderate, and high) and the density and diversity of bird species 9 years after the catastrophic Aspen Fire in the Santa Catalina Mountains north of Tucson, Arizona. We detected significantly greater numbers and species of birds in burned areas than in unburned areas. This suggests that wildfires may be necessary for maintaining populations of bird species, in addition to many plant species. When comparing species density and diversity among specific levels of burn severity, we found (1) significantly greater densities of birds in areas of low and high burn severity, than in unburned areas and (2) significantly greater species diversity in areas affected by low severity fires than in unburned areas. Low burn severity fires may most closely resemble historic fire conditions and as a result, areas of low burn severity may be preferred by a wider variety of bird species. Improving our understanding of the effects of burn severity on bird populations can have important implications for forest management.

127.1 SCHOLTZ, G; MARTIN, Peer*; Humboldt-Universitaet zu Berlin; *gerhard.scholtz@rz.hu-berlin.de*

Happy Birthday Marmorkrebs! Ten years of research on an enigmatic crayfish

In the last decade of the 20th century some rumors occurred in internet discussion groups of hobby aquarists dealing with an enigmatic crayfish with strange reproductive behavior and of unknown origin. In 2003 this crayfish, popularly named Marmorkrebs (marbled crayfish), was introduced to science. In the publication the parthenogenetic reproduction mode and the affinity to American Cambaridae could be revealed. These results made the Marmorkrebs a highly interesting candidate for further studies. Over the last decade numerous papers have been published addressing aspects of the biology of this crayfish. These related to the mode of parthenogenesis, embryonic and postembryonic development, species identity, geographical origin, epigenetic variation, ecology, conservation issues, etc. Despite this progress in knowledge about the Marmorkrebs, a number of its riddles are still unresolved. Our presentation provides a summary of the research activities of the last ten years and develops a perspective for future investigations.

P2.9 SCHRAM, J.B.*; SCHOENROCK, K.M.; MCCLINTOCK, J.B.; AMSLER, C.D.; AMSLER, M.O.; ANGUS, R.A.; Univ. of Alabama at Birmingham; *jbschram@uab.edu*

Sub-lethal impacts of ocean acidification and elevated temperature on two molluscs from the western Antarctic Peninsula

Current changes in anthropogenic atmospheric carbon dioxide concentrations are increasing at unprecedented rates and altering ocean carbonate chemistry (ocean acidification). Coupled with rapidly rising sea surface temperatures along the western Antarctic Peninsula, this region of the Southern Ocean is projected to be undersaturated with respect to calcite and aragonite before warm water environments, thus putting additional abiotic stress on calcifying marine organisms. The present study examines the sub-lethal effects of decreased seawater pH and increased temperature on buoyant and wet weight as well as righting responses in the common Antarctic limpet *Nacella concinna* and mesogastropod *Margarella antarctica*. Experimental animals were collected by hand using SCUBA within 3.5 km of Palmer Station, on Anvers Island off the central western Antarctic Peninsula. We selected two pH levels (pH 8.0, 7.6) and two temperatures (1.5ºC, 3.5ºC) to measure sub-lethal impacts in both species over a 43-day period. The pH levels selected represent current mean ambient seawater conditions in the vicinity of Palmer Station, Antarctica (pH 8.0, 1.5ºC) and a pH predicted to occur by year 2100 (pH 7.6, 3.5ºC). Following analysis, we found no significant changes in wet or buoyant weights over the experimental period. There also were no pH-temperature mediated differences in the proportion of *N. concinna* to right in 24-hours or the time to right for *M. antarctica*. This common molluscan macrograzer (*N. concinna*) and mesograzer (*M. antarctica*) appear to be resistant to a 43-day exposure to conditions predicted for the western Antarctic Peninsula.

S2-1.2 SCHREY, Aaron*; ALVAREZ, Mariano ; FOUST, Christy; KILVITIS, Holly; LIEBL, Andrea; MARTIN, Lynn B.; RICHARDS, Christina; ROBERTSON, Marta; Armstrong Atlantic State Univ., Univ. S. Florida; *aaron.schrey@armstrong.edu*

Ecological Epigenetics: Beyond MS-AFLP

Ecological Epigenetics studies the relationship between epigenetic variation and ecologically relevant phenotypic variation. As molecular epigenetic mechanisms often control gene expression, even across generations, they may impact our understanding of many evolutionary processes. We define epigenetics as the study of factors that alter gene expression without changing the DNA sequence. There are several molecular epigenetic mechanisms, but DNA methylation has so far dominated the Ecological Epigenetic literature. We review the molecular techniques used to screen DNA methylation in Ecological Epigenetics, and then focus on the most common technique, MS-AFLP, which is used to identify methylation states at particular restriction sites throughout the genome. We present data from multiple studies across taxa that show the commonalities in molecular methods and the general themes from these results. Next, we identify the characteristics of the studies that provide the greatest inference, and we make specific suggestions for future MS-AFLP work using these exemplary studies as a guide. Then, we review the short-comings of MS-AFLP approaches and suggest other techniques such as bi-sulfite sequencing and microarrays that might address some of these short-comings. Finally, we identify questions that are most compelling and tractable in the short term using available techniques and discuss how future epigenetic approaches will illuminate behavioral ecology, phenotypic plasticity, and short term adaptation.

S9-2.4 SCHULTE, PM; University of British Columbia; *pschulte@zoology.ubc.ca*

Evolution of tolerance to multiple interacting stressors in fish

Anthropogenic environmental change, which involves changes in multiple interacting environmental stressors, is having important effects on animals living in aquatic environments. Although we have a fairly good understanding of the effects of abiotic stressors in isolation, our understanding of the effects of these stressors in combination is limited, which limits our ability to make predictions about the responses of fish to anthropogenic environmental change. Here, I review the available literature on the responses to interacting abiotic stressors such as temperature, hypoxia and salinity in fishes, with a focus on work from my laboratory on killifish (*Fundulus heteroclitus*), threespine stickleback (*Gasterosteus aculeatus*) and Atlantic salmon (*Salmo salar*). These data suggest that these stressors may act synergistically such that small shifts in multiple stressors could result in large effects on organismal performance. There is substantial intraspecific variation in tolerance to individual stressors in many species of fish that could act as the raw material for evolution of improved tolerance. However, the potential for adaptive evolution in the face of multiple interacting stressors will depend, in part, on the genetic correlations among tolerance traits. For example, negative genetic correlations (or trade-offs) between temperature and hypoxia tolerance could limit the potential for adaptation, while positive genetic correlations might be of benefit. The limited data currently available suggests that hypoxia and high temperature tolerance may be positively correlated in at least in some species of fish suggesting the possibility for adaptive evolution in these traits in response to anthropogenic environmental change.

68.1 SCHULTZ, EM*; HAHN, TP; Univ. of California, Davis; *emschultz@ucdavis.edu*
The environmental and physiological factors modulating immunity in an opportunistic breeder
In order to be optimally suited to the current environment, organisms must choose when and how to allocate limited energy resources to the most essential physiological process. This conflict often results in a trade-off between investing in future survival (e.g., immune function) or current reproduction. Much research on these tradeoffs has focused on seasonally breeding organisms that constrain reproduction to times of year when environmental conditions are benign. In contrast, organisms such as the red crossbill *Loxia curvirostra* specialize on conifer seeds which are unpredictably available in space and time, and so have evolved temporally flexible reproductive schedules allowing them to reproduce 10 months a year if seeds are abundant. In this study we examined variation in allocation to three measures of constitutive innate immunity: differential white blood cell counts, hemolysis-hemagglutination and microbial killing assays. We compared those results between breeding and non-breeding individuals across seasons (summer, winter) and years of high and low food availability. In general, crossbills are able to invest more in both reproduction and immunity if environmental conditions are benign (summer, good cone crop). However, if environmental conditions are harsh (winter, poor cone crop), immunity tends to be lower, even in good cone years. Data collected from this summer (a poor cone year) will be used to augment prior data. Results from this study will provide novel information regarding environmental and physiological modulators of immunity in free-living animals, as well as providing a unique opportunity to investigate how harsh environmental conditions and reproductive effort may interact to shape investment patterns and life history evolution.

P1.196 SCHUNK, C.*; CHIU, C.; SWARTZ, S.M.; BREUER, K.S.; Brown University, Providence RI; *cosima_schunk@brown.edu*
Velocity fields in the near-wake of E. fuscus
Particle image velocimetry (PIV) in the plane perpendicular to the flight direction (Trefftz plane) provides valuable insight into flight performance and changes in lift generation that occur over the wingbeat cycle in bats. The majority of PIV studies of bat flight have visualized flow in the transverse, or Trefftz plane. However, combining measurements from a parasagittal plane with Trefftz plane measurements allow for a much more detailed understanding of the complex wake structures and can offer an improved understanding of the nature of the temporal evolution of force generation over the wingbeat, as well as the spatial distribution of the aerodynamic force over the wingspan. Here, we present a quantitative description of some of these structures we have observed previously in bat wakes, particularly the strong starting and stopping vortices that appear at the wingtip during the beginning and end of the downstroke. We trained several Big Brown Bats, *E. fuscus* to fly at a fixed position in the test section of a wind tunnel at wind speeds between 4.5 m/s and 7 m/s. We measured the air flow around the left wing of the bat and in the wake immediately behind it using time-resolved (200 Hz) stereo PIV. In addition, three high-speed cameras (400 Hz) captured the position and movement of the bat to reconstruct wing kinematics. We captured the wake over multiple consecutive wingbeats. Differences in the pattern and strength of starting and stopping vortices suggest that early in downstroke, as lift generation begins, the site of primary lift production travels gradually from the wingroot to the wingtip and the termination of lift generation at the end of the downstroke is sudden. This pattern may be unique in flying animals studied to date. Research supported by AFOSR.

59.6 SCHWAB, D.B.*; KIJIMOTO, T.; MOCZEK, A.P.; Indiana University - Bloomington; *schwabd@indiana.edu*
Genetic, developmental, and ecological determinants of resource allocation tradeoffs in the horned beetle, Onthophagus taurus
During ontogeny, growing structures may compete for a shared pool of limited resources to sustain their development. Such interactions may lead to tradeoffs, where the elaboration of one structure must come at the expense of another. Tradeoffs have the potential to constrain the production of phenotypic variation and to bias evolutionary trajectories. In *Onthophagus* beetles, large males produce extravagant horns used to secure matings. Previous studies suggest tradeoffs between horns and both proximally- (i.e. antennae, eyes, wings) and distally-located (i.e. genitalia) structures; however, the developmental mechanisms underlying these interactions and their evolutionary significance are unknown. Here we explore the nature of tradeoffs between head horns and eyes in the horned beetle *O. taurus*. We investigate (a) relative investment into horns and eyes among discrete populations and find that tradeoffs are absent in established populations, but may be present in populations at the edge of an invasion front. Using common garden rearing, we show that (b) relative investment into horns and eyes changes under laboratory conditions. We then (c) contrast exotic populations that have diverged heritably in horn investment. We find that reduced horn investment results in reduced investment into horns, opposite to predictions based on tradeoffs. Lastly, we (d) altered horn investment via RNAi of the somatic sex-determination gene *doublesex*, which results in greatly reduced horns in males. Again, we find that horn reduction also results in reduced investment into eyes. These results suggest that resource allocation tradeoffs between developing structures may depend greatly on genetic, developmental, and environmental contexts. This context-dependency may therefore limit the degree to which tradeoffs can be detected in natural populations or constrain their evolutionary trajectories.

122.3 SCHWAGER, E.E.*; MENG, Y; EXTAVOUR, C.G.; Harvard University; *eschwager@oeb.harvard.edu*
Spider vasa is required for early embryogenesis but not for germline specification
Metazoans specify their germline either early in development by maternally transmitted cytoplasmic factors (inheritance), or later in development by signaling factors from neighboring tissues (induction). The molecular principles of the inheritance mode have been thoroughly studied in model organisms such as flies, worms and fish, whereas the molecular basis of induction is only known from two vertebrates, mouse and salamander. Nevertheless, induction is hypothesized to be the ancestral mechanism of germline determination. Still currently we are lacking molecular and functional descriptions of inductive germ cell specification from protostomes. Arthropods are one of the metazoan clades that exhibit both induction and inheritance. We therefore examined germ line development in the spider *Parasteatoda tepidariorum*, an emerging chelicerate model organism. Even though spiders have repeatedly been the subject of classical embryological research, there have been only vague descriptions of putative spider germ cells to date. Our results, based on gene expression patterns of the germline marker genes *vasa* and *piwi*, and using spider-specific antibodies against Vasa and Piwi proteins, show that germ cells in the spider are likely formed by induction: neither Vasa nor Piwi protein appear localized before primordial germ cell clusters emerge as paired segmental clusters in opisthosomal segments 2-6. To investigate the molecular basis of the inductive germ cell specification in the spider, we next examined the function of the *vasa* gene in this process. Maternal vasa knockdown led to embryos that died shortly after initiating gastrulation. To circumvent this maternal effect of the *vasa* gene, we next knocked down *vasa* zygotically. Our experiments show that these embryos develop normally and still form germ cells, implicating that *vasa* is not required for germ line specification.

38.5 SCHWALBE, M.A.B.*; WEBB, J.F.; University of Rhode Island; *mbergstrom@my.uri.edu*

The Contributions of Sensory Morphology and Prey Detection Behavior to Trophic Niche Differentiation in Two Sand-Feeding Lake Malawi Cichlids

The adaptive radiations of African cichlids resulted in a diversity of feeding morphologies and strategies, but the role of sensory biology in niche partitioning remains largely unexplored. Fishes in the Lake Malawi genera *Aulonocara* and *Tramitichromis* both feed on benthic invertebrates, but differ in sensory morphology and foraging strategies. *Aulonocara* slowly swims just above the sand and detects flows generated by prey with neuromasts in its widened lateral line canals. In contrast, *Tramitichromis* fills its mouth with sand and sifts out prey, but the role of the narrow lateral line system (less sensitive than widened canals) in prey detection is unknown. We hypothesized that *Aulonocara* and *Tramitichromis* use their visual and mechanosensory capabilities differently while foraging. To test this, we evaluated the ability of *Aulonocara stuartgranti* and *Tramitichromis*sp. to feed on live and dead adult brine shrimp under light and dark conditions. Prey detection behavior (# prey strikes, detection distance and angle, prey preference [live vs. dead]) was analyzed. Both species ate vigorously in the light, but *Tramitichromis* detected prey at longer distances and with a narrower range of detection angles than *Aulonocara*, suggesting a particular dependence on vision. In the dark, *Tramitichromis* tended not to feed while *Aulonocara* successfully captured prey and preferred live prey (that produced hydrodynamic stimuli to which the lateral line system responds). Thus, *Aulonocara* and *Tramitichromis*, which differ in lateral line morphology, employ distinct foraging and prey detection capabilities, and we hypothesize that these factors are important for trophic niche differentiation in these sand-feeding taxa. Supported by NSF grant IOS-0843307 to JFW, NSF EPSCoR contract EPS-1004057.

141.1 SCHWARTZ, TS*; BRONIKOWSKI, AM; Iowa State University; *schwartz@iastate.edu*

Plasticity and evolution of stress response networks in divergent life-history phenotypes

The complex molecular network that underlies physiological stress response is comprised of nodes (proteins, metabolites, mRNAs) whose connections span cells, tissues, and organs. Variable nodes are points in the network upon which natural selection may act. Our aim is to identify variable nodes that will reveal how the molecular stress network may evolve among populations, and how it might impact life-history evolution. We utilize natural populations of garter snakes (*Thamnophis elegans*) that have diverged along the pace-of-life continuum; the slow-living phenotype has slower growth, smaller reproductive bouts, and extended median lifespan relative to the fast-living phenotype. We take a multifaceted approach to test whether these phenotypes vary concomitantly at candidate nodes of the stress response network under unstressed and induced-stress conditions. In response to heat stress, some measures increased in both life-history phenotypes: plasma corticosterone; State III mitochondrial respiration; expression of heat shock proteins; and transcription of mitochondrial rRNAs. As well, the phenotypes diverged at multiple nodes: overall mitochondrial transcription; State IV mitochondrial respiration; circulating levels of ROS; and DNA damage. Additionally, mitochondrial haplotypes were unique to each phenotype. Our results indicate these evolutionarily divergent life-history phenotypes have diverged in their molecular stress response networks; and we identified specific nodes involved in oxidative stress and mitochondrial function at which selection appears to be acting. Further, these results support the prediction of tightly integrated molecular interactions between stress networks and life-history traits.

109.4 SCOBELL, S.K.*; JAQUES, J.T.; JONES, A.G.; Texas A&M University, Texas A&M Veterinary Medical Diagnostic Laboratory, Texas A&M University; *skscobell@tamu.edu*

Androgen profiles across the male pregnancy cycle in the sex-role reversed Gulf pipefish

Male pregnancy is a phenomenon found only in the teleost fish family Syngnathidae (seahorses, seadragons, and pipefish). The male accepts eggs from the female into a ventral brood pouch where they are fertilized and brooded until birth. Recent studies in syngnathids have shown that males aerate and osmoregulate the brood pouch fluid, and likely provide nutrients and immunity to embryos during the pregnancy. However, few studies have examined the hormonal regulation of male pregnancy in syngnathids. Hormones are well established in teleost fish as primary regulators of puberty, gonadal development, mating, and reproductive behaviors, and thus are likely candidates for mediating male pregnancy in seahorses and pipefish. Previous work on syngnathids suggests an important role of androgens in development of the brood pouch, maintenance of the testes, and spermatogenesis. However, to our knowledge there have not been any studies that correlate circulating plasma androgens with these traits across the reproductive cycle. We conducted a field study of circulating testosterone and 11-ketotestosterone levels in male and female Gulf pipefish, *Syngnathus scovelli*. We first asked whether there was a reversal of plasma androgen levels in the sexes of this polyandrous, sex-role reversed species. We then examined whether androgens correlated with gonad mass or body size in both sexes. Finally, we compared testes mass and circulating androgen levels across various stages of the male reproductive cycle. Our data show no reversal of plasma androgen levels between the sexes, but they do suggest that male Gulf pipefish modulate androgens across the reproductive cycle to regulate alternating cycles of spermatogenesis and pregnancy.

P3.56 SCRIBER, K.E.*; AMSLER, C.D.; MCCLINTOCK, J.B.; University of Alabama at Birmingham; *KEVSCRYB@UAB.EDU*

Feeding Rates of the Freshwater Amphipod Hyalella azteca for Aquatic Vascular Plants and Macroalgae

Numerous factors influence the feeding preferences of fresh water and marine invertebrates. Most consumers discriminate between the plants and animals they consume. This study tests the null hypothesis that there is no difference in the palatability of the common omnivorous freshwater amphipod *Hyalella azteca* for sympatric aquatic vegetation; vascular plants and green algae. Non-choice feeding assays were utilized to measure feeding rates (palatability) on exposed foliage of three species of vascular plants and two species of green algae. Statistical analysis indicated high variation in the palatability of the three vascular plants, with *Vallisneria americana* being least palatable (<12% consumed, mean mass per unit time). The remaining two vascular plants were moderately palatable (mean range = 34.6 –41.9% of mass consumed). The two species of green alga were both palatable (mean range = 37–48 % of mass consumed) and feeding rates were similar to those on the two moderately palatable vascular plants. In order to evaluate one factor responsible for differences in food palatability, penetrometry was used to measure food toughness. As both green algae were filamentous they were not subjected to penetrometry. Measurements of Force (Newtons/mm2) for the three vascular plants indicated that the force required to penetrate the least palatable species, *V. americana*, was significantly greater than that the other two species. Ongoing studies are examining additional metrics for food quality (protein content and chemical defense). The present study indicates that at least one measure of food quality, toughness, may have an influence on food palatability in the common and ecologically important freshwater amphipod *H. azteca*.

P3.1 SEARS, BF*; ROHR, JR; Univ. of South Florida; *bsears@mail.usf.edu*

Host life history influences parasite encystment location and tolerance in tadpoles

Larval trematodes, called cercariae, frequently parasitize anuran tadpoles that can resist or tolerate these infections. We have previously demonstrated that encystment location of cercariae can be affected by anesthesia; therefore, we experimentally infected tadpoles with armatae-type cercariae, which encyst throughout the skin, to determine whether behavior in non-anesthetized tadpoles can actively influence location of parasite encystment. Tadpoles were exposed to parasites for 1 hour while anesthetized or not anesthetized, as well as for 24 hours while not anesthetized. Encystment location of cercariae did not vary within or among species between anesthesia treatments, but did vary among species when hosts were exposed to cercariae for 24 hours. Strikingly, encystment location was strongly correlated with host species and life history. Cercariae infected the head and body of small, rapidly developing ("fast-paced") tadpole species but infected the tail of large, slowly developing ("slow-paced") species. Furthermore, slow-paced, tail-infected species had better tolerance of their infections, exhibiting less mass loss post-infection, than fast-paced species. This pattern of encystment location suggests that slow-paced hosts, which are more likely to encounter trematode parasites, might shunt parasites to the least deleterious location. Conversely, the parasites themselves might seek different body regions in different host species in order to maximize the likelihood of transmission to the definitive host. Patterns of trematode infection should be further investigated to assess whether encystment location affects sensory systems (head) and locomotion (tail), which might impact survival in the presence of predators and/or definitive hosts.

24.1 SEARS, MW; Clemson; *sears3@clemson.edu*

Toward a spatially-explicit thermal ecology: predicting activity from the dispersal of individuals through thermally-structured landscapes

An ongoing challenge for ecologists is to predict the responses of organisms to changing climates. Process-based modeling approaches that incorporate physiological and behavioral mechanisms are rapidly becoming powerful tools to make such predictions. Key to these approaches are understanding the biophysical constraints on activity budgets. Typically, models assume an all-or-nothing approach where, as long as environmental temperatures overlap individual preferences, all individuals in a population are active and accrue (or lose) energy from the environment. Due to the thermal heterogeneity of many environments, such responses of activity by all individuals are not possible. Here, I demonstrate how activity patterns can be generated by the movements of individuals under thermoregulatory constraint and how these models predict activity similar to that observed in natural populations. Further, results will be contrasted with those predicted by other modeling approaches to note the potential pitfalls when small scale environmental heterogeneity is not considered.

1.4 SECOR, S.M.; University of Alabama, Tuscaloosa; *ssecor@biology.as.ua.edu*

From field metabolic rates to genomics, the integrative digestive physiology of snakes

Snakes feed across a continuum of feeding habits, however little is known regarding the frequency at which snakes feed. Following a 3-year field study on their feeding habits and field metabolic rates, Ken Nagy and I calculated that active foraging coachwhips (*Masticophis flagellum*) feed on average at 10-day intervals, whereas sit-and-wait foraging sidewinders (*Crotalus cerastes*) feed at 40-day intervals. These findings sparked the question: might snakes exhibit variation in their digestive physiology given differences in natural fasting durations? Our studies on nearly two dozen species revealed that snakes which feed relatively frequently in the wild narrowly regulate intestinal performance, whereas species which routinely experience long fasting episodes widely regulate intestinal form and function with each meal. The evolutionary rationale for this dichotomous response resides in energy conservation. The mechanistic bases for the two modes of regulation stems from whether intestinal microvilli maintain length with fasting (narrow regulation) or dramatically shorten with fasting and then length with feeding (wide regulation). For infrequently feeding Burmese pythons, the increased expression of more than 2400 genes underlie the rapid postprandial transformation of their intestinal morphology and function. I have had the good fortune to gain from Ken and my other mentors that in order to decipher the evolutionary and proximate mechanisms of adaptation, work needs to start in the field before continuing with approaches in the laboratory that then can transcend multiple levels of design.

135.4 SEFTON, E.M.*; PIEKARSKI, N.; HANKEN, J.; Harvard University; *esefton@oeb.harvard.edu*

A dual embryonic origin of the vertebrate pharyngeal skeleton

The pharyngeal-arch skeleton is a hallmark of vertebrates. In basal taxa, it supports the gills and muscles of the pharynx, whereas in more derived groups it surrounds the larynx and trachea. That most of the pharyngeal-arch skeleton is derived from embryonic neural crest was first demonstrated in the mudpuppy in the late 19th century, and this result has since been confirmed in additional species. Yet, the evolution and extent of neural crest contributions to the pharyngeal skeleton is incompletely understood. In this study, we fate map neural crest in the axolotl, *Ambystoma mexicanum*, using transplantations from GFP-transgenic donors into wild-type hosts. We found that neural crest does not contribute to all elements of the pharyngeal skeleton: the ventral midline element *basibranchial 2* was never labeled. Based on this result we also constructed a fate map of cranial mesoderm. Our results positively demonstrate for the first time a mesodermal contribution to the pharyngeal skeleton. Cranial mesoderm contributes to *basibranchial 2*, suggesting distinct patterning mechanisms in this region. Our results demonstrate a dual embryonic origin of the pharyngeal skeleton, from both neural crest and cranial mesoderm, and shed new light on its development and evolution.

12.5 SELF, CJ*; HERRING, SW; University of Washington, Seattle; *cjself@uw.edu*
Morphology of the rabbit periodontal ligament and the effect of reduced bite force
The periodontal ligament (PDL) transmits occlusal loads from the teeth. This study was undertaken to describe the morphology of rabbit molar PDL as an example of an evergrowing cheek tooth and to determine the effect of reduced loading on the PDL. Under reduced loading, decreased architectural uniformity and collagen amount were expected. To achieve partial unloading rabbits received a single dose of either botulinum toxin (BTX) or saline into one masseter muscle (n=7-8). After 4 weeks specimens were sectioned horizontally or coronally and stained with picrosirius red. Linearly polarized light was used on coronal sections to measure fiber orientation. Horizontal sections were evaluated under circularly polarized light to quantify collagen content. Values from the left and right sides were averaged. In control PDLs collagen content was 21.6۪±8%, lower than 35% reported in murine molars, which are not evergrowing and thus have relatively short, stable roots (Beertsen et al 1975). Average angle of fiber attachment was 61˚, more obtuse than the reported 30˚ for humans (Raspanti et al. 2000) but similar to rats (61˚, Komatsu and Chiba 1997), mice (51˚, unpublished), and cows (50˚, Pini et al. 2004). Although more comparative data are needed, these findings suggest that relative root length can compensate for low collagen content and that obtuse PDL orientation correlates with horizontal-plane chewing. Nonparametric comparisons of reduced vs. normal bite force groups showed slight reductions in collagen and attachment angle, but these were non-significant, reflecting the small sample size and modest decrease in force. However, there was no trend for variability to increase. PDL uniformity may be related to chewing direction rather than occlusal force. Supported by PHS DE018142.

S10-2.3 SERB, J.M.*; KRAUSE, A.J.; Iowa State University; *serb@iastate.edu*
Uncovering gene family expansion and molecular convergence of the photoreceptive protein opsin in scallop (Bivalvia: Pectinidae)
Gene duplication is one of the key factors driving genetic diversification and innovation, and may play an important role in phenotypic novelty. We investigated how small-scale, gene-specific duplications in invertebrate visual systems affect function and how diametrically opposed processes of divergence and constraint act on the underlying molecular system by studying the diversity of visual pigments in the mirror-type eyes of the scallop. These bivalves inhabit an array of photic environments and exhibit a diverse set of species-specific behaviors ranging from sessile attachers to mobile long-distance swimmers. Using a comparative transcriptomic and gene-targeting approaches, we identified an expansion of the photoreceptive protein opsin, a member of the G-protein coupled receptor family. Focusing on the Gq-coupled (rhabdomeric or "r-") opsins, we generated a gene phylogeny from 530 sequences of 33 species across the Pectinidae. Scallop opsins segregated into two major clades, A and B, that differ by 45% in amino acid sequence, yet retain the functional motifs required for chromophore binding. Within each major clade, there was evidence for additional gene duplication events, but the number of duplication events, degree of divergence, and gene loss varied. We then tested the hypothesis that gene duplication events are associated with the spectrum of visible light available in the species' habitat or with particular behaviors. We found multiple gene loss associated with sedentary lineages, while more mobile species had a suite of opsin copies. Interestingly, we identified molecular convergence in opsin within long-distance swimming lineages, which presumably rely more heavily on visual information. Our results suggest that both the retention and diversification of opsin copies in scallops are correlated with visual-mediated behaviors.

128.3 SETTE, CM*; VREDENBURG, VT; ZINK, AG; San Francisco State University; *carla.sette@gmail.com*
Temporal and spatial variation of cytridiomycosis across Batrachoseps attenuatus populations
Batrachochytrium dendrobatidis (Bd) is a highly virulent fungal pathogen which causes chytridiomycosis in amphibians. This rapidly-spreading disease is implicated in the decline and extirpation of amphibian populations throughout the world. Because the fungus' flagellated zoospores spread by swimming through water or or along amphibians' moist skin, it is considered an aquatic disease. However, it has recently been detected in completely terrestrial salamanders, such as the California slender salamander, *Batrachoseps attenuatus*. We used quantitative PCR to detect the presence of Bd in up to 20 randomly-selected individuals from seven decades and across twelve counties within *B. attenuatus*' range. Results from these 1300 samples reveal temporal and spatial variation in the presence and infection intensity of Bd across populations. Because *B. attenuatus* is highly gregarious in its nesting behavior, we propose that social behavior may provide an opportunity for transmission of Bd.

105.4 SEYMOURE, B. M.*; MCMILLAN, W. O.; RUTOWSKI, R. L. ; Arizona State University, Smithsonian Tropical Research Institute; *brett.seymoure@gmail.com*
Convergence and Divergence of Eye Morphology in Mimetic Butterflies
Within the animal kingdom there are many groups of mimetic organisms that have converged on phenotypes. Within the tropical butterfly genus of *Heliconius, the amounts of mimetic groups are astounding. In the former canal zone of Panama, there are at least five different mimetic groups of Heliconius that have converged on the same wing color and shape, flight pattern, and ecological niches. Previous research has shown that these different mimetic groups occupy different microhabitats within the forest and that these microhabitats differ in light environment. We asked whether co-mimics have converged on eye morphology. We hypothesized that eye morphology has converged within co-mimics because certain eye morphologies are more adaptive in certain light environments. In darker light environments, compound eyes should be structured to heighten sensitivity while in brighter environments, compound eyes should be structured to heighten acuity. We performed three separate studies to test the hypothesis. We measured interommatidial angles, eye size, and facet diameters for two different mimetic groups: postman and blue-white. The postman group consisted of H. erato and H. melpomene, the blue-white consisted of H. cydno and H. sapho. We predicted that the three parameters: eye size, interommatidial angle, and facet diameters will be similar within the mimetic groups but different between mimetic groups. We show similarities and differences in eye morphology for the different mimetic groups and conclude that convergence and divergence has occurred in eye morphology within this mimicry complex.*

P2.64 SEYMOURE, B.*; BORCHERT, J.; LESSIOS, N.; LIGON, R.; GANESH, T.; WEBBER, A.; Arizona State University; *brett.seymoure@asu.edu*

Graduate Partners in Science Education: A graduate student-led program focused on hands-on science education for middle school students

Graduate Partners in Science Education, is a graduate student run program that focuses on the development and implementation of inquiry-based modules at Title I schools in the Phoenix metro area. We have implemented two different models over the 8 years of our program. One model had a low student to mentor ratio (4:1) and focused on middle school students developing their own science projects. The other model had a higher student to mentor ratio (12:1) and focused on curricula development and implementation at multiple middle schools. There are advantages and disadvantages of both model systems. Here, we discuss these costs and benefits in an attempt to provide information for individuals interested in developing outreach programs focused at underrepresented groups in the sciences.

P1.37 SHABEL, A; BRIM, M*; University of California, Berkeley; *shabel@berkeley.edu*

Ecological factors and the biogeography of two morphologically divergent species of African clawless otter (Aonyx)

The clawless otters of Africa (*Aonyx*) include two major types: a small-toothed type from the Congo region (*A. congicus*) and a large-toothed type that is more widespread (*A. capensis*). Here we relied on a combination of field and museum data to map the major morphological features of *Aonyx* in relation to vegetation and climate variables, and we generated a predictive model of otter population distribution to identify areas of critical conservation interest. More than 600 *Aonyx* individuals from 32 countries were identified in 34 museum collections, including 80 paleontological specimens from 31 fossil localities (Lower Pleistocene to present). Molar size in the large-toothed type (*A. capensis*) was positively correlated with latitude in both fossil and modern contexts, but it is not clear if this is related to diet, climate, or some other factor. The small-toothed type (*A. congicus*) was found across the lower Guineo-Congolian forest zone, from the Cross River on the Nigeria–Cameroon border to the western branch of the Rift Valley. Extralimital specimens of *A. congicus* from the Kaimosi/Kakamega region of Kenya were identified at sites with relictual patches of Guineo-Congolian habitat. Whereas the durophagous *A. capensis* relies heavily on hard-shelled invertebrate prey—including crustaceans—the microdont *A. congicus* relies on softer foods—including earthworms, eels, lungfish, frogs, and snails (the latter are opened by hand). The Congo clawless otter is apparently unique among the lutrines of the world in having a diet based on soft foods (malakophagy). Ecology, morphology, and biogeography are deeply intertwined in the evolution of the African clawless otters.

83.1 SHADWICK, R.E.*; GOLDBOGEN, J.A.; POTVIN, J.; PYENSON, N.D.; VOGL, A.W.; Univ of British Columbia, Cascadia Res. Collective, St. Louis University, Smithsonian Inst., Univ. of British Columbia; *shadwick@zoology.ubc.ca*

Novel muscle and connective tissue design controls engulfment volume in lunge-feeding whales

Rorqual whales feed by engulfing and filtering large volumes of water containing schooling prey. The ability to engulf a mass of water on the order of the entire body mass is facilitated by highly compliant ventral groove blubber (VGB) and underlying muscle that make up the buccal cavity outer wall. Muscle fibres are in two strata, one is parallel to the body long axis (LS), the other is oblique (OS), at 45º to the LS. Based on a geometric model of engulfment we estimated the maximal circumferential VGB strain. For comparison we measured VGB strain from the relative separation of adjacent ridges seen in photos of lunging fin, blue, sei, Bryde's and minke whales. In both cases we found that at full engulfment the VGB experiences circumferential strain of up to 160%. But how can the VGB muscles accommodate apparent strains as high as 160%? Histological examination showed that LS fibres are loosely connected and readily separate laterally with increasing VGB circumferential strain. OS fibres are embedded in a dense matrix of elastic tissue quite unlike other skeletal muscle. In the unloaded state we found that retraction of the elastin actually compresses the muscles by about 30%. The combination of re-orientation of the OS muscle fibres with VGB expansion, and their straightening as elastin is stretched, together allow for VGB strains of 160% to occur with only a 55% stretch in the muscle fibres. These results support the hypothesis that the VGB muscles play an active role in controlling the size and filling rate of the ventral cavity during engulfment feeding (J. Potvin et al. 2009, J. Royal Soc. Interface).

P2.128 SHADWICK, R.E.*; WHALE, J.C.; LIN, S.C.; GOLDBOGEN, J.A.; PYENSNON, N.D.; Univ of British Columbia, Cascadia Res. Collective, Smithsonian Inst.; *shadwick@zoology.ubc.ca*

Mechanical design in fin whale mandibles

Mandibles in large rorquals such as fin and blue whales are highly modified to function as load bearing elements that support the engulfment apparatus and the large forces experienced during lunge-feeding. Each mandible typically represents ~20% of the total body length and, as such, these bones represent the largest single ossified elements in the animal kingdom. Here we explore two questions regarding their mechanical design. 1. Considering the high aspect ratio and high degree of curvature, are the mechanical properties of the mandible uniform or heterogeneous along its length? 2. How is the compressive stiffness related to mineral density distribution within the structure? From the mandible of a freshly dead 18m fin whale we cut sections from eight locations along the entire length, and made density maps of each by CT scanning. Test samples 1 cm in diameter were removed with a plug cutter mounted in a drill press. We determined wet density, dry density, compressive stiffness, breaking strength, and mineral content of each. The results show two very distinct regions; the dense cortical bone (max. of 1.99g/cc) is located in a relatively narrow peripheral layer while much less dense and oil filled trabecular bone (min. of 0.91g/cc) occupies the central core. Compressive stiffness is strongly correlated with mineral content and density, with modulus of the cortical layer ranging from 1-8GPa compared to only 0.05-0.40GPa in the trabecular bone. It appears likely that the superficial cortical layer is the main load bearing element, while the mechanical contribution from the central trabecular region is minimal, somewhat reminiscent of avian long bones.

89.3 SHAMBLE, P.S.*; BEATUS, T.; COHEN, I.; HOY, R.; Cornell University; *pss92@cornell.edu*
Terrestrial Locomotor Mimicry at the Kinematic Level: Does the ant-mimicking jumping spider Myrmarachne formicaria walk like an ant?
Most studies of mimicry have focused on phenotypically static traits, such as color pattern and body shape. However, new research--to which this work contributes--suggests that behavior and motion are highly important in enhancing likeness between mimics and models. Our work examines locomotory mimicry, involving a jumping spider (*Myrmarachne formicara*) that has a striking resemblance to ants. This species is a convincing morphologically visual, static mimic, but it is also widely-believed to walk like an ant. It solves the 8 legs (spider) vs. 6 (ant) problem by waving its forelegs like antennae, "functionally reduc[ing] the number of legs in the mimic from four pairs to three" (Cushing 1997). How good is the mimicry when set in motion? Our research is the first to reconstruct *M. formicaria's* actual gait. We used high-speed video to reconstruct the spider's limb movements in 3D. Our results show that *M. formicaria* actually break their motion into two parts: 1. a mobile phase in which they walk with an eight-legged jumping spider gait; 2. a stationary phase in which they mimic ants by elevating their forelegs. We conclude that the timing of these distinct locomotive phases--combined with aspects of the spider's static appearance--are responsible for creating the illusion of "ant-ness." Our findings reinforce the need for researchers to consider behavior and motion in studies of mimicry systems.

16.4 SHARABI, O.*; VENTURA, T.; MANOR, R.; AFLALO, E.D.; SAGI, A.; Ben Gurion University of the Negev, University of the Sunshine Coast, Queensland, Australia; *omrisha@post.bgu.ac.il*
Dual function of a putative epidermal growth factor receptor in the decapod crustacean Macrobrachium rosenbergii
Epidermal growth factor receptors (EGFRs) are highly conserved members of the tyrosine kinase receptor superfamily found in all multicellular organisms. In arthropods, EGFRs have been found to be involved in proper development of embryos and of adult wings, legs, ovaries and eyes, as well as to affect body size. In search for genes involved in growth and development in our model organism, the decapod crustacean *Macrobrachium rosenbergii*, we used next generation sequencing to create a comprehensive transcript library of larvae and juveniles. We have identified the expression of several genes assigned to the cross-talking signal transduction pathways activated by EGFRs and insulin receptors, including a transcript coding for an *M. rosenbergii* EGFR (*Mr-EGFR*). The deduced protein showed sequence similarity to other arthropod EGFRs. The gene was found to be expressed in most, but not all, tissues. We examined its role in juvenile animals using functional genomics methods, by temporary silencing of the *Mr-EGFR* transcript through weekly injections of double-stranded *Mr-EGFR*. This resulted in a significant reduction in growth, a delay in the appearance of a male secondary sex character (*appendix masculine*).The *EGFR* silenced animals development abnormal eyes which included irregular organization of the ommatidium, unorganized receptor cells occupying large area of the dioptric portion and lack of the crystalline tract layer. However, all portion of the optic ganglion appeared to have normal morphology. To our knowledge, this is the first report of an *EGFR* identified in crustaceans, and its proven involvement in decapod growth and development demonstrates its significance.

P1.112 SHARICK, JT*; VAZQUES-MEDINA, JP; ORTIZ, RM; CROCKER, DE; Sonoma State Univ., Univ. of California, Merced; *jeffsharick@gmail.com*
Oxidative stress in fasting adult breeding northern elephant seals
Prolonged fasting is associated with oxidative stress including increases in the production of reactive oxygen species, oxidative damage and inflammation. Oxidative stress mechanisms in fasting-adapted species are not well understood. Elephant seals undergo prolonged fasts while maintaining high metabolic rates, particularly during breeding. Weaned pups undergoing developmental fasts up-regulate anti-oxidant enzymes to levels that are sufficient to avoid oxidative damage. We measured plasma changes in the activity of the oxidant producing protein, xanthine oxidase (XO), oxidative damage and inflammatory markers and antioxidant enzymes in 30 adult male and 35 adult female northern elephant seals across a 1-3 month breeding fast. XO levels, a marker for pro-oxidant stress, were high and increased across the fast in both sexes. Anti-oxidant enzymes, catalase and glutathione peroxidase, increased in both sexes. With the exception of nitrotyrosine (NT), a marker for protein oxidation, plasma markers of damage or inflammation did not change in females. Plasma markers of lipid peroxidation (8-isoprostanes and 4-hydroxynonenal) and inflammation (tumor necrosis factor-α) increased across the fast for males. In contrast, plasma NT levels declined in males. XO, damage and inflammatory markers and antioxidant enzymes were strongly correlated in males but these relationships were weaker in females. These data suggest strong anti-oxidant responses during fasting. Oxidative stress associated with the longer (3 month) fast in males may exceed these responses creating oxidative damage as a physiological cost of breeding. Anti-oxidant responses in females appear to prevent damage or inflammation during the 1 month fast.

P1.45 SHARMA, N*; DHAWALE, N; VENKADESAN, M; National Centre for Biological Sciences, Bangalore; *neelimas@ncbs.res.in*
Limits on the body size and shape of animals
Material strength of bone and muscle impose limits on body mass and on aspect ratio (width/height) as a function of body mass. Does the need for stability during standing and locomotion also impose limits on the size and shape of animals? We model standing animals as an inverted pendulum with neural feedback, and locomotion (seen head-on) as a passive rectangular box on uneven ground. The first model refines the existing upper limit on body mass based on strength of materials. The second predicts that small animals have to sprawl with a body shape that is "landscape" and not "portrait", complementing the material strength theory that requires heavy animals to be "portrait". The success or failure to maintain balance during standing is governed by the relative magnitude of two time scales; neural delays in sensorimotor feedback control versus the mechanical time scale associated with the inverted pendulum like body. Having smaller neural feedback delays than the mechanical time scale leads to an upper limit on the height. Using published allometry of height to mass we find an upper bound on mass that is comparable to the Apatosaurus, the heaviest known land animal. To understand how aspect ratio affects lateral stability of an animal, we compare two angles; the critical angle beyond which a passive rectangular box will fall versus the angle of tilt imposed by terrain unevenness, i.e. maximal height differences between points on the terrain that the box is resting on. The tilt depends on how terrain unevenness scales with the width of the box. We find that the aspect ratio has a lower bounded for a broad class of power law relationships of terrain unevenness as a function of base width. This suggests the hypothesis that small animals sprawl like a "landscape" because they face an unfavorably rough terrain.

33.1 SHARMA, P/P*; SCHWAGER, E/E; GIRIBET, G; JOCKUSCH, E/L; EXTAVOUR, C/G; Harvard University, University of Connecticut; *psharma@post.harvard.edu*

Distal-less and dachshund pattern both plesiomorphic and apomorphic structures in chelicerates: RNAinterference in the harvestman Phalangium opilio (Opiliones)

The discovery of genetic mechanisms whereby a morphological structure is transformed from a plesiomorphic (=primitive) state to an apomorphic (=derived) one is a cardinal objective of evolutionary developmental biology. However, this objective is often encumbered for many lineages of interest by limitations in taxonomic sampling or in genomic resources for the few available laboratory model organisms. In order to investigate the evolution of appendages within Chelicerata, the putative sister group of the remaining arthropods, we sequenced a developmental transcriptome of the harvestman *Phalangium opilio*. Concomitantly, we developed an RNAinterference protocol for this species. We silenced the leg gap genes *Distal-less* (*Dll*) and *dachshund* (*dac*) in the harvestman via zygotic injections of double-stranded RNA. Consistent with the conserved roles of these genes in patterning the proximo-distal axis, we observe that embryos injected with *Dll* dsRNA lack distal parts of appendages or appendage-like structures, such as the labrum, the chelicerae, the pedipalps, and the walking legs; whereas embryos injected with *dac* dsRNA lack the medial podomeres femur and patella in the pedipalps and walking legs. In addition, we observe the involvement of these genes in patterning structures that do not occur in well-established chelicerate models (spiders and mites). Embryos injected with *Dll* dsRNA additionally do not develop the preoral chamber formed from pedipalpal and leg coxapophyses, or the ocularium, a dorsal outgrowth that bears the eyes. A single embryo injected with *dac* dsRNA was observed to lack the proximal segment of the chelicera, a plesiomorphic podomere wherein *dac* is expressed in wildtype embryos.

97.1 SHARPE, S.S.*; MASSE, A.; TAZ, H.; GOLDMAN, D.I.; Georgia Tech, Wesleyan College; *ssharpe@gatech.edu*

Limb Use During Burial of the Sandfish Lizard

Desert dwelling animals like the sandfish lizard (*Scincus scincus*) dive into sand to escape heat and predators. The sandfish swims subsurface using a traveling wave along its body with little movement of the limbs. However, above surface, limbs are used during initial burial into the substrate and burial occurs in approximately 1.5 body undulations (< 1 s). To investigate the role of limbs during burial, we track limb movements during burial in 0.3 mm diameter glass particles using high-speed visible-light video and x-ray imaging. Sandfish (N = 3 animals, mass = 16.2 ± 1.4 g) use a stereotyped limb pattern and body undulation during burial. During the first undulation cycle the forelimbs are pressed against the body sequentially just before each side of the body becomes convex and stay there for the remainder of swimming. Hindlimbs adduct sequentially during the first undulation cycle, just after forelimb adduction and when the body is maximally convex. We hypothesize that since the hindlimbs are the last to adduct, these limbs are important for burial. To test this, we examine burial performance while restraining limbs using adhesive tape. Each animal was given 10 minutes to bury subsurface with limb restraints, and trials were accepted when animals attempted to bury. Animals readily buried when hindlimbs were bound but took a larger number of undulations (4 ± 2, $P < 0.01$) to bury than unbound animals. When forelimbs were bound, animals buried in 7 of 15 trials (N = 5 animals, n = 3 trials each), and all trials except one took over 4 undulations. When all limbs were bound, burial occurred in only 1 of 15 trials. These results imply that appropriately timed limb-ground interactions are critical to facilitate rapid burial.

P1.117 SHAUGHNESSY, C. A.*; RADLOFF, J.; BYSTRIANSKY, J. S.; BALFRY, S. K.; DePaul University, Vancouver Aquarium; *ciaran.a.shaughnessy@gmail.com*

Osmoregulation in wolf eel (Anarrhichthys ocellatus) during acclimation to dilute seawater

Once strictly considered a marine stenohaline species, the wolf eel (*Anarrhichthys ocellatus*) is now shown to tolerate a wider range of salinities than previously suspected. The present study monitored the effects of sustained exposure to various reduced salinities on the physiology and growth of juvenile wolf eel. Over an eight week period, fish were maintained in triplicate groups of 25 individuals under varying (6, 9, 14, and 30 ppt) salinity regimes. To assess salinity tolerance, mortality rate, specific growth rate, plasma ion levels and muscle water content as well as gill Na+K+-ATPase activity were determined. Mortality rate was low in the 6ppt treatment group (~5%), while all individuals maintained at 9, 14 or 30 ppt survived throughout the experiment. While growth did slow in a step-wise fashion with exposure to reduced salinity, specific growth rate remained positive (2.036, 2.908, 3.259, 3.522 % body weight day^{-1}, respectively), suggesting these animals have the capacity to acclimate to dilute seawater. The results of this study present a better understanding of the ability of the wolf eel to tolerate diluted seawater, and add to a body of literature suggesting a wider salinity tolerance in many fish species previously thought to be strictly stenohaline.

35.6 SHAWKEY, MD*; D'ALBA, L; VINTHER, J; AHMED, M; LIU, S; University of Akron, College of Wooster, University of Bristol, Lawrence Berkeley National Lab; *shawkey@uakron.edu*

Melanin chemistry and color in feathers

Melanin has great potential as a uniquely multifunctional material because of its high light absorption and conversion efficiency, its physical toughness that enables it to persist for millions of years in unaltered form and its likely high refractive index (estimated at ~1.8-2.0) that enables it to produce strong optical effects. However, our understanding of the chemistry of melanin remains limited, primarily based on samples from human hair and squid ink sacs and stuck in an overly simplified eumelanin/pheomelanin paradigm. Avian melanosomes have an unparalleled diversity of form that almost certainly mirrors a diversity in chemistry. However, their chemistry remains virtually unstudied, even though it is critical to understanding questions of both fundamental and applied interest. We are using Vacuum Ultraviolet Laser Desorption Mass Spectrometry (VUV-LDMS) to determine the chemical structure of melanin from samples of melanic non-iridescent (black, brown, grey) and iridescent feathers. The mass distributions of these samples are determined on an imaging mass spectrometer coupled to VUV synchrotron radiation, and the probable chemical arrangements and structure determined by comparing fragmentation patterns upon varying photon energy and using bioinformatics and electronic structure calculations. While there is considerable variation, the spectral data for each of the color categories are relatively consistent (see Fig. 3), indicating that they have distinct chemical signatures. These data suggest a direct correspondence between molecular color and structure in avian melanin and suggest that our method is useful for reconstructing color of fossilized feathers.

P1.5 SHEEDY, R.R.*; HOESE, W.J.; California State University Fullerton; *rsheedy@fullerton.edu*

How do black phoebe, Sayornis nigricans, songs differ along a gradient of noise pollution?

Low-frequency, high-amplitude noise pollution overlaps with bird songs, interfering with songbirds' ability to communicate effectively. Individuals in noisy areas often sing differently from conspecifics in quiet areas, presumably to avoid masking from noise pollution. Populations exposed to high noise levels increase time spent singing, increase song amplitude, increase song frequency, increase repetition, and change the time of day they sing compared to populations exposed to low noise levels. We examined a common sub-oscine songbird, the black phoebe (*Sayornis nigricans*), with an innate song, exposed to extreme noise levels in southern California. We hypothesized that black phoebes exposed to high noise levels would sing differently from populations exposed to lower noise levels. We measured background noise levels and recorded songs from 11 males at three study sites along a noise gradient. Minimum frequencies of black phoebe songs are positively correlated with noise pollution levels, to a point. Songs sung in quietest sites (<30 dBA) had average minimum frequencies of 2.877 kHz while individuals singing in background noise between 50-60 dBA averaged 3.312 kHz. Songs sung in noisiest sites (>70 dBA) had average minimum frequencies of 3.272 kHz. Similarly, in previous research, a sub-oscine, the ash-throated flycatcher (*Myiarchus cinerascens*), showed they increased song minimum frequency up to a threshold of 70 dBA, above which minimum frequencies no longer increased. Increasing minimum frequencies reduces song bandwidth. Costs of changing songs beyond a certain point may outweigh the benefits of reduced masking. Investigating how urban adapted species cope with noise helps us understand how species can persist with expanding urban development.

P2.198 SHEETS, E.A.*; RUIZ, G.M.; ROCHA, R.M.; COHEN, C.S.; Romberg Tiburon Center for Environmental Studies and Department of Biology, San Francisco State University, Smithsonian Environmental Research Center, Departamento de Zoologia, Universidade Federal do Paraná; *bethsheets@gmail.com*

Global population structure of the widely introduced tropical ascidian Botrylloides nigrum

Studies of marine introductions in tropical regions are extremely limited, and our current understanding of global invasion events is based mainly upon studies in temperate habitats. New surveys are highlighting tropical marine invasion hotspots, and this presents a great need for studies characterizing invasion processes in these areas. Here, we are using a multi-gene approach to investigate global population structure of the broadly introduced tropical ascidian *Botrylloides nigrum*, by comparing mitochondrial cytochrome oxidase subunit I (COI) with nuclear polymorphic markers. We have currently analyzed a 529-bp region of COI in 181 samples from 12 populations (9 Atlantic and 3 Pacific locations). We have found 3 haplotypes and 12 singletons at this locus, and two of these haplotypes are very abundant, where one is globally distributed and the second appears to be restricted to the Atlantic Ocean. Populations at each entrance to the Panama Canal share the global haplotype, suggesting that the Panama Canal may serve as an invasion corridor between the Atlantic and Pacific Oceans. To date, the highest haplotype diversity (~0.622) is found in the Caribbean region (4 of our sampled populations). We are expanding our sampling with additional locations and loci to test hypotheses about invasion pathways.

S6-1.7 SHELDON, B.C.; University of Oxford; *ben.sheldon@zoo.ox.ac.uk*

Constraints and the importance of adaptive plasticity to climate change

Phenotypic plasticity is regarded as a key mechanism by which populations adapt to changing climates, but we know little about the importance of plasticity for population persistence, or what limits the scope of adaptive plasticity. In this talk I will present two different strands of work, derived from long-term studies of a temperate songbird (the great tit), which assess the limits on, and importance of, adaptive plasticity in response to phenology of the environment. First, I will argue that the evolution of population-level responses to the environment are constrained by (i) spatial variation, and (ii) temporal dissociation of breeding decisions from the phenological events that cause selection. These effects will act in different ways, with the common effect of constraining the evolution of plasticity. Second, I will present an analysis of a mechanistic model developed by Chevin et al. that predicts the critical rate of temperature change above which populations are inviable. Parameterisation of this model suggests that the importance of phenotypic plasticity for adaptation to climate change is strongly life-history dependent.

20.4 SHELTON, RM*; JACKSON, BE; HEDRICK, TL; Univ. of North Carolina, Chapel Hill; *rmshelto@email.unc.edu*

High speed pursuit in barn and cliff swallows

Birds require visually guided interception techniques to catch prey in flight, to track down potential mates, and to chase off competitors. While the visually guided tracking strategies of various insects including houseflies, hoverflies, and dragonflies have been well documented through lab experiments, birds only exhibit these behaviors in natural settings. Here we used a set of three high-speed cameras to capture a series of barn and cliff swallow chase sequences where one bird follows the other through a series of turns, sprints, dives and climbs. From these recordings we extracted 3D body and wing kinematics including the instantaneous velocity, acceleration, angular velocity, and angular acceleration of each bird, and various distances and angles between the two birds. We found a strong correlation between the total accelerations, angular accelerations, and angular velocities of the two birds with phase lags of approximately 89 ms, 71 ms, and 87 ms, respectively. These phase lags are slightly larger than the mean wingbeat period of the chasing bird (~70ms) suggesting that these birds may only be able to initiate a major flight maneuver once per flapping cycle, and that the response latency of the trailing bird is the sum of neurosensory and biomechanical lags. No simple visual targeting model precisely fits the response of the trailing bird suggesting that swallows may use a combination of sensory cues in planning pursuits. When comparing the flapping latency between the lead and chasing birds we observed a non-random distribution which could contribute to a complex chasing algorithm.

P3.23 SHELTON, DS*; ALBERTS, JR; Indiana University-Bloomington; *delsshel@indiana.edu*

Ontogenesis of Group Regulatory Behavior in Mouse Litters

Individual developmental trajectories are shaped by social stimuli (e.g., parental care, dominance relations), and environmental cues (e.g., light, temperature, food). In theory, both kinds of cues should also affect group behavior that emerges from individual interactions, but such relations have not been studied systematically. In the microenvironment of the natal nest, litters of mouse pups behave adaptively as a group. We tested the effects of environmental variables on the group behavioral regulation in developing mice (*Mus musculus*, C57BL/6). Huddle surface areas of Postnatal Day (PND) 2, 4, and 8 mice were monitored on flat and concave substrates at 22°C and 36°C. Group behavioral regulation was seen at all ages, with the litters forming compact huddles at cool temperatures and more dispersed aggregations at warm temperatures. On the concave, but not on the flat surface ‘pup flow’ was manifested, as individuals appeared and disappeared throughout the group. Pup flow rate was temperature-dependent. Huddles of six pups made an average of 215 flow movements/hr at 22°C; flow rate decreased by >40% at lower and higher temperatures. There was also a developmental emergence of temperature-modulated direction in pup flow. These findings provide insight into how physical and behavioral parameters of a nest environment shape individual behaviors from which adaptive group behavior emerges.

63.2 SHERIDAN, M.A.; North Dakota St. Univ.; *mark.sheridan@ndsu.edu*

Control of animal growth: Where are we and where do we go from here?

Since the description of the secretotropic action of growth hormone (GH) and the emergence of the “dual effector theory” of growth control in mammals, the study of non-mammalian model organisms, particularly teleost fish, has advanced our understanding of how organismal growth is regulated. In particular, the unique structures of the pituitary and the endocrine pancreas (Brockmann body) of teleosts have lent themselves to the study of GH and pancreatic hormone secretion (e.g., insulin, somatostatins), and the interaction of these hormones in growth control. Teleosts also have provided novel insight into peripheral modulation of GH and insulin-like growth factor (IGF) sensitivity as well as of GH and IGF action. As a result of teleosts having undergone a genome duplication event during their evolution (ca. 320 MYA), they possess multiple genes encoding major elements of the growth control system (GH receptors, IGF receptors, etc.), which provides a unique opportunity to examine the functional significance of duplicated genes. Moreover, teleosts provide an opportunity to examine the molecular basis of GH multi-functionality and to resolve its anabolic (growth promoting) and catabolic (lipolytic) actions.

56.1 SHERIFF, MJ*; LOVE, OP; University of Alaska Fairbanks; *mjsheriff@alaska.edu*

Maternal stress as a driver of adaptive phenotypic responses in offspring

Maternal stress has become widely recognized as a driving factor affecting offspring phenotypes, and evolutionary biologists and medical practitioners are investing great effort in determining the role of maternally-derived stress (MDS) as a significant inducer of trans-generational phenotypic plasticity in offspring. Given the large contribution by the medical community to the literature, many of the phenotypic responses of prenatal stress are viewed as unavoidable negative outcomes by the ecological community. However, these studies offer a biased underestimate of the potential advantages of MDS-induced phenotypic plasticity as they are not designed to recognize, or experimentally test, the evolutionary history and ecological relevance of the maternal stress-offspring phenotype relationship. Here I will present emerging evidence from free-living systems that are beginning to show how and why MDS may act as a translator between the quality of the maternal or ecological environment and the potentially adaptive phenotypic responses in offspring. A recurring finding is the necessity to examine MDS-induced phenotypic adjustments within the evolutionary life-history context of the species as well as both the immediate environmental context in which they occur and the longer-term environmental context that offspring face as reproductive adults. As such, maternal stress effects can be considered adaptive or maladaptive depending upon whether they reliably translate the maternal environment into an appropriate offspring response (i.e., dependent upon the degree of maternal-offspring environmental matching).

26.6 SHERO, M.R.*; PEARSON, L.E.; GOETZ, K.T.; ROBINSON, P.W.; HÜCKSTÄDT, L.A.; COSTA, D.P.; BURNS, J.M.; Univ. of Alaska Anchorage, Univ. of California Santa Cruz, Univ. of California Santa Cruz; *mrshero@alaska.edu*

How Weddell seals stay in shape: Using morphometric and isotopic dilution techniques to assess seasonal changes in body condition

Adult Weddell seals (*Leptonychotes weddellii*) haul-out on the ice in Oct/Nov for their pupping and breeding period and remain relatively inactive for ~4 months until their molt in Jan/Feb. Because phocid seals rely on stored lipid reserves for fuel across periods of reduced foraging, seasonal changes in body composition are indicative of past foraging success and energy allocated towards reproduction. In this study, body composition was assessed via morphometric (truncated cones) and isotopic dilution (^3H_2O) techniques for pre-breeding (Oct/Nov; 34F:5M) and post-molt (Jan/Feb; 51F:11M) seals. Nine females were handled in both seasons. Blubber mass estimated by morphometric models was significantly correlated with lipid mass estimated by isotopic dilution(P<0.001). However, morphometric models overestimated body mass by 20.6±0.6%, indicating that this method cannot be used as an unbiased estimate of Weddell seal mass or condition, as in other pinniped species. Therefore, seasonal comparisons were based on lipid content estimated via tritiated water. While there was no seasonal difference in lipid stores (as %body mass) in the cross-sectional study(P=0.691), individual animals that were handled in both seasons were larger (kg) in October (lipid mass increased 33%, lean mass 22%). These findings suggest that animals lose both lipid and lean mass during the summer reproduction and molt periods, but regain it during the winter months. In addition, larger and fatter Weddell seals made significantly longer dives during the 8 weeks following tagging in Jan/Feb (P<0.001), likely affecting the Weddell seal's ability to regain mass after the breeding period.

89.1 SHINE, C*; MCGOWAN, C; ROBBINS, C; NELSON, L; University of Idaho, Moscow, Washington State University, Pullman, Washington State University, Pullman; *shin0453@vandals.uidaho.edu*

Unique movements of Ursidae: kinematics of the forelimb in walking grizzly bears.

Bears (family Ursidae) are large, quadrupedal, plantigrade animals and represent an unusual evolutionary branch; few animals are plantigrade and none that are the size of bears. Also unique to this group is an unusual rotation of the wrist and position of the elbow during locomotion. The cause and/or effect of this movement are as yet unknown; however, preliminary data from skeletons suggests that the wrist movement may be due to a more ancestral elbow joint structure. Specifically, the articulation surface of the olecranon is extended and curved to form an S-shape, which likely causes rotation with respect to the humerus during flexion and extension. In this study, we aimed to quantify the movement of the joints via high speed video. We recorded two adult female grizzly bears (*Ursus arctos horribilis*) at slow to moderate walking speeds with three high speed cameras. The videos were digitised and used to generate 3-D coordinates for points on the shoulder, elbow and foot of the left forelimb. Preliminary results show that at ground contact the lateral edge of the foot contacts first at an angle of 34.3+/-1.7 degrees, relative to the ground. The elbow is unusually adducted during stance, with a frontal plane angle of 20.1+/-5.3 relative to vertical, and the forefeet have a substantial medial deviation (67.6+/-3.7 degrees, relative to the direction of travel). Future research will include more detailed kinematics during both swing and stance coupled with ground reaction force data to establish a comprehensive understanding of the relationship between the novel elbow joint morphology and the resulting walking mechanics of bears.

51.2 SHIPLEY, M.S.; PATZ, K.S.; NEDVED, B.T.; HADFIELD, M.G.*; University of Hawaii at Manoa; *hadfield@hawaii.edu*

Mechanisms of Metamorphic Remodeling in Hydroides elegans (Polychaeta).

Larvae of the serpulid polychaete *Hydroides elegans* are competent to settle and metamorphose five days after fertilization. At that stage, they are classical 3-setiger nectochaete larvae that are propelled by a well developed ciliary prototroch that also provides their filiter-feeding current. On contact with an appropriate bacterial biofilm, the larvae transform into a tube-dwelling, tentacle-feeding juveniles within 10 hrs. During the process, ciliated trochal bands and apical sensory organ disappear, the mouth is relocated from a ventral to an anterior-terminal position, and the feeding tentacles differentiate and elongate. We employed laser-scanning confocal microscopy and (1) acridine orange and TUNEL labeling to detect cell-death processes, and (2) Click-iT EdU labeling to detect cell proliferation, during and following metamorphosis in larvae of *H. elegans*. Apoptosis accounts for the loss of the prototroch and metatroch cells, the apical sensory organ and large numbers of epidermal cells on the larval episphere, especially at the anterior tip of the larva where the mouth will be positioned. Rapid cell proliferation produces the tentacles. After the tentacles are sufficiently developed for feeding, groups of apparent stem cells remain at their bases to accomplish tentacle elongation as the worm grows.

141.2 SHIRKEY, NJ*; GARLAND JR., T; Univ. of California, Riverside; *nshir001@ucr.edu*

Kidney mass of passerine birds in relation to diet, habitat, and phylogeny

The kidney plays an important role in electrolyte homeostasis, acid-base balance, osmoregulation, water conservation, and waste removal (in particular nitrogenous waste). Diversity in such factors as diet (e.g., protein content) and habitat (e.g., water availability) may cause variation in the selective regime and, ultimately, lead to evolutionary changes in kidney size and/or structure. A previous interspecific comparative study (Barcelo et al. 2012) found no relationship between kidney mass (corrected for body mass) and the % invertebrates in the diet of passerine birds, but suffered from a relatively small sample size (n=16). In this study, data for kidney and body mass were collected for 100 species of passerine birds, along with corresponding diet and habitat data. Conventional and phylogenetically informed (multiple) regressions were performed with log kidney mass as the dependent variable, log body mass as a covariate, and all possible combinations of diet (% invertebrates in 5 categories, treated as a continuous variable), habitat (categorical: aquatic, mesic, semi-xeric, xeric), and clade (categorical: 6 superfamilies). Phylogenetic signal (Blomberg et al. 2003) in relative kidney mass was statistically non-significant, and conventional statistical methods consistently produced the best-fitting models. Diet was included as a variable in all top-performing models, and greater dietary consumption of invertebrates was a significant positive predictor of kidney mass. Neither habitat nor clade was a significant predictor of kidney mass. Our results suggest that the amount of dietary nitrogen consumed may be one factor that led to diversification of kidney size (and possibly structure) in passerine birds.

P2.4 SHOWS, A.; JENSEN, D.A*; SHUSTER, S.M.; Northern Arizona University; *dj274@nau.edu*

Seasonal variation in abundance and reproductive activity in the calcareous sponge, Leucetta losangelensis (deLaubenfels).

Leucetta losangelensis is a calcareous sponge known to inhabit intertidal zones in the northern Gulf of California. Like most sponges, the basic biology of this species is poorly known. To document seasonal variation in sponge availability and reproductive activity, we recorded monthly abundances and body volumes for sponges growing on and under boulders within a 21 m2 area located within the mid-intertidal zone near Puerto Peñasco, Sonora, Mèxico. To document reproduction, we collected a 1 cm3 core sample from the center of 1-3 sponges in each census, and examined this material microscopically for the presence of oocytes and larvae. We found a significant negative relationship between sea surface temperature and total sponge volume. Oocytes and/or larvae appeared in all core samples indicating year-round reproduction in this species. However, we found no significant correlation between sea surface temperature and the number of reproducing sponges. This sponge is known to provide habitat for a number of infaunal invertebrate species. Our results suggest that the relative abundance of *L. losangelensis* in the northern Gulf of California decreases with increasing temperature, possibly making its availability to dependent species sensitive to climate change.

105.5 SICILIANO, AM*; PORTER, ME; KAJIURA, SM; Vassar College, Florida Atlantic University; *avsiciliano@vassar.edu*
Are you positive? Discrimination between poles of electric fields by elasmobranch fishes.
Elasmobranch fishes use electroreception to detect cryptic prey at close range. Behavioral assays demonstrate that they respond to prey-simulating dipole electric fields by sharply turning and biting at the electrodes. However, it is unknown whether they are able to discriminate between positive and negative poles, and, if they can, whether they prefer to bite at one pole or the other. To address these questions, and hence to better understand the mechanisms underlying elasmobranch electroreception, we employed behavioral assays to test whether the yellow stingray (*Urobatis jamaicensis*) can distinguish between the positive and negative charges of an electric dipole in a saltwater tank. We used positive food rewards to train rays to only bite at one pole of a dipole electric field. We trained two groups of animals: one group (N=6) was trained to feed from the positive pole and the other group (N=7) was trained to feed from the negative pole. After training daily for 4 weeks, yellow rays were scored based on their responses to polarity. We found that rays preferred to bite at the pole to which they were trained. This successful training is the first evidence that elasmobranch fishes may be able to resolve the orientation of a localized electrical field. This perceptual ability may have consequences not only for detecting prey, but also for short and long range navigation, since the geomagnetic field varies locally and globally. In addition, elasmobranch fishes may perceive underwater cables and power supplies with unknown biological consequences.

67.8 SIGWART, JD*; SCHROEDL, M; Queen's Univerity Belfast, Zoologische Staatssammlung Munich; *j.sigwart@qub.ac.uk*
Consensus and confusion in molluscan phylogeny
Molluscs are the second largest and morphologically most disparate animal phylum, they are ubiquitous, and have a formidable fossil record. Monophyly of the eight Recent molluscan classes is undisputed, but relationships between these groups and patterns of early molluscan radiation have remained elusive. Molecular, fossil and anatomical data show apparently contradictory evidence for branching patterns within Mollusca. The traditional reductionist model of the 'hypothetical molluscan ancestor' has hampered the resolution of molluscan topology; some hypotheses rejected as artifacts (e.g. Serialia) continue to find additional support and cannot be dismissed conclusively. Derived conditions in major body plan modifications, such as shell-loss, have occurred repeatedly in most groups. Rather than interesting sidelines, these anomalies, and evidence for rampant reversals, apparently represent the true norm of molluscan evolution. Based on new molecular clock results—the first to include multiple exemplars of all 8 classes—diversification of molluscs started immediately in the early Cambrian and was far more rapid and more complex than previously appreciated. Extensive evolutionary plasticity by heterochronic shifts in development and multiple convergent adaptations, as demonstrated in extant molluscs, were already within the evolutionary potential of their Cambrian forebears, and continue today.

S6-2.1 SIH, A.; University of California, Davis; *asih@ucdavis.edu*
Behavioral responses to human-induced rapid environmental change (HIREC)
A key issue in animal behaviour is the need to understand variation in behavioral responses to human-induced rapid environmental change (habitat loss, exotic species, pollution, human harvesting, and climate change). Why do some individuals exhibit maladaptive behaviors, while others show adaptive responses to evolutionarily novel situations? At present, we lack a unified conceptual framework for generating predictions and guiding empirical and theoretical work on this critical question. Drawing from the concept of ecological traps, I suggest that a conceptual framework for explaining this variation should include 4 main points: 1) behavioral responses (adaptive or not) are the result of cue-response systems, or behavioral 'rules of thumb'; 2) limited or imprecise, unreliable information often underlies suboptimal behavior; 3) the organism's behavioral flexibility affects its response to novel situations, and 4) evolution (and development) in past environments has shaped cue-response systems, responses to imperfect information, and degree of behavioral flexibility to be adaptive in past environments, but not necessarily in novel environments. The degree of match/ mismatch between past environments and novel environments altered by HIREC is thus a key to explaining adaptive vs maladaptive behaviors. I discuss several existing frameworks that address these 4 points, and that are thus potentially useful for explaining behavioral responses to HIREC: signal detection theory, adaptive plasticity theory, extended reaction norms, and cost-benefit theory on variation in learning. I further discuss more complex aspects of reality that it would be useful to add to these existing frameworks.

99.6 SIKES, J.M.*; NEWMARK, P.A.; University of San Francisco, Howard Hughes Medical Institute, University of Illinois; *jsikes@usfca.edu*
Restoration of anterior regeneration in a planarian species with limited regenerative potential
Why can some animals, but not others, regenerate missing tissues? Based on their amazing regenerative abilities, planarians have become important models for understanding the molecular basis of regeneration. However, some planarian species exhibit limited regenerative abilities. To understand this loss of regenerative potential, we examine *Procotyla fluviatilis*, a planarian with restricted ability to replace missing tissues. Although these animals heal wounds and initiate a proliferative response to wounding, they fail to re-establish axial polarity in regeneration- deficient regions. Using next-generation sequencing we defined the gene expression programs active in regeneration-permissive and regeneration-deficient tissues. We found that Wnt signaling is aberrantly activated in regeneration-deficient tissues. Remarkably, down-regulation of canonical Wnt signaling in regeneration-deficient regions restores regenerative abilities: blastemas form and new heads regenerate in tissues that normally never regenerate. This work reveals that manipulating a single signaling pathway can reverse the evolutionary loss of regenerative potential.

16.1 SILVA, N; MIRY, S; OMONDI, C; ABDON, B; NJIE, C; RAMOS, L; MOFFATT, C; FUSE, M*; SFSU; *fuse@sfsu.edu*
Systemic responses to ionizing irradiation-induced imaginal discs in the larval hornworm, Manduca sexta
The imaginal discs are progenitor cells in holometabolous insects such as *Manduca sexta* and *Drosophila melanogaster*, which are destined to become adult structures such as wings or antennae. Damage can be induced by the administration of high doses of x-ray irradiation during larval development, due to the highly proliferative nature of the discs. But these tissues are extremely resilient and are repaired extremely efficiently when damaged. It has been proposed that imaginal disc repair is facilitated by an endocrine-induced delay in pupation via the inhibition of the developmental hormones Prothoracicotropic Hormone (PTTH) and the ecdysteroids, to accommodate repair of the damaged tissue. This delay is suggested to arise from the actions of secreted blood-borne factors from the damaged discs acting on the endocrine system. We therefore assessed the ability of a putative factor, adenosine, to delay development when injected into control *M. sexta* by assessing pupation rates. We further measured changes in the stain intensity of PPTH in cells of brains from x-rayed and control larvae, using immunohistochemistry with a PTTH-specific antibody, as a gauge of PTTH abundance. Our preliminary results showed that while adenosine induced developmental delays in *M. sexta*, this appeared to be through altered growth rates, a phenomenon not noted after irradiation. Furthermore, the continuous increase in PTTH stain intensity noted in control brains over a three-day test period was not noted in irradiated larvae. By the third day of development, PTTH levels appeared to plateau, suggesting that production was inhibited in irradiated larvae at this time. Experiments are currently underway to assess the effects of a second putative factor, Dilp-8 (an insulin-like peptide), in delaying development.

P1.214 SIMKINS, JS*; BENOWITZ-FREDERICKS, ZM; KENNY, TC; Bucknell University; *jws049@bucknell.edu*
Effect of pre-hatch aromatase inhibition on post-hatch immunity in chickens (Gallus gallus)
Exposure to testosterone ("T") during development can suppress immune function in many avian species. However, it is unclear whether this is caused by direct activation of androgen receptors. At least two lines of evidence suggest that estradiol ("E2") is involved: E2 receptors are expressed on B- and T-lymphocytes and their progenitors, and E2 can inhibit lymphocyte production in vitro and in vivo. E2 is synthesized from T by the enzyme aromatase and this conversion is a necessary step in many T dependent signaling pathways. We hypothesized that immunosuppressive effects of in ovo T exposure are mediated by conversion to E2 by aromatase. To test this, we inhibited aromatization of endogenous T during a crucial period of pre-hatch immune system development and measured post-hatch immune activity (total IgY antibodies, response to PHA challenge, and size of thymus and bursa of Fabricius). On day 13 of incubation, when E2 receptor expression is at a maximum in bursal tissues, chicken eggs were injected with 0.1mg of the aromatase inhibitor fadrozole in saline or saline only. On day 14 post-hatch, chicks were injected in the wing web with 0.1mg of phytohemagglutinin (PHA) in PBS buffer. 24 hours later, swelling, an indicator of inflammation due to T-cell recruitment, was measured. Blood samples were taken on post-hatch day 3, day 13 (pre-PHA challenge), and day 15 (post-PHA challenge) and analyzed for total IgY antibody count. Thymus and bursa were weighed on day 16. We predicted that if immunomodulation by T were dependent on aromatization to E2, then fadrozole treatment would promote immune activity by inhibiting the pathway. Conversely, if T were acting on immune tissues directly by binding to androgen receptors, then fadrozole treatment would instead suppress immune activity by increasing T levels.

17.10 SIMPSON, GM*; WILLIS, MA; Case Western Reserve University; *gms67@case.edu*
The Effect of Loss of Sensory Input from the Tegula on the Flight Behavior and Muscle Activation Patterns of the moth Manduca sexta
The tegula is a sensory structure at the base of each of an insect's wings. It provides the central nervous system with feedback about the movement of the wing during flight. To understand the role of the tegula in moth flight we measured the effects of the loss of tegulae inputs on the flight behavior and underlying activation patterns of elevator and depressor flight muscles in the tobacco hornworm moth *Manduca sexta*. We predicted that, as previously seen in locusts, removal of tegula input would affect the activation of the wing elevator muscles and thus the ability of the insect to fly. *M. sexta* males were challenged to track a female pheromone plume upwind in a wind tunnel and the flight behavior was recorded using high speed video cameras. Flight muscle activation data was collected by inserting electrodes into wing elevator and depressor muscles and synchronized with the video recordings. Initial analyses shows that the onset time of the elevator muscle activation is inconsistent in moths without tegulae compared to intact moths. Moths without tegulae fly for shorter periods of time and, in extreme cases, will not fly at all. So far, our analyses show that the effects of removing the tegulae on moth flight are not exactly consistent with that seen in locusts, but there is a clear effect of loss of tegulae input. We thank Jennifer Avondet for her assistance in managing the insect colony and help with all aspects of this project. G.M.S. was supported by the Howard Hughes Medical Institute funded Summer Program in Undergraduate Research. M.A.W. was supported by an Air Force Office of Scientific Research grant FA9550-07-0149.

S9-1.1 SINCLAIR, BJ*; MACMILLAN, HA; FERGUSON, LV; SALEHIPOUR, G; University of Western Ontario; *bsincla7@uwo.ca*
Cross-tolerance and cross-talk in the cold: relationships between low temperature and other stressors in insects
Insects are the most successful group of terrestrial animals, having overcome the challenges of variable temperatures and desiccating conditions. Overwintering temperate, polar and alpine insects are exposed simultaneously to a range of stressors, among which low temperature, desiccation, and starvation are the most important in determining insect success. Molecular and physiological evidence suggests that physiological responses to these stresses are often shared or co-activated. In addition, multiple lines of evidence suggest that exposure to low temperature activates the insect immune system, likely resulting in important consequences for insect-parasite interactions and overwintering success. How biotic and abiotic stressors, and the responses to them, may interact in the face of climate change is unclear, partly due to the poorly understood effects of climate change on microhabitat. Both synergistic and antagonistic interactions among these stressors are possible, and there is potential for the cold stress-immune response axis to mediate significant impacts of climate change on overwintering insects via enhancement of biotic interactions caused by responses to abiotic stress.

P2.51 SINDERBRAND, C.S.*; BARTOL, I.K.; Old Dominion University; *csind001@odu.edu*

Biomechanics and behavior of anti-predator responses in squid Lolliguncula brevis

Squids have evolved a variety of anti-predator strategies, including having high sensory acuity, using adaptive coloration, generating ink clouds and pseudomorphs, and employing a powerful escape jet. To better understand the locomotory biomechanics and behavior of escape jetting, high-speed video and defocusing digital particle tracking velocimetry (DDPTV), a volumetric (3D) approach for flow visualization, were used to record body movements and jet flows produced by brief squid *Lolliguncula brevis* during escape responses. An artificial predator was used to elicit an escape response and all experiments were conducted in either a viewing chamber or water tunnel. Kinematic parameters, such as body orientation, swimming speed, response time, and response direction were studied, and 3D wake characteristics of the escape jet were visualized and quantified. The direction, point of release and shape of the inking response were also examined. Squid responded to the artificial predator by producing ink clouds at the beginning and throughout the escape response. Jets consisting of elongated regions of concentrated vorticity with high velocity cores were also generated, which propelled the squid rapidly away from the predator in a tail-first orientation.

MOORE.1 Singer, SR; Carleton College; *ssinger@carleton.edu*

Promising Practices in Undergraduate Science and Engineering Education: Why Don't We Implement Them?

Improving undergraduate science and engineering education for all students is a national imperative, called out in many recent reports, including the President's Council of Advisors on Science and Technology's (PCAST) *Engage to Excel and Excel*. Globally we face profound challenges to provide adequate resources to a growing human population in the face of climate change, pollution, and loss of biodiversity that can be addressed, in part, by scientists, engineers, and a scientifically literate society. Undergraduate science education serves a range of purposes from providing foundational knowledge for all students, to preparing the future teachers who will be using the new *Framework for K-12 Science Education*, to preparing a STEM workforce. A shortage of STEM workers is predicted in the coming decade and improving retention of undergraduate STEM majors through improved STEM education in the first two years of college is a solution called out in the PCAST report. The National Research Council's *Discipline-based Education Research: Understanding and Improving Learning in Undergraduate Science and Engineering* report provides the evidence base for effective teaching practices in undergraduate science and engineering. This presentation will explore what is known about improving students' problem solving skills and conceptual understanding in science and engineering through more effective teaching and unpack the challenges to widespread uptake of these practices.

53.5 SKIBIEL, A.L.; SPEAKMAN, J.; HOOD, W.R.*; Harvard University, University of Aberdeen, Auburn University; *wrhood@auburn.edu*

The costs of current reproduction are not traded against maternal survival or subsequent reproductive performance in the Columbian Ground Squirrel

Life history evolution is contingent upon proximate and ultimate costs of reproductive effort. Allocating a greater amount of limited resources, such as energy, to current reproduction can reduce the amount of energy available for somatic maintenance and in turn ultimately impair future breeding success or maternal survival (i.e. cost of reproduction hypothesis). Although there is some support for the cost of reproduction hypothesis in birds, few empirical studies of mammals have demonstrated a tradeoff between current and future reproduction. Furthermore, most studies testing ultimate costs neglect to confirm that the proximate costs of reproduction are high. We experimentally manipulated litter size in a wild population of Columbian ground squirrels for 2 years to examine the proximate energetic and ultimate fitness (i.e. survival and breeding) costs of reproduction. Although females raising augmented litters had field metabolic rates that were almost 1.5 times greater than females raising control or reduced litters, there were no negative impacts on the probability of maternal survival or future reproduction. However, pups from augmented litters grew more slowly during the lactation period, were smaller at weaning and had a lower probability of survival over-winter. Thus, although females are capable of raising more young than they give birth to, our observations suggest that it is not an energy allocation tradeoff that restricts litter size, but rather the reduced offspring survival associated with raising larger litters.

58.1 SLATER, GJ*; FRISCIA, AR; Smithsonian Institute, Univ. of California, Los Angeles; *gslater@ucla.edu*

Where should we expect to find Early bursts of trait evolution? A case study using Carnivora.

George Gaylord Simpson famously postulated that higher taxa originated as adaptive radiations – early bursts of lineage and phenotypic evolution that slowed through time as niches became saturated. Simpson was a paleontologist, and his ideas were based, in large part, on his reading of the mammalian fossil record. Yet recently developed phylogenetic methods have failed to find broad support for early burst type models in phenotypic datasets of extant taxa. Here, we assemble a comparative ecomorphological dataset for extant Carnivora and use a series of phylogenetic comparative methods to investigate tempo and mode of phenotypic evolution. We find strong support for an early burst of evolution in the dominant axis of ecomorphological evolution in carnivores, with different models supported for other axes. Significantly, an early burst is not supported for body size data, even though body size is often held to correlate with ecology. Simpson's observations, which were based largely on ecomorphological traits, appear to hold for carnivores. The pervasive use in comparative methods of body size data as a surrogate for species' ecology may obscure the underlying mode of evolution of higher taxa.

143.1 SLAY, C.E.*; ENOK, S.; HICKS, J.W.; WANG, T.; University of California, Irvine, University of Aarhus, Aarhus, Denmark; *cslay@uci.edu*

Anemia amplifies postprandial cardiac hypertrophy in Burmese pythons

Burmese pythons (*Python molarus*) are intermittent feeders, capable of surviving prolonged fasts punctuated by periods of voracious feeding. The postprandial period in *P. molarus* is characterized by a rapid and significant increase in metabolic rate and a several-fold increase in oxygen consumption. Tasked with meeting elevated O_2 demand during digestion, the heart may enlarge by as much as 40% within 48 hours, though the "trigger" and universality of this response remain unclear. We hypothesize that this postprandial cardiac hypertrophy is triggered by a mismatch between oxygen demands and oxygen delivery. To test this hypothesis, we reduced the oxygen transport capacity of pythons by halving arterial blood oxygen levels (anemia). Animals were then fed meals equivalent to 25% body mass. 48 hours after feeding occurred, heart rate and blood pressure data were collected, all animals were sacrificed, and visceral organs were dissected. Fed anemic snakes experienced a 125% increase in heart rate and fed control snakes exhibited a 78% increase above fasted controls. Gastrointestinal hypertrophies occurred in both controls and anemic animals, however only fed anemic animals exhibited a significant postprandial cardiac hypertrophy (a 38% increase in ventricular mass over fasted controls animals). These results support our hypothesis that a mismatch between oxygen demand and oxygen delivery may serve as the upstream stimulus for postprandial cardiac hypertrophy in Burmese pythons. Funding was provided by the Danish Research Council to TW and NSF grant IOS 0922756 to JWH. CES would like to acknowledge support from an NSF Graduate Research Fellowship and a SICB FGST.

78.1 SLOAN, T.J.*; TURINGAN, R.G.; Florida Institute of Technology; *tsloan2009@my.fit.edu*

Invariant feeding kinematics of two trophically distinct nonnative Florida fishes, Belonesox belizanus and Cichlasoma urophthalmus across environmental temperature regimes

Nonnative fishes have the ability to adapt to environmental conditions in the invaded ecosystem and utilize resources that may have been absent in their native ecosystem. *Belonesox belizanus* and *Cichlasoma urophthalmus* are both invasive fishes in Florida. Ecomorphological studies conclude that *C. urophthalmus* is a trophic generalist while *B. belizanus* is a trophic specialist. The current Florida distribution of these species indicates that *C. urophthalmus* spreads northerly into the colder regions of Florida at a faster rate than *B. belizanus*. Is it conceivable that this variation in rate of spread is due to difference in temperature response between this ecomorphologically distinct nonnative fishes? This study was designed to test the hypothesis that the prey-capture kinematics and behavior differ between *C. urophthalmus* and *B. belizanus* at a given temperature and across temperatures. Two-Way Repeated Measures Multivariate Analysis of Covariance (MANCOVAR) revealed that (1) at a given temperature, excursion and timing variables differed between species and (2) the kinematics of prey-capture did not vary across temperatures in both species. This interspecific comparison suggests that both species have the same temperature tolerance and that any difference in their rate of spread across Florida may be driven by factors other than species-specific physiological tolerance to temperature.

73.1 SLOAN, L.M.*; MARKS, S.B; Humboldt State University; *lmsloan@alaska.edu*

Population Structure and Life History of Western Pond Turtles, Actinemys marmorata, in Lentic Habitats in the Trinity River Basin, CA

As populations of a species decline, an understanding of the regional variation in population health can aid in focusing conservation efforts. Over the past century Western Pond Turtle (*Actinemys marmorata*) populations have declined throughout much of their range (Baja California through Washington) as a result of habitat loss, overexploitation, introduced species, and water course alterations. The Trinity River, in northwestern California, has been modified from its natural state by damming and flow regulations; these alterations have decreased river quality for turtles. We investigated the health of Western Pond Turtle populations in alternative, lentic habitats adjacent to the Trinity River and its tributaries using four indicators of population health: 1) age structure, 2) size structure, 3) adult size, and 4) growth rate of young turtles. Of six lentic habitats sampled, four were biased towards large, old turtles. These habitats had prolific Bullfrog populations, while the other two sites lacked Bullfrogs. Given that Bullfrogs will eat hatchling turtles, it appears that Bullfrogs are inhibiting turtle recruitment. The same four lentic habitats also had turtles with faster growth rates and larger adult sizes, likely a result of warmer water temperatures. Overall, conservation efforts should focus on creating or preserving ephemeral lentic habitats that dry in late summer; turtles and native anurans do not require permanent water, but Bullfrog larvae usually take two years to metamorphose.

P1.10 SLOWINSKI, S.P.*; WHITTAKER, D.J.; KETTERSON, E.D.; Indiana University, Bloomington, BEACON Center for the Study of Evolution in Action, Michigan State University; *sslowins@indiana.edu*

Odor sharing among kin in birds: assessing whether female songbirds transfer preen oil to their nestlings during brooding

Avian preen oil, secreted by the uropygial gland, contains odorous volatile compounds that likely play a role in intraspecific communication. Odor may be important for kin recognition in birds, and is known to affect songbird parental care. Research on mammals suggests that a possible mechanism for the similarity of odors among kin may be the transference of odor-producing microbes in secretions. We investigated whether free-living female Dark-Eyed Juncos (Junco hyemalis) transfer preen oil (and, consequently, their own odor) to their nestlings during the early brooding stage at The Mountain Lake Biological Station in Pembroke, Virginia. Brooding females were captured at the nest using potter traps and mist nets. We applied 30 ul of glo-germ, a non-toxic gel that glows under ultra-violet light, to the preen gland before releasing each focal female. We returned to the nest 4 to 7 hours after the original capture and application of the gel and removed the nestlings from the nest and inspected them under an ultra-violet light in dark conditions. We were able to detect glo-germ on twelve out of a total of twenty-one nestlings that we inspected following our treatment (57.1% of nestlings inspected). Our results support the hypothesis that female songbirds transfer preen oil to their nestlings during early brooding and suggest that a nestling's odor may be influenced by the odor of the mother. Future research will assess whether microbes that may be transferred from mother to offspring via preen oil affect the ontogeny of preen oil volatiles in nestlings, leading to similar odors among nest-mates and their mothers.

132.1 SMALL, TW*; BRIDGE, ES; SCHOECH, SJ; University of Memphis, University of Oklahoma; *twsmall@memphis.edu*

Food supplementation of Florida Scrub-Jay (Aphelocoma coerulescens) nestlings: long-term effects on hypothalamic-pituitary-adrenal axis responsiveness

In a wide variety of animals, plasma glucocorticoid levels rapidly increase in response to a stressor. In Florida Scrub-Jays (*Aphelocoma coerulescens*), the magnitude and time course of increased corticosterone (CORT) during a restraint stress can vary greatly between individuals. These differences can be detected within a few months post-fledging, and are repeatable throughout the life of the animal, suggesting that these differences are a persistent aspect of the individual's phenotype. Further, the differences in stress responses are correlated with life history and behavioral traits, such as an individual's life span and degree of neophobia. The CORT phenotypes of offspring are correlated with parental CORT phenotype, but it is currently unknown if this similarity is due to genetic inheritance or other factors, such as differences in parental care, early life nutrition, or other environmental conditions. To investigate which factors are important in the development of the CORT stress response, we used a novel "*SmartFeeder*" design that utilizes radio-frequency identification (RFID) technology to food supplement specific individuals within a population of free-living Florida Scrub-Jays. With these feeders we delivered live mealworms to specific adult jays caring for nestlings, and thereby supplement their nestlings. Behavioral observations at supplemented and control nests confirm adults feed mealworms to nestlings. Supplemented nestlings were not larger than control nestlings and nestling baseline CORT did not differ between treatments; however, supplemented nestlings had lower stress-induced CORT levels at approximately 50 days post-fledging. Continuing research will determine if these differences persist into adulthood and if they are correlated with behavioral differences and individual success.

P2.217 SMITH, R. J.*; COHEN, S; San Francisco State University , San Francisco State University; *rjoysmith24@yahoo.com*

Phylogeography of Leptasterias aequalis Near Terrestrial Runoff Sources in the San Francisco Bay Area

Small six-rayed seastars, *Leptasterias* spp., form a cryptic species complex commonly found in the rocky intertidal zone from Alaska to southern California. In 2008, *L. aequalis* were sub-divided into four finer scale clades (Flowers & Foltz, 2008). In 2009, an additional clade were detected in Central California, resulting in an unresolved taxonomic status (Coleman & Cohen, 2009). While many sea star species have a planktonic larval stage, *Leptasterias* spp. brood their larvae and after direct development, the young crawl away. This limited dispersal potential may lead to establishment of semi-isolated populations where local differentiation and adaptation to local conditions may occur. To gain insight into patterns of local distribution of *Leptasterias* spp., we compare population genetic diversity to population density and local environmental features, specifically terrestrial runoff into the ocean. We hypothesize that local populations at sites either separated by freshwater flow or impacted by urban runoff will show local differences in clade compositions. At sites with nearby outlets in Sonoma, Marin, San Francisco and San Mateo counties, we have categorized oceanic and anthropogenic habitat variation in comparison to genetic composition. We are comparing a 300 nt. fragment of the mitochondrial control region in 215 *Leptasterias* spp. samples to estimate patterns of clade distribution related to geographic features. The results will allow us to map the cryptic species complex of *Leptasterias* spp. in order to determine if their distribution is affected by local sources of terrestrial runoff, a possible indication of local environmental conditions within their diverse range.

27.5 SMITH, A. M.; Ithaca College, NY; *asmith@ithaca.edu*

Double network gels and biological glues: a powerful new toughening mechanism

Limpets, marsh periwinkles and some terrestrial slugs produce remarkable glues that are gels. A key question has been how they can achieve tenacities on the order of several hundred kilopascals using only a dilute gel that is a modified lubricating mucus. Previous work has shown that the essential change is the addition of relatively small, cross-linked proteins. Nevertheless, highly cross-linked gels are typically brittle and fail easily. Molluscs may avoid this through the use of a "double network". Recent work in materials science has found that combining two highly dissimilar, interpenetrating gel networks can increase gel strength by a factor of 100 to 1000 over the strength of the two gels separately. A prototypical double network gel combines a deformable network of very large polymers and a highly cross-linked network of much smaller polymers. Initial fracture occurs in the stiffer, highly cross-linked network. Fracturing the soft network as well, though, requires extensive deformation. This deformation damages the rigid network in a large volume surrounding the crack. This can increase the energy required to propagate the crack by several orders of magnitude. Such a mechanism is likely at play in molluscan adhesive gels given their structure. In fact, any biological gel containing proteoglycans or similarly large polymers in combination with smaller cross-linked proteins has the potential to operate this way. This talk will outline the structural and mechanical criteria for double network gels and consider the applicability of this mechanism to different biological materials.

67.3 SMITH, AJ*; ROSARIO, MV; EITING, TP; DUMONT, ER; UMass, Amherst; *ajsmi1@cns.umass.edu*

A conundrum of covariation: The effects of missing data on disparity analysis

Disparity, or morphological diversity, is an important metric of biodiversity used to analyze evolutionary trends in form over geological timescales. Although missing data are common in fossil datasets, we do not fully understand how different disparity metrics respond to increasing levels of missing data. Past research investigated this by randomly removing morphological characters from simulated taxa. However, the loss of anatomical characters is not a random process; characters in close physical proximity to one another are likely to be correlated in presence or absence. First we calculated covariation in character loss from 12 extinct taxa coded for 196 characters, then used that covariance structure to remove characters from a data-rich matrix of 49 extant taxa coded for the same characters. Starting from a maximum of all characters present, we sequentially removed characters in every taxon from the extant matrix such that the average character loss across taxa represented 0% to 75% loss. At each character loss step, we calculated morphospace range and variance (average spread and dissimilarity among taxa respectively). We then repeated this process without character covariation (i.e., randomly removing characters). With covariation, our range metrics exhibited inverse exponential declines whereby the slope changes at ~40% missing characters before declining rapidly. Our variance metrics declined linearly with confidence intervals narrowing as loss increased. Without covariation, range metrics displayed linear declines, while variance metrics exhibited exponential declines. Our results show that character covariation has important consequences for disparity metrics, and should be taken into consideration in future disparity studies.

47.1 SMITH, K. A.*; DUNNE, J. P.; SARMIENTO, J. L.; Princeton University, NOAA Geophysical Fluid Dynamics Laboratory; *kas3@princeton.edu*

Predicting the effect of multiple stressors on respiratory niches in the pelagic ocean over the next century

Global climate change is rapidly altering temperature, oxygen, and acidity in the ocean environment and the effect that these changes will have on pelagic fisheries and ecosystems is an increasing concern. Oxygen availability is one of the most important factors for determining the distribution of fish in the pelagic ocean environment. Oxygen is extracted from the ocean environment in the gills. The extraction process requires oxygen to diffuse through the gill membrane and into the red blood cell where it binds with hemoglobin. The rate of hemoglobin oxygenation is sensitive to both temperature and acidity and is highly variable among species. A fish is unlikely to use habitat where aerobic metabolism is impeded by low rates of hemoglobin oxygenation. We use the P_{50}, the oxygen tension at 50% hemoglobin oxygen saturation, as a proxy to determine available habitat in the ocean. The effects of temperature and acidity on P_{50} are incorporated into the analysis. Habitat thickness is predicted for a range of physiological traits in the global ocean using temperature, oxygen and pH data from NOAA's Geophysical Fluid Dynamics Laboratory Earth System Models. Results indicate that there will be habitat compression in the next century.

P1.61 SMITH, FW*; GOLDSTEIN, B; JOCKUSCH, EL; University of Connecticut, University of North Carolina; *frank.smith@uconn.edu*

The Tardigrade Hypsibius dujardini and Body Plan Evolution within Panarthropoda

The panarthropodan lineage includes the phyla Arthropoda, Onychophora and Tardigrada. Arthropods are known for their jointed appendages and an incredible degree of tagmosis. Ancestral panarthropodans had homonomous lobopodal leg-like appendages and a much lower degree of tagmosis. Like onychophorans, tardigrades retain the ancestral lobopodal appendage type. Tardigrades also show the lowest degree of tagomosis of the extant panarthropodan phyla. Here we present results emanating from an EDEN sponsored research exchange to develop both *in-situ* hybridization and immunostaining protocols for the tarigrade species *Hypsibius dujardini*. Using a metazoan cross-reactive α-tubulin antibody, we have found that *H. dujardini* adults have a rope-ladder like nervous system with segmental commissures like arthropods, but unlike onycophorans. Using a combination of DAPI and phalloidin staining, we have found that the legs of *H. dujardini* adults lack intrinsic musculature, like onychophorans, but unlike arthropods, which have intrinsic musculature in their appendages. Finally, we have cloned orthrologs of the candidate leg patterning genes *Distal-less* (*Dll*), *extradenticle* and *dachschund* and have discovered a single *homothorax* ortholog in preliminary genomic reads. *Dll in-situ* hybridization shows expression throughout the developing limb bud, unlike in onychophorans and arthropods, where Dll expression becomes more restricted to the distal appendage domain. These results and preliminary *in-situ* hybridization results for the other leg patterning gene orthologs will be presented and the implications for panarthropodan body plan evolution discussed.

P2.3 SMITH, V.L.*; ROSENTHAL, G.G.; Texas A&M University; *victoria424242@gmail.com*

Neuroendocrine Mechanisms of Female Reproductive Behavior in the Swordtail X. birchmanni

It is well accepted that animals integrate external environmental cues (predation, anthropogenic disturbance, social interactions) with information regarding their current physiological state to inform behavioral output. This is of particular importance with regards to the timing of reproductive behaviors. The mechanisms underlying the transduction of this information into changes in reproductive behavior, however, are poorly understood. Changes in an animal’s environment are capable of producing a behavioral stress response which often includes suppression of reproductive behavior and across vertebrate taxa, stress and the associated release of high levels of glucocorticoid hormones have been correlated with the suppression of reproductive physiology. Interestingly, several studies have also shown that, in some taxa, low levels of glucocorticoids may actually facilitate female reproductive function at the physiological level. Taken together, these findings suggest that glucocorticoids are a viable candidate for a role in modulation of reproductive behavior. Despite this, surprisingly few studies to date have focused on the role of glucocorticoids in female reproductive behaviors. The swordtail *Xiphophorus birchmanni* is a well-characterized model in evolution and behavioral ecology and is ideally suited for studies of female reproductive behavior. We hypothesize that individual differences in cortisol titer predict reproductive behavior in female *X. birchmanni*. To begin to address this hypothesis we have first conducted a field study comparing wild caught female reproductive condition with cortisol titre and glucocorticoid receptor expression in the brain. Following the field study we will conduct laboratory behavioral trials in which female glucocorticoid levels will be manipulated and compared with reproductive behaviors.

87.4 SMOOT, S.C.*; PLANTE, C.J.; PODOLSKY, R.D.; College of Charleston; *scsmoot@gmail.com*

Separating the effects of the deposition substrate and habitat on the anti-microbial properties of egg masses of Haminoea vesicula

Several marine invertebrates reproduce by encapsulating embryos inside gelatinous egg masses until hatching. Previous studies have shown that the anti-microbial activity of egg masses of a given species can vary among field locations. This observation suggests that anti-microbial activity may be affected by the nature of the deposition substrate or by other aspects of between-site variation. If differences in anti-microbial activity across habitats depend strongly on the deposition substrate, then adults provided different substrates in a common garden should produce egg masses with different levels of anti-microbial activity. We compared anti-microbial activity in egg masses of the opisthobranch mollusc *Haminoea vesicula* in two ways: when laid on different macrophyte substrates at a single field site, and on the same substrate (the green alga *Ulva lactuca*) at different field sites. Methanol (MeOH) and ethyl acetate (EtOAc) extracts were then tested for anti-microbial activity against marine type cultures and several environmental strains using a 96-well plate bacterial growth assay. The level of anti-microbial activity depended strongly on the substrate the egg mass was laid on and minimally on the field site. These results suggest that chemicals produced by macrophytes or their associated microbial communities could be influencing the level of anti-microbial activity of deposited egg masses, suggesting that these differences may play a role in oviposition preference of *H. vesicula* adults.

P2.154 SMOOT, S.C.*; PLANTE, C.J.; PODOLSKY, R.D.; College of Charleston; *scsmoot@gmail.com*

Variation in anti-microbial activity in egg masses of 19 mollusc species in relation to variation in habitat an deposition site

Gelatinous egg masses are used by several species of marine invertebrates to encapsulate embryos until hatching. The high protein and mucopolysaccharide composition of these egg masses make them particularly susceptible to microbial infection. Previous studies have found chemical compounds in benthic egg masses that deter microbial infection. Furthermore, levels of anti-microbial activity vary by field location and deposition site. We compared the antimicrobial activity of egg masses from 18 molluscan species that varied in deposition substrate and field site around the San Juan Islands, WA. Egg masses were collected from the field, lyophilized, and extracted with non-polar ethyl acetate (EtOAc) and polar methanol (MeOH) solvents. The extracts were then tested and quantified for antimicrobial activity against two marine pathogens: *Bacillus subtilis* and *Vibrio harveyi*, and three environmental pathogens in a 96-well plate assay. We observed differences in the anti-microbial activity among different molluscan species with the strongest inhibition in extracts of the cephalaspids *Haminoea vesicula* and *Melanochlamys diomedea*. Anti-microbial activity also appeared to vary among egg masses within species that had been deposited on different substrates. These results suggest wide interspecific and intraspecific variation in the degree of anti-microbial protection afforded by encapsulating structures. We are examining whether these patterns of protection suggest a greater role for the type of encapsulating structure or for the microenvironment at the site of deposition.

S2-1.7 SNELL-ROOD, EC; University of Minnesota; *emilies@umn.edu*

The role of learning in mediating transgenerational responses to nutrition

Understanding how organisms cope with variation in the quantity and quality of nutrition is relevant to predicting their responses to changing nutritional environments and may have implications for human health. In many species, parents gain both direct and indirect information about the future nutritional environment of their offspring. How does such information impact parental investment and offspring survival? This talk discusses how different life cycles may determine whether parental experience can result in adaptive transgenerational responses to nutritional variation. I present data from butterflies suggesting that adult learning experiences may prepare offspring for novel nutritional environments through effects on energy allocation to eggs. Finally, I will discuss developmental mechanisms, such as gene expression stochasticity and DNA methylation, which may underlie such transgenerational responses to nutrition.

S6-2.4 SNELL-ROOD, EC*; MOREHOUSE, NI; University of Minnesota, University of Pittsburgh; *emilies@umn.edu*

The effects of changing nutrient inputs on sexual selection dynamics and life history evolution

Discussions of rapid human-induced environmental change often focus on the loss or disruption of critical resources, such as habitat destruction, pesticide contamination or drought in the face of climate change. However, humans are also significantly increasing the availability of crucial nutrients or resources that were once limited. For instance, salt, nitrogen, phosphorus and lipid availability have increased in certain habitats or regions due to human activity. In some cases, such changes may have positive impacts on the growth and development of individuals. This talk discusses the longer term evolutionary consequences of such changes in nutrient availability. In particular, increased availability of once limited nutrients may relax sexual selection intensity and shift selection to novel traits. Changing nutrient dynamics may also alter patterns of energy allocation that are relevant to life history evolution. We present data from a butterfly system illustrating the potential impacts of altered nitrogen availability on mating systems and conclude with suggestions for future research in this area.

P2.97 SNYDER, N. M.*; CLARK, M. E.; REED, W. L.; North Dakota State University, Fargo; *nicole.snyder@my.ndsu.edu*

Growth and Immune system function in juvenile Franklin's gull

How offspring respond to variation in reproductive timing is not well studied. Evolutionary theory predicts, and empirical evidence indicates, that investments in offspring decline across the reproductive season. Thus, offspring produced later in the season may need to compensate for a poor start in order to survive to breeding age. Franklin's gull (*Leucophaeus pipixcan*) eggs laid later in the season are smaller and produce structurally smaller hatchlings than eggs laid early in the season. In a laboratory study with *ad libitum* feeding, chicks from late season eggs exhibited faster growth rates than chicks from early season eggs, yet their asymptotic masses did not differ. We hypothesized that late season chicks compensate for the initial lower investment at the cost of immune system development, ability to repair DNA damage, and ability to withstand a short-term diet restriction. We tested our hypotheses in a laboratory study of chick growth. We artificially incubated early and late season gull eggs, randomly assigned hatchlings to a diet restriction or control group, measured chicks daily until age 40 days. At age 20 days, we evaluated immune system function with a PHA challenge to the patagium and circulating heterophil: lymphocyte ratios. We evaluated DNA damage at this age with single cell gel electrophoresis (comet assay). We found no differences among groups in patagial swelling, but late season chicks had thinner initial patagia than early season chicks. The comet assay indicated fragmented DNA in cells of late season and diet-restricted chicks. Our findings suggest that late season offspring can compensate for low parental investments without compromising immune function, but may incur costs that inhibit tissue repair or self-maintenance.

123.6 SNYDER, S*; KOHIN, S; CHILDERS, J; FRANKS, P.J.S.; Scripps Institution of Oceanography, UCSD, Southwest Fisheries Science Center; *smsnyder@ucsd.edu*

Thermal Physiology of albacore tuna, , as revealed through archival tagging data

Juvenile albacore, *Thunnus alalunga*, were tagged with archival tags in two regions of the Northeast Pacific: (i) off Northern Baja California, and (ii) off Washington and Oregon between 2001 and 2006 with the objective of describing seasonal movements, migration patterns, vertical distribution, and thermal physiology. Twenty tags were recovered with times at liberty ranging from 63 to 697 days. The tags' sensors recorded depth, ambient temperature, relative light levels, and the temperature of the tuna's peritoneal cavity every minute for the duration of the deployment. Analysis of this data revealed diel diving behavior, with repeated dives below the thermocline during the day and restriction to the mixed layer throughout the night. As temperatures below and above the thermocline are fairly homogeneous, the vertical movements of the albacore resulted in a cycling between relatively stable cold and warm thermal regimes. These cold and warm regimes were used as *in situ* incubation treatments. By calculating the change in internal temperature during *in situ* incubation treatments, the rate of heat loss due to the thermal gradient between the tuna and the surrounding water temperature was estimated. Incorporating this parameter into a heat budget model, the predicted body temperature given only the heat loss due to the temperature gradient was calculated. Change in body temperature due to metabolic heat input was then estimated as the difference between the predicted temperature and the observed temperature. Preliminary results suggest that the diving behavior and the thermal structure of the water column affect the juvenile albacore's ability to regulate and maintain their internal temperature.

P1.29 SNYDER, T.J.*; DOLCEMASCOLO, P.; ARAYA-JARA, L.V. ; HAZARD, L.; MONSEN, K.J.; Montclair State University; *snydert3@mail.montclair.edu*

Habitat Use and Population Demographics of Two Aquatic Turtle Species in a Temperate Forest Lake

We studied syntopic populations of common musk turtle (*Sternotherus odoratus*) and eastern painted turtle (*Chrysemys picta*) in Lake Wapalanne, a 5.67 ha lentic ecosystem at the New Jersey School of Conservation (Sussex Co., New Jersey). The turtles were caught by hand netting, hoop traps, and basking traps in 2011 and 2012; 68 *S. odoratus* and 155 *C. picta* individuals were measured and permanently marked. *S. odoratus* were found near large cover objects along the edge of the lake. *C. picta* was distributed equally throughout the habitat. Sexual dimorphism was only prevalent in *C. picta*, in which females were larger than males. Sex ratio of *C. picta* was slightly male biased, and was equal for *S. odoratus*. We found that 97.1% of the *S. odoratus* and 91.6% of the *C. picta* individuals were adults, which could represent lack of juvenile recruitment or trapping bias. We also measured levels of leech parasitism, injuries and other abnormalities, and carapacial algae load for both species. Results differed from those expected based on available data for comparable populations and will be further investigated through long-term monitoring.

65.3 SOBOLEWSKI, ME*; BROWN, JL; MITANI, JC; University of Michigan; *mesobole@umich.edu*

Anticipatory Stress, Territoriality and Hunting in Wild Chimpanzees

Territoriality and hunting are energetically and psychologically demanding aspects of male chimpanzee behavior. The stress response allows an individual to quickly alter its physiological and behavioral profile to successfully navigate such behaviors. The discrete nature of these competitions permitted us to investigate any anticipatory urinary hormone variation associated with these behaviors in the Ngogo chimpanzee community, in Kibale National Park, Uganda. Here, we investigated the correlation between cortisol, a stress hormone, territorial and hunting aggression. Our results indicated that territoriality and hunting are facilitated by increases in adrenal activity and cortisol production. More importantly, these data showed that cortisol increases before any aggression transpires. In an earlier study, we found that male chimpanzees display anticipatory increases in testosterone in advance of territorial behavior but not hunting. Therefore, we investigated two correlates of territorial behavior, large male party size and location in territory, in an attempt to identify cues associated with these anticipatory hormone increases. However, neither correlate explained the increases in anticipatory hormone concentrations. Being on the periphery of their territory was not associated with elevated cortisol or testosterone concentrations. Group size was not associated with testosterone variation and cortisol levels, contrary to expectation, were higher when males were in smaller groups. The potential cues that explain the observed anticipatory increases in cortisol are still unknown.

P3.102 SODA, KJ*; SLICE, DE; NAYLOR, GJP; Florida State Univ., College of Charleston,SC; *kjs11w@my.fsu.edu*

The use of geometric morphometrics and artificial neural networks to identify teeth to species in requiem sharks (Carcharhinus sp.)

Although many species of shark are identifiable based on tooth morphology, smooth continuous gradients in morphology from the front to the back of the jaw are common. Finding appropriate comparisons for isolated fossil teeth along this gradient, and thereby identifying species, can be difficult. A large pool of fossil shark teeth could contribute to research if a method for identifying species existed. This study introduces a method to identify upper jaw teeth from four extant species of requiem shark, *Carcharhinus acronotus*, *C. leucas*, *C. limbatus*, and *C. plumbeus*. For each species, the morphology of every upper jaw tooth in 15 specimens (178-217 teeth/species) was described using the coordinates of 13 landmarks. Using Procrustes analysis, the coordinates were standardized to remove location, orientation, and size. These coordinates were used to train a multilayer perceptron (MLP) to sort each tooth to species. MLPs are a class of artificial neural network where data is given to a set of nodes. These nodes pass their values to new nodes with each value weighted based on recipient. Each subsequent node sums its inputs, evaluates a function of the sum, and passes the result weighted by recipient. The final nodes represent species and the function evaluation is the probability that the tooth belongs to that species. The classification accuracy of the method was assessed using a 10-fold cross validation and a set of teeth from new individuals (5-15 individuals (68-215 teeth)/species). Both validation methods estimate the accuracy to be over 90% for all species. MLPs trained with Procrustes coordinates could be effective in identifying fossil teeth, as well as other hard structures that are distinct across taxa.

S9-1.6 SOKOLOVA, Inna; University of North Carolina at Charlotte; *isokolov@uncc.edu*

Energy homeostasis as a tool to integrate the effects of multiple stressors in animals

Energy balance plays a key role in survival and stress tolerance of all organisms due to the need to balance energy demand with sufficient energy supply for survival. In animals, both the amount of available energy (through food uptake and assimilation), as well as the capacity of metabolic energy conversions and ATP synthesis are limited resulting in the trade-offs between the energy fluxes that support different fitness-related processes. Environmental stress can result in the negative shifts of energy balance due to the increased metabolic demand for stress protection and damage repair, stress-induced damage to the organismal functions such as food and oxygen uptake and delivery and/or impaired cellular metabolic capacity. These shifts have direct consequences for the organism's fitness due to the reduced aerobic scope available for growth, reproduction and/or survival. Thus, studies of the energy balance provide a common yardstick to compare and integrate the effects of multiple stressors regardless of their nature and molecular mechanisms, and to predict the ecological consequences of these effects. Bioenergetic thresholds can also be used to distinguish between the moderate stress when the long-term survival of the organisms and their populations is possible albeit at the expense of the reduced growth and reproduction, and the extreme stress incompatible with the long-term survival. Here I present the general concept of energy-limited stress tolerance in animals, describe the bioenergetic markers useful in distinguishing between the moderate and extreme stress exposures and illustrate the applicability of this concept to integrate of the interactive effects of multiple stressors using an example of marine bivalves exposed to trace metals, temperature, salinity stress and ocean acidification. Supported by NSF IOS-0921367 and IOS-0951079.

P2.33 SOKOLOVA, I.*; IVANINA, A.; BENIASH, E.; University of North Carolina at Charlotte, University of Pittsburgh; *isokolov@uncc.edu*

Elevated CO_2 levels affect cellular uptake and homeostasis of trace metals in hard shell clams Mercenaria mercenaria

Estuarine bivalves are susceptible to environmental stressors such as ocean acidification and heavy metal pollution which can interactively affect their performance and survival. We studied the interactive effects of elevated PCO2 (hypercapnia) and metals (Cd and Cu) on acid-base and metal homeostasis in isolated mantle cells of a hard shell clam Mercenaria mercenaria. Isolated cells were exposed for 2 h to 0.04, 1.52 or 3.01 kPa PCO2 [representative of the ambient CO2 conditions and the hemolymph PCO2 at the ambient and elevated CO2 (400 and 800 ppm, respectively)] to five different metals concentrations: control (no added metals), 25 µM Cd, 100 µM Cd, 1 µM Cu or 5 µM Cu. Extracellular and intracellular pH decreased with increasing PCO2 but was not affected by the metal exposure. Exposure of the mantle cells to Cd resulted in a concentration-dependent increase in the level of total and free intracellular Cd2+. Notably, Cd uptake was significantly lower at elevated PCO2. Cd exposure also led to a dramatic increase in free intracellular [Zn2+], which was considerably higher at low PCO2 levels and strongly correlated with the total intracellular Cd burdens. In contrast, Cu exposure did not affect free intracellular [Zn2+] but led to a significant increase in the intracellular levels of free Cu2+ and Fe2+, which was strongly potentiated by elevated PCO2. Exposure to metals resulted in the elevated levels of reactive oxygen species during the ambient air exposure but not at elevated PCO2. These data suggests that environmental CO2 levels can strongly modulate uptake and toxicity of trace metals in clams and that toxic effects of Cu are likely to be increased at elevated PCO2, whereas cellular toxicity of Cd may be partially alleviated by hypercapnia. Supported by NSF IOS-0951079.

49.4 SOLOMON-LANE, TK*; PRADHAN, DS; WILLIS, MC; CRUTCHER, JB; GROBER, MS; Georgia State Univ., Atlanta, Rhodes College, Memphis; *tsolomonlane1@student.gsu.edu*

Playing the margins: the fitness consequences of individual behavioral variation in the bluebanded goby (Lythrypnus dalli)

Social hierarchies affect individuals at multiple biological levels. Although behavioral differences among statuses are central to dominance, within-status individual behavioral variation persists in many social species and has reproductive consequences. In the bluebanded goby (*Lythrypnus dalli*), a highly social, sex-changing fish, the influence of social behavior on the reproduction of group members is status-specific. Individual variation in female behaviors influence the quantity of eggs laid in the social group; male behavior affects hatching success. Aggression by the highest-ranking female (alpha) has the most dramatic effect, reducing the number of egg clutches and total quantity of eggs laid in a social group. The mechanisms underlying the negative effect of aggression on reproduction remain unclear, however, because we were previously unable to measure individual fitness. Here, we developed a simple method of quantifying female fitness using injections (ip) of food dye that persisted in the yoke throughout egg development. Using this method, we tested the effect of social behavior on alpha female fitness and social group reproductive patterns. Specifically, we hypothesize that alpha female aggression affects clutch laying decisions, an influence that may be unique to alpha status. We tested this hypothesis by quantifying social behavior, egg laying, and hatching success in stable social groups over 4 weeks. Elucidating how social behavior influences fitness is critical to understanding the evolution of sociality and the trade-offs between social structure maintenance and individual self-interest.

69.1 SOMERO, GEORGE; Stanford University ; *somero@stanford.edu*

Lessons from cold-adapted enzymes: Can protein adaptation to temperature be simple and quick?

Fascination with how proteins manage to work well at near-freezing temperatures has led to detailed study of enzymatic and structural proteins of Antarctic notothenioid fishes. Discovery that lactate dehydrogenase (LDH) orthologs of notothenioids have extremely high intrinsic rates of activity (kcat values) and appropriate substrate binding affinities (Km) for function in the cold has prompted investigation of the underlying changes in amino acid sequence that generate these adaptations. One key finding of these comparative studies is that adaptation to cold can be achieved by only one or two amino acid substitutions and need not involve a wholesale redesign of protein structure. This discovery has prompted wide-ranging studies of other proteins and other taxa, to see if such a 'simple' solution to temperature adaptation is prevalent. Indeed, studies of orthologous malate dehydrogenases (cMDHs) of several invertebrate lineages have shown that (i) a single amino acid substitution can suffice to achieve adaptation, (ii) a number of sites in the sequence are candidates for adaptive change, and (iii) the primary effect of these amino acid substitutions is to modify the conformational mobility of regions of the enzyme that move during function. Active (catalytic) sites themselves are fully conserved. Importantly, studies of different proteins suggest that not all proteins are as thermally sensitive as LDH and cMDH. Thus, temperature adaptation may not involve modification of the entire proteome. These findings have implications for rates of protein evolution, notably in the context of a rapidly warming planet.

P2.214 SOSA, AE*; GERMAN, DP; Univ. of California, Irvine; *sosaae@uci.edu*

Evolution of herbivory in the family Stichaeidae (Teleostei)

The goal of this project was to generate a molecular phylogeny for fishes in the family Stichaeidae, which represent a vertebrate model for understanding the evolution of dietary specialization on the physiological level. Tissues (muscle or fin) from stichaeids were obtained either from museums, or directly from fishes in their natural habitats in California and Washington, and DNA was extracted. Polymerase Chain Reaction (PCR) conditions were optimized for three genes, two mitochondrial (16s and cytb) and one nuclear (tmo4c4). The analysis included 154 individuals representing 46 species of the family Stichaeidae and adjacent families in the order Zoarciformes. Sequences were aligned using Codon Code alignment software and the Bayesian phylogenetic topology was generated using Mr. Bayes. The phylogenetic hypothesis for the Stichaeidae shows some agreement with a previously generated phylogenetic tree based on morphological characteristics, although some portions of the family (e.g., tribe Xiphisterini) are not monophyletic. This latter result suggests that herbivory evolved twice, independently within the Stichaeidae, not once as was previously assumed. The phylogenetic tree generated in this study will advance the field of nutritional physiology by providing the backdrop for rigorous, phylogenetically informed analyses in subsequent studies.

P2.65 SPAIN, D.D.*; REED, K. D.; BUSELLI, M. ; Dominican University of California; *diara.spain@dominican.edu*

Assessing Communication Skills in an Introductory Science Research Class

College graduates should be able to communicate effectively, both written and verbally. This is especially important for graduates with a degree in science. As a result, it is important to teach undergraduate science students appropriate communication skills by incorporating relevant assignments into their classes. Our department has created a series of research based classes that students take over four semesters. We have modified the first class, which students take as second semester freshman, to include several short writing and oral presentation assignments. The expectation is that our students will learn important skills and improve their ability to successfully communicate their ideas. The project goal was to determine whether fostering in both topic areas has allowed them to improve their mastery of communication skills. We monitored the success of the assignments by administering a survey twice, at the start and the completion of the introductory course. We compiled data from the introductory class gathered over three semesters. The preliminary survey results are variable, there is a positive increase in several areas although in some areas there is no apparent change. For example, in the spring 2010 semester there was a 15% increase in the number of students giving the highest rating (5 on a 1-5 scale) to the importance of having good verbal communication skills. This result may have been from gaining experience in giving oral presentations and receiving constructive criticism and positive feedback. However, that same group of students answered another survey question on their confidence level in using written communication skills and showed no change in the highest rating category. In this case the assignments may not have been challenging to the students or their writing mastery may have been at a high level already.

65.6 SPARKMAN, AM*; PALACIOS, MG; BRONIKOWSKI, AM; Westmont College, California, National Council for Scientific and Technologic Research, Argentina, Iowa State University, Iowa; *sparkman@westmont.edu*

Long-term elevation of indicators of physiological stress in captive garter snakes

The physiological response to captive stress varies among species, with some adapting quickly to captive environments, but others adjusting slowly or exhibiting long-term deviation from baseline patterns in the wild. To evaluate the effects of captivity on any given species, it is essential to compare captive measures with measures taken in the wild. We tested for hematological indicators of captive stress in juvenile and adult western terrestrial garter snakes, *Thamnophis elegans* . We measured baseline plasma corticosterone and heterophil to lymphocyte (H:L) ratios in both juvenile and adult snakes upon capture in the field, and in adult females after one and three months in captivity. Corticosterone and H:L ratios were also measured at three and thirteen months of age in captive-born offspring of wild-caught females. Interestingly, while corticosterone levels were strongly positively correlated to H:L ratios in the field, the relationship between the two disappeared over time spent in captivity, and was not present in juveniles born in captivity. Longitudinal samples of adult females showed higher levels of both corticosterone and H:L ratios in captivity than in the field; both variables were at their highest levels after three months in captivity. Offspring corticosterone and H:L ratios were also significantly higher than a mixed-age sample of animals in the field. Our findings suggest that captivity has long-term consequences for physiological indices of stress in *Thamnophis elegans* , and that these consequences are manifest in both wild-born and captive-born individuals.

1.5 SPEAKMAN, J.R.; Rowett Research Institute; *J.speakman@adbn.ac.uk*

The contribution of DLW to understanding problems in human nutrition: a comparative perspective

The doubly-labeled water method has been a valuable tool to quantify human energy expenditures over a range of daily energy demands. With the increase in a more sedentary lifestyle over the past half century, human daily energy expenditure (DEE) relative to resting metabolic rates (RMR) had become relative modest compared to that of wild animals. Humans are spending a majority of their metabolic expenditure on rest, whereas wild animals spend most of their expenditure on activities. This reduced DEE/RMR relationship for humans is evident in the increase incidence of obesity in Western societies. Described in this talk will be the determinants of human energy flux, the interplay between changes in daily expenditure and levels of nutrition in altering body composition and activity, and the insights gained from animal studies on the human physical condition.

106.1 SPEISER, DI*; OAKLEY, TH; Univ. of California, Santa Barbara; *dispeiser@gmail.com*
The molecular evolution of chiton 'shell' eyes
Understanding the evolution of complex traits has been a major goal of biologists for generations. When studying the origin of a particular complex trait, it is useful to first ask about the separate evolutionary histories of its components. In the case of an image-forming eye, for example, these components likely include sets of genes involved with phototransduction, pigment synthesis, and organogenesis. Chitons (Phylum Mollusca; Class Polyplacophora) are a promising system in which to study the process of eye evolution. All chitons have "aesthetes", small sensory tentacles that fill narrow channels in the dorsal shell plates. In certain chiton species, some of the aesthetes terminate in a 'shell eye' with a pigment layer, retina, and aragonite lens. From a phylogenetic perspective, these eyes are clearly a derived trait; further, from a historical standpoint, they may be the most recently evolved animal eyes – the chiton fossil record extends back to the Cambrian, but eyed chitons have only diversified within the last 25 million years. Using immunohistochemistry we find that the aesthetes, but not the eyes, of the chiton *Acanthopleura granulata* express an r-type opsin similar to those expressed by the cephalic eyes of many other invertebrates. Next, through transcriptome sequencing, we find that chiton aesthetes generally express a wide range of vision-related genes, including opsins and arrestins, pigment synthesis genes, and canonical "eye development" transcription factors such as Pax6. We hypothesize that both *A. granulata*'s aesthetes and eyes are light-sensitive, but that they operate via different phototransduction pathways and mediate different photo-behaviors. Further, our work suggests that the extra-ocular expression of vision-related genes may be a widespread trait in mollusks.

116.7 SPERLING, EA*; FEUDA, R; ROTA-STABELLI, O; ROBINSON, J; PETERSON, KJ; PISANI, D; Harvard University, NUI-Maynooth, Fondazione Edmund Mach, Dartmouth College; *sperling@fas.harvard.edu*
New insights into the position of the metazoan root from multi-criterion outgroup selection and microRNAs
There are several phylogenetic hypotheses relating the different sponge classes, but all agree on the same unrooted tree. Most studies place the metazoan root between the sponges and all other animals (Porifera monophyletic), or between the Silicea and all other animals, (Porifera paraphyletic). The nature of outgroup sequences can strongly affect the position of the root, especially if outgroup taxa are long-branched or compositionally-heterogeneous. Here, we conducted multi-criterion outgroup selection (Rota-Stabelli and Telford, 2008, MPE 48:103) on three different datasets. Analyses with outgroups that were ranked objectively better by the selection process, as well as analyses designed to alleviate compositional heterogeneity, found support for sponge paraphyly. Analyses with outgroups ranked worse found decreased support for sponge paraphyly or support for sponge monophyly, suggesting that sponge monophyly may be an artifact driven by compositionally-heterogeneous choanoflagellate outgroups. These results were tested by examining the presence/absence of microRNA genes, which have given insight into the phylogeny of other metazoan clades, from all major lineages of sponges. Comparison of microRNAs in calcareans and homoscleromorphs with those previously described from siliceans and eumetazoans reveals that these newly described genes are novel, with each metazoan lineage (Silicea, Calcarea, Homoscleromorpha and Eumetazoa) characterized by a non-overlapping repertoire of microRNAs. Thus while microRNAs cannot resolve between sponge mono- vs. paraphyly, these data suggest the intriguing possibility that microRNAs may have evolved multiple times independently within animals, with important implications for the evolution of gene-regulatory networks.

P1.149 SPERLING, EA*; KNOLL, AH; MACDONALD, FA; JOHNSTON, DT; Harvard University; *sperling@fas.harvard.edu*
A basin redox transect at the dawn of animal life
Multiple eukaryotic clades make their first appearance in the fossil record between ~850-715 Ma. Molecular clock studies suggest that the origin of animal multicellularity may have been part of this broader eukaryotic radiation. Animals require oxygen to fuel their metabolism, and low oxygen levels have been hypothesized to account for the temporal lag between animal origins and the Cambrian radiation of large, ecologically diverse animals. Here, paleoredox conditions were investigated in the Fifteenmile Group, Ogilvie Mountains, Yukon, Canada, which hosts an 811 Ma ash horizon and spans the origin and early evolution of animals. Iron-based redox proxies, redox-sensitive trace elements, and carbon and sulfur isotopes were analyzed in six stratigraphic sections along two parallel basin transects. These data suggest that for this basin, oxygenated waters on the shelf overlay generally anoxic deeper waters. The anoxic water column likely oscillated between euxinic and ferruginous conditions, with the lower portion of the Reefal Assemblage characterized by euxinia and the upper portion by ferruginous conditions. Theoretical considerations and the ecology of modern oxygen-deficient settings suggests that the inferred oxygen levels would not be prohibitive to the presence of sponges, eumetazoans or bilaterians. Thus the appearance of the earliest animals was probably not limited by the low oxygen levels that characterized the Neoproterozoic, although these inferred levels would limit animals to very small sizes and low metabolic rates.

131.1 SPONBERG, S*; DYHR, JP; HALL, R; SALCEDO, M; DANIEL, TL; Univ. of Washington; *bergs@uw.edu*
Background luminance alters tracking performance of freely flying hawkmoths revealing variable delays in optomotor processing
Does the context in which sensory signals are acquired and processed alter the performance of motor control tasks? Hawkmoths, *Manduca sexta*, hover and track moving flowers during natural foraging in variable, low light environments. Neural recordings of motion sensitive optic lobe cells have shown interspecific differences in spatiotemporal tuning properties that correspond to different preferred luminance levels for foraging. These results are consistent with a sensing strategy that integrates visual cues at low light levels. Such a strategy raises the possibility that reducing luminance could increase the time delay for integrating sufficient visual information. Hence performance of motion tracking tasks may vary with the background sensory environment. We tested this hypothesis with freely flying moths feeding from an actuated artificial flower under luminance levels of 0.3 or 300 lux. Flower motion was composed of the superposition of multiple sine waves (0.2-20 Hz), allowing reconstruction of the moth's frequency response. By calculating the gain, phase delay, and coherence at each frequency, we discovered that moths reliably track at frequencies exceeding 5 Hz. As predicted, we observed significantly lower phase lags between the moth's response and the flower's movement under high luminance conditions. This phase difference corresponds to a 16 ms reduction in processing delay at high luminance. At low luminance, moths actually overcorrected, with gains significantly above 1 at peak tracking frequencies (1-2 Hz), possibly due to longer integration delays. The background sensory environment significantly alters the performance of an ecologically-relevant tracking behavior as predicted from sensory neurophysiological mechanisms.

97.2 SPRINGTHORPE, D.*; GRAVISH, N.; MAZOUCHOVA, N.; GOLDMAN, D.I.; FULL, R.J.; Univ. of California, Berkeley, Georgia Institute of Technology, Temple University; *dspringthorpe@berkeley.edu*
Burrowing biomechanics of the ghost crab.
Burrowing encompasses a wide range of behaviors, including substrate liquefaction, crack propagation, and lateral-undulatory 'swimming' and variants of digging, where animals manipulate the substrate with teeth, limbs or head. Digging to construct permanent or semi-permanent burrows can involve a combination of specialized postures, locomotion in confined environments, and goal-directed control of the substrate. Here we present the first description of such a behavioral suite for free excavation in damp sand (gravimetric water content: 0.16) by the ghost crab, *Ocypode quadrata*. Observations enabled by a novel method of x-ray imaging with detailed leg and body markers showed that crabs excavated circular burrows using a hook-and-pull motion at average rate of 0.65 cm/min, corresponding to an average mass transport rate of 10 g/min. During excavation, crabs employed a particular posture to anchor themselves within the burrow by pressing against burrow walls with their chelae and the rear of the cephalothorax. Crabs rotated up to 180° within the sagittal plane while excavating. After the substrate was collected, crabs manipulated and transported the sand with both the chelae and walking legs. Sand packets, to be transported to the burrow entrance or compacted within the burrow, were carried by these limbs or passed under the body. Results not only quantify the biomechanics of excavation, but also reveal new insights relevant to the field of mobile manipulation. Further experiments, using the techniques we have developed will likely lead to a new generation of bio-inspired robots capable of excavation and subterranean, confined space locomotion.

P1.30 SPRINGTHORPE, S.K.; Salem College, Winston-Salem, NC; *sarah.springthorpe@salem.edu*
MODELS FOR PREDICTING THE POPULATION DYNAMICS OF LASIURINE BAT SPECIES AND THEIR PREY IN WESTERN NORTH CAROLINA
In Western North Carolina, the 13 known species of bat are central not only to the health of the ecosystems, but also to the health of the agricultural industry. Because each species of bat in this area has its own insect prey preferences, they all contribute to the population control of insects, many of which are agricultural pests. With the confirmed spread of White Nose Syndrome (WNS) into North Carolina in 2010, there has been a decrease in the abundances of affected species, such as the six *Myotis* species and *Perimyotis subflavus*. These particular species of bats tend to be generalist predators that eat a variety of smaller, soft-bodied insects like flies (Diptera). Conversely, the unaffected Lasiurine species, which include *Lasiurius borealis* and *L. cinereus*, tend to be more specific in their prey preferences, specializing in larger moths (Lepidoptera) and beetles (Coleoptera). The limited overlap between the diets of the WNS-affected and -unaffected species indicates a need for models predicting ecological effects of losing the generalist predators affected by the fungus. Assuming that the population sizes of affected bat species are decreasing, I generated three models, each describing a possible corresponding pattern in the population dynamics of *Lasiurus* and prey insect species. In particular, these models serve as a basis for predicting effects of decreasing, increasing, or stable *Lasiurus* populations on abundances in insect prey. These models were evaluated for likelihood of occurrence based on reports of bat species abundances in Western North Carolina and estimates of the degree of overlap between their different diets. Additionally, the implications of these models for future agricultural pest control were considered.

93.5 SQUIRE, M.E. *; VEGLIA, M.K.; DRUCKER, K.A.; HAHN, T.P; WATTS, H.E.; The University of Scranton, The University of California, Davis, Loyola Marymount University; *maria.squire@scranton.edu*
Estrogen Dose Influences Medullary Bone Quantity and Density in Female Pine Siskins
Medullary bone is a non-structural type of bone tissue that can serve as labile calcium reservoir for the production of calcified eggshells. Previous research has shown that medullary bone formation precedes eggshell formation and is influenced, in part, by rising estrogen levels. In the current study, we examined the effect of estrogen (E2) treatment on medullary bone quantity and mineralization in female Pine Siskins (Carduelis pinus). Over a five-month period, females received one of three treatments: high dose E2 (n=4), low dose E2 (n=3), or no E2 (n=8). After sacrifice, high resolution (10 µm) micro-computed tomography scanning (Scanco Medical, SUI) was done on the femora and humeri to determine average medullary bone quantity (BV/TV) and its density (mg HA/ccm) across the two bones for each bird. In the 15 females examined, medullary BV/TV ranged from scant (3%) to abundant (83%) and minimally (490.0 mg Ha/ccm) to highly (1184.6 mm Hg/ccm) mineralized. We found that the E2 dose had a significant effect on the average medullary BV/TV and average density for each bird ($p<0.05$), with the high estrogen treatment group having the greatest average medullary BV/TV (78.6%) and the highest average density (1161.9 mg HA/ccm). We are currently investigating the relationship between bone measures and ovarian development and future studies are needed to examine the timeline of medullary bone formation and resorption in greater detail.

P2.106 SQUIRE, M K*; ROSENTHAL, G G; Texas A&M University; *squiremk@gmail.com*
Reproductive Skew in a hybrid population of swordtail fish
Understanding the myriad processes by which speciation may occur is a central goal in evolutionary biology. Natural hybrid zones, where the genomes of two different species collide, afford researchers a unique opportunity to study how species are maintained and how new species may develop. In this study, adults from a wild hybridizing population of the live-bearing fish, Xiphophorus malinche and X. birchmanni, were collected from a pool of the Aquazarca river drainage in southeastern Mexico during the dry season. Embryos were dissected out of females for parentage analysis using microsatellites. After genotyping offspring, dams, and males from the population, Cervus 3.0 will be used to determine number of fathers per brood, and to determine which males are the most likely sires. Reproductive skew will then be determined and correlated with morphological characteristics of the males to obtain a measure of pre-copulatory sexual selection in this hybrid population. We aim to compare this to previous paternity analyses and behavioral experiments done in both parental species of fish in order to get a better idea of how sexual selection and mating systems vary when two species come together in a hybrid zone.

P2.114 SRINIVASAN, A.*; GATTO, R.; SHAWKEY, M.D.; University of Akron, Ohio; *as180@zips.uakron.edu*

Coffee-ring formation by melanosomes with high aspect ratios

Small particles suspended in water sometimes aggregate around the edge of drying drops, forming so-called “coffee rings.” Recent research suggests that this phenomenon is limited to low aspect ratio particles. However, these results were obtained using a single type of synthetic material (polystyrene), and thus the observed limitation may be due to the constraints of the material itself rather than aspect ratio per se. Therefore, tests using additional materials with varying aspect ratios are needed. We performed dewetting experiments using droplets containing melanin-containing organelles (melanosomes) that vary extensively in aspect ratio. We used melanosomes from three avian species, pigeon *Columba livia*, red-winged blackbird *Agelaius phoeniceus* and peacock *Pavo cristatus*, with aspect ratios ~ 4, 5.5 and 7.2 respectively. In a series of experiments, we varied surface tension, pH level, speed of evaporation and concentration of melanosomes to determine under what conditions these particles may form rings. Contrary to previous experiments with high AR polystyrene particles, all three types of melanosomes formed rings when suspended in deionized water. Similar to previous experiments with low AR particles, ring assembly was inhibited by low pH and high surface tension of the suspension liquid, strengthened by high pH and low surface tension, and unaffected by melanosome concentration. These results demonstrate that ring formation is not always limited by aspect ratio and that some biological materials may have properties that make them particularly prone to self-assembly.

44.1 SRYGLEY, R.B.; USDA-Agricultural Research Service; *robert.srygley@ars.usda.gov*

Dietary effects on enzymatic immunity of migrating Mormon crickets

Migration is often associated with movement away from scarce nutrients or other resources, and yet migration itself is energetically demanding. Migrating Mormon crickets lack nutrients, and supplementation of deficient nutrients slows migratory movements and enhances specific aspects of their immune systems. Migrants deficient in proteins have less spontaneous phenoloxidase (PO) activity, whereas those deficient in carbohydrates have less anti-bacterial activity. To investigate the relationship between diet, movement, and immunity further, we removed Mormon crickets from a migratory band and offered each cricket one of five diet treatments: high protein, high carbohydrate, equal weight proteins and carbohydrates (P+C), vitamins only, or water only for one hour. We then attached a radio, returned each to the migratory band, and recaptured them 18-24h later. Crickets fed protein moved furthest, those without diet or only vitamins moved less, and those fed carbohydrates or P+C moved the least. Standard intake trials also indicated that the Mormon crickets were deficient in carbohydrates. Consistent with a previous study, anti-bacterial activity was greatest in those fed carbohydrates, and there was no difference between those fed water, protein, or P+C. Total PO activity also differed between treatments and was greatest in those fed protein and least in those fed water or vitamins only. In a second experiment, we fed crickets from the same migratory band a diet treatment for 1 h and then held them in captivity until blood was drawn 4-24 h later. Dietary effects on total PO activity were not different between captive and migrating crickets, but to have a dietary effect on anti-bacterial activity the crickets had to be migrating freely. Thus a direct compromise between migratory and anti-bacterial activities is evident, whereas PO is compromised by poor protein nutrition independent of migratory activities.

142.2 STAAB, KL*; BETANCUR-R., R; HERNANDEZ, LP; George Washington Univ; *kstaab@gwu.edu*

Correlated evolution of jaw muscles and trophic niche in cypriniform fishes

Cypriniform fishes occupy a wide range of trophic niches that include insectivory, planktivory, and benthic feeding. However, no quantitative study has investigated the evolutionary history of feeding in this important group. All cypriniform species (e.g. goldfish, zebrafish, loaches) are characterized by having a protrusible jaw dependent on contractions of the A1 division of the adductor mandibula muscle. Our previous work suggested that the architecture of the adductor mandibula likely allows for fine-tuning of jaw protrusion associated with these distinct trophic niches. Here we reconstruct the evolutionary history of adductor mandibula structure and trophic diversity within Cypriniformes. A time-calibrated molecular phylogeny was constructed using six nuclear genes and 23 fossil calibration points. Mouth position and diet data were used to characterize extant species as benthic, mid-water, and surface feeders and to test for correlations between trophic niche and architecture of A1. We present morphological data for representatives from each major clade in the order. We test hypotheses regarding both the correlated evolution of jaw morphology and trophic niche as well as subsequent diversification among the clade. We also confirm the recently proposed hypothesis that the most recent common ancestor to cypriniforms was a benthic fish. A divided A1 is highly correlated with an inferior mouth position, suggesting that this particular arrangement of A1 is important for benthic feeding. Our results strongly suggest that the most recent common ancestor to the order had an inferior mouth like many of the extant species inhabiting the benthos. Thus, the success of the world’s most speciose clade of freshwater fishes may be due in part to an initial radiation from a benthic species.

P2.103 STAGER, M.*; CHEVIRON, Z. A.; Univ. of Illinois at Urbana-Champaign; *stager2@illinois.edu*

Signatures of natural selection across the mitochondrial genome in Tachycineta swallows.

Over the last century, latitudinal variation in avian life-history traits has formed the foundation for general theories of life-history evolution. This variation can be summarized as a slow-fast continuum such that tropical species fall on one end, exhibiting low reproductive rates, slow development, and long lifespans, while on the opposing end, temperate species exhibit the opposite traits. *Tachycineta* swallows exemplify this pattern across their broad latitudinal range (Alaska to Cape Horn), making them an ideal group to investigate the mechanistic basis of avian life history variation. Because much of the temperate-tropical variation in avian life histories is tied to differences in rates of energy expenditure, studies of metabolic traits are particularly well-suited to establish mechanistic links between physiological and life-history traits. The vertebrate mitochondrial genome contains 13 protein-coding genes that are central to aerobic metabolism, making it a promising candidate locus for studying the mechanistic basis of metabolic trait differences that may underlie life-history variation among closely related species. We took advantage of a robust nuclear DNA phylogeny and complete mitochondrial genome sequences that were recently published for all nine species of *Tachycineta* swallows to test for signatures of natural selection across the entire mitochondrial genome. Our preliminary results suggest that although purifying selection is the dominant selective force influencing the evolution of the mitochondrial genome in *Tachycineta* , several mitochondrial genes contain regions that exhibit signatures of positive diversifying selection, suggesting that they may contribute to metabolic differences between temperate and tropical species.

P2.12 STAHLSCHMIDT, ZR*; ADAMO, SA; Dalhousie University; *zrs@dal.ca*

What contributes to variability in behavioral thermoregulation?

Because many life history traits are influenced by temperature, behavioral thermoregulation can significantly improve animal fitness. However, considerable inter-individual variation in preferred body temperature (T_{pref}) persists within species. Thus, to our knowledge, we used the most comprehensive experimental approach to date to understand what contributes to T_{pref} variability. Specifically we used the adult Texas field cricket (*Gryllus texensis*) and manipulative approaches to clarify the independent and interactive effects of sex, adult stage (young virgin or older mated), morphology (e.g., body size and condition), fecundity, nutritional state (e.g., acute or chronic food limitation), and immune challenge on T_{pref}. We demonstrate that environmental variables (food availability and immunogen exposure), adult stage, and morphological traits exhibit complex interactions among each other and with regard to behavioral thermoregulation. Although we successfully manipulated body condition and reproduction, our results failed to support dogmatic predictions about the role of these two variables in T_{pref}. Males and more robust (high body condition) females exhibited low T_{pref}. Crickets that were not food limited and those that were larger, heavier, and more robust exhibited a more variable T_{pref}. Adult stage and fecundity (oviposition rate) did not affect T_{pref}. Previous research demonstrates warm temperatures are beneficial to crickets (e.g., improved current reproduction). However, our results suggest maintaining a high, stable body temperature may be offset by considerable ecological costs (e.g., increased predation risk) or costs conferred to offspring (e.g., reduced hatching success) that warrant further consideration. We provide evidence that understanding a given behavior requires examining the independent and interactive roles played by several important life history traits.

31.3 STAHLSCHMIDT, ZR*; ROLLINSON, N; ACKER, M; ADAMO, SA; Dalhousie University; *zrs@dal.ca*

Are all eggs created equal? Food availability and the fitness tradeoff between reproduction and immunity

Reproduction and self-maintenance (e.g., immune function) are critical processes, but organisms can rarely optimize both of these traits. Such reproduction-immunity tradeoffs may be "facultative" and appear only when resources are scare, or they may be "obligate" and occur regardless of resource availability due to underlying physiological mechanisms. While the role of resource availability in reproduction-immunity allocation tradeoffs has been studied, measuring resource allocation alone may be insufficient when gauging the fitness consequences of reproduction-immunity tradeoffs. Thus, we used the Texas field cricket (*Gryllus texensis*) to provide the first test of whether resource availability influences a fitness tradeoff between these two traits—that is, how does chronic food limitation and immune challenge affect lifetime fecundity and reproductive success? We used a 2 x 3 design to manipulate food availability and immune status throughout adulthood in a factorial fashion. We demonstrate that reproduction-immunity tradeoffs are "obligate" in crickets because immune challenge resulted in reduced fecundity and reproductive success regardless of food availability. Food availability significantly affected fecundity, reproductive success, and hatchling size where females with *ad libitum* access to food produced more abundant and larger hatchlings. There was no effect of food availability or immune status on egg size, egg phenoloxidase activity, incubation duration, hatching success, or hatchling energy stores. In sum, we clarify the independent and interactive roles of two widespread environmental factors (food availability and immunogen exposure) on the dynamics of reproduction. Future work will investigate the underlying role of immune-induced oxidative damage in reproduction-immunity tradeoffs.

S4-1.6 STAJICH, JE*; JONESON, S; ABRAMYAN, J; AHRENDT, S; RAMAMURTHY, R; SAIN, D; SHIU, SH; ROSENBLUM, EB; Univ of California, Riverside, Univ of Wisconsin - Waukesha, Univ of British Columbia, Michigan State Univ, Univ of California, Berkeley; *jason.stajich@ucr.edu*

Tools and pipelines for comparative genomics with application to evolution in Fungi

Comparative analyses can extract information from the now readily available genome sequence data of organisms in order to study how gene and genome content change over time. Connecting these genomic changes to the evolution of traits or lifestyles can help determine the molecular basis for adaptations. Several existing tools exist for the comparison of fungal genome sequences including the new database platform FungiDB - http://fungidb.org. The application of this system to discover patterns in gene families, gene content, and inference of gene function from model systems to less tractable study systems will be demonstrated. These approaches are useful in both studies of recently emerged pathogens and evolution of traits across the fungal Kingdom. Comparisons to identify factors underlying pathogenesis in the amphibian killing chytrid fungus *Batrachochytrium dendrobatidis* (*Bd*) revealed potentially important gene family changes. These families included a large number of protease and metabolism related functions. Gene families of some potential cell wall proteins are highly expanded when comparing *Bd* to a closely related non-pathogenic species. In addition, comparisons of the early diverging chytrid fungi and with the Dikarya group of fungi revealed changes in gene content that suggest changes that underly the transition from single-celled aquatic chytrid fungi to the multicellular filamentous mushrooms and molds.

27.1 STARK, A.Y.*; NIEWIAROWSKI, P.H.; DHINOJWALA, A.; BADGE, I.; Integrated Bioscience Program, The University of Akron, OH, Department of Polymer Science, The University of Akron, OH, Department of Polymer Science, The University of Akron, OH; *ays3@zips.uakron.edu*

The Effect of Water on the Gecko Adhesive System

Although we now have thousands of studies focused on the nano, micro and recently whole animal mechanics of gecko adhesion on clean, dry substrates, we know very little about the effects of water on gecko adhesion. For many species of gecko however, rainfall frequently wets the natural surfaces they navigate. We investigated performance of the gecko adhesive system on surfaces fully submerged in water as well as those that were misted with water droplets (as might occur after rain). Although we found distinct limitations of the gecko adhesive system related to surface water and wetting of the adhesive toe pads, we also found that in certain conditions gecko adhesion is not significantly affected by water. While this result is not surprising based on the native environments many geckos inhabit, such as the tropics, anecdotal observations of geckos slipping on wet laboratory surfaces has been noted for years. The loss of adhesion on wet surfaces can be affected by a number of variables including interspecific variation, orientation of the surface, surface chemistry and surface utilization (e.g., clinging vs. running). To test these variables we compared locomotor performance on wet and dry surfaces at different orientations and with multiple species endemic to different environments. We also considered the effect of substrate surface chemistry, noting that geckos often perch and move on plant surfaces such as leaves. While loss of adhesive capability could be detrimental, it is possible that limitations on wet glass surfaces are not necessarily predictive of adhesive system performance on surfaces that are more similar to those in their native environment.

P1.148 STARR, M. J.*; COLLIN, R.; Smithsonian Tropical Research Institute; *mjs3424@louisiana.edu*

Enzyme Activity in Early Life Stages of Planktotrophic Slipper Snails (Gastropoda: Calyptraeidae)

Enzymatic activities of 19 intracellular enzymes were studied in four planktotrophic species of calyptraeid gastropods (*Crepidula incurva*, *Crepidula cf. marginalis*, *Crucibulum spinosum*, and *Bostrycapulus calyptraeformis*). Standardized embryo homogenates were assayed for 19 enzymes at four embryonic stages and once after hatching and exposure to exogenous food. Eight enzymes showed significant species differences. When differences were observed among species, generally *C. incurva* and *C. spinosum* were different. Enzyme activity in *C. incurva* was significantly higher than the other species for three enzymes and lower for three. For *C. spinosum* activity was higher for five and lower for one enzyme. Differences among developmental stages varied for the enzymes assayed. Alkaline phosphatase, α-fucosidase, N-acetyl-β-glucosaminidase, and Esterase Lipase (C8) increased significantly throughout development. Two enzymes increase significantly early in development then remained constant (Acid phosphatase and Naphthol-AS-BI-phosphohydrolase). β-glucosidase increased significantly after hatching and after exposure to isochrysis. Two enzymes showed high activity throughout development (Leucine arylamidase and Esterase (C4)). Three enzymes peaked in mid development (α-mannosidase, Cystine arylamidase, α-chymotrypsin). Seven enzymes showed little (β-galactosidase, β-glucuronidase, Caline arylamidase, Lipase (C14)) or no (Trypsin, α-galactosidase, and α-glucosidase) activity and no significant changes during development. Few interactions between species and stage were observed, suggesting that planktotrophs all show the same general patterns. This study is a useful baseline against which to compare enzyme expression in other modes of development.

P3.40 STAUDINGER, M.D.; MCALARNEY, R.J.*; MCLELLAN, W.A.; PABST, D.A.; University of Missouri Columbia, University North Carolina Wilmington; *mcalarneyr@uncw.edu*

The feeding ecology of the pygmy (K. breviceps) and dwarf (K. sima) sperm whale inferred from diet and stable isotope analyses.

A paired approach of stomach content and stable isotope analyses was used to characterize the foraging ecology of pygmy (*K. breviceps*) and dwarf (*K. sima*) sperm whales in the mid-Atlantic, utilizing samples collected from stranded specimens along the Virginia and North Carolina coasts. Contents were identified to the lowest taxonomical level possible and prey size estimated using published equations. Whale δ^{13} C and δ^{15} N values were used to estimate trophic level and foraging area. Both species were found to feed opportunistically in the mesopelagic and bathypelagic zones and squids from families Histioteuthidae, Enoploteuthidae, Cranchidae and Ommastrephidae dominated their diets. While sample sizes were not equivalent, pygmy sperm whales exhibited a more diverse diet than did dwarf sperm whales. Relative prey sizes were equivalent in the diets of pygmy and dwarf sperm whales, and the majority (≥90%) were small (≤5%) relative to predator body size. Pianka's index value show high dietary overlap across whale species (O_n=0.92) and sexes (O_n=0.96). Pygmy sperm whale muscle δ^{15} N values tended to be enriched, and δ^{13} C tended to be depleted, relative to those of the dwarf sperm whale, although no statistical differences between species were detected. Collectively, these results suggest that the feeding ecologies of the pygmy and dwarf sperm whales are similar in the mid-Atlantic.

15.4 STEFFEN, MA*; BONETT, RM; University of Tulsa; *michael-steffen@utulsa.edu*

Pheromone Evolution and Reproductive Isolation in Dusky Salamanders

Conspecific mate recognition signals can delimit species boundaries and structure communities. However, signals and mate choice are evolutionarily labile, and few studies have examined the impact of signal discordance on lineage diversification in adaptive radiations. Salamanders produce highly variable, proteinaceous courtship pheromones. Dusky salamanders of the genus Desmognathus are endemic to eastern North America, and display dramatic disparity in ecology, body size and life history. However, some distantly related species are highly convergent in these traits, and behavioral studies have shown varying degrees of prezygotic isolation among divergent, yet ecologically similar species. In this study, we analyze the transcripts of pheromone genes (plethodon modulating factor and sodefrin precursor factor) in Desmognathus. We specifically test how convergence and introgression play a role in the geographic distributions of these pheromones, and if pheromone divergence is correlated with patterns of behavioral reproductive compatibility or isolation.

119.3 STEFFENSON, M.M.*; FORMANOWICZ, D.R.; University of Texas at Arlington; *mmsteff@uta.edu*

Autotomy and its effects on wolf spider foraging success

Autotomy, or voluntary loss of various body parts, has been shown as an effective predator escape mechanism in many different taxa. The autotomy of a limb has the short-term benefit of escaping a predator. This defensive mechanism has associated costs: decreased mating success, diminished locomotive proficiency, and reduced territory size. Autotomy has also been hypothesized to negative effect foraging ability. However, few studies have actually tested this theory, particularly in spiders. The objectives of this study were to identify whether losing specific limbs through autotomy had different effects on foraging success. Mature *Rabidosa rabida* were captured from a creek bed in the Chiricahua mountains. *R. santrita* were separated into three groups: control (missing no legs), 1st leg (in which the 1st walking leg was autotomized), and 4th (in which the 4th walking leg was autotomized). The running speed of each individual was recorded both pre and post-autotomy. Each individual was introduced into an experimental chamber with five *Pardosa valens* (a local spider that is frequently preyed upon by *R. santrita*). Spiders were observed for 1 hour and the number of prey items captured was recorded every 15 minutes. Preliminary data analysis indicates that the running speed of spiders did not differ when any limb was removed. Additionally, the number of prey items consumed by the predator did not differ significantly, though a trend was observed of intact spiders consuming the highest proportion of available prey items, those missing a 1st walking leg consuming somewhat less, and individuals missing their 4th walking leg consuming the lowest proportion of available prey. Results indicate that while missing specific legs may affect a predator's ability to forage, it does not do so significantly.

P3.157 STEINWORTH, BM*; WILLIAMS IV, R; HALE, ME; University of Chicago; *bsteinworth@uchicago.edu*
Sensitive spikes and spines: The pectoral spines of catfish function as touch sensors
The first pectoral fin ray of catfish is modified into a sharp-tipped, serrated spine, in some species associated with a poison gland and presumed to be employed in defense. While functions of the catfish pectoral fin have been extensively studied, little is known about its sensory capabilities. We investigated mechanosensation in pectoral fins of the catfish *Pimelodus pictus*. During rhythmic swimming and when stationary, *P. pictus* holds the pectoral fins angled outward from the body. Work on pectoral fin mechanosensation in other species has focused on fin rays used as propulsors or in active probing. The stiff spine and relative immobility of the catfish fin suggests that its rays may not be as responsive to mechanical stimulation as those of fish with more mobile fins. In addition, the cranial barbels of catfish are putative tactile sensors, making it unclear to what extent the pectoral fins are needed for this function. Immunostaining shows extensive innervation of the fin rays, including the spine. Because minimal muscle is associated with the rays, this innervation suggests sensory function. We used extracellular recordings from afferent nerves to assess the function of these processes. Nerves responded robustly to tactile stimulation of the ventrolateral and dorsomedial surfaces of the pectoral fin, as well as the leading edge of the spine. Our findings suggest that the pectoral spine and soft rays complement the barbels as tactile sensors. Tactile sensation may contribute to the defensive function of the spine, perhaps triggering the release of poison or an escape response, or serve other roles not considered previously.

P2.220 STENGEL, A.*; KOHL, K.D.; DEARING, M.D.; University of Utah; *ashley.stengel@comcast.net*
Isolation of toxin-degrading bacteria from the gut of an herbivorous rodent
For decades, it has been suggested that gut microbes facilitate ingestion of toxic diets by herbivores through microbial degradation of plant secondary compounds. We isolated tannin-protein complex degrading bacteria (T-PCDB) from the feces of the desert woodrat (*Neotoma lepida*), which feeds largely on a tannin-rich plant, creosote bush (*Larrea tridentata*). Feces were plated on tannin-treated agar, and isolates exhibiting zones of clearance were further characterized through 16S rRNA sequencing and measurement of tannase activity. We characterized 9 isolates belonging to 4 species, *Enterobacter cloacae, Enterococcus faecalis, Bacillus subtilis*, and *Escherichia coli*. Isolates of *E. cloacae* did not show positive tannase activity. Tannase activity of other isolates varied significantly by bacterial species, as well as isolate within a species. We propose that these T-PCDB facilitate the ingestion of tannin-rich plants by herbivores. This hypothesis can be more easily tested in the future given that we now have both functional characterization and 16S rRNA sequences for T-PCDB.

P1.206 STEVENSON, RA*; EVANGELISTA, D; LOOY, CV; University of California, Berkeley; *rstevenson.cal@berkeley.edu*
Reconstruction of the flight characteristics of winged seeds of Late Paleozoic conifers
Fossil seeds of a voltzian conifer from the late Early Permian (~270 million years ago) in north-central Texas, are the earliest known conifers that produce samaras (winged seeds). Extant conifers predominantly produce single winged samaras. The cone scales of this early voltzian conifer are exceptional in that they produce a range of winged-seed morphotypes. They bear either one or two wings on the chalazal end of the seed, with the second wing ranging in size from a stub to a wing equal in size to that of the primary wing. To examine the aerodynamics of the different wing types and their implications on dispersal potential, we present the flight performance of 1:1 scale models of the geometric morphometric consensus of three morphotypes of the samaras. To test the validity of such modeling as an inferential tool, descent of model samaras was captured with high speed video. The flight characteristics were compared to morphologically similar samaras of extant *Agathis* taxa as well as similarly created *Agathis* models. Based on our model observations, we infer ranges of descent speeds, auto-rotational stability, possible descent patterns, and dispersal potentials for the voltzian seeds. Reconstruction of these early forms of seed flight provides insight into why the single winged samaras are prevalent in extant taxa. Winged seeds may be used as proxy for minimum height in Late Paleozoic conifers.

P3.166 STEVES, I.D.; MEHRABANI, H*; ROSE, C; MOK, A; MCCLELLAND, Z; CHIRICO, J; DUDLEY, R; University of California, Berkeley; *hmehrabani5110@gmail.com*
Landing Performance of Anna's Hummingbird (Calypte anna) in Variable Wind Conditions
Hummingbirds are able to perform maneuvers that require precision, such as approaching feeders or landing on small perches, despite in-flight perturbations from real, windy environments. To measure how wind speed affects landing maneuvers, we filmed Anna's Hummingbirds (*Calypte anna*) landing on a perch in a wind tunnel at constant wind speeds ranging from 0 to 9 m/s, and analyzed overall trajectory and detailed body kinematics. Landing consisted of three phases: (1) approach – horizontal movement to the perch ending in leg extension; (2) descent – vertical lowering with small horizontal adjustments; and (3) docking – a grasp onto the perch and the end of flapping. At different wind speeds, the largest variation in path was observed during approach, in some cases including 180 deg rotations and controlled backwards flight. Velocities of approach and of descent also changed with wind speed, with the slowest approach and descent speeds observed at the highest oncoming wind speed. Despite an 80% increase in oncoming wind relative to typical flight speeds, hummingbirds were still able to complete the maneuver with only small changes in trajectory despite large changes in body kinematics. This suggests further work to understand the mechanical and neuro-muscular controls underlying their robustness in more realistic environments, including those with time-varying gusts of wind.

P3.85 STEVES, I.D.*; WRIGHT, M.L.; CALDWELL, R.L.; University of California, Berkeley; *isteves@berkeley.edu*

Evolution of Rostrum Shape Variation in Mantis Shrimp

Widespread in tropical waters, mantis shrimp rely on their powerful raptorial appendages and keen eyesight to smash or spear their prey. Examined in isolation, the rostrum, a segment of exoskeleton at the base of mantis shrimp eyes, appears to have a singular function: to protect the eye stalk. The rostrum's large interspecific variation in shape (triangular, trispinous, semi-circular, etc.) suggests that a combination of selection pressures are acting on it. Here, we investigated whether sexual selection facilitated changes in rostrum shape by testing for (1) sexual dimorphism and (2) changes in rostrum proportions associated with sexual maturity. To study the effects of sex and age on the rostrum, we measured rostrum lengths and body sizes of eight species (approximately 40 individuals each) across five superfamilies. An analysis of covariance showed that rostrum lengths differed significantly between males and females in five of the eight species measured. Rostrum proportions in these species generally remained constant across adult body size, but decreased among the Gonodactyloid mantis shrimps. A preliminary examination of these results indicates that the presence or absence of sexual dimorphism may be associated with ecological factors related to habitat, such as space competition and predation style.

32.1 STEWART, TA; Univ. of Chicago; *tomstewart@uchicago.edu*

Multiple origins of the adipose fin and the morphological diversification of novel vertebrate appendages

Adipose fins are appendages found between the dorsal and caudal fins of some teleost fishes. Their evolutionary history is poorly understood, as is their function. These fins are often regarded as vestigial in the literature, and adipose fins are clipped off by the millions by fishery agencies as a means of tracking salmon. Using a recent phylogeny of actinopterygian fishes I demonstrate that adipose fins have evolved independently at least twice, once in the Otophysi clade excluding Cyprprinidae (i.e.: Characiformes, Siluriformes, and Gymnotidae), and again within the Euteleostei. Thus, as convergent novel appendages, I argue for their functionality and explore the diversity of adipose fin anatomies that have evolved within these two groups by comparing their variation in shape and composition. From these surveys I identify muscles that insert upon the adipose fins of several families of catfishes (Siluriformes). This implies the repeated innovation of musculoskeletal linkage systems among adipose fins. This study highlights these structures as an emerging model system by which to study the evolution of structural complexity and function in vertebrate appendages.

S1-3.2 STEWART, WJ*; NAIR, AM; MCHENRY, MJ; Univ. of California, Irvine; *wstewart@uci.edu*

The sensory cues for predator evasion in fish

Prey fish can survive an encounter with a predator fish by detecting the predator's approach and quickly responding with an evasive maneuver. While the ability to detect predator attacks is critical for prey, the sensory signals that trigger prey responses are unclear. Predator fish produce both fluid and visual stimuli during approaches, but identifying the specific cues sensed by prey fish has been unfeasible due to the variable nature of predator-prey encounters. To simplify this behavioral variability and reveal the sensory cues that alert prey fish to predator attacks, we controlled the approach kinematics of a predator fish in light and dark conditions and recorded the resultant escape responses of prey in detail. This was achieved with a high-precision linear motor that translated a preserved predator (zebrafish adult, *Danio rerio*) towards live prey (zebrafish larvae, *Danio rerio*) over a range of repeatable and realistic approach speeds. Two high-speed cameras attached to the motor recorded prey escape responses in 3D from the predator frame of reference. The flow field around the approaching predator was quantified in 3D with particle image velocimetry, which allowed us to determine the fluid signals experienced by prey when startled. Video recordings and flow measurements showed that, in dark conditions, nearly all prey responded rapidly after encountering the disturbed flow ahead of the approaching predator. However, when approached slowly in light conditions, the prey behaved differently by swimming away from the predator at lower speeds before encountering the disturbed flow. These results suggest that flow sensing is critical for rapid prey responses to predators approaching at high speed or in the dark, while vision mediates more gradual responses when conditions permit.

P1.38 STILLER, J.*; ROUSSET, V.; PLEIJEL, F.; CHEVALDONNé, P.; VRIJENHOEK, R.; ROUSE, G.; SIO, UCSD, Univ. of Gothenburg, Station Marine d'Endoume Marseille, MBARI; *jstiller@ucsd.edu*

Phylogeny, biogeography and systematics of hydrothermal vent and methane seep Amphisamytha (Ampharetidae, Annelida)

Amphisamytha has five currently recognized species. Of these, *A. galapagensis* has been reported from various hydrothermal vents and hydrocarbon seeps across the Pacific Ocean. Here, *Amphisamytha* from a range of Pacific habitats, as well as *Amathys lutzi* from Atlantic vents, have been studied using morphology and DNA sequences. The phylogenetic analyses revealed a clade associated with chemosynthetic habitats comprising most of the known species, and three lineages that are regarded as new species. One new species is from vents of the northeast Pacific, another spans much of the East Pacific Rise, and is sympatric with *A. galapagensis* for part of its range. The third is in sympatry with *A. vanuatuensis* at western Pacific hydrothermal vents. The morphologically distinct *A. lutzi* was nested within *Amphisamytha* and is regarded as a junior synonym. The range of the 'cosmopolitan' *A. galapagensis* is restricted to the southern East Pacific Rise and the Galápagos Rift. *A. fauchaldi*, previously only known from the Gulf of California, is recorded from cold seeps off Costa Rica and Oregon. To assess the evolutionary ages of the lineages, previously published nucleotide substitution rates were employed. According to a molecular clock calibrated for shallow-water invertebrates, the Atlantic-Pacific species pair split less than three million years ago – a time where the Panamanian sill was already too high for deep-water dispersal – implying that this clock is 'too fast' for *Amphisamytha*. A slower clock specific for deep-sea annelids dates the most recent common ancestor for the deep-water clade at 40 million years, and the separation of the Pacific and Atlantic species to about 15 million years.

7.4 STOCKING, J.B.*; RIPPE, J.P.; REIDENBACH, M.A.; University of Virginia; *jbs4yq@virginia.edu*

Boundary layer flow effects on dissolved oxygen exchange and photosynthesis in scleractinic corals

To investigate the interaction between flow environment and coral photosynthesis, *in-situ* field measurements of boundary layer flow, photosynthetic quantum yield, and dissolved oxygen levels were obtained over the scleractinic corals *Porites furcata* and *Siderastrea siderea* in the coastal ocean of Bocas del Toro, Panama. A vertical profile of three-dimensional velocity structure was obtained using a high-resolution profiling acoustic Doppler velocimeter. Estimates of Reynolds stress, turbulent kinetic energy, and wave orbital motion were derived from these velocity measurements. Local rates of coral photosynthesis were measured using a pulse-amplitude modulated (PAM) underwater fluorometer, and dissolved oxygen (DO) concentrations were measured at the same location using a fluorescence-based optical needle probe. Results show that periods of higher root-mean square (RMS) velocity in the free water column correlate to higher maxima of turbulent kinetic energy (TKE) in the momentum boundary layer directly above the coral-water interface. Larger TKE values also correlate with higher levels of photosynthetic quantum yield and with increases in dissolved oxygen concentration at the coral-water interface. The combined measurements suggest that turbulent eddies act to break down the diffusional boundary layer at the coral surface, thereby promoting DO exchange out of the coral polyp and driving the reaction kinetics of photosynthesis. The results provide *in-situ* evidence for flow-induced physical control over coral physiology and for consideration of flow as a key parameter in coral health.

P3.217 STOEHR, A.*; FOWLER, A.; SEPULVEDA, C.; BERNAL, D.; Univ. of Massachusetts, Dartmouth, Pfleger Institute of Environmental Research; *astoehr@umassd.edu*

Heat Transfer in Free-Swimming Swordfish, Xiphias gladius

Swordfish, *Xiphias gladius*, are large, active pelagic predators renowned for their ability to undertake extensive, prolonged vertical movements and rapid temperature changes in excess of 18C. Several high performance fishes maintain elevated body-core temperatures relative to ambient, and are capable of physiological thermoregulation; yet despite the presence of morphological traits typical of regional endothermy (i.e. medial red muscle, central rete, muscular lateral vessels), elevated temperatures have not been definitively characterized in swordfish. This study analyzed water and deep tissue temperatures from archival tags deployed on six free-swimming swordfish in the Southern California Bight, and developed an alternative mathematical model to investigate the effects of conduction, retial convection, and myogenic heat production during foraging dives. Results indicate rapid changes in whole-body thermal conductivity resulting in faster rates of heating compared to cooling during ascents and descents, respectively. Estimated body temperature curves indicate that less than 5% myogenic heat retention is necessary to simulate heat balance during dives, changes in heat exchanger efficiency become increasingly important with heat production, and both tissue temperature and efficiency are affected by volumetric blood flow rate. For swordfish, it appears that physiological thermoregulation retards the effects of rapid ambient temperature change and permits foraging expansion into disparate thermal regimes.

103.5 STORZ, J. F.*; NATARAJAN, C.; PROJECTO-GARCIA, J.; MORIYAMA, H.; WEBER, R. E.; FAGO, A.; Univ. of Nebraska, Lincoln, NE, Aarhus Univ., Aarhus, Denmark; *jstorz2@unl.edu*

Mechanisms of hemoglobin adaptation in high-altitude vertebrates: insights from protein engineering

Is it possible to predict which molecular mechanisms are most likely to contribute to biochemical adaptation? Can we predict which mutations - or which types of mutation - are most likely to contribute to adaptive changes in protein function? To address these questions about the inherent predictability of adaptive evolution at the molecular level, I'll present results of recent research on molecular mechanisms of hemoglobin adaptation to high-altitude hypoxia in birds and small mammals. These studies integrate evolutionary analyses of sequence variation with experimental studies of hemoglobin function using site-directed mutagenesis.

111.5 STRADER, ME*; MATZ, MV; University of Texas at Austin; *strader@utexas.edu*

Color vision in coral larvae? Insights into settlement behavior and possible function of fluorescent proteins

Corals express multiple GFP-like fluorescent proteins (FPs) that result in an array of phenotypes within and between species. The suggested functions of fluorescent proteins range from visual communication with fish to innate immunity, but thus far the support for any of these hypotheses has been scarce. In *Acropora millepora* larvae, red fluorescent protein (RFP) is expressed in epidermal cells located on the aboral pole, which is the region with which the larva probes the substrate prior to settlement metamorphosis. We hypothesize that RFP serves a sensory function involved in this behavior. We set up an experiment to see if light field modifications would affect the process of larval settlement and also whether this response would correlate with the fluorescent phenotype of the larva. We monitored settlement of individual larvae of two species, *A. millepora* and *Diploria strigosa*, under light of different color equalized for total photon flux (intensity) over 3 days. *A. millepora* exhibits red/green fluorescent polymorphism between full sibs, while D. strigosa expresses only green. In *A. millepora*, green light strongly enhanced settlement while red light reduced settlement, compared to the settlement rate in the dark. The larvae that settled in the dark were almost exclusively red-fluorescent. In *D. strigosa*, both green and red light strongly reduced settlement compared to the blue light and darkness. The correlations between fluorescence of the larvae and settlement rate, as well as specific response to green light in *A.millepora* both agree with our hypothesis of the sensory function of the RFP. It is reasonable to expect that coral larvae would need to avoid light of longer wavelengths since *in situ* its abundance would indicate direct downwelling light and therefore exposed nature of the location.

87.5 STRATHMANN, R.R.*; BRANSCOMB, E.S.; VEDDER, K.; Univ. of Washington, Friday Harbor; *rrstrath@u.washington.edu*

Plasticity in Hatching in Response to Predators and Individual Variation in Duration, Frequency, and Seasons of Brooding in the Barnacle Balanus glandula

Hatching in response to predation reduces a potential cost of holding larvae until conditions in the plankton are favorable. Broods of barnacles hatch when the clumps of embryos (lamellae) are dissected into smaller groups. Predation on brooding barnacles can have a similar effect. Escape or death of brooded offspring depends on the predator. In the laboratory, when crabs (*Cancer oregonensis*) ate adult barnacles (*Balanus glandula*), the barnacles' tests were broken, and nauplii hatched from broods; in contrast, when the whelk *Nucella ostrina* ate barnacles, the barnacles' wall plates and opercula remained in place, and fewer or no nauplii were released. In some cases numerous nauplii were trapped within the test of the killed mother. At a field site with abundant whelks, many dead barnacles had opercular plates in place. Hatching of some barnacles is also known to occur when phytoplankton induces the parent to stimulate hatching of its brooded larvae. To examine synchrony and variation in brooding among individuals of *B. glandula*, we non-destructively observed late-stage (dark-colored) broods in individuals that had settled on glass plates. For the first brood of the year, first appearances and disappearances of late-stage broods were consistent with a synchronizing environmental stimulus for hatching. The dates that broods reached advanced stages varied more than the dates that they were released. An exception to synchronization among individuals was that a few of the broods that reached advanced stages early also hatched early. In subsequent broods (later spring and summer), advanced stages were held more briefly. Either an environmental stimulus for hatching was not needed later in the season or it was more frequently present. Individuals appeared to vary greatly in number of broods per year.

107.3 STREICHER, J.W.*; MEIK, J.M.; SMITH, E.N.; FUJITA, M.K.; Univ. of Texas, Arlington; *streicher@uta.edu*

Limits and opportunities of diversification in barking frogs of the Craugastor augusti complex

Craugastor augusti is among the most widely distributed direct-developing frogs in North America, occurring from the southwestern United States to the Isthmus of Tehuantepec in southern Mexico. Across this distribution, *C. augusti* exhibits relatively low genetic diversity but extensive phenotypic variation in color patterns, integumentary characteristics, and breeding vocalizations. Furthermore, these frogs inhabit diverse habitats from deserts to tropical forests, and are the only *Craugastor* species to have invaded a temperate biome. These patterns are uncommon in vertebrates with low vagility such as amphibians, which often exhibit high endemism and habitat specialization. These generalist attributes make *C. augusti* an ideal system for investigating limits and opportunities of diversification. Here we describe preliminary phylogeographic patterns in this complex and relate them to patterns of morphological diversity. Using mitochondrial and nuclear DNAs (a total of 2064 bp) we recovered eight geographically circumscribed clades, each of which has distinctive patterns of morphological variation. We also used canonical correlation analysis and mantel tests to evaluate the importance of various bioclimatic variables as predictors of morphology, while controlling for spatial autocorrelation. We discuss these results in the context of the evolutionary history of these frogs as unique direct-developing colonizers of xeric habitats.

P2.210 STUMP, E.*; ROCHA, L.; ROCHA, C.; CARPENTER, K.; Old Dominion University, California Academy of Sciences; *estum002@odu.edu*

Insights from a preliminary phylogeny of the Sharpnose Pufferfishes (genus Canthigaster)

The genus *Canthigaster*, popularly known as the Tobies or Sharpnose Pufferfishes, currently consists of 35 globally distributed tropical and subtropical marine fishes. These fishes are small (usually under 12cm), omnivorous, highly derived teleosts and are typically found in shallow waters associated with coral or rocky reefs. *Canthigaster* are morphologically conserved, and are notable for the "monotonous sameness of external morphology from species to species" (Allen and Randall 1977). Consequently, color is used as the primary tool for distinguishing between species and in the recent diagnosis of new species. Here, we take the first steps towards developing the first comprehensive phylogeny of the genus *Canthigaster* based on mitochondrial and nuclear molecular markers. A partial phylogeny based on the mitochondrial CO1 gene is presented, from which I propose the following hypotheses: 1) *Canthigaster* recently colonized the Atlantic basin from the Indian Ocean 2) The wide-ranging Indo-Pacific species *C. solandri* may be a complex of two or more species. A complete phylogeny of this genus will ultimately contribute to our growing understanding of evolutionary processes in the marine environment and the role of ecology and behavior in maintaining the diversity of reef fishes with high disbursal potential. This phylogeny will also be relevant in the discussion of color as a diagnostic for detecting evolutionary partitions and delineating taxonomic species units.

P2.117 SU, A.; Cleveland State University, OH; *a.su@csuohio.edu*

Comparative trabecular bone morphology in two locomotor-diverse primates

The morphology of mammalian trabecular bone has been shown in controlled experiments to reflect habitual locomotor loads. It is thus widely hypothesized that trabeculae from wild animals with different observed locomotor repertoires would have different morphologies. In this study of the primate astragalus, high resolution micro-computed tomography images were analyzed and the distribution of trabecular structure was compared between two species with clearly different locomotor modes: *Indri indri*, a vertical clinger and powerful leaper, and *Chlorocebus aethiops*, a digitigrade/semiplantigrade terrestrial quadruped. It was predicted that *Indri* would show a trabecular bone distribution pattern related to habitually dorsiflexed talocrural joints and that that of *Chlorocebus* would reflect more varied joint loading postures. The results showed that overall *Indri* had thinner, more numerous trabeculae versus thicker, fewer trabeculae in *Chlorocebus*. In pattern of distribution, *Indri* was found to have significantly thicker trabeculae (Tb.Th) in the anterior regions of the astragalus versus the posterior regions as predicted. However, no differences were found among regions in *Indri* in the other standard measures of morphology: overall bone volume (BV/TV), number of trabeculae (Tb.N), or degree of anisotropy (DA). Among regions of the *Chlorocebus* astragalus no significant differences were found in Tb.Th, BV/TV, Tb.N, or DA. Surprisingly few differences were found between the two species, underscoring the complex structure-function relationship of trabecular bone.

53.3 SUMMERS, M.M.*; ROUSE, G.W.; Scripps Institution of Oceanography, UCSD; *msummers@ucsd.edu*
Untangling the trees of obligate symbionts: myzostomes and echinoderms
The obligate association of myzostome worms (Myzostomida) with echinoderms, in particular with crinoids, is an ideal system in which the evolution of symbiotic lifestyles and body plans can be investigated using phylogenetic inference. An association that has persisted since before the Jurassic, the body plans of myzostomes vary considerably and are consistent with four prominent symbiotic lifestyles (free-living, gall-forming, cyst-forming, and internal) in which the myzostome steals food from or directly consumes the host. Those living freely are mainly disk-shaped and tend to "mimic" the host by adapting similar colors and/or appendages that resemble the host, traits which are lacking in those that live internally or form cysts and galls. This variety of life histories and dependence on an echinoderm host over long time-scales presents the opportunity to compare the evolutionary histories of myzostomes and their hosts, as well as investigate the evolution of character traits related to this symbiosis. In this study we combine new and previously published sequence and morphological data to present a systematic revision of Myzostomida and their echinoderm hosts, assess congruence between host and symbiont phylogenies, and infer possible evolutionary events leading to the current diversity of myzostome species, lifestyles, and body plans.

25.4 SUNDAY, JM*; BATES, AE; DULVY, NK; Department of Biological Sciences, Simon Fraser University, Institute for Marine and Antarctic Studies, University of Tasmania,; *sunday@sfu.ca*
Global patterns of thermal tolerance and range limits predict climate change responses in ectotherms
How species ranges are shaped by environmental gradients is a central goal of ecology and has come under renewed relevance given the new challenges posed by global climate change. Here we present a comparative analysis of thermal tolerance limits in ecotototherms on land in the ocean, and test the hypothesis that species occupy latitudes that correspond to their thermal tolerance windows. We find that marine and terrestrial ectotherms differ in the degree to which they fill their potential thermal ranges. Terrestrial ectotherms are excluded from the warmest regions of their latitudinal range, while marine species more fully occupy the extent of latitudes tolerable within their thermal niche. These findings suggest that terrestrial species may be less sensitive to climate warming at their warm range boundaries. We test this hypothesis by collecting global observations of climate-induced range shifts at poleward and equatorward range boundaries in systematic assemblage surveys. We find that in the ocean, shifts at both range boundaries have been equally responsive, while on land, equatorward range boundaries have lagged in their responses to climate warming, matching predictions. These results indicate that marine species' ranges conform more closely to their limits of thermal tolerance, while terrestrial species' ranges do not. Understanding the relative contribution of other factors in controlling warm range boundaries on land is necessary for predicting the rate of local extinction at trailing range boundaries.

35.2 SUSTAITA, D*; RUBEGA, M; HARTMAN, G; University of Connecticut, Dept. of Ecol. and Evol. Biology, University of Connecticut, Dept. of Anthropology; *diego.sustaita@uconn.edu*
When biomechanics meets biogeochemistry: functional correlates of Loggerhead Shrike (Passeriformes: Laniidae) feeding ecology based on stable isotopes analysis
Loggerhead Shrikes are medium-sized (~50 g) passerines that feed on arthropods and vertebrates. Differences in the physical and behavioral attributes of their prey are likely to impose disparate demands on their beaks and jaws. For instance, capturing and dispatching vertebrate prey may select for greater length and curvature of the bill hook, as well as greater bite force capabilities. These features, however, might trade-off against one another, because longer hooked tips may be more susceptible to fracture under greater loads. Previously, we reported a significant negative relationship between a bill shape characterized by increasing hook tip length and curvature, and bite force, in a wild population of Loggerhead Shrikes. Furthermore, we found that bite pressure (force/area) is unrelated to bill tip shape, suggesting that, across individuals and populations, shrikes of different bill tip shapes can achieve functional equivalence in terms of force/area by modulating bite force. Here we use analysis of carbon (d13C) and nitrogen (d15N) stable isotopes of feathers and prey items to place shrike morphology and performance in the context of their feeding ecology. Upper bill shape variables are uncorrelated with isotopic values, but bite performance is negatively related to d13C and quadratically related to d15N. It is as yet unclear specifically how these isotope values relate to prey use, however these results suggest that bite performance might not only mitigate the effects of variation in bill tip shape, but might also mediate the relationship between bill morphology and a dynamically changing prey base.

P2.47 SUSTAITA, D; University of Connecticut, Dept. of Ecol. and Evol. Biology; *diego.sustaita@uconn.edu*
The kinematics of a shrike bite: force, velocity, and an argument for power in Loggerhead Shrikes (Passeriformes: Laniidae)
Loggerhead Shrikes (*Lanius ludovicianus*) are medium-sized (~50 g) passerines that feed on arthropods and vertebrates. Differences in the physical and behavioral attributes of these prey types are likely to impose disparate demands of force and speed on their jaws that might trade-off against one-another. While the relationship between bill shape attributes, bite force, and feeding ecology are explored in another paper, here I examine interrelationships among kinematic and kinetic attributes of bite performance, alone. I used high-speed (120 fps) video of shrikes biting a force transducer in lateral view to obtain corresponding measurements of bite force and upper and lower bill elevation and depression. The data indicate varying degrees of upper bill (about the craniofacial hinge) and lower bill (about the quadratomandibular joint) coordination across bite sequences within and among individuals, but in most cases upper bill depression appears to play an important role in imparting bite forces. As expected on theoretical grounds, bite velocity varies considerably more with weaker bites than with harder ones. However, shrikes appear to bite with velocities and forces that optimize power, suggesting an additional emergent performance property of potential ecological relevance.

P3.69 SUTTON, T.R.*; WOLFF, S.W.; HAVEN, T.S.; VELDHOEN, N.; HELBING, C.C.; PROPPER, C.R.; Northern Arizona University, Flagstaff, USA, University of Victoria, BC, Canada; *trs228@nau.edu*

Thyroid Hormone Induces Up-Regulation of Two Genes Sensitive to Endocrine Disruption During Amphibian Metamorphosis

Thyroid hormone (TH) is critical to developmental pathways and essential in the normal function of the cardiovascular, central nervous, digestive and reproductive systems. In amphibians, TH is vital to the reorganization of these systems during metamorphosis and involves reprogramming of gene expression. Our studies using microarrays found that expression of fibroblast activation protein alpha (FAPα) and corticotropin releasing hormone binding protein (CRHBP) were highly TH-responsive and disrupted by exposure to environmental contaminants. CRHBP has been shown to be an important modulator of amphibian metamorphic timing, and altered FAPα expression is linked to several human cancers. Expression of these genes is clearly under TH control during development, therefore it is important to gain a better understanding of the functional role they play in tissue organization. In order to further evaluate the TH sensitivity of these genes, we exposed *Xenopus laevis* to 0, 0.1, 1.0, 10, and 50nM of T3 for 48 and 72 hours and measured changes in mRNA abundance using real time PCR relative quantification. We compared the results to standard morphometric shifts in development. FAPα and CRHBP mRNA expression was increased as early as 48 hours as low as 10nM and 50nM T3, although the 10 and 50 nM doses did not differ from each other. By 72 hours post-exposure, FAPα mRNA levels were increased in a dose-dependent manner and sensitive to 1 nM T3. CRHBP also showed TH responsiveness at 72 hrs, with the lowest effective dose being 10 nM. These results indicate that FAPα and CRHBP are effective gene expression markers for thyroid sensitivity.

37.2 SWEENEY, A.M.*; JOHNSEN, S; GAGNON, Y; MORSE, D.E.; STRAMSKI, D.; University of Pennsylvania, Duke University, Scripps Institute of Oceanography, UCSB; *alisonsw@physics.upenn.edu*

Jurassic marine photonics: Squid dynamic iridescence and predation by large extinct marine reptiles

Dynamic iridescence in Loliginid squids has been fascinating and well-studied from an ultrastructural and biochemical point of view. However, its function has remained mysterious, especially the fact that the predominant color of the dynamic iridescence has a peak in the far-red, at 670 nm, which is counter-intuitive for a marine organism. Here we demonstrate that the dynamic red reflectance of the *Loligo* dorsal surface is likely an adaptation for camouflage against upwelling long wavelength Raman-scattered ocean light, and that this camouflage likely originated at the time of the Jurassic origin of this group in response to predation by large marine reptiles. At the time of origin of the Loliginidae, several major groups of apex marine predators such as Ichthyosaurs, Metriorhynchids, Mosasaurs and Teleosaurs included squids as major portions of their diets. An evolutionary analysis demonstrates that all these groups were likely to have a tetrachromatic visual system with oil droplet filters to increase wavelength specificity of the four cone types. Visual system modeling of an extant squid-eating member of this lineage, the Shearwater *Puffinus pacificus*, demonstrates that Raman-scattered light is easily visible to these animals, and that prey without an ability to camouflage against this phenomenon will be more visible to these birds. Our findings are an intriguing insight into the visual world of large Jurassic reptiles and suggest other possibilities for reconstructing the visual ecology of these extinct animals.

BART.1 Sweeney, A.; University of Pennsylvania; *alisonsw@physics.upenn.edu*

Animal photonics: an integrated, comparative view

One of the fundamental physical forces shaping life on earth is light from the sun. My work so far has sought to elucidate the photonic sophistication of evolved structures in animals, and I have tried to not only describe novel light-resonant structures but also to place those structures in an environmental, behavioral context to better understand the nuances of their structural/optical function. I will discuss the evolution of the graded index lenses required for cephalopod vision, the photonic structures underlying deep-sea squid camouflage, and the optical structure of photosymbiosis in giant clams and demonstrate how keeping the animals in their environmental context shows the way to understanding these systems.

P1.126 SWEET, HC*; WOLTMAN, RA; WOOD, ME; ARMSTRONG, JM; SPIECKER, BJ; BORDER, CT; ROGGE, BJ; Rochester Institute of Technology; *hxssbi@rit.edu*

Development of a vitellaria larva in the brooding brittle star Ophioplocus esmarki

Many echinoderms with abbreviated development quickly form the pentamerous juvenile stage and largely bypass a bilaterally symmetrical, feeding larval stage. In addition, brooding echinoderms often have highly derived forms of development. In this study, the larval form of the brooding brittle star *Ophioplocus esmarki* was examined. The embryos and juveniles were stained for different tissue specific markers. External features and general developmental patterns were observed. The external morphology throughout development shows typical vitellaria structures, including an anterior preoral lobe that is resorbed through time, transient transverse ciliary bands on the aboral surface, and development of juvenile structures on the mid-ventral side. A marker for a digestive enzyme is not seen in early vitellaria stages, but is present in the developing juvenile gut, suggesting that the gut is not functional until later stages of development, as in other abbreviated forms. The first skeletal elements to form are in pentamerous symmetry; there are no remnants of bilateral ophiopluteus larval spicules. Even though this is a brooding brittle star, the larvae retain the classic vitellaria shape and structure. However, they develop over a much longer period of time and they are unable to swim in the water column like non-brooded vitellaria larvae.

110.5 SWIDERSKI, D. L.*; ZELDITCH, M. L.; Univ. of Michigan, Ann Arbor; *dlswider@umich.edu*
Mouse Jaw Ontogeny in Tres Partes Divisa Est
The mouse mandible is a popular model system that continues to be the focus of studies in evo-devo and other fields. Yet, little attention has been given to the role of postnatal growth in producing the adult form. Using cleared and stained specimens, we describe the timing of tooth and jaw development and changes in jaw size and shape from postnatal day 1 (p1) through weaning (c. p21) to adulthood (c. p35). We found that tooth development is relatively advanced at birth, and that the functional adult dentition is in place by p15 (just before the start of weaning). Shape analysis showed that the trajectory of jaw shape changes direction at least twice between birth and adulthood, with the first change around p7 and the second around p15. Before p7, the tooth bearing horizontal ramus deepens more than it elongates while the bone keeps pace with the growing molar crowns; the posterior processes also expand rapidly, increasing space for muscle attachment well in advance of the shift from nursing to chewing. After p7, the ramus deepens more slowly, with the teeth erupting while the roots are still growing; and the posterior processes widen more than elongate. After p15, the ramus increases curvature with the incisor, while the main changes in the posterior processes are deepening of the angular and elongation of the coronoid. Thus, at each stage there are changes in shape to all tooth and muscle bearing regions, and at each change of direction, all regions change their pattern of growth. In each interval (p1-7, 7-15, 15-35), the amount of shape change is nearly the same, as is the amount of size change. So although the jaw and teeth are close to adult form at the end of weaning, this last phase still affords ample opportunity for the environment to exert a direct effect on jaw size and on the shapes of all parts of the jaw.

P2.63 SWITZER, C.M.; Harvard University; *cswitzer@fas.harvard.edu*
Inspiring future scientists in primary school, using place-based inquiry
Many obstacles stand in the way of students' science learning in K12 education. Some obstacles, such as school culture and pervasive attitudes that "science is not cool" are difficult to address. Less than half of public-school students currently achieve proficient scores on state tests. With great burdens and distressing statistics, what can teachers do? One approach is to make relatively easy, short-term changes in pedagogy that will increase motivation and interest in their students. This project explored place-based inquiry, which allows students to use the natural environment in which they live as an inquiry-based learning environment. Students gained knowledge and learned skills that could apply across the curriculum. In a low-income middle school in northwestern New Mexico, 160 students engaged in a mini-unit that broadly explored the nature of ecological research. Students designed an observational study, formulating questions, writing procedures, collecting data, and drawing their own conclusions. This type of pedagogy was successful for two reasons. First, students were motivated because they were addressing questions that could not be answered by simply looking at a textbook. Second, students gained knowledge and skills that could be used across the curriculum, linking what they learned to other subjects and to other aspects of their lives. They realized that human impact on the environment changes the types of animals and plants that can live in certain areas. In addition to using metric measurement in meaningful ways, students evaluated hypothesis, based on collected evidence.

33.6 SWORE, J.J.*; KOHN, A.B.; KOCOT, K.M.; SWALLA, B.J.; NOREKIAN, T; MOROZ , L.L.; Univ of Florida, Auburn Univ, Univ of Washington; *jjswore@students.nwc.edu*
On the Origins of Glutamatergic Signaling: Insights from the ctenophore genome (Pleurobrachia bachei)
Ctenophores are extant representatives of one of the earliest animal lineages. Yet, as pelagic predators, they developed remarkable behavioral complexity with 'true' neurons and muscles. Here, we performed a genome-wide survey of neurotransmitters in the ctenophore *Pleurobrachia bachei* focusing on the characterization of glutamate (Glu) mediated signaling. Specifically, we identified and characterized the molecular organization and expression of 14 ionotropic Glu receptors (iGluR), and associated components of Glu synthesis and uptake. In *Pleurobrachia*, we discovered an unprecedented molecular diversity of Glu signaling; a diversity that far exceeds the situation observed in other animals including humans. There is also an extremely unusual genomic organization of many iGluRs. All cloned receptors showed remarkable cell-type specific expression both in development and in adults, but only a small subset of receptors is associated with neuronal-type elements, suggesting pre-neuronal origins of Glu-mediated transmission. In summary, we revealed the presence of well-developed Glu signaling in Ctenophores. However, this type of signaling is substantially different from other animals and can be explained in terms of extensive parallel evolution. On the other hand, Ctenophores might preserve one of the earliest designs of neural organization among animals, with a number of unique innovations absent or lost in other animal lineages.

P3.116 SZYMASZEK, J.F.*; ANGELINI, D.R.; University of Colorado, Boulder , Colby College ; *julie.szymaszek@colorado.edu*
Functional analysis of bantam microRNA in Tribolium castaneum
RNA-mediated gene silencing is an important means of studying gene function. RNA interference makes use of the microRNA pathway. This experiment is a functional analysis of synthetic bantam mimic microRNA and its effects on the body size of *Tribolium castaneum*. bantam was injected into pygmy size mutant, goliath size mutant and wildtype *T. castaneum* beetles during the larval juvenile stage. The mean body and limb size of the injected pygmy beetles showed a significant growth increase in the limbs. However, several defect phenotypes and lethality were observed. It is hypothesized that over-expression of bantam is lethal in the wildtype and goliath beetles, but contributes to the size increase in the pygmy beetles due to the up-regulation of bantam in pygmy. However, further studies must be conducted to determine bantam's concentration lethality as well as potentially identifying targets of bantam that lead to this size increase.

86.4 TAFT, BN; Univ. of Wisconsin, Parkside; *truthauction@gmail.com*

Constraints on song complexity generalize across multiple songbirds

Complex signals may evolve in response to different selection intensities, either continuously increasing in elaboration or reaching a steady state that is maintained by constraints. Detailed quantitative measures of signal complexity can help identify these different patterns of signal evolution and elucidate the mechanisms that produce them. Here I demonstrate a general method for quantifying the complexity of signal elements, derived from a new automated method for describing sounds as landmarks. I found that the acoustically dissimilar songs of four passerine species seem to have similar constraints between song element complexity and the rate of element production. Individuals from species with complex song elements sing at a slower rate than those from species with simple elements. Two of the species also show the same pattern of constraints among individuals. Element complexity also increases during the vocal learning process of a third species. The tradeoff between complexity and element rate is consistent with a hypothesis of production tradeoffs, does not appear to correspond to overall strength of sexual selection, and may also be explained by selection for effective communication in the face of tradeoffs in auditory perception or processing.

P1.204 TAFT, NK*; LAUDER, GV; SHUBIN, N; University of Wisconsin-Parkside, Harvard University, University of Chicago; *taft@uwp.edu*

Morphological variation in the pectoral fin lepidotrichia in basal actinopterygian fishes

Actinopterygian fishes are named for the bony fin rays (lepidotrichia) that support the fins. The curvature and position of the fin rays largely defines the shape and function of the fins, but little is known about the morphological and functional diversity in this key structure. Until recently, the lepidotrichia have been thought to be relatively uniform within living Actinopterygii. Previous work has demonstrated that the morphology of the fin rays of a benthic species *Myoxocephalus octodecimspinosus*, is morphologically and functionally distinct from this more generalized type. Here, we expand our sample to investigate morphological diversity at the base of the actinopterygian tree by examining the morphology in three basal species, *Polypterus senegalus*, (bichir), *Acipenser brevirostrum* (shortnose sturgeon) and *Lepisosteus osseus* (gar). We used a microCT scanner to examine the microstructure of the lepidotrichia of the pectoral fins of these taxa. We found significant morphological variation, particularly in the cross-sectional shape and degree of segmentation, of the pectoral lepidotrichia both within and among these three species. For example, the lepidotrichia of the sturgeon have a unique wishbone-like shape in cross section. These species also vary in the degree of segmentation along individual rays. In the bichir the lepidotrichia are segmented for almost their entire length, while those of gar and sturgeon remain unsegmented for almost a third of their total length. Cross-sectional shape and segmentation are features that affect the curvature of lepidotrichia. Therefore, we hypothesize that the morphological variation will result in specific functional consequences that will be experimentally tested in future work.

P3.33 TAKAGI, KK*; JAMES, CR; WRIGHT, WG; Chapman University; *takagi@chapman.edu*

A model system for predicting the effects of global warming: Acute and chronic effects of warm temperature on feeding behavior of Pagurus samuelis

Conservative global warming predictions estimate that an increase of 2°C will occur within the next century (IPCC 2007). Because intertidal organisms are particularly vulnerable to high episodic temperatures (Southward et al. 1995), they may represent a useful model species to understand the effects of global warming on natural populations. Here we examine feeding behavior in the hermit crab, *Pagurus samuelis*. We hypothesized that hermit crabs kept in elevated water-temperatures (21°C, 25°C, and 29°C), equivalent to that on warm days, during low tides (K. Takagi, pers. obs.), would reduce feeding relative to animals kept at ambient, oceanic temperature (16°C). We found that hermit crabs ate significantly less than control animals when exposed to a temperature spike of 25°C or 29°C, respectively. We also tested whether these acute effects persisted after water temperature was returned to ambient. In particular, we tested the recovery of feeding responses in ambient water after a 75 min temperature spike. We observed significant inhibition of feeding, 10, but not 25 or 45 min after a 29°C spike. Increasing the spike temperature to 31°C inhibited feeding for at least 25 min, but also resulted in 50% mortality. Interestingly, increasing the holding temperature from 16°C to 20°C before spiking to 31°C eliminated mortality, yet still produced significant feeding inhibition 25 min after the temperature spike. These results demonstrate that global temperature increases can exert non-lethal effects on populations that could indirectly, yet powerfully, impact them. This evidence establishes a framework for further examination of global warming-related non-lethal effects in other temperature-stressed species.

7.5 TARRANT, AM*; MCCORKLE, DC; DEPUTRON, SJ; CHURCH, C; HENRY, J; COHEN, AL; Woods Hole Oceanographic Institution, Bermuda Institute of Ocean Sciences; *atarrant@whoi.edu*

Variation in size of juvenile corals and sensitivity to ocean acidification

Anthropogenic input of carbon dioxide into the atmosphere has resulted in a decline of pH in the surface ocean (ocean acidification), leading to decreases in the carbonate ion concentration and aragonite saturation state. In laboratory experiments, decreased aragonite saturation state can lead to decreases in skeletal growth of both adult and juvenile corals. In experiments conducted with corals and other animals, individuals vary in their apparent resistance or sensitivity to the effects of acidification. To investigate possible maternal effects on coral growth and sensitivity to ocean acidification, we collected brooded larvae released by nine maternal colonies of *Porites astreoides*, settled them on tiles and reared them for two weeks under conditions of ambient or elevated carbon dioxide (targeting aragonite saturation states of 3.6 and 1.6, respectively). The maternal colonies produced larvae that varied substantially in settlement success, ranging from 2-54%. After two weeks, polyp diameter and weight varied significantly among maternal colonies, but little to no difference was observed in response to CO2. These experiments demonstrate that over a short time period, *P. astreoides* juveniles appear to be relatively insensitive to moderate acidification. Under controlled conditions, maternal colonies produce offspring that vary dramatically in their settlement rates and size, which may lead to differential survival and eventual recruitment. Further experiments are needed to identify the environmental and/or genetic factors that contribute to these differences.

P3.101 TATARIAN, A.F.F.*; ROOPNARINE, P.D.; Wesleyan University, California Academy of Sciences; *atatarian@wesleyan.edu*

Bringing Order to Taxonomic Chaos: Using Geometric Morphometrics and Elliptical Fourier Analysis to Distinguish Morphologically Equivocal Lirophora Species

Lirophora (Family: Veneridae) is a diverse bivalve genus which originated in the western Atlantic 35 mya. Since its first appearance in the southeast United States, the genus has spread throughout the tropical western Atlantic and eastern Pacific. It is well represented in the fossil record and by at least 4 Recent species, but species are generally difficult to distinguish using qualitative morphological characters. *Lirophora latilirata*, as originally described, is a Miocene species from the Calvert Formation of Maryland; however, a widespread Recent species bears the same name. Because the western Atlantic experienced significant oceanographic changes and high extinction after the Miocene, it is unlikely that the Recent and Miocene species are the same. Our goal is to determine how many species are represented in the sub-tropical western Atlantic from the Miocene to the Recent. To do this, we applied geometric morphometrics and elliptical Fourier analysis to specimens from the Miocene, Pliocene, Pleistocene, and Recent. Our results indicate that the Recent group is a distinct species. Our results also support the separation of two Miocene species, *L. alveata* and *L. vredenburgi*, from each other and from the Plio-Pleistocene species *L. athleta*. We found that all Pliocene and Plio-Pleistocene specimens belong to *L. athleta*, though whether some groups deserve further separation requires additional study. These results indicate a need for taxonomic revision of the genus *Lirophora*, and continued scrutiny of Neogene tropical American taxa in general. Such corrections will increase the accuracy of origination and extinction rate estimates.

P3.7 TATE, T*; JAROSZEWSKI, J; ROWE, A; ROWE, M; , ; , ; , ; , ; , ; , ; , ; Sam Houston State, Appalachian State, Univ. Texas, Austin; *tgt007@shsu.edu*

Do grasshopper mice actually eat noxious bark scorpions in the field?

Grasshopper mice (*Onychomys* spp.) are voracious predators on arthropods, including scorpions, although work-to-date has examined only benign genera such as stripe-tailed scorpions (*Vaejovis* spp.). In many regions the mice are also sympatric with bark scorpions (*Centruroides* spp.), a genus possessing extremely painful stings containing potentially lethal, vertebrate-specific neurotoxins. Our studies show that grasshopper mice unhesitatingly attack and consume bark scorpions, protected by structural changes in the mice's neurons and muscle cells that make them completely resistant to the venom components causing death, but only partially resistant to the venom components causing pain; these results may explain why grasshopper mice prefer to attack and consume a less painful stripe-tailed scorpion when presented simultaneously with a more painful bark scorpion. Here, we examine how the mice's neurophysiological adaptations to bark scorpion venom may have influenced their predatory behavior in the field. We analyzed the fecal samples of 135 wild-caught grasshopper mice from 5 different populations variously sympatric or allopatric with bark scorpions (stripe-tailed scorpions were present at all 5 sites). Attempts using molecular techniques to identify prey species from scat were unsuccessful, as were efforts to identify prey from the finely masticated pieces deposited in the feces. Thus, we are using a dissecting scope with UV illumination to simply identify the presence or absence of scorpion exoskeleton in the feces of each mouse. When coupled with the geographic mosaic of the mice and scorpions, these data should nonetheless permit us to determine whether grasshopper mice avoid bark scorpions in locations where more palatable species of arachnids are also available.

P3.49 TATE, KB*; CROSSLEY II, DA ; Univ. North Texas; *kevtate@gmail.com*

Dehydration stress during embryonic development alters autonomic regulation of the cardiovascular system in the American alligator (Alligator mississippiensis)

The incubation environment has a profound influence on development. Egg-laying amniotes, such as the American alligator (*Alligator mississippiensis*), develop within an egg case that may be particularly susceptible to changes in the local nest environment. Hydric conditions in the alligator nest have been documented to change based on seasonal conditions. In laboratory studies, alligator embryos exposed to dehydration events are markedly smaller and have altered cardiovascular function late in incubation. Thus, the current study was undertaken to determine if autonomic regulation of embryonic cardiovascular function is altered by dehydration stress during development. We hypothesized that the previously reported relative bradycardic response to chronic dehydration was the result of early maturation of vagal tone on the system. Dehydration events produced similar morphological changes as previously reported and resulted in vagal tone depressing resting heart rate during the final 10% of incubation. Angiotensin II (Ang II), a key water conservation humoral regulatory peptide, produced a hypertensive bradycardia when delivered. Treatment with atropine, a cholinergic antagonist, abolished the bradycardic response suggesting activation of the vagus in response to the Ang II induced hypertension. Treatment with phentolamine, an alpha adrenergic antagonist, attenuated the Ang II hypertensive response. Collectively it appears that dehydration alters autonomic regulation of heart rate, while the mechanisms of the Ang II response are unaffected. NSF CAREER IBN IOS-0845741 to DAC

42.2 TAYLOR, KR*; NISHIKAWA, KC; Northern Arizona University; *kt375@nau.edu*

The effects of a titin mutation on tremor frequency during shivering thermogenesis

Muscular springs, such as titin, play an important role in determining muscle properties. The muscular dystrophy with myositis (*mdm*) mouse model is characterized by a deletion in the N2A region of titin. Previous work suggests that muscles from *mdm* mutants are stiffer when passive and more compliant when activated than wild type muscles. Shivering frequency is an ideal way to measure the *in vivo* consequences of muscle stiffness because frequency of tremor (f) should be directly proportional to $(k/m)^{1/2}$ where k is stiffness and m is body mass. Because mutants have more compliant active muscles (i.e., decreased k), we expected that mutant mice would exhibit lower frequency tremors during shivering than predicted based on body mass. Further, we predicted that wild type and heterozygous mice would exhibit tremor frequencies expected based on body mass. Shivering was elicited by reducing ambient temperature, and tremor frequency was measured using an accelerometer attached dorsally to the trunk. The predicted tremor frequencies and the observed frequencies were not significantly different for wild type (expected: 41.5 Hz +/- 0.5 Hz; observed: 40.5 Hz +/- 3.5 Hz) and heterozygous mice (expected: 40.8 Hz +/- 0.8 Hz; observed: 39.5 Hz +/- 3.0 Hz). However, the observed tremor frequency for mutant mice (19.2 Hz +/- 4.1 Hz) was significantly lower than predicted by body mass (50.5 Hz +/- 0.7 Hz). These results support the hypothesis that the *mdm* mutation results in reduced active muscle stiffness *in vivo*. Thus, the results of this study demonstrate the important role that muscle stiffness, provided by titin, has in setting shivering frequency. Supported by NSF IOS-1025806.

P1.202 TAZ, H*; SHARPE, S/S; GOLDMAN, D/I; Wesleyan College, Georgia Institute of Technology;
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Limb drag during sand-swimming
The sandfish lizard (*Scincus scincus*) buries into granular media like desert sand using body undulations and limbs. Once the animal is subsurface, the limbs are placed near the body and the animal propels itself using body undulation. We hypothesize that the sandfish does this to minimize drag. To test this prediction, we added simple limbs to a previously developed robotic model [Maladen et al, J. *Royal Society Interface*, 2011] of the sandfish. The body of the robot consisted of 6 servo-motors (HSR-5980SG) and these motors were controlled such that a single period approximately sinusoidal traveling wave propagated from head to tail. Without limbs, using similar wave kinematics to the animal, the robot achieved swimming performance (characterized by the wave efficiency η, the ratio of the forward swimming speed to the speed of the travelling wave), comparable to the animal. We added two forelimbs to the robot, located at approximately 30% of the robot's body length (measured from the front) on either side of its body. Each limb structure consisted of a servo motor attached to a flat 8cm x 7cm plastic plate. The robot and limbs were covered in a spandex skin to prevent particles from jamming the motor joints. The addition of the limbs caused η to decrease from 0.34 (the value without limbs) to 0.28 ± 0.005, when the limbs were held parallel to the body. We next varied the angle relative to the body at which limbs were held (such that they extended away from the body midline). Increasing the angle from 0° to 90° resulted in a linear decrease in η, confirming our hypothesis that streamlining is possible in granular swimming. Future studies will actuate these limbs with different timing patterns to investigate how these limb structures could aid or disrupt the burial process.

53.1 TEICHHOLTZ, P.J. ; University of Michigan;
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Developmental mode, poecilogony, and population structure of the pyramidellid snail Boonea impressa
Poecilogony, the expression of more than one developmental mode in a single species, is usually not viewed as an evolutionarily stable strategy. Poecilogonous species are typically considered transitional states between discrete developmental modes. However, poecilogony may also represent a successful bet-hedging strategy that maximizes fitness under unpredictable conditions. Although species with this condition offer promising systems for illuminating the evolution of life histories, aspects of larval ecology and implications of different developmental modes on population dynamics, poecilogony is difficult to confirm in many cases, and only a few poecilogonous species are known. Many suspected poecilogonous species turn out to be cryptic species complexes. Proper recognition of cryptic speciation is thus necessary for determining the actual prevalence of this condition and identifying appropriate systems for further study. Here I investigated a potential case of poecilogony among Gulf coast populations of the marine snail *Boonea impressa*. Populations of *B. impressa* from Galveston Bay and Aransas Bay have been reported as exhibiting direct development and lecithotrophy, respectively. To determine whether cryptic speciation was present in, I utilized molecular phylogenetic and population genetic approaches based on analyses of mitochondrial (COI) and nuclear (ITS2) gene sequences to assess reproductive isolation and genetic structure of three Gulf coast populations of *B. impressa*. While no clear evidence of cryptic species was found, significant population structure was evident both within and between populations. This pattern is similar to the substantial population structure observed among other confirmed poecilogonous species. Together these results show that intraspecific variation in developmental mode contributes to the diversification of marine invertebrates.

117.5 TELEMECO, R.S.*; ADDIS, E.A.; Iowa State Univ., Ames, Gonzaga Univ., Spokane, WA; *telemeco@iastate.edu*
Are extreme temperatures physiologically stressful? An experimental examination of thermal variation on corticosterone levels in two species of alligator lizard
Temperature profoundly affects organisms and extreme temperatures can compromise vital functions. Exposure to such extremes might be highly stressful, particularly for ectotherms. A common indicator of stress is elevated levels of glucocorticoid hormones (GCs). At high levels, these hormones induce responses that promote survival; however, continued GC elevation (chronic stress) may negatively affect fitness. If extreme temperatures induce elevated GC levels, chronic stress may be important near the thermal limits of species' geographic ranges and as climate changes. Surprisingly little work has been done to measure the effects of thermal conditions on GCs in ectotherms. To help bridge this gap, we experimentally tested the effects of variation in body temperature on plasma GC levels in two congeneric lizards adapted to different thermal environments, southern and northern alligator lizards (*Elgaria multicarinata* and *E. coerulea*). Using a randomized repeated measures design, we quantified circulating plasma GC levels in 15 adults of each species after 5 hrs exposure to four ecologically relevant thermal treatments (10, 20, 28, and 35 C). For comparison, we also quantified baseline GC levels for each individual. Thermal treatment had no effect on GC levels in *E. multicarinata* but *E. coerulea* exposed to warm temperatures had slightly increased GC levels compared with those exposed to cold temperatures. Even so, GC levels after thermal treatments were never significantly different from baseline GC levels. These results suggest that while exact GC response to thermal conditions may be species dependent, extreme temperatures may not induce GC levels indicative of physiological stress.

19.6 TEPOLT, CK*; SOMERO, GN; Stanford University;
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Cardiac thermal tolerance and acclimatory plasticity in diverse populations of the invasive green crab, Carcinus maenas
Widespread invasive species successfully enter a broad range of novel habitats, often over short time scales, and exhibit remarkable abilities to thrive under new conditions, e.g., of temperature. These qualities make them ideal systems for examining traits underlying success in novel environments. *Carcinus maenas*, the green crab, ranges from Morocco to Norway in its native range and is globally invasive. Thus, this eurythermal species offers an opportunity to examine the thermal traits that facilitate success across a wide range of temperatures, and how those traits vary among populations of a widespread species. We characterized thermal tolerance and acclimatory plasticity for seven populations of *C. maenas* across 22 degrees of latitude in the native and invasive ranges. Using non-invasive cardiac physiology, we measured high and low temperature tolerance of cardiac activity (critical thermal maxima and heart rates at 0°C, respectively) for field-acclimatized crabs and for crabs given 3 – 4 weeks of laboratory acclimation at 5°C or 25°C. We show that the species has a high heat tolerance compared to other temperate species, with critical maxima of 30.8 – 37.0°C depending on source and acclimation. Both heat and cold tolerance were plastic; cold-acclimated crabs had heart rates at 0°C 3 – 5 times higher than their warm-acclimated counterparts. High and low temperature tolerances appear to be coupled, with higher heat tolerance accompanied by lower cold tolerance and vice-versa. We discovered some inter-population differences in thermal tolerance, potentially due to genetically different stocks. However, across all populations sampled, *C. maenas* maintains high thermal tolerance and acclimatory plasticity, even in populations with low genetic diversity due to sequential founding bottlenecks.

P1.155 TERUSAKI, A/T*; PUENGYAM, P; TSUKIMURA, B; California State University, Fresno, Prince of Songkla University, Songkhla, Thailand; *Aterusaki@gmail.com*

Cloning of a Putative Elongation Factor 1α Gene from the Ovaries of the Ridgeback Shrimp, Sicyonia ingentis

Elongation factors are a group of highly conserved proteins important in the translation of proteins. The elongation Factor 1α (EF1α) catalyzes the binding of the aminoacyl tRNA to the ribosome during translation. To catalyze this binding, EF1α utilizes energy provided by the hydrolysis of GTP. In this study we isolated a full length cDNA sequence of the EF1α gene from the ovaries of the ridgeback shrimp, *Sicyonia ingentis*. Ovaries were excised from shrimp and total RNA was extracted and cDNA was generated using the CloneMiner cDNA Library kit. Sequences generated from our cDNA were analyzed using BLAST analysis. From our search, a 1,589 bp sequence with high similarity (94%) to EF1α mRNAs from other penaeoid species was chosen for further study. Within this full length cDNA is a ORF of 864 bp encoding a polypeptide of 287 amino acids. A comparison of our sequence to EF1α of the, Ecuadorian white prawn, *Litopenaeus vannamei* showed homologous amino acid sequences in regions identified as GTP binding domains, 118-183, 295-321, 355-387, 403-438, 535-564. Furthermore, a 16 amino acid GTPase effector domain within our *S. ingentis* EF1α sequence was homologous to one identified previously in *L. vannamei*, 226-273. The homology of our sequence to EF1α of *L. vannamei* provides strong evidence that the gene we isolated encodes the protein EF1α in *S. ingentis*. However, further studies will need to be performed to verify the functionality of this identified gene sequence.

P1.12 TESSITORE, K.A.; CONTINO, G.J.; IYENGAR, E.V.*; Muhlenberg College; *iyengar@muhlenberg.edu*

Hiding from the enemy: behavioral responses of isopods to bluegill sunfish kairomones

Inducible defenses are triggered by biotic cues, such as the presence of a predator. We investigated whether aquatic isopods (*Caecidotea communis*) from ponds show behavioral changes in habitat preference when exposed to water with and without chemical cues from predatory fish (bluegill sunfish: *Lepomis macrochirus*). Isopods are thigmotactic, and are often found burrowing under or within leaf litter. We provided single isopods a checkerboard pattern of four choices of habitat (four replicates of each habitat within a single container): elevated shelters that provided shade, food pouches that disallowed thigmotaxis, and two benthic sources of layered mesh allowing thigmotaxis: a dark one providing shading and a translucent one allowing light penetration. We monitored the habitat choice of each isopod over an eight minute period and calculated the overall percentage of time spent in each habitat. Each individual isopod was tested in both water with and without fish cue and we examined the responses of small (N = 24) and large (N = 20) isopods separately. There was no significant effect of fish cue on habitat choice. The small isopods tended to spend more time in the mesh habitats than in shade or with food, while the large isopods used all habitats to the same extent. Our experimental animals came from a fishless pond. We are now repeating the experiment with a subpopulation from a pond with fish, to see if the natal environment affects behavioral responses in isopods.

S8-1.1 THACKER, R.W.; Univ. of Alabama at Birmingham; *thacker@uab.edu*

Assembling the Poriferan Tree of Life: Integrative Taxonomy and Systematics Reveal New Patterns of Sponge Evolution

The highly collaborative research sponsored by the NSF-funded Assembling the Porifera Tree of Life (PorToL) project is providing insights into some of the most difficult questions in metazoan systematics. Our understanding of phylogenetic relationships within the Phylum Porifera has changed considerably with increased taxon sampling and additional molecular markers. PorToL researchers have falsified earlier phylogenetic hypotheses, discovered novel phylogenetic alliances, found phylogenetic homes for enigmatic taxa, and provided a more precise understanding of the evolution of skeletal features, secondary metabolites, body organization, and symbioses. These exciting new discoveries will be shared during the talks that form this symposium. Specific case studies will be drawn from our analyses of nearly 1000 28S ribosomal subunit gene sequences. We recovered monophyletic clades for all four classes of sponges, as well as the four major clades of Demospongiae (Keratosa [G1], Myxospongiae [G2], Haploscleromorpha [G3], and Heteroscleromorpha [G4]), but our phylogeny differs in several aspects from traditional classifications. In most major clades of sponges, families within orders appear to be paraphyletic. While additional gene and taxon sampling are needed to establish whether this pattern results from a lack of phylogenetic resolution or from a paraphyletic classification system, many of our results are congruent with those obtained from 18S ribosomal subunit gene sequences and complete mitochondrial genomes. These data provide further support for a revision of the traditional classification of sponges.

44.5 THAWLEY, C.J.*; ROBBINS, T.R.; LANGKILDE, T.; Pennsylvania State University; *cjt171@psu.edu*

Survival at what cost?: Consequences of a native lizard's adaptations to invasive fire ants

Anthropogenic environmental change, including introductions of non-native species, imposes novel selective pressures on native species. A population's ability to persist under these threats can depend on its capacity to adapt accordingly. However, responses to an altered fitness landscape may not be optimal across all environments or life stages. We conducted a field transplant experiment using Eastern Fence Lizards, (*Sceloporus undulatus*) to investigate how a population's history of coexistence with predatory red imported fire ants (*Solenopsis invicta*) affects fitness (survival). Fence lizards in fire ant invaded sites have altered behavior and morphology, which are assumed to increase survival under this novel threat. We show that both adult and juvenile lizards from populations historically invaded by fire ants have higher survival in the presence of fire ants than do lizards from uninvaded populations. Adult lizards from invaded populations, however, appear maladapted when fire ants are absent, having lower survival than naïve lizards under these conditions. Juvenile lizards show an advantage associated with exposure to fire ants but do not experience the same costs as adults. These ontogenetic differences in the consequences of adaptation to fire ants may derive from the specific outcomes associated with each adaptation. Adults from fire ant invaded sites exhibit behaviors that promote escape from fire ants but expose them to mortality via native predators; whereas juveniles demonstrate innate avoidance of eating fire ants, which protects them from envenomation. Studying the downstream effects of pressures imposed by invasive species can provide insights into the longer-term consequences of environmental change on community interactions and the persistence of biodiversity.

17.3 THEOBALD, J. C.*; CABRERA, S; Florida International University; *theobald@fiu.edu*
Flying fruit flies correct for visual sideslip using motion parallax cues
Fruit flies possess tiny brains, but still depend on sophisticated flight skills to navigate to food, mates, and oviposition sites. A tenet of stable flight is the ability to correct for deviations from an intended course, such as by a gust of wind. One means by which flies do this is optic flow stabilization; when the visual world abruptly seems to move to the left, flies steer to the left to compensate. In previous experiments with static flies immersed in moving flow fields of points, forward motion had no effect on these side corrective responses. In other words, flies that appeared to be moving forward slowly, quickly, or even backwards responded identically to sideways visual perturbations. However optic flow during forward flight is a mix of images that seem to move faster or slower depending on their distance. When just the faster, seemingly nearer points move sideways, flies respond more robustly than when just the slower, seemingly farther points move, and this holds regardless of absolute forward speed. This result is consistent with the theory that flying flies, which cannot use binocular or accommodation cues for depth, use motion parallax to attend to nearer, more relevant features

38.1 THOMAS, W H*; FUNG, J K; THOMAS, F; University of Hawai'i- Windward Community College; *hoaka.thomas@me.com*
Water Quality of Kāne'ohe Bay Using Indicator Species Tripneustes Gratilla
Over the years the populations of the sea urchin *Tripneustes gratilla* have decreased drastically in Kāne'ohe Bay, Hawaii. The loss of this opportunistic grazer from its waters has coincided with an increase in invasive algal species like *Gracilaria salicornia* that impact the coral reef ecosystem. The goal of this study was to measure the water quality of Kāne'ohe Bay by tracking the effect of naturally occurring waters from off shore and near shore sites on early development in *T. gratilla* . The results of these experiments were compared to a reference toxicant (copper) over a range of concentrations. A gamete-extraction protocol was performed to produce fertilized urchin eggs. The urchin embryos were allowed to grow in 20 mL beakers of onshore, offshore, and control seawater, and seawater containing varying concentrations of copper. Concentrations range from 5 µg per liter to 200 µg per liter. Larvae were allowed to develop for three days. After which tallies were taken to see how the larvae developed. The larvae were categorized as normal, abnormal or underdeveloped. In the copper-toxicity test, urchin larvae showed sensitivity to copper above concentration of 20µg per liter, with normal development dropping to 30 % normal development at this concentration. In naturally occurring water, samples from onshore had more underdeveloped and abnormal larvae than those developing in offshore water samples. The onshore samples had similar levels of abnormal and underdeveloped larvae to concentrations of copper ranging from 20 µg per liter to 200 µg per liter. This could mean that chemicals with properties similar to those of copper are in high concentration along the shores of Kāne'ohe Bay.

13.8 THOMETZ, N.M.*; WILLIAMS, T.M.; University of California, Santa Cruz ; *nthometz@ucsc.edu*
Ontogeny of oxygen storage capacity and diving ability in southern sea otters (Enhydra lutris nereis)
As the smallest members of the smallest marine mammal species, immature sea otters face extraordinary physiological challenges as they transition from dependent pups to independent foragers. High energetic demands and limited oxygen stores severely limit the diving ability of a variety of immature marine mammals, potentially impacting their ability to respond to changes in prey distribution and abundance. We examined the ontogeny of blood and muscle oxygen stores and calculated aerobic dive limit (cADL) in southern sea otters. Key blood and muscle parameters, including hemoglobin (Hb), hematocrit (HCT), red blood cell (RBC) count, mean corpuscular hemoglobin content (MCHC), and myoglobin (Mb) content were determined for pups, juveniles in their first year post-weaning, and adults. Pups had oxygen stores between 69-89% of adult values depending on size and age, while juveniles had oxygen stores similar to adults. Neonates displayed minimal Hb levels (11.76±0.36 g/dL) which increased in large pups (15.78±0.32 g/dL) and juveniles (18.13±0.35 g/dL). Mb levels were particularly low in neonates (0.31±0.15 g/100g tissue) and medium pups (1.24±0.30 g/100 g tissue) but reached adult levels in juveniles (3.4±0.14 g/100g tissue). Small and medium pup cADL was between 1.0-1.9 minutes, while large pup cADL ranged from 2.1-2.9 minutes. Despite similar oxygen storage capacity, juvenile cADL was only 2.7-3.6 minutes compared to 3.0-4.1 minutes for adults, due to increased metabolic demands. As benthic foragers, limited aerobic capacity will likely impact the ability of young otters to compete with adults for limited food resources.

119.2 THOMPSON, D. M.*; LIGON , D. B.; Missouri State University; *denise.thompson17@gmail.com*
Rocky Raccoon Must Die: Nest Predation Patterns in a Population of Reintroduced Alligator Snapping Turtles
Predation of turtle nests is the primary cause of egg mortality and can be as high as 100% in some populations. In North America, raccoons (*Procyon lotor*) are significant predators of turtle nests; however, the importance of different sensory cues to nest detection and predation by raccoons has not been investigated. We experimentally tested the importance of visual and olfactory cues by measuring raccoons’ response to artificially constructed nests composed of: a) visual cues alone; b) olfactory cues alone; c) both visual and olfactory cues; and d) controls with no sensory cues. Research was conducted in southern Oklahoma at Tishomingo National Wildlife Refuge at ponds containing reintroduced alligator snapping turtles (*Macrochelys temminckii*). Artificial alligator snapping turtle nests were created to represent the three aforementioned nest treatments. A total of 16 trials were run from 2–27 June, 2011 and monitored with time-lapse, infrared game cameras. Initial raccoon detection of nests in each trial resulted in 9 (56%) of the 16 visitations occurring at the visual treatment, 7 (44%) at the visual-olfactory treatment, and none occurring at the olfactory or control treatments. Similarly, predation events were evenly distributed between visual and visual-olfactory treatments, with each being the first to be predated 7 times, while olfactory nests were the first nest predated only once. In 85% of trials the olfactory nest was the last nest to be predated, and on one occasion was not predated at all for an entire 3-day trial. We conclude that visual cues play a far more important role in raccoon detection and predation of alligator snapping turtle nests than do olfactory cues.

P2.5 THOMPSON, D. M.*; FILLMORE, B.; LIGON, D. B.; Missouri State University, Tishomingo National Fish Hatchery; *denise.thompson17@gmail.com*

Direct and Remote Methods of Assessing Turtle Nesting Behavior

Although nesting behavior has been described for a few well-studied species, detailed information is lacking for most turtles. Interspecific variation in nesting behavior is of ecological and evolutionary interest, but such behavior is particularly relevant for species of conservation concern. We employed three techniques to investigate nesting behavior in a captive population of alligator snapping turtles (*Macrochelys temminckii*), a species for which head-start programs have been initiated. Visual observations, time-lapse cameras, and temperature data loggers were all used to assess nesting activity at different resolutions. Visual observations provided the most detailed information on nesting activity. However, it was not possible to observe all turtles' activities, especially when multiple animals' terrestrial activity overlapped. Time-lapse cameras were most useful for capturing absolute activity times and terrestrial activity frequency, but were unable to generate comparable detailed resolution of behavior. Finally, temperature loggers provided reliable data to obtain information on general activity patterns and nesting events for all marked females. In combination, these three complimentary techniques provided a robust description of most aspects of the species' nesting behavior. Additional observations of these turtles in coming years will provide more information about within-individual variation in nesting behavior.

P3.216 THOMPSON, CL*; WILLIAMS, SH; GLANDER, KW; TEAFORD, M; VINYARD, CJ; NEOMED, Ohio University, Duke University, High Point University; *cthompson@neomed.edu*

Too hot, too cold, or just right: thermal challenges facing mantled howling monkeys (Alouatta palliata) in a dry tropical forest

Free-ranging mammals are confronted with the challenge of maintaining an energetically neutral body temperature within a thermally dynamic environment that changes daily, seasonally, and annually. While many laboratory studies have been conducted on primate thermoregulation, we know comparatively little about the thermal pressures primates face in their natural, evolutionarily-relevant environment. We examined thermoregulation of free-ranging mantled howling monkeys in a lowland tropical dry forest in Guanacaste province, Costa Rica. We recorded subcutaneous (T_{sc}) and near-animal ambient temperature (T_a) from 11 animals at 10 min intervals over 1606 sample hours. We found significant positive daily cross-correlations between T_a and T_{sc} (average r=0.70±0.17) with a modal (44% of days) lag time <10 min. T_{sc} increased with higher T_a, but plateaued at T_a>41°C. Similarly 95% of dry season cases with T_a>T_{sc} occurred at T_a>38.1°C, which implies that howlers use a cooling response to prevent rising temperatures over a threshold T_a. However, this cooling response was relatively infrequent, with T_{sc} being below T_a in only 14% of dry and <1% of wet season samples. The magnitude of cool vs. warm stress differed as well, showing a maximum deviation of 4.8°C when T_a>T_{sc}, vs. 15.4°C when T_a<T_{sc}. Our data support a hypothesis that, despite inhabiting a dry tropical environment, howling monkeys experience more 'cool' than 'heat' stress. This suggests that cool temperatures may be a prevalent thermoregulatory challenge for primates, particularly smaller primates living at higher latitudes and/or altitudes. Support: NSF, OU Baker Award, DU A&S Council.

19.2 THOMPSON, A.B.; BOYLES, J.G.*; MCKECHNIE, A.E.; MALAN, E.; HUMPHRIES, M.M.; CAREAU, V.; McGill Univ., Southern Illinois Univ., Univ. of Pretoria, Univ. of California, Riverside; *jgboyles@siu.edu*

Resource needs and climate means contributing to a global heterothermic continuum in mammals

Thermoregulatory patterns are a defining characteristic of all animals, but endotherms have garnished special attention in this area, presumably because of the ecological and evolutionary success these species have gained from their ability to control body temperature (T_b) via metabolic thermogenesis. We evaluated ecological and evolutionary factors that affect T_b patterns in mammals using two complementary metrics that place variation in Tb on continuous scales (Thermoregulatory Scope, TS; and Heterothermy Index, HI). Body mass, season, latitude, and hoarding were important predictors of TS, a proxy of the variation in T_b a species is capable of displaying. Similarly, body mass, latitude, and average environmental temperature were important predictors of HI, a measure of the variation in Tb displayed under natural conditions. During winter, there was a strong positive relationship between latitude and heterothermy, suggesting species at high latitudes are more likely to display large fluctuations in Tb. However, during summer, HI values were negatively related to latitude, suggesting that factors other than temperature (e.g. water or food availability) more strongly affect T_b patterns. Phylogenetically older taxa exhibited high TS values, suggesting they are capable of allowing T_b to fluctuate more than phylogenetically young taxa. However, the phylogenetic pattern was less clear in HI values, suggesting that although older taxa may be more capable of displaying heterothermy, T_b patterns in the wild are strongly controlled by ecological factors.

23.5 THOMPSON, JA*; VALVERDE, RA; University of Georgia, Southeastern Louisiana University; *jthom2006@gmail.com*

2,4,6-TRICHLOROBIPHENYL DISRUPTS THE HYPOTHALAMIC-PITUITARY-ADRENAL AXIS IN RED-EARED SLIDER TURTLES (TRACHEMYS SCRIPTA ELEGANS)

Polychlorinated biphenyls (PCBs) represent a continuing threat to the health of humans and other taxa. The disruptive effects of PCBs have been studied primarily in the context of thyroid and gonad function, while, in comparison, adrenocortical function has received little attention. Juvenile turtles were subjected to an immobilization stress protocol, and sampled at 0 (control), 1, and 4 hours. We quantified pituitary POMC mRNA expression and plasma corticosterone levels in turtles exposed to 2,4,6-trichlorobiphenyl at doses of 0 (vehicle), 1, 10, and 100 µg/g body weight. Basal POMC expression approximated the hormesis (inverted u) dose-response, while basal corticosterone levels increased linearly with PCB dose. Stress-induced POMC expression was inversely related to PCB dose, as was plasma corticosterone concentration; this suggests adrenal suppression via modulation of pituitary function. This is the first evidence of hypothalamic-pituitary-adrenal disruption in an aquatic reptile, and should serve as a basis for future assessment of contaminated waterways throughout the country.

P2.54 THORNTON, S.W.*; MCLELLAN, W.A.; ROMMEL, S.A.; PABST, D.A.; Univ. of North Carolina Wilmington; *swt9459@uncw.edu*

Functional morphology of dorsal acoustic structures in pygmy (Kogia breviceps) and dwarf (K. sima) sperm whales

Odontocete cetaceans produce echolocation clicks to interrogate their environment and search for prey. These clicks are generated by pneumatically-driven phonic lips within their nasal passage, and propagated through specialized lipid structures within the forehead into the water. The echolocation clicks of kogiids, the pygmy and dwarf sperm whales, are produced using nasal morphologies that deviate dramatically from those of other odontocetes. Kogiids display marked left-right soft tissue asymmetry and possess accessory structures within their nasal system whose functions have not yet been adequately described. Our goal is to investigate the functional morphology of this system through gross and histological examinations, computed tomography (CT) imaging, and physical tissue manipulations. Preliminary results indicate that the kogiid phonic lips likely serve as sound generators and are composed of epithelial, connective, and muscular tissues. A labyrinth of air crypts and dense connective tissues are found within a dome-shaped “vocal cap,” a tough yet deformable structure that envelops the phonic lips. The morphology of the vocal cap, an autapomorphic feature of kogiids, suggests it functions as a sound reflector/absorber. The vocal cap, phonic lips, and spermaceti organ (a cornucopia-shaped fat channel that contacts the caudal-most phonic lip) are all acted on by facial muscles, suggesting that the kogiid acoustic system is highly tunable. Such muscular control may permit these animals to change the acoustic characteristics of their echolocation sounds and/or focus the sound “beam” in a desired direction.

142.3 TKINT, T*; DE MEYER , J; HELSEN, P; BOONE, M; VERHEYEN, E; ADRIAENS, D; Ghent University, Belgium, Antwerp University, Belgium, UG-CT, Ghent, Belgium, Royal Belgian Institute of Natural Sciences, Brussels, Belgium, Ghent University, Belgium ; *Tim.tkint@ugent.be*

Phenotypic plasticity of jaw morphology as a response to diet in two cichlid species and their hybrid

To explain the very high rates of speciation of cichlids in the East-African Lakes several hypotheses have been suggested. The decoupling of the oral and pharyngeal jaws is considered their most important key innovation, but it has been found that several other factors may also play a role in their adaptive radiation. Local adaptive responses, resulting from phenotypic plasticity, may allow cichlids to rapidly adapt to environmental changes during their lifetime and through processes like genetic assimilation such a response has the potential of becoming a heritable trait. Genetic studies have also confirmed that hybridization has occurred in the wild and that this potentially leads to novel phenotypes through transgressive segregation. We investigated phenotypic plasticity in response to different feeding modes in two cichlid species from Lake Victoria: *Haplochromis piceatus*, a suction feeder and *H. fischeri*, a biter. We raised groups of both species and their hybrid on food with the same nutritional quality, but different physical characteristics, simulating different feeding modes: (1) suction feeding from the water column, (2) scraping food and (3) biting on hard pellets. To visualize the plastic response we performed a geometric morphometric analysis of head morphology and we also compared feeding performance based on morphological proxies (theoretical bite force, KT,…). Furthermore we focused on the lower jaw, one of the most important elements in the oral apparatus. Based on micro-CT scans we compared ossification patterns and analyzed shape differences using 3D morphometrics. To some degree, the observed morphological variation between treatments seemed to be related to improving the imposed mode of feeding.

122.1 TOLCHIN, S; MEYER, NP*; Clark Univ.; *nmeyer@clarku.edu*

Notch signaling during neural development in the annelid Capitella teleta

Central nervous system development begins with fate specification of neural precursor cells, which generate the brain and nerve cord. Comparisons between vertebrates and arthropods have provided important insights into neural development, but studies in spiralians are still lacking. To understand the evolution of nervous systems, we are investigating brain development in the spiralian annelid *Capitella teleta*. *C. teleta* has a dorsal anterior brain that has several hundred cells. Brain development begins at the end of gastrulation with the ingression of single cells from localized areas of anterior ectoderm. During ingression, cell divisions are restricted to apical cells in the anterior ectoderm, while neural differentiation markers are basally localized. In both vertebrates and arthropods, proneural bHLH genes and Notch signaling play a role in neural fate specification and differentiation, although their function seems to be somewhat different between organisms. Based on expression of the proneural gene homologs *Ct-ash1* and *Ct-ngn*, and preliminary functional analysis of *Ct-ash1*, we hypothesize that cells expressing the highest levels of proneural genes ingress and then differentiate into neurons. Furthermore, *Ct-notch* and *Ct-delta* are expressed in the region of the developing brain. To test a possible function of Notch signaling in specifying neural fate or in preventing neural differentiation, we treated embryos with the gamma secretase inhibitor DAPT, which blocks cleavage-mediated activation of Notch. Despite apparent phenotypes in other tissues, notably the developing foregut, we did not see a strong phenotype in the developing nervous system. If true, these results would provide an interesting contrast to neural development in other animals.

46.4 TOMANEK, L; California Polytechnic State University; *ltomanek@calpoly.edu*

Environmental Stress Proteomics of Blue Mussel (Genus Mytilus) Congeners

The warm-adapted Mediterranean blue mussel species *Mytilus galloprovincialis* invaded southern California during the last century and has since replaced the cold-adapted native *M. trossulus* from its southern range, possibly due to climate change. Furthermore, *M. galloprovincialis* is more sensitive to lower salinity levels than the native. Both, temperature and salinity changes have been hypothesized to contribute to the range shifts and limits. Using proteomics, we characterized the underpinnings of interspecific differences in thermal and salinity tolerance limits. We conducted several experiments: an acute heat stress experiments to 24ºC, 28ºC and 32ºC, followed by a 24 h recovery at 13°C; a 4-week long temperature acclimation (7°C, 13°C and 19°C) experiment and an acute hyposaline (35, 29.8 and 24.5 psu seawater) exposure for 4 h followed by a 24 h recovery. Using gill tissue, we applied 2D gel electrophoresis and mass spectrometry to separate and identify proteins. The results suggest that acute heat stress triggers a shift from pro-oxidant NADH- to anti-oxidant NADPH-producing pathways to reduce the production of reactive oxygen species (ROS) and increase the cell’s capacity for ROS scavenging. Temperature acclimation showed that *M. trossulus* induces molecular chaperones at 19°C. Cold acclimation increased oxidative stress proteins and molecular chaperones in both congeners, although more so in *M. galloprovincialis*, suggesting a ROS-induced challenge to protein homeostasis at lower temperatures. The responses to hypo-salinity stress suggest that *M. galloprovincialis is able to respond to 29.8 psu but not to 24.5 psu, in contrast to the native M. trossulus, which can respond to both. The results suggest that increased ROS production correlates with metabolic depression and reduced protein synthesis in all three treatments.*

P3.43 TOMMERDAHL, A.P.*; BURNETT, L.E.; BURNETT, K.G.; College of Charleston; *annatommerdahl@gmail.com*

Characterizing the response of penaeid shrimp hemocyanin to chronic moderate hypoxia exposure

As the size, intensity, and frequency of hypoxic zones continues to increase in nearshore marine habitats worldwide, it is important to understand the potential effects this will have on marine organisms. The penaeid white shrimp *Litopenaeus setiferus* and brown shrimp *Farfantepenaeus aztecus* are both found in high abundances in Charleston Harbor and provide good model organisms to study these effects; they inhabit estuaries that regularly experience hypoxia and play important ecological and economical roles. The related species *Litopenaeus vannamei* (Pacific whiteleg shrimp) is the most common aquacultured shrimp species worldwide, giving economic importance to understanding their ability to cope with hypoxia commonly found in aquaculture ponds. Previous studies have shown that hemocyanin (Hc), the respiratory pigment in these species, increases in concentration and oxygen affinity following chronic moderate hypoxia exposure. Our goals are to determine differences in Hc concentration and O_2 affinity among the three species and characterize the effects of chronic hypoxia (30% air saturation) on these parameters. *L. vannamei* [Hc] (10.0±0.27SEM g/100mL, n=35) is much higher than that found in both wild brown (4.7±0.53SEM g/100mL, n=7) and white (8.4±0.45SEM g/100mL, n=20) shrimp, with significant increases in [Hc] occurring in both wild species after at least 25 days in hypoxia. No discernible change in oxygen affinity was detected over this time. In contrast, selection for high growth and disease resistance in the aquaculture shrimp has presumably contributed to high basal [Hc] and O_2 affinity that do not appear to respond to chronic hypoxia exposure. (NSF IOS-1147008)

P2.72 TORSON, A/S*; KEMP, W/P; RINEHART, J/P; YOCUM, G/D; BOWSHER, J/H; North Dakota State University, USDA-ARS Red River Valley Agricultural Research Center, North Dakota State Univeristy; *Alex.S.Torson@ndsu.edu*

Seasonal Timing and Gene Expression in the Blue Orchard Bee Osmia lignaria

The blue orchard bee, Osmia lignaria, a native North American megachilid bee with an affinity for orchard tree species, especially almonds, is being developed as an alternative pollinator to the honeybee (Apis melifera). During development, Osmia lignaria experiences two periods of extended dormancy. The first occurs during the prepupal stage in late summer and lasts one to two months in UT populations studied thus far. However, it is currently unclear whether this is a true diapause. The second is understood to be a true diapause and occurs during the overwintering period after the cocooned prepupae have developed into adults. The genetic pathways regulating diapause in these bees are currently unknown. In this study, a host of candidate genes known to be differentially expressed during diapause in other insects will be assayed using real-time quantitative PCR to determine: 1) If changes in gene expression are witnessed in diapausing versus non-diapausing individuals, 2) If there are equivalent gene expression profiles during prepupal and adult dormancy, and 3) whether gene expression patterns support the hypothesis that the summer dormancy period is a true diapause.

P3.135 TOUSIGNANT, K.A.S.*; SHERMAN, R.L.; Nova Southeastern University; *kshade@nova.edu*

Preliminary Anatomical Comparison of Choroid Rete Structure Between Diurnal and Nocturnal Reef Fishes

The choroid rete is a richly vascularized network of capillaries within the teleost eye that provides oxygen to the avascular retina. Parallel arrangement of capillaries within the rete allows for efficient countercurrent exchange of gases and materials. Previous studies have suggested that more visually-dependent fish exhibit increased development of the choroid rete; however, no comparisons between diurnal and nocturnal reef fish rete structure have been made to date. Vascular corrosion casting techniques were applied to two nocturnal specimens (20cm *Lutjanus griseus* and 20.9cm *Lutjanus apodus*) and two diurnal specimens (34cm *Carangoides ruber* and 21.1 cm *Lagodon rhomboides*) captured on reef patches off southeastern Florida. Resulting choroid rete casts were photographed via scanning electron microscopy to examine and measure differences between the vasculature of the two groups. In diurnal species, we found an average choroid rete diameter-to-body length ratio (CRD-BLR) of 0.045 and capillary complexity of 13.7 vessels/0.01mm^2. In nocturnal species, we found an average CRD-BLR of 0.04 and capillary complexity of 18.9 vessels/0.01mm^2. Though preliminary, these results show no significant difference in CRD-BLR or capillary complexity between diurnal and nocturnal reef fish, suggesting any differences may lie in vascular physiology, rather than choroid rete structure, of these two groups. Further corrosion casting results, together with biochemical analysis of oxygen consumption in the retinal tissue, will be used to determine possible differences in eye vasculature structure and function between diurnal and nocturnal reef fish.

P3.67 TRINH, R*; DEL GIZZI, A; HATFIELD, I; UC Berkeley; *fish.r.awsome@gmail.com*

Moon Phase and Nutrient effects upon Diel Vertical Migration Patterns of Zooplankton and Myctophids in the North East Pacific

Diel vertical migration (DVM) is understood to be a circadian rhythm in which the light-dark cycle of day and night are key exogenous factors, but little is known about how available moon light impacts this behavior. To further understand DVM patterns exhibited by myctophids, small pelagic fish of both environmental and economic importance, moon phase percent was taken into account and compared to myctophid bio-density found throughout the water column at night, in order to assess the impact moon light alone has on DVM. Bio-density of myctophids was obtained by counting the number of myctophids found in net tows deployed nightly between the times of 2300 and 0000 along the cruise track, at three different depths: a neuston-net (.25 m), and two meter-nets (50-100 m and 200-300 m) from which myctophids were collected and identified from each tow. To account for variations in myctophid bio-density not explained by changes in moon phase percent, zooplankton biodensity (ml/m3), nutrients (µM) in surface waters, varying latitudes (degrees) and water masses traveled through, and genera of myctophid found were all investigated to determine corresponding relationships regarding DVM. It was found that zooplankton bio-density and myctophid bio-density were inversely correlated, indicating a predatory relationship, as expected and that as moon phase increased, myctophid bio-density decreased in each net, also as expected since many organisms that undergo DVM, do so to remain hidden from well lit, shallow waters. Further analysis and research on myctophids in the North Easter Pacific Ocean and their DVM is still required but this study hopes to shed some light on myctophids' dynamic DVM patterns in order to better understand moon light's effects on DVM as a whole, and to understand their distribution and behaviors in the world's oceans.

136.6 TROWBRIDGE, C.D.*; LITTLE, C.; STIRLING, P.; PILLING, G.M.; DLOUHY-MASSENGALE, B.L.; Oregon Institute of Marine Biology, Beggars Knoll, Westbury, UK, Secretariat of the Pacific Community, New Caledonia; *cdt@uoregon.edu*

Lusitanian nemertean species in Lough Hyne Marine Reserve, SW Ireland

The warm-water nemertean *Paradrepanophorus crassus*, described from Mediterranean shores, was first recorded in Lough Hyne in County Cork, Ireland in 1931 by Renouf. During a long-term monitoring program (1994–2012) of Lough Hyne, we documented that the large, orange nemertean has increased in frequency, particularly in 2009–2012. Why the population is expanding in Lough Hyne is unclear but may include northward proliferation of Lusitanian species due to climatic warming and/or increased habitat availability. The nemertean forms membranous tubes under low intertidal to shallow subtidal rocks—a habitat previously occupied by purple urchins (*Paracentrotus lividus*) until their recent population decline. Nemertean eggs were noted within the membranous tube in June 2012. Polychaetes recorded in and around the nemertean tubes included species in three families (Polynoidae Amphinomidae, Dorvilleidae). The most frequently observed polychaete (*Dorvillea rubrovittata*) was a frequent, but not obligate, associate: sometimes the nemerteans occurred in sympatry with the red polychaetes and other times they were each allopatric (at the scale of individual rocks).

P3.201 TSAI, H.T.*; HOLLIDAY, C.M.; Univ. of Missouri, Columbia; *hptkr7@mail.missouri.edu*

Anatomy of archosaur hip joint soft tissues and its significance for interpreting hindlimb function

Reconstructing the appendicular joint anatomy of archosaurs is critical for understanding their posture, locomotor behavior, ecology, and evolution. Soft tissue significantly contributes to the shape and size of archosaur joints, such that fossil archosaurs often exhibit incongruent bony articular surfaces. This study infers the amount of soft tissue once present in archosaur hip joints via congruence tests, as well as investigates the hip joint cartilage anatomy of archosaurs. Differences in the mediolateral depth, as well as dorsoventral and craniocaudal diameters of the femoral head and the acetabulum are used to test for congruence of the hip joint in each axis. Hip joints of suchians and basal dinosaurs (i.e. *Shuvosaurus* and *Coelophysis*) are more congruent along the craniocaudal axis than those of derived non-avian dinosaurs (i.e. hadrosaurids, sauropods, tetanurans). Furthermore, non-avian dinosaurs exhibit mediolaterally longer femoral articular surface than the depth of the acetabulum, whereas basal suchians exhibit mediolaterally wider acetabulum than the femoral articular surface. Dissections and histology of extant archosaur hip joints show that articular cartilage exhibits localized morphological differences associated with assumed loading regimes. These results indicate that an increased amount of femoral articular cartilage is associated with the medial rotation of the proximal femur during non-avian dinosaur evolution, which impact our hypotheses of femoral regional homology and hip joint function.

P1.85 TULGA, S*; FERRER, E; WERNING, S; Univ. of California, Berkeley; *sarahtulga@berkeley.edu*

Parthenogenetic whiptail lizards vary more between year classes than by size, age or habitat

Genetic, ontogenetic, environmental, and sexual differences all contribute to observed morphological variation within species, but teasing apart the genetic contribution is difficult even when controlling for sex, age, and habitat. This limits our ability to determine what “baseline” levels of variation we should expect in the absence of these factors. Parthenogenetic species provide ideal tests of whether reduced genetic variation results in lower morphological variation. We analyzed 27 skulls of Aspidoscelis velox, a parthenogenetic whiptail lizard, using geometric morphometrics. To reduce the effects of factors resulting from habitat difference, these were primarily collected in 2010 and 2011 from a 500 square meter area. We photographed each skull in dorsal, lateral, and ventral views, and statistically quantified variation across 67 landmarked points using Procrustes superimposition. We analyzed the data using tpsRelw, MorphoJ, and Coorgen. We grouped specimens based on year collected, field-assessed age, and size based on skull length. Dorsal landmarks varied with collection year and size, whereas the ventral and lateral data showed shape trends in all three groups. Year collected was the strongest influence in all orientations, with a large shape difference between the two years. This large split is visible in all CVA, PCA and regression plots, and the general variation shown by these groupings is greater than expected. This suggests that epigenetic factors contribute greatly to individual morphological variation even when age, sexual, genetic, and habitat variations are low. Continuing research includes a comparative assessment of variation in gonochoristic whiptail species and further investigation into climate or environmental changes between the years collected.

P3.111 TURNER, MA*; CHAPMAN, A; BALTZLEY, MJ; Western Oregon University; *mturner11@wou.edu*

Effects of foot size on crawling speed in mucociliary locomotion

Most snails crawl using muscular contractions of the foot. However, a number of snails and slugs crawl using mucociliary locomotion, where propulsion is generated by beating cilia within a layer of secreted mucus. In species that crawl using muscular locomotion, crawling speed is correlated with foot size: the longer the foot, the faster the snail crawls. It has been hypothesized that crawling speed is not correlated with foot size in mocuciliary crawlers. We tested this hypothesis in two species thought to crawl using mucociliary locomotion, *Stagnicola* sp. and *Helisoma anceps*. We also tested whether applying a 0.01 M NaCl solution to the snail could be used to reliably stimulate crawling. The average crawling speed before we used the NaCl solution for *Stagnicola* sp. was 1.09 ± 0.16 mm/sec (± SEM), similar to the average maximum crawling speed for other species in the family Lymnaeidae. For *H. anceps*, the average crawling speed before we used the NaCl solution was 0.34 ± 0.08 mm/sec. There was no significant change in speed of crawling in either species after we used the NaCl solution. We also found no significant relationship between foot size and speed of crawling in either species. For comparison, we will also present data on the relationship between foot size and crawling speed in *Helix aspersa*, a snail that crawls using muscular locomotion.

P3.203 TURNER, CR*; STILLMAN, JH; DORFMAN, RE; PAGE, TM; California State University, Monterey Bay, Romberg-Tiburon Center: San Francisco State University; *cturner@csumb.edu*

Thermal Sensitivity of Heat Shock Protein Gene Expression in Newly Settled Porcelain Crabs

Intertidal zone organisms are adapted to thermal extremes, and upper vertical zonation limits are known to be set by thermal tolerance limits. While much is known of thermal tolerance in adults, there are fewer studies that have examined the impact of heat waves on newly settled juveniles that were not exposed to thermal variation in their larval planktonic period. In order to examine the impact of heat waves among newly settled juvenile porcelain crabs, we determined the induction temperatures for heat shock protein (hsp) gene expression in two porcelain crab species that inhabit different intertidal zones: the less heat tolerant low intertidal *Petrolisthes manimaculus* and the more heat tolerant mid-upper intertidal *Petrolisthes cinctipes*. Due to the ecological differences between the species, we hypothesized that hsp gene expression will begin at lower temperatures for *P. manimaculus* than for *P. cinctipes*. To assess organismal response to heat stress, we performed quantitative real-time PCR using housekeeping gene α-Tubulin and target genes hsp40 and hsp90α, both of which were highly expressed in prior microarray studies of thermal stress responses in adult *P. cinctipes*. Hsp40 induction occurred between 23-25.5°C in both *P. manimaculus* and *P. cinctipes*. In contrast, hsp90α induction was between 21- 23°C in *P. manimaculus*, but 25.5°C in *P. cinctipes*. Our initial analyses suggest that interspecific differences in thermal stress tolerance may be in part due to differences in induction temperatures of hsp90 between species. Further work is needed to quantify whether we observe ontogenetic shifts in the hsp90 induction temperature in each species.

P1.191 TWYMAN, CA*; HALES, K; SOCHA, JJ; Virginia Tech; *catwyman@vt.edu*

How do flying snakes land on a branch? Kinematics and impact forces of landing in Chrysopelea ornata

For vertebrate gliders, becoming airborne can be as simple as jumping, but landing on a hard substrate such as a tree trunk may entail a high risk of injury. At the end of a glide trajectory, gliders such as flying squirrels can maneuver to a favorable body position that allows for a foot-first contact upon landing, but snakes lack this capability. Here we address the question, how do gliders with no appendages land safely on an arboreal substrate? When landing on the ground, flying snakes (genus *Chrysopelea*) tend to land tail-first, which aids in decreasing impact forces by increasing the duration of the landing. In preliminary recordings of snake landings onto tree branches, some snakes contacted the branch near the mid-body, and then the anterior and posterior sections wrapped partly around the branch, perhaps carried forward from the momentum of the trajectory. We hypothesize that, when landing on a cylindrical substrate, flying snakes maximize the percentage of body that wraps around the cylinder, resulting in longer landing durations and smaller impact forces. Using body markers and three high-speed cameras, we recorded the landing kinematics of *Chrysopelea ornata* to determine landing duration and degree of branch-wrapping of the body. Additionally, we instrumented the horizontal landing cylinder with strain gauges to measure the forces involved in landing. This is the first study to address limbless landing, lending insight into a novel use of the axial body as a locomotor 'brake'.

40.1 TYTELL, E.D.; Tufts Univ.; *eric.tytell@tufts.edu*

The intrinsic dynamical properties of muscle are self-stabilizing for rhythmic movements

Animal locomotion is a rhythmic behavior that requires the effective coupling of multiple feedback loops, including mechanical coupling between the animal's body and the environment, coupling between muscular force production and body movement, and sensory feedback. Computational models were used to analyze how the intrinsic dynamical properties of neural and mechanical systems interact to produce stable, but adaptable locomotion. Floquet theory, a branch of nonlinear dynamics, includes ways to analyze how such rhythmic systems respond to perturbations. We analyzed the dynamics of a mathematical model of lamprey muscle and developed several robust ways of estimating the Floquet modes of a rhythmic system, which are canonical patterns of activity after a perturbation. We found that when a block of muscle is forced to change length sinusoidally and is cyclically activated, as in the standard work-loop protocol, it is strongly self-stabilizing, even with no sensory feedback. When two muscles act antagonistically, as they do around most vertebrate joints, then the system is less stable naturally. However, if the animal has sensory input regarding the joint position, it can be stabilized very easily.

31.1 UHRIG, E.J.*; FRIESEN, C.R.; MASON, R.T.; Oregon State University; *uhrige@science.oregonstate.edu*

Endoparasitic infections in the red-sided garter snake, Thamnophis sirtalis parietalis

Garter snakes have been model organisms for numerous studies of reproductive behavior, endocrinology, and chemical ecology. Such aspects of biology are known to be affected by parasites in a variety of other organisms yet parasite-mediated effects have been little studied in garter snakes. Indeed, even the composition of parasite communities has not been well described for most *Thamnophis* species including the red-sided garter snake. Our current study presents data on the prevalence and intensity of endoparasitic infections in red-sided garter snakes, specifically two distinct populations in Manitoba, Canada; thus we are able to make both inter- and intrapopulational comparisons. Snakes from both populations harbor at least five genera of endoparasites including nematodes (*Rhabdias* sp.) and trematodes (*Lechriorchis* sp.) in the lung, cestodes in the digestive tract, and trematode mesocercariae concentrated in the visceral fat deposits (*Fibricola* sp.) and the tail tissue (*Alaria* sp.). We investigate patterns of parasite distribution including potential variation in infection prevalence and intensity based on host sex and body size. We also examine whether measures of infection are correlated with host fat stores and/or reproductive structures. Of particular interest is our finding that, in at least one host population, the presence of *Lechriorchis* trematodes is negatively associated with ductus deferens mass suggesting potential implications for male reproductive investment. The results of this study provide an important basis for future work investigating parasite-mediated fitness effects in garter snakes.

S10-1.5 ULLRICH-LUTER, Esther; ARNONE, Maria Ina*; Univ. of Bonn and Natural History Museum, Berlin, Stazione Zoologica Anton Dohrn, Napoli; *miarnone@szn.it*

Watch your steps! Opsins and photoreceptors in sea urchin tube feet

Sea urchins, due to their derived morphological body plan, have long been considered to be of limited value regarding the reconstruction of ancestral deuterostome character states. In contrast, recent molecular findings show that the animals express a huge variety of vertebrate and even mammalian gene orthologs, including such essential for function and development of photoreceptors. We recently demonstrated that one of the six sea urchin opsin (photopigment) proteins is expressed within microvillar, r-opsin expressing photoreceptors cells (PRCs). These PRCs are located in the animal's numerous tube feet and, surprisingly, lack any associated screening pigment. Indeed, one of the tube foot PRC clusters may account for directional vision by being shaded through the opaque calcite skeleton. Since juveniles display no phototaxis until skeleton completion, we suggest a model in which the entire sea urchin, deploying its skeleton as PRC screening device, functions as a huge compound eye. Moreover, we are currently investigating on another sea urchin photoreceptor system, expressing a c-type opsin, phylogenetically clustering with chordate and protostome ciliary opsins. Specific antibodies and mRNA detection revealed expression in the sea urchin dermis and internal nervous system as well as in spines of other echinoderms. Analysis of the observed expression patterns does not indicate involvement of c-opsin in sea urchin directed vision. However, the c-opsin expressing cells might comprise the corresponding receptor for the long proposed "dermal light sense" and might have a function in "shadow responses" of echinoderms. Investigating the echinoderm c-opsin system is promising regarding information about c-opsin function at the base of deuterostomes.

P2.173 UNSER, A.J.*; DEAROLF, J.L; RICHMOND, J.P.; Hendrix College, Conway, AR, Univ. of North Florida, Jacksonville, FL; *unseraj@hendrix.edu*

Investigating the presence of a venous sphincter in the bottlenose dolphin (Tursiops truncatus) diaphragm

Adaptations of deep diving marine mammals include a sphincter around the vena cava where it passes through the diaphragm, which prevents pressurized blood from rushing back to the heart. Sphincters are composed of slow-twitch muscle fibers, which contain more mitochondria than their counterparts, fast-twitch fibers. A standard marker for the presence of mitochondria is the enzyme citrate synthase (CS). Thus, if bottlenose dolphins have a caval sphincter, muscle tissue around the vena cava should have higher CS activity than the costal region of the diaphragm. To test this hypothesis, CS kinetic assays were performed on muscle samples from three regions of ten bottlenose dolphin diaphragms: costal, dorsal caval (region directly dorsal to the caval foramen), and ventral caval. The CS activity of each sample was determined in 50 mM imidazole buffer (pH 7.5 at 37°C), 0.25 mM DTNB, 0. mM acetyl-CoA, and 0.5 mM oxaloacetate using a microplate reader. The activities were calculated from the rate of change of the assay absorbance (412 nm) at the maximal linear slope (Vmax). After comparative analyses, it was concluded that there was a difference in CS enzyme activity between the costal and caval regions of the diaphragm. However, on average, the costal region showed higher CS activity at 6.30 ± 0.40 µmol/min·g than the dorsal and ventral caval regions, which averaged 4.31 ± 0.43 and 5.40 ± 0.63 µmol/min·g, respectively. These results do not support our hypothesis that a sphincter exists in the caval region of the bottlenose dolphin diaphragm. These findings suggest that bottlenose dolphins rely on other adaptations for diving to depth, and since these cetaceans are typically shallow divers, they may not require a caval sphincter.

6.1 USHERWOOD, JR; The Royal Veterinary College; *jusherwood@rvc.ac.uk*

The basic mechanics of pronking, bounding or frog-hopping — the costs of pitching accounts for much of the diversity of fast quadrupedal gaits.

Quadrupeds show a fascinating range of gaits, both between species and across speeds. Accounting for the selection of these gaits, and understanding them within the context of mechanics, body form and locomotory requirements remains challenging. Current extreme reductionist models provide a range of insights, but fail to account for many aspects of gait selection. Here, I build on the principles of collisional mechanics developed for quadrupedal locomotion pioneered by Ruina, Bertram and Srinivasan, and develop a numerical 'pseudo-impulsive' approach to account for the energetic requirements of pronking, bounding and frog-hopping, including the consequences of pitching. This allows two complications to the point-mass model to be considered: points of force application on the ground being distributed (because of a finite back length); and the forces are allowed to apply torques about the centre of mass (because of a finite pitch moment of inertia). In effect, this model treats a quadruped as a stiff table. This approach successfully accounts for why horses gallop with only a gathered aerial phase (and frogs extended). However, if the body geometry does not vary with speed, no account is made for a transition from pronking to pitching gaits (or trotting to galloping) with increasing speed. Indeed, the energetic costs of non-pitching gaits (pronking, trotting and pacing) are predicted to be independent of speed, while pitching gaits (bounding, frog-hopping, galloping etc.) are predicted to increase with speed. So, while the model provides novel and, in retrospect, intuitive insight into the footfall timing and direction of forces during pitching gaits, it also predicts a gallop to trot transition with increasing speed. Likely limitations of the model assumptions will be considered.

17.4 VAN BREUGEL, F*; DICKINSON, M; Caltech, University of Washington; *floris@caltech.edu*

Foraging for food: multimodel sensory fusion in freely flying fruit flies.

The ability to find food by tracking wind-borne odor plumes to their source is one of the most critical yet difficult tasks an insect performs. In a natural environment, turbulent air breaks apart the odor distribution in a plume, resulting in packets of high concentration interspersed with clean air. The visual sense, however, provides continuous information about where objects are, but very little about what they are. Thus, it would seem prudent for an animal to integrate the two sensory cues to maximize their ability to localize food sources. In this study we focus on the fruit fly, and how they are able to track a time varying plume of an attractive odor to its physical source, and whether or not they decide to land on it. To answer these questions we built an experimental rig capable of delivering predictable pulses of odor into a windtunnel with minimal turbulence. We used a mini PID to characterize the odor pulses and build an accurate model, allowing us to predict the time varying odor landscape in the wind tunnel. To study how the flies integrate this olfactory cue with their visual sense we added a vertical black post near the plume. Using a 9-camera tracking system we were able to track the flies in 3D as they flew through the wind tunnel with different olfactory and visual scenarios. Preliminary results suggest that flies that recently passed through an odor plume are 3 times more likely to land on a nearby object (N=699), compared to flies who have not experienced any odor, yet flew within the same general area (N=879). Furthermore, the effect of the odor stimulus appears to persist - flies that have experienced odor, but less recently, are 7 times more likely to land than in the control case (N=679, 686, resp.). In summary, our unique experimental paradigm has allowed us to begin probing the roles of olfaction, vision, and memory, in food finding behavior in freely flying fruit flies.

3.4 VAN LEEUWEN, J L ; MULLER, U K*; Wageningen University, California State University Fresno; *umuller@csufresno.edu*

Body dynamics of larval fish - implications for the mechanics of large-amplitude swimming

Body and center-of-mass dynamics are fundamental to the mechanics of locomotion. Experimental studies have shown that small swimmers and flyers are relatively strong, since they generate forces and torques that are large compared with their body weight. However, small organisms must overcome relatively high drag forces, so their locomotion is characterized by high thrust and low efficiency. In this study, we quantify the center-of-mass kinematics of zebrafish larvae from video recordings of C starts and cyclic swimming. During cyclic swimming, the larval tail produces high torques as part of thrust generation: torque correlates with tail velocity (rather than tail acceleration, or velocity of anterior body sections). Torque increases with swimming speed, as do kinetic energy and power output. A maximum power output of 20 W/kg is observed at swimming speeds of 0.2 m/s at tail beat frequencies of 100 Hz. This value approaches the maximum power of fast and superfast muscles. Strouhal number decreases with increasing speed and Reynolds number, from values above 2 at Re 100 to 1 at Re 1000, indicating that swimming efficiency increases with speed. Previous studies on C starts suggested that fish begin to translate in the preparatory phase (stage 1, formation of the "C"). Our data show that the center of mass moves outside the body during stage 1, but does not translate in the earth-bound frame of reference. Translation begins during the propulsive phase (stage 2). Translational kinetic energy during stage 1 is near zero; rotational kinetic energy is high during stages 1 and 2, indicating that the change of heading during a C start is the net result of the large torques generated during both stages. We did not find the previously reported inverse relationship between forward speed and turning angle.

S3-2.1 VAN WASSENBERGH, S.*; MICHEL, K.; Univ. Antwerpen, Belgium; *sam.vanwassenbergh@ua.ac.be*

Feeding and swallowing on land

An important step towards understanding the evolution of terrestriality in vertebrates is to identify how the aquatic ancestors of tetrapods were able to access ground-based prey. Since several extant lineages of bony fishes show an amphibious feeding lifestyle, these fishes can be used to study the biomechanical requirements of successful aquatic to terrestrial transitions to capture and transport prey in their buccopharyngeal cavity. We analyzed the functional morphology and kinematics of two morphologically distinct and distantly related species that are both successful terrestrial feeders: the mudskipper (*Periophthalmus barbarus*) and the eel-catfish (*Channallabes apus*). During prey capture, the mudskipper pivots over its strong pectoral fins, and uses its complex system of oral jaws to pick up pieces of food on land. Notably, we found that this species still makes use of water carried along in the buccopharyngeal cavity to assist prey capture, and to provide intra-oral transport of food towards the esophagus by performing suction movements. This mechanism is markedly different from the eel-catfish, which curls into a position where the head is strongly bended ventrally, scans the surface by moving its head and chemotactile barbels from side to side, and performs a typical rostro-caudal wave of buccopharyngeal expansion of the jaws, hyoid and opercular system (as in most suction feeding fish). These findings show that having weightbearing pectoral fins is not a prerequisite for capturing prey on land in a fish that has a flexible body. Unlike the mudskipper, the eel-catfish does not use a hydrodynamic tongue to swallow the prey, but returns to the water to perform the necessary food transport. Consequently, these examples show two clearly different strategies to overcome the problems imposed by the shift from an aquatic to a terrestrial environment for feeding.

P3.4 VANATTA, K.J.*; POTTER, K.A.; WOODS, H.A.; Univ. of Montana; *kyle.vanatta@umontana.edu*

The Effects of Abiotic Factors on Host Finding by Trichogramma Wasps

Trichogramma wasps are important agents of biological control used commonly around the world in agricultural settings. Despite their importance, little is known about physical factors that affect their probability of finding and parasitizing host eggs. Using wild populations of *T. deion* and *T. sathon*, we examined the effects of three abiotic factors (temperature, humidity, & ultraviolet light) on patterns of adult movement and parasitization, using both choice and non-choice tests. In choice experiments that did not include host eggs, *Trichogramma* wasps showed greater preference for higher humidities and higher UV-B intensities. In some UV preference tests, the wasps preferred higher levels of UV-B but also were damaged by those levels. In non-choice experiments a higher proportion of *Manduca sexta* host eggs were parasitized in more moderate temperatures, higher humidities, and under higher intensities of UV-B. Further experimentation showed that *Trichogramma* were negatively affected by UV-B after being exposed to it during the entire larval and early pupal stages, leading to lower numbers of emerging adults. This study showed that abiotic factors had a strong influence on where the wasps went and how many eggs they parasitized. Because *Trichogramma* are small and difficult to track this approach helps to indicate the abiotic limits within which wasps prefer to stay, and within which they parasitize eggs successfully. The abiotic preferences and limits we found provide a way to define microhabitats in which *T. deion* and *T. sathon* actually forage in complex agricultural landscapes. With a greater understanding of where the wasps are foraging, we can better predict which pest species *Trichogramma* are best suited to control.

141.3 VANDENBROOKS, J.M.*; MUNOZ, E.E.; WEED, M.D.; HARRISON, J.F.; Arizona State University, Penn State University, University of Arizona; *jvandenb@asu.edu*

Fluctuations in Historical Oxygen Levels Impacted Insect Body Size and Physiology

Fluctuations in atmospheric oxygen over the last 500 million years have been hypothesized to have driven a number of evolutionary changes, including Paleozoic insect gigantism. However, the fact that not all insect groups exhibited gigantism coupled with the paucity of the fossil record and the complex interactions between oxygen, organisms and communities makes it difficult to definitively accept or reject the oxygen-size link. Yet, evidence from a series of modern insect rearing experiments does support this link: 1) dragonflies and other insects develop larger body sizes in hyperoxia, 2) almost all insects develop smaller body sizes in hypoxia, 3) tracheal system investment is inversely correlated with rearing oxygen, and 4) rearing oxygen affects insect physiology including growth, development, and fecundity even in insects that show no increase in body size. These results point to not just an effect of oxygen on maximum size, but a strong effect on average body size and insect physiology. Therefore, we have carried out a series of fossil studies focused on average body size across geologic times of both high and low oxygen levels. The results of these studies further support the link between fluctuations in oxygen and insect evolution: 1) the maximal and average size of *Protodonata* and *Paleodictyoptera* fossils correlate positively with modeled atmospheric oxygen, 2) *Blattodea* fossils showed little variation in maximum size, but average size was correlated with atmospheric oxygen, and 3) the Triassic hypoxic event appears to have a larger impact on insect body size than the Paleozoic hyperoxic event. The results from this combination of modern and fossil studies suggest that historical fluctuations in atmospheric oxygen would have influenced insect size, physiology and fitness. Supported by NSF EAR 0746352.

P2.209 VANDEPAS, LE*; ROCHA, RM; HIROSE , E; LEE, SCS; OLIVEIRA , LM; SWALLA, BJ; University of Washington, Universidade Federal do Paraná, Brazil, University of the Ryukyus, Okinawa, Japan, National University of Singapore; *lvandepa@uw.edu*

The native range of Phallusia nigra: is it really black and white?

Phallusia nigra (Savigny, 1816) is a cosmopolitan ascidian which has been described as introduced in a number of regions (India, Japan, Hawaii). Its native range is unknown, but the first published description was from the Red Sea (Savigny, 1816). The taxonomic description of *P. nigra* includes a striking smooth, black tunic and large size (up to 10 cm). However, there are at least two related *Phallusia* – *P. philippinensis* (Millar, 1975) and *P. fumigata* (Grube, 1864) – which can also have dark black tunics and then are difficult to discern from *P. nigra*. The distribution of *P. nigra* broadly overlaps with that of *P. philippinensis* in the Indo-Pacific and *P. fumigata* in the Mediterranean. As part of a 2011 NSF-PASI Tunicate Taxonomy course in Bocas, Panama, this group of ascidian biologists decided to investigate the range of *P. nigra* with morphological and molecular studies. We sequenced 18S ribosomal DNA and cytochrome oxidase B of individual ascidians from Singapore, Japan and Brazil. Our results show that these three species form a monophyletic group within the phlebobranch ascidians. This clade includes *Phallusia mammillata*, which has a very different external appearance (bumpy) and coloring (white). We examined historical reports and the present locations of *P. nigra*, *P. fumigata*, and *P. philippinensis* in the literature. We are interested in how these species display similar phenotypes and we are currently working to determine the native ranges of all four *Phallusia* species.

P2.95 VANDER LINDEN, A.*; CLANCY, D.; COHEN, C.S.; Romberg Tiburon Center, San Francisco State University, CA; *avanderl@uw.edu*

Inter-colony fusion in the invasive colonial tunicate Didemnum vexillum

The colonial tunicate *Didemnum vexillum* has aggressively invaded coastal marine habitats around the globe. Many ecological aspects of this species are not well understood, including the occurrence of fusion between colonies. Fusion is known in other colonial tunicates, most notably *Botryllus schlosseri*, in which it occurs only between individuals sharing an allele at a highly variable allorecognition locus. In the didemnid family, a genetic basis for fusion was not found in *Diplosoma listerianum*, but has been suggested for *D. vexillum*. The exact mechanism of fusion in *D. vexillum* is still unknown, but if there is a genetic component, we would expect to see higher rates of successful fusions in colonies that are genetically similar. To investigate the phenomenon of fusion within the *D. vexillum* population of San Francisco Bay, we carried out colony fusion assays at field sites and observed the frequency and details of the fusion process. Self-fusions had an 80% success rate (n=6), and inter-colony fusion occurred in 53% of assays (n=17). Genetic analysis revealed that four different haplotypes were present at the mitochondrial cytochrome oxidase subunit 1 (CO1) locus in the colonies collected for fusion assays. Although CO1 serves as a measure of genetic similarity and does not itself determine fusion, the increased rate of fusion in conjunction with lower genetic diversity when compared to other studies of the native range suggests a genetic component to fusion in *D. vexillum*. Comparison of CO1 sequences between colonies shows a preliminary trend of higher fusion rate in pairs with identical haplotypes. However, further genetic data from fusion pairs is needed to support this relationship and provide insight into the competitive strategies of invasive populations.

109.2 VANDERMEER, C.L.*; BEZNER KERR, W.; GUGLIELMO, C.G.; MACDOUGALL-SHACKLETON, S.A.; Univ. of Western Ontario, London; *cvande67@uwo.ca*

Effects of testosterone on spring nocturnal migratory restlessness and body composition in Zonotrichia albicollis

Photoperiod influences a number of hormonal cascades that modulate seasonal changes in behaviour and physiology. In the spring, many bird species migrate to breeding grounds, where androgens and estrogens promote courtship and territory defence behaviours. Testosterone also increases muscle mass and fat deposition rates via hyperphagia, supplying migrating birds with additional fuel. Captive birds exposed to photoperiod cycles display migratory restlessness in the form of nocturnal hopping activity (*Zugunruhe*). Precise endocrine modulation of this migratory behaviour and physiology is unclear, however castrations decreased the rate of spring *Zugunruhe* in prior experiments. Our study compared *Zugunruhe* and body composition in castrated and intact white-throated sparrows (*Zonotrichia albicollis*) following photoperiod and hormone manipulation. Intact sham-operated males kept on short days (non-migratory) did not exhibit *Zugunruhe* behaviour, while those switched to long days did. Long-day castrates implanted with androgen blockers (flutamide) and an aromatase inhibitor (ATD) displayed minimal nocturnal activity intermediate to that of short-day and long-day intact males. Long-day castrates given testosterone replacement exhibited higher levels of nocturnal activity than the three other groups. Flight muscle, heart and liver mass differed among the four treatment groups, generally showing greater size in the testosterone replacement group. Our results indicate that long day exposure in spring will elicit *Zugunruhe*, but that testosterone enhances photoperiod-induced migratory restlessness and organ changes.

130.5 VARSHNEY, S.*; ZOLOTOVSKY, E.; LI, Y.N.; BOYCE, M.C.; OXMAN, N.; ORTIZ, C.; Massachusetts Institute of Technology; *svarsh19@mit.edu*

Morphometric origins of biomechanical flexibility in fish armor

Morphometric analysis was used to identify the design principles of the articulating, mineralized exoskeleton in the armored fish *Polypterus senegalus*. Excised fish scales were scanned via X-ray micro-computed tomography and 3D reconstructed for landmark-based morphometric analysis. A morphometric map was developed to quantify the spatially-dependent geometric variations of individual armor units from the entire body of *P. senegalus* and to correlate them with local functionality. The full morphometric profile informed how heterogeneous armor assemblies utilize variable rigid unit geometries on multiple length scales, articulated arrangements of units, functional joints, and unit-to-unit overlap to provide uniform protection from predatory attacks while maintaining agility and maneuverability. The results served as the basis for developing 3D-printed bio-inspired prototypes of flexible body armor for human use.

9.5 VASQUEZ, M.C.*; MURILLO, A.; BROCKMANN, H.J.; JULIAN, D.; University of Florida, Gainesville, FL; *mcvasquez@ufl.edu*

Multiple stressor interactions delay horseshoe crab embryo development

Fertilized eggs of the American horseshoe crab, *Limulus polyphemus*, are buried in shallow nests above the high tide line, where they are exposed to variations in abiotic conditions during early development. We examined whether the rate of embryonic development is affected by exposure to environmentally-relevant combinations of three factors: temperature (T; 25°, 30° and 35° C), salinity (S; 5, 15 and 34 ppt), and dissolved O2 (DO; 5%, 13% and 21% O_2). Newly fertilized eggs collected from nests of individual mating pairs were returned to the lab and incubated under fully-factorial stressor combinations for 14 d, then placed in "control" conditions (30° C, 34 ppt, 21% O_2) for an additional 14 d. Growth rate was measured every 2 d throughout the experiment. We assessed 8 embryos from each of 6 mating pairs at each of the 27 treatment combinations (1296 eggs). We found that although the effect of isolated stressors (high T, low S or low DO) on development was minimal, stressor combinations showed stronger effects with evidence of complex interactions. For example, whereas high T and low S in isolation each had no effect, they were lethal in combination, and although low T in isolation slightly decreased the rate of development, it reduced the negative effects of low S and/or low DO. Furthermore, low DO increased the effect of high T, but it did not affect the response to low S. Low DO also appeared to pause development, which then resumed upon return to control conditions, but only after a 4 d lag. These data demonstrate that complex, synergistic interactions among environmentally-relevant levels of abiotic stressors can substantially alter the development of a coastal invertebrate in ways that may not be predicted from the effects of the stressors in isolation.

P1.94 VEGA, CM*; DOUGHERTY, A; ADEYEMI, T; HRISTOV, N; ASHLEY-ROSS, MA; Wake Forest University, Winston-Salem State University, Center for Design Innovation; *vegacm11@wfu.edu*

See You on the Flip Side: Tarantula Post-Molt Flipping

Chilean rose hair tarantulas (*Grammostola rosea*) shed their hard exoskeletons to accommodate growth. Prior to molting, the tarantula will flip over and lay on its back to "shrug" out of the old exoskeleton. A tarantula's willingness to remain on its back for extended periods of time is unique to when they are molting as this position makes the tarantula more vulnerable to predator attacks. When not molting, tarantulas that are placed on their backs will quickly flip over onto their feet. We used high-speed video, kinematic analysis, and computer modeling to characterize the essential features of the flipping behavior. External markers were painted on the legs and abdomen for digitizing; these markers were tracked in MatLab for the duration of the flip. Marker positions, combined with scans of a *G. rosea* exoskeleton, were used to create a 3D computer model of the spider in Maya in order to measure kinematic variables and determine the role of each limb during the flip. The fourth (most posterior) pair of legs is used to lever the cephalothorax off of the substrate, assisted by the third pair of legs. The second pair of legs is typically used to gain purchase with the substrate via the scopular hairs, a motion that involves long-axis twisting of the leg. Once attachment to the substrate is made by one foot, the tarantula appears to pull itself over, using the end of the abdomen as a pivot, finally landing on its feet right-side-up.

P1.115 VELETA, K*; TOKAR, DR; CANZANO, J; HAHN, DA; HATLE, JD; Univ. of North Florida, Univ. of Florida; *k.veleta.129534@unf.edu*

Vitellogenin RNAi treatment halts oocyte growth without decreasing protein translation

Organisms must allocate resources to either somatic storage or reproduction, yet the physiological mechanisms coordinating this trade-off are poorly understood. In the lubber grasshopper, vitellogenin (Vg) is the precursor protein to vitellin, which constitutes 90% of protein in mature oocytes. Previously, to investigate how investment into somatic storage is affected by reproductive protein resources, we utilized RNA interference (RNAi), reducing Vg-mRNA in the fat body 30-fold, however Vg protein in the hemolymph increased. Additionally, Vg-RNAi treatment halted ovarian growth and doubled fat body mass. In this study, we measured hemolymph levels of 90 kDa hexameric storage protein (Hex90), ovarian vitellin content, and rates of Vg production by the fat body. We compared Vg-RNAi treated individuals to Hex90-RNAi or buffer-injected controls by injecting dsRNA before vitellogenesis and sampling from early to late vitellogenesis. Hex90-RNAi treatment reduced Hex90 levels when compared to the buffer-injected and Vg-RNAi groups combined ($P=0.04$). The Vg-RNAi group had significantly lower vitellin content per gram of ovary compared to buffer-injected ($P=0.006$), but not the Hex90-RNAi ($P=0.360$) group, indicating that Vg-RNAi treatment may prevent Vg from being sequestered into developing oocytes. In addition, rate of Vg production by the fat body was higher at 19 d than at 26 d ($P=0.002$) but was not affected by Vg-RNAi treatment ($P=0.383$). Together, these results suggest that Vg-RNAi treatment does not reduce the translation rate of Vg-mRNA, but nonetheless halts sequestration of Vg into developing oocytes and increases fat body mass, consistent with a trade-off between reproduction and storage.

139.2 VELOTTA, J.P.*; MCCORMICK, S.D.; O'NEILL, R.J.; SCHULTZ, E.T.; University of Connecticut, United States Geological Survey; *jonathan.velotta@uconn.edu*

Freshwater transitions and the evolution of osmoregulatory function in alewives (Alosa pseudoharengus)

Among fishes, ecological transitions into freshwater environments are often associated with episodes of diversification and adaptive radiation. The functional changes that accompany these transitions have rarely been characterized. In this research, we identify evolutionary shifts in osmoregulatory capacity and ion regulation associated with freshwater transitions in populations of alewife (*Alosa pseudoharengus*), some of which maintain the ancestrally anadromous migratory habit and some of which have become landlocked. Juvenile landlocked and anadromous alewives were experimentally challenged with a range of salinities both *in situ* and in the laboratory. We detected differentiation between population types in salinity tolerance and osmoregulatory performance, as well as in the expression of candidate genes for osmoregulation (Na^+, K^+, $2Cl^-$ cotransporter (NKCC), and cystic fibrosis transmembrane conductance regulator (CFTR)) and Na^+, K^+, ATPase activity. Overall, evolutionary changes upon restriction to freshwater include enhanced osmoregulatory function in freshwater and reduced osmoregulatory function in seawater, as well as a diminished response of several salt-secreting pathways.

P1.23 VENESKY, M.; LIU, X.; SAUER, E.*; ROHR, J.; The University of South Florida, Chinese Academy of Sciences; *erinsauer@mail.usf.edu*

Linking manipulative experiments to field data to test the dilution effect

The dilution effect, the hypothesis that biodiversity reduces disease risk, has received support in some systems. However, few dilution effect studies have examined the effects of diversity on more than a single host species or have linked mechanistic experiments to field patterns to establish both causality and ecological relevance. We tested the dilution effect hypothesis in an amphibian-Batrachochytrium dendrobatidis (Bd) system. We show that tadpoles can filter feed Bd zoospores and that the degree of filter feeding was positively associated with their dilution potential. The obligate filter feeder, G. carolinensis, generally diluted the risk of chytridiomycosis for B. terrestris and H. cinerea tadpoles, whereas B.terrestris, an obligate benthos feeder, generally amplified infections for the other species, and species richness was a significant negative predictor of Bd abundance. Field data, at the scale of the entire United States, a scale to which the dilution effect has never been tested, corroborated these laboratory findings and were predictable based on host characteristics, providing hope that there are traits of hosts that can predict their diluting and amplifying capabilities.

107.2 VENZON, M.*; ALFARO, M.E.; Univ. of California, Los Angeles; *mvenzon@ucla.edu*

A phylogenomic approach to the evolution of the coral reef fish fauna

Coral reefs, while only making up a mere 1% of the oceans' area, are home to over a third of all the marine fish species. The reef-associated fish fauna is polyphyletic. Approximately 160 out of 450 families of ray-finned fishes include coral reef associated species. Nearly all of the major reef fish families fall within Percomorpha, a group comprising ~16,000 species. Due to the poor phylogenetic resolution of the percomorph tree of life, major questions regarding the evolution of the reef fish fauna remain unanswered. For example, the number of transitions to reef habitats, the timing of radiations of reef families, and the influence of geo-historical events such as changing sea levels and temperatures on the reef fish fauna are poorly understood. To begin to address the evolution of the percomorph reef fish fauna, we sampled 10 major reef-associated families as well as other non-percomorph lineages. We employed a new phylogenomic approach using targeted enrichment and massively parallel sequencing of >1300 ultraconserved DNA elements (UCEs). Our sampling strategy is designed to recover the crown ages of these 10 families to begin evaluating hypotheses regarding the timing of their colonizations and occurrence of concurrent radiations. Our long term goals include increasing the density of sampling within these groups as well as generating UCE-based phylogenies for 22 additional poorly studied reef clades.

S9-2.1 VERBERK, W.C.E.P.*; BILTON, D.T.; CALOSI, P.; SPICER, J.I.; Radboud University Nijmegen, The Netherlands, Plymouth University, UK; *wilco@aquaticecology.nl*

How oxygen and temperature changes across latitude and elevation determine ecological distribution patterns

Oxygen may set thermal tolerance limits. Such oxygen limitation arises when an individual's capacity to supply oxygen to its tissues is insufficient to meet mitochondrial oxygen demand. Understanding the role of oxygen in limiting aquatic ectotherms is complex: temperature affects both oxygen demand and the availability of oxygen. We derived an index of oxygen supply (IOS) from first principles of gas diffusion, which incorporated both partial pressure and solubility and tested its ability to explain published patterns in body size and species richness across environmental clines linked to differences in both oxygen partial pressure (e.g. altitude) or oxygen solubility (e.g. salinity). We also experimentally tested wether thermal maxima of aquatic insects arise from a mismatch between oxygen supply and demand. Our IOS better explained patterns in biodiversity and body size than either solubility or partial pressure alone, thus resolving the question whether partial pressure or solubility limits oxygen supply in nature. Intriguingly, by returning to the first principles of gas diffusion, it became clear that more oxygen is actually available in warmer waters, counter to current wisdom. The experiment support oxygen limitation at thermal extremes: hypoxia lowered thermal maxima, whilst hyperoxia increased them. At the same time, individuals that strongly increased oxygen uptake at elevated temperatures had lower thermal maxima. Our discovery that oxygen supply is actually higher in warmer habitats, represents a significant shift in our understanding of how oxygen shapes aquatic communities and has major implications for our understanding of how thermal limits may arise, and our ability to predict the impacts of climate change.

97.4 VETTER, K. M.*; BUMP, P.; Denison University, Univ. of Hawaii, Manoa; *ksmvetter@gmail.com*

Rapid Burrowing by the Mantis Shrimp Squilla empusa

Mantis shrimp rely on their burrows for shelter, protection from predators, reproduction efforts, and food manipulation. While some species incur great costs during burrow construction and consequently maintain each burrow for a long time, *Squilla empusa* can create simple burrows very rapidly. We investigated *S. empusa* burrowing by collecting nine animals and filming their burrowing motions in the laboratory using high speed video and particle image velocimetry. We also released captive animals back into their native habitat and filmed the resulting burrow excavation in situ. In both in the laboratory and in the field, *S. empusa* employed two methods of moving sediment: pleopod fanning, which directed stirred-up sediment posteriorly, and bulldozing, in which the animals carried sediment forward in a basket made of their maxillipeds. Pleopod fanning occured in short bursts: *S. empusa* formed depressions deep enough to accommodate their body in about two minutes. After this stage, maxilliped bulldozing became the dominant excavation method. Video analysis suggested that pleopod fanning effectiveness was improved by rotational movements of the pleopods that directed the resultant current medially. Scanning electron micrographs indicated that the extremely setose nature of the pleopods greatly increased their surface area, facilitating current generation. The formation of the maxilliped basket was enhanced by a complex arrangement of setae, especially on maxilliped pairs 3-5, that interlocked to form a robust chamber able to carry substantial amounts of varied substrate. Together, the morphology of the appendages and the dynamics of their movement made it possible for *S. empusa* to make completely new burrows in less than thirty minutes, and to carry out daily adjustments to already existing burrows.

P3.221 VEZINA, F.*; GUGLIELMO, C.G.; DEKINGA, A.; PIERSMA, T.; Universite du Quebec a Rimouski, University of Western Ontario, Netherlands Institute for Sea Research, University of Groningen; *francois_vezina@uqar.ca*

Flexible adjustments of internal organs in cold acclimated shorebirds

Seasonal cold acclimatization in the red knot (*Calidris canutus islandica*), a long distance migratory shorebird, has been shown to result mainly from adjustments in body mass. Since pectoral muscles are the largest shivering muscles in birds and because their size tracks variations in body mass, adjusting body mass to cold temperatures results in higher shivering heat production capacity (summit metabolic rate: Msum) and cold endurance. However, little is known on possible adjustments of other body components that may play an essential role in cold acclimatization. In this study we investigated the effects of thermal treatments on body composition, metabolic performance and tissue metabolic intensity of captive individuals maintained under constant cold (5°C) and constant thermoneutrality (25°C). As expected, preliminary results show that when controlling for body size cold acclimation is associated with a higher body mass and metabolic performance (basal metabolic rate: BMR and Msum). Dissection data also revealed significant increases (8-30%) in the mass of the intestines, stomach, liver, kidney, heart, flight muscles (pectoralis and supracoracoid), leg muscles and carcass (skeleton and other muscles). Enzyme analyses in muscles (pectoralis, leg, heart), kidney and liver highlighted no changes in lactate dehydrogenase (LDH), 3-hydroxyacyl-CoA dehydrogenase (HOAD) and citrate syntase (CS) but a significant increase in the activity of carnitine palmitoyl transferase (CPT) in pectoralis and leg muscles of cold acclimated individuals. These findings suggests that, in addition to flight muscles, most internal organs increase in size during cold acclimation and that an upregulation of fatty acid transport in mitochondria may be required to improve fuel delivery to support shivering in skeletal muscles.

P1.64 VICKREY, A/I*; DOMYAN, E; KRONENBERG, Z; SHAPIRO, M/D; University of Utah; *u0574826@utah.edu*

The Developmental Basis of Head Crests in the Domestic Pigeon

The domestic rock pigeon exhibits dramatic variation in a wide range of morphological traits, including plumage structures. We investigated the molecular and developmental basis of the head crest, a morphological trait characterized by a reversal in the direction of feather growth on the back of the head. These structures occur in many pigeon breeds, and similar structures are important in mate choice in wild bird species. Preliminary studies indicate that all crested domestic pigeons share a common single nucleotide variant. Furthermore, gene expression assays demonstrate that molecular polarity within the feather buds of the crest region has been reversed. This work provides new insights into feather development in the domestic pigeon, and can be used to help understand feather development and evolution in other avian species. In this presentation, we discuss the outcomes and protocols emerging from this work supported by the EDEN Research Coordination Network.

S6-1.3 VISSER, M.E.*; SCHAPER, S.V.; CARO, S.P.; Netherlands Institute of Ecology (NIOO-KNAW); *m.visser@nioo.knaw.nl*

Global climate change leads to natural selection on the physiological mechanisms underlying seasonal timing

Animals need to use information from their environment, so called cues, to accurately time their seasonal behaviours. These cues should be predictive for the time when conditions will be favourable for reproduction, moult, migration or other energy-demanding life-history stages. Due to global climate change however, the predictive value of the cues have been modified. As animals continue to use these cues in as in the past, their seasonal behaviour has become mismatched with their altered environment. This will lead to selection on how animals convert cues into seasonal behaviour, i.e. there will be selection on the underlying physiological mechanisms. To understand how natural selection may change the way cues are perceived and transduced, we not only need to understand how these physiological mechanisms function, but we also need to know where in these mechanisms the genetic variation lays. To forecast genetic change we also need to measure selection on the mechanisms in the wild. We will illustrate this conceptual framework with our work on great tits (*Parus major*), a small insectivorous bird. We studied the physiology and genetic background in 36 climate controlled aviaries and we measured selection in our long-term wild population. We show that the birds use increasing temperatures, rather than temperature *per se*, as a cue and that there is genetic variation in how cues are converted in timing of breeding (egg laying date). Gonadal development on the other hand is not affected by temperature, possibly constraining the advancement of laying dates in the wild. Integrative studies like these are essential to forecast the impact of future climate change on animals.

P1.11 VLAUTIN, CT*; FERKIN, MH; University of Memphis; *ctvlutin@memphis.edu*

Female meadow voles, Microtus pennsylvanicus, do not alter their over-marking in response to female conspecifics that differ in nutritional status. FEMALE MEADOW VOLES, MICROTUS PENNSYLVANICUS, DO NOT ALTER THEIR OVER-MARKING IN RESPONSE TO FEMALE CONSPECIFICS THAT DIFFER IN NUTRITIONAL STATUS

Engaging in direct interactions with competitors can be costly. To avoid such encounters, many terrestrial mammals will deposit scent marks and over-marks as a proxy for direct, face-to-face interactions. Territorial individuals, like female meadow voles, will also use over-marks to signal presence in an area and willingness to mate to nearby males. Male and female meadow voles mate with multiple partners. Male voles are attracted to the scent marks of female conspecifics that have not been food deprived compared to those of females that were food deprived. Male vole subjects exposed to an over-mark in which the top-scent female was not food deprived and the bottom-scent female was food-deprived later spend more time investigating the scent mark of the top-scent female to that of the bottom-scent female when the two scent marks were encountered separately. Thus, it is expected that female voles should place their scent marks on top of those of neighboring females at a rate that will maximize their chances of attracting male conspecifics. We tested the hypothesis that subject female meadow voles will tailor the number and proportion of scent marks of females that they over-mark to reflect whether the subjects and the donors were food deprived for 6 hours or not food deprived. Both subjects that were food deprived and those that were not deposited a similar number of scent marks, used a similar proportion of their scent marks as over-marks, and over-marked a similar proportion of the scent marks of donor females independent of the dietary condition of the donors. This suggests that in this case, female-female over-marks may not be used for same-sex competition.

P1.41 VLECK., D*; VLECK, C ; FOOTE, C; WINKLER, D; Iowa State Univ, Ames, Cornell Univ. Ithaca NY; *dvleck@iastate.edu*

Telomeres: ghosts of stressors past and harbingers of things to come?

Telomeres shorten with cell replication and oxidative stress. Shorter telomeres are correlated with reduced long-term survival. We produced a long-term metabolic stress in breeding tree swallows by attaching a 1-g backpack that the birds carried for a year. Doubly-labeled water data suggests this handicap (~5% of bird's mass) increased metabolic rate ~6%. Over the course of the year, mean telomere length measured by telomere restriction fragment analysis of nucleated erythrocytes decreased by 0.4 kb (95%CI±0.2) in metabolically stressed birds, significantly more (p=0.002) than occurred in control birds (mean loss 0.08 kb, 95%CI±0.1). Plasma innate immunity, total antioxidant defense and H_2O_2 level and comet analysis of cellular DNA damage did not differ between groups. Increased telomere shortening suggests that metabolic stress increased oxidative damage. In the first year, we found no difference in return rate to breeding sites (an index of survival) in backpack-carrying and control birds, but the odds ratio of return after a second year was strongly influenced by both the bird's initial telomere length (longer telomeres increased the odds of return) and its rate of shortening (greater shortening decreased odds of return). In our sample, sex, age, breeding site and year did not affect return odds. These data support the idea that telomere length and its rate of shortening reflect past stressors and predict future survival. Telomeres, which can be repeatedly measured in the same individual, may provide an integrative measure of individual quality and individual history, and provide a tool for predicting future ramifications of stress associated with experimental procedures or environmental variation.

92.4 VOLTZOW, J.; Univ. of Scranton; *voltzowj2@scranton.edu*

An exchange of countercurrents: Models, demos, and raps

Many students learn better when they are actively involved in manipulations or other hands-on exercises. In content-rich courses like introductory biology, these exercises can be especially effective to help students make connections between seemingly diverse topics. Countercurrent exchange is a basic mechanism used by animals to enhance the diffusion of respiratory gases across their gills, to reduce heat lost to the environment through the surfaces of extremities, and to concentrate excretory products. This important concept arises several times over the semester in units on respiration, homeostasis, and excretion. I wanted students to appreciate that these functions depend upon the same underlying basic mechanism. Towards the end of the course, therefore, I ask students to build models or present demonstrations of countercurrents to the class. I give them a large amount of leeway, but they are required to do something that is three-dimensional or involves an activity. The assignment has resulted in games, skits, and even a rap video with thousands of hits on YouTube. The exercise helps students appreciate the shared principles that permit these multiple applications and gives them the opportunity to share their understanding with their peers. Most importantly, they have fun doing it and appear to remember it longer because they created something original using fundamental biological principles.

P1.195 VOLZ, L/J*; TAYLOR, E/M; SIMPSON, K/B; FIELD, B/S; MCCLOUD, E/S; DAVIS, J/L; University of Southern Indiana; *jldavis2@usi.edu*

Flexural Stiffness & False Head Behavior in Lycaenidae Hind Wings

Insect wing mechanics have been studied with the motivation of characterizing the relationship between flight and mechanical properties, including flexural stiffness. Lyceanid butterflies offer a different mechanism for which flexural stiffness may contribute to behavior. Lycaenidae have characteristics of their hind wings that are described as a false head; including posteriorly oriented wing projections called tails. While maneuvering on a substrate many Lycaenidae fold and oscillate their hind wings along the cephalic-caudal axis. At this time, the tails oscillate in a peculiar bouncing motion. This is called false head behavior. One of the predictions from the "False Head" hypothesis posits that false head behavior deflects predator attacks away from the vulnerable body and head toward a weaker decoy region of the insect that can break away upon attack similar to the autotomizing tails of lizards. We predict that this weaker region in the hind wing may be a result of decreased modulus. We measured flexural stiffness profiles of butterfly wings along the length of the wing. We used these measurements along with finite element models to predict average modulus of the wing. Uniform moduli of wing membrane and wing vein structures can predict the flexural stiffness to within approximately 18% of mechanically tested wings. However, preliminary results indicate regional variation of wing moduli allows us to better capture the flexural stiffness profile observed in experimental data. In addition, dynamic analysis of the wing models indicate that there may be a mechanical relationship between hind wing movement and tail bouncing.

100.9 VON BUSSE, J.R.S.*; MOSTOWY, M.; BRUCE, H.; SWARTZ, S.M.; Brown University; *rhea_vonbusse@brown.edu*

Kinematics of swimming and flying big brown bats, Eptesicus fuscus - a comparative study

Bats are extremely maneuverable and versatile fliers. Although there has been substantial research concerning the kinematics of bat flight, it is less widely appreciated that bats are also good swimmers. Here, we ask: how do bats modify the basic movements of the wing when encountering a fluid of much greater density and viscosity than air? To explore this question, we carried out a comparison of 3D wing, hindlimb, and body kinematics in swimming and flight in the big brown bat, *Eptesicus fuscus*. We videographed swimming in a water tank, from above and below the water surface, carried out flight trials in a variable-speed wind tunnel, and reconstructed 3D kinematics. Two propulsion phases could be identified in the swimming stroke, and the data suggests that both forelimbs and hindlimbs contribute to the thrust production. However, the three individuals used in this study differed greatly in the timing of the propulsion and in the swimming speed. The comparison between swimming and flight data revealed that wing beat frequency is similar during swimming and slow flying. While swimming, the wrist amplitude in the stroke plane and the stroke plane angle was lower, while the span ratio and the downstroke ratio was higher than in flying, which reflects the greater importance for thrust than lift production in swimming.

59.2 VON DASSOW, G*; EMLET, RB; MASLAKOVA, SA; University of Oregon; *dassow@uoregon.edu*

How the pilidium larva feeds

The nemertean pilidium is a novel larval type that is difficult to relate to other invertebrate larval forms, except inasmuch as the pilidium - like the actinotroch, the mitraria, the endolarva of *Polygordius*, or the dipleurulas - consists of an inflated, transparent larval body bearing ciliated bands by which it swims and feeds, and within which a juvenile develops from growing rudiments. Like those superficially-similar larval forms, the pilidium feeds on small phytoplankters. The heteronemertean *Micrura alaskensis* can be raised in the lab from egg to metamorphosis when fed solely with the cryptomonad *Rhodomonas*. We used high-speed video to describe the feeding mechanism of *Micrura*'s pilidium. Flow generated by the primary ciliated band brings food particles past the band margins. Edible cells, but rarely inert particles, trigger rapid flicks of the pilidial lobes and lappets, re-directing a food particle and surrounding parcel of water into an atrial chamber. Non-beating cilia within the band are the likely sensors that detect edible cells. Once a parcel of food-containing water is engulfed, a secondary ciliated band beats in reverse, as if to barricade the exits while expelling excess water. Slow flow within the esophagus gently moves the cell toward the stomach entrance. Most captured *Rhodomonas* make repeated attempts to escape by firing ejectisomes, but the size of the chamber and the persistent flow within it seem to defeat the captured cells' efforts, until, their ammunition exhausted, they are drawn defenseless toward the gastric sphincter. This feeding mechanism is striking both for its novelty - it's not like any other larva - and for its familiarity: in inventing its own way to eat, the pilidium converged upon strategies used by Venus' fly trap, a FACS, and the baleen whales.

P2.155 VON DASSOW, G*; MASLAKOVA, SA; University of Oregon; *dassow@uoregon.edu*

How the pilidium larva pees

In the course of our ongoing studies of how the pilidium larva feeds and and how the pilidium larva grows, we quite unexpectedly learned how the pilidium larva pees. Relatively early in the larval life of the heteronemertean *Micrura alaskensis*, a pair of protonephridia appear, associated with the forming trunk imaginal disks. Initially containing a single terminal unit each, the nephridia are located just behind the ciliated ridges at the back of the esophageal chamber. On each side a short nephridioduct penetrates the trunk disk and opens into the amniotic cavity, which is connected to the outside world at the underside of the posterior lobe via the amniotic pore. This happens to be approximately where an excurrent leaves the esophageal chamber. This means that these protonephridia filter the blastocoelic fluid into the amniotic space, which in turn remains open to the outside, and that the products of excretion are likely carried away from the mouth by the excurrent. As the juvenile develops, additional units appear on branches of the same duct, and are incorporated into the young worm alongside the developing juvenile foregut. Pilidial nephridia, which may have been identified by Otto Bürger in 1894 but apparently went unnoticed by others until now, are significant developmentally because they represent an early-forming, larval organ which is retained by the adult after metamorphosis; the only other organ so retained is the stomach.

P1.122 VON DASSOW, M; Duke Univ. Marine Lab; *mvondass@gmail.com*

The mechanism of blastula expansion in sand dollars

Because of its simple geometry, blastula expansion in echinoids provides an ideal model system for studying how biomechanics mediates interactions between environment and development. To realize this potential, we need to know the mechanism of blastula expansion. One model proposes that the osmotic pressure of the blastocoel fluid drives expansion. Another model suggests that blastula expansion is due to the geometric constraints of packing dividing cells into a single layer. To test these hypotheses, sand dollar (*Dendraster excentricus*) embryos were allowed to develop in solutions containing polymers (20 kD polyethylene glycol or 148 kD dextran) which osmotically squeeze the embryo since they cannot penetrate the fertilization envelope surrounding the embryo. The expansion of the cell layer, expansion of the extracellular matrix, and recovery after squeezing were investigated. Preliminary results suggest that osmotic squeezing causes the embryo to buckle and collapse, rather than shrink uniformly. This indicates that the cell layer continues to expand as the embryo is squeezed from the outside. This early result suggests that the expansion of the cell layer is not driven by swelling of the blastocoel, but by the dividing cells maintaining themselves in a single layer. Interestingly, this result contrasts with results seen in other echinoids, suggesting that different mechanisms may drive blastula expansion in different species. These different mechanisms could affect their responses to salinity variation.

P2.156 VON DASSOW, Y.J.*; RITTSCHOF, D.; Duke University; *yasmin.vondassow@duke.edu*

Switch and bait: use of artificial egg masses to investigate predation on embryos

Many marine invertebrates package their embryos into benthically-deposited egg structures, some of which take the form of gelatinous masses with embryos embedded inside. If the gelatinous matrix is attractive to predators, its protective functions must balance two major costs: energetic costs associated with producing the jelly, and attraction of/lack of protection from predators. In previous work, we observed that for the gastropod *Haminoea vesicula* and the polychaete *Axiothella mucosa*, the jelly is implicated in attracting predators to egg masses. Here we employ artificial egg masses, made from alginate cured in calcium chloride solution, to explore the physical and chemical nature of predator attraction. The cold polymerization of the alginate allows us to embed live embryos in the artificial masses, and masses can be made in many different shapes and sizes. We investigate the following questions: 1.) How can we produce artificial egg masses that sustain live embryos? 2.) Are embryos inside artificial masses just as attractive to predators as those in real masses? 3.) What can artificial masses tell us about the costs and benefits of benthic development that relies on gelatinous egg masses?

92.2 VONWETTBERG, E.J.B.; Florida International University; *ericvonwettberg@yahoo.com*

Successes and pitfalls in the inversion of a large enrollment major's Evolutionary Biology course

Creating learner-centered classrooms through the inversion of instruction has the potential to create more engaged students and improve student achievement at a time of rising enrollments and cutbacks. I examine the deployment of several strategies, including Peer-Led Team Learning (PLTL) and peer Learning Assistants (LA), research-focused case-studies, and electronic clickers in a large enrollment upper-division majors course in Evolutionary Biology at a minority serving university. Although I find some improvement in student performance on test materials following the adaption of PLTL, LAs, case studies, and iclickers, the gains are limited. Student feedback suggests that improved PLTL leader and LA training, and better web-based materials may further improve student performance.

128.6 VOYLES, J*; POORTEN, T; TOOTHMAN, M; KNAPP, R; BRIGGS, C; VREDENBERG, V; ROSENBLUM, EB; Univ. of California, Berkeley, Univ. of California, Santa Barbara, Univ. of California, Santa Barbara, San Francisco State Univ; *jamie.voyles@gmail.com*

Focusing on survivors: Understanding how some amphibian populations persist beyond chytridiomycosis outbreaks

Mountain yellow-legged frogs (*Rana muscosa*) are among the most imperiled of all amphibian species. Over the past few decades, these frogs have disappeared from >93% of their historic range. One of the most pressing threats to Mountain yellow-legged frogs is chytridiomycosis, a disease is implicated in the decline of amphibians around the world. Chytridiomycosis is caused by a fungal pathogen, *Batrachochytrium dendrobatidis* (Bd), which can spread rapidly into naïve amphibian populations and cause high rates of mortality. In the Sierra Nevada mountains, a chytridiomycosis epidemic has been linked to mass mortality events and resulted in catastrophic losses of frog populations. Here we present results from exposure experiments that indicate *Rana muscosa* survive with Bd-infection and from field resurveys in populations that have survived initial chytridiomycosis outbreaks. The mechanisms by which some populations survive while other die out have not been fully resolved, but we propose that investigating evolutionary shifts in both host and pathogen responses to infection may reveal how some populations persist with a tolerance for the disease. Investigating the mechanisms of population persistence through epidemic outbreaks (i.e. focusing on survivors) is critical to amphibian conservation because many species are being bred in captivity with the idea of one day reintroducing them to the wild. Because Bd is now ubiquitous in many parts of the world, characterizing survival traits will facilitate population recovery and the repatriation of captive amphibians where devastating losses of amphibian biodiversity have occurred.

45.5 VUARIN, P*; DAMMHAHN, M; HENRY, PY; UMR 7179 CNRS-MNHN, Muséum National d'Histoire Naturelle, France, Behavioral Ecology & Sociobiology Unit, German Primate Center, Germany; *vuarin@mnhn.fr*

Torpor-based compensation of energy shortage: a review of evidences from field experiments

Hibernation and daily torpor are considered to be adaptations to seasonal energy shortage and environmental uncertainty. Although energy availability is commonly assumed to determine heterothermy patterns, few field data support this hypothesis. Yet, as climate and habitats change, energy availability is expected to become more variable, i.e. less predictable, in time, space and substrate. Recent literature suggests that hibernating mammals optimize the use of torpor expression according to energy availability, so that the trade-off between benefits (reduction of energy requirements, enhancement of survival) and costs (somatic damage, reduced immunocompetence) of torpor remains favorable. Most studies focused on species from temperate and boreal climates, exposed to severe winter conditions, however heterotherms from tropical climates may be exposed to different energetic constraints. In this study, we review published evidences from field experiments on the role of energy availability in determining torpor use. In addition, we present results of the first field experimental test based on food supplementation in a heterothermic tropical primate, the grey mouse lemur (*Microcebus murinus*). The nutritional content of the available food, like the composition in fatty acids or in anti-nutrients, also likely constrains the efficiency of torpor at compensating energy shortage. We outline what field experimental data are still missing and which alternative mechanisms need to be tested to achieve a robust understanding of the role of energy and nutrient availability as the proximate cues for fine-tuning torpor use.

P1.173 WAALKES, W.C.*; BERGMAN, D.A.; Grand Valley State University; *waalkesw@mail.gvsu.edu*

Nonylphenol Effects on Chemosensory Orientation Behavior of the Crayfish, Orconectes propinquus

Proper sensory input and motor output relies on constant nervous system activity. We proposed to test the neurological effects of a chemical pollutant on crayfish, *Orconectes propinquus*. Nonylphenol is a chemical used in detergents and pesticides that is commonly concentrated in crayfish, fish, and birds. Crayfish were exposed to 0.20 µL of nonylphenol for seven days. At the conclusion, crayfish behavioral responses were tested by allowing crayfish to find food in a Y-maze. Data recorded included percent success finding food, time to find food, time spent motionless, and time spent in the food arm of the Y-maze. In phase two of experiments, primary sensory and motor neurons were isolated to test changes in membrane potential across axonal membranes. By doing so, we will elucidate any alterations in neuronal signals due to nonylphenol exposure. For example, a reduction in neuronal signaling would indicate the pollutant directly affects the crayfish nervous system.

117.1 WADA, H*; ALLEN, NR; KRIENGWATANA, B; SCHMIDT, KL; SOMA, KK; MACDOUGALL-SHACKLETON, SA; Auburn University, University of Western Ontario, University of British Columbia; *haruka@auburn.edu*

Corticosterone and fitness: effects of incubation temperature

In the recent years, there has been growing interest in how glucocorticoids mediate fitness. Two non-mutually exclusive hypotheses, the "Cort-fitness" hypothesis by Bonier et al and the "Cort-condition" hypothesis by Breuner and Hahn, posit that baseline corticosterone and/or the amplitude of adrenocortical responses should relate to fitness. However, such relationships between corticosterone and fitness-related traits will likely dependent on the developmental environment and context. To explore how developmental stress and context alter this relationship, we manipulated egg incubation temperature (36.2, 37.4, 38.4ºC) and examined the effect of prenatal stress and mate's behavior on the relationships between stress physiology (adrenocortical responses, responses to ACTH and dexamethasone), reproductive performance, and survival in captive zebra finches (Taeniopygia guttata). Suboptimal incubation temperature had no effect on reproductive performance but lowered survival. Stress physiology did not correlate with survival but significantly correlated with several measures of reproductive performance. However, this relationship depended on incubation temperature. Days to first egg was negatively correlated with adult adrenocortical responses but only in 37.4ºC. Egg viability was linked to nestling baseline corticosterone but the direction depended on the incubation temperature. Parental behavior was not affected by stress physiology but affected mostly by the mate's behavior. The results suggest a complex relationship between corticosterone and fitness altered by developmental stress.

P2.180 WADDELL, DS*; HADDOCK, AN; University of North Florida; *d.s.waddell@unf.edu*

Transcriptional Regulation of Dual specificity phosphatase 4 (Dusp4) by Muscle specific RING Finger 1 (MuRF1)

Skeletal muscle atrophy is caused by a range of physiological conditions, including immobilization, spinal cord damage, inflammation and aging. The muscle specific RING finger 1 (MuRF1) protein is an E3 ubiquitin ligase that is induced under nearly all atrophy conditions and is believed to promote protein degradation. The data described in this study however, provide evidence that MuRF1 may also regulate the transcriptional activity of a number of genes that show differential expression following nerve damage-induced atrophy (i.e. denervation). A preliminary investigation using microarray to analyze changes in gene expression in the skeletal muscle of wild-type and MuRF1-null mice following denervation revealed a set of genes with altered expression profiles following nerve damage-induced atrophy in the absence of MuRF1, including the Dual specificity phosphatase 4 (Dusp4) gene. Dusp4 is part of a family of mitogen-activated protein kinase phosphatases (MKP) that have the ability to dephosphorylate and inactivate mitogen-activated protein kinases (MAPK). Furthermore, the Dusp family is able to dephosphorylate both serine/threonine and tyrosine kinases, which could impact a number of important signal transduction cascades. In order to further characterize transcriptional regulation by MuRF1, a fragment of the Dusp4 promoter was cloned into a SEAP reporter plasmid and then transfected into the C2C12 mouse muscle cell line in combination with a MuRF1 expression plasmid. In cells with ectopic expression of MuRF1, there was a significant increase in Dusp4 reporter activity, suggesting that MuRF1 may function as a muscle specific transcriptional regulator. The preliminary findings described in this study offer intriguing evidence of a new function for MuRF1 in controlling skeletal muscle atrophy.

P2.143 WADSWORTH, T*; CARRIMAN, A; FUSE, M; San Francisco State University; *ttww86@gmail.com*

Establishing the Presence of a Circadian Rhythm Regulating Ecdysis in the Stick Insect, Carausius morosus.

Circadian rhythms are involved in behavior modifications of an organism to allow for behavioral processes to occur during the least vulnerable and most beneficial times of the day. To determine if there is a circadian rhythm regulating the onset of ecdysis in the stick insect, Carausius morosus, a population of 32 stick insects, 2 weeks after hatching, were marked with white-out and placed in their own labeled jars within a controlled environment, influenced only by varying light regimes. A 17h light: 7h dark photoperiod and its reversed light regime were used. A hands-free video system recorded the insects and precise timing of ecdysis behaviors, as characterized by the shedding of the white-out marked cuticle, was assessed from the video footage. Data showed that the majority of insects ecdysed just before lights on for all photoperiods, suggesting that light was the influential zeitgeber. Establishing the presence of a circadian rhythm regulating ecdysis in the stick insect will allow for identification of vulnerable times to be targeted for eco-friendly pesticides as well as to facilitate further understanding of behavioral processes that are conserved within hemi and holometabolous insects.

P3.72 WAGGONER, C.M.*; REYES, J.A.; ARMSTRONG, J.L.; ALLEN, B.J.; KELLEY, K.M.; California State University, Long Beach, Orange County Sanitation District; *Claire.Waggoner@gmail.com*

Hepatic Protein Expression, Endocrine Disruption, and Relationships to Contaminant Exposures in Wild English Sole in Coastal Southern California

A variety of anthropogenic contaminants have been measured in the tissues of English sole and other fish residing in urban-impacted coastal waters of southern California. Contaminant exposures in these fish are being linked to potentially deleterious phenotypic changes, including altered endocrine pathways, detoxification responses, and physiological systemic effects (e.g., on metabolism, growth, reproduction). Findings also indicate that different types of phenotypic effects are significantly correlated with exposures to specific classes of contaminants. Increasing concentrations of chlordanes in fish are significantly related to thyroid disruption, while certain polychlorinated biphenyl (PCB) congeners and biphenyl are instead related to disruption of the stress-response (cortisol) endocrine system. Using 2D gel electrophoresis and MALDI-TOF-TOF mass spectrometry to identify and measure protein expression in tissues of impacted fish, it has been found that detoxification processes (e.g., in GST, Se-binding protein), metabolic adaptation (e.g., catabolic enzyme changes), cellular acclimation (e.g., HSPs, signaling, cell structure), and oxidative stress (e.g., catalase, peroxiredoxin) processes may be impacted, among others. These changes are correlated with different types of endocrine disruption and contaminant exposures. An integrative analytical approach, based on multiple measures, is pointing to possible underlying mechanisms of environmental effects and their potential causative agents. (Supported by NOAA-USC Sea Grant Program and CSU COAST).

P2.14 WAGNER, J.T.*; PODRABSKY, J.E.; Portland State University; *josw@pdx.edu*

Mechanisms underlying photorepair and photoprotection of Ultraviolet-C irradiated Austrofundulus limnaeus embryos and implications for a novel developmental stage

Populations of the annual killifish *Austrofundulus limnaeus* are able to persist in ephemeral pond habitats through production of drought and anoxia tolerant embryos that enter diapause while buried in desiccated mud. Annual killifish, including *A. limnaeus*, are unique among teleosts because their normal embryonic development involves a process of complete blastomere dispersion across the yolk surface by 4 days post-fertilization (dpf). The embryonic blastomeres subsequently reaggregate at a random site on the yolk surface to form the embryonic axis by 10 dpf, developing into the embryo proper. Previous investigators have suggested that the dispersed cell phase might buffer embryos against environmental stresses by allowing surrounding undamaged blastomeres to divide mitotically and replace damaged or dying cells. We explored the validity of this hypothesis by exposing embryos of *A. limnaeus* to massive doses of Ultraviolet-C (UV-C) radiation. Our results indicated a high tolerance of UV-C when embryos are allowed to recover in photoreactivating light. Without photoreactivating light, significantly higher proportions of embryos develop abnormally if UV-C irradiation occurs during embryonic axis formation when compared to dispersed blastomere stages or diapausing embryos. We also profiled the expression of stem cell-specific transcription factors and axis-formation factors during the dispersion and reaggregation phases of *A. limnaeus* development using real-time qPCR. The mechanisms that support tolerance of UV-C irradiation of *A. limnaeus* embryos and the evolutionary implications of the apparent “developmental buffering” observed in the dispersed cell phase are explored.

5.5 WAGNER, DN*; GREEN, DJ; COOPER, JM; LOVE, OP; WILLIAMS, TD; Univ. of Miami - RSMAS, Simon Fraser Univ., Cooper, Beauchesne, & Associates, ltd., Univ. of Windsor; *dwagner@rsmas.miami.edu*

Impact of hydroelectric operations on the physiology of songbirds during Fall migration

Habitat quality in riparian zones used by Neotropical passerine migrants, important during migration, will vary with changes in water level. This is an important management consideration for operation of hydroelectric facilities. We conducted a three-year study monitoring physiological condition of Fall migrants in relation to variation in water levels in four passerine species (*Geothlypis trichas*, *Setophaga petechia*, *Oreothlypis celata*, & *Cardellina pusilla*) in Revelstoke, British Columbia. Birds were blood-sampled during migration and we measured plasma metabolites (triglyceride, glycerol, & β-hydroxybutyrate) and corticosterone (CORT) as indicators of fattening rate and environmental stress, respectively. Individuals had low baseline CORT and showed a robust stress response following capture, contradicting the Migration-Modulation Hypothesis, which proposes that baseline CORT levels are elevated in migratory birds to facilitate hyperphagia and lipogenesis, and that further elevation of CORT in response to acute stress is suppressed. Additionally, there was significant annual variation in timing of the stress-induced increase in CORT, and individual variation in the rate of increase in CORT was correlated with Julian day, being higher later in the migration period. Estimated fattening rate (triglyceride) increased with time of day and date, reflecting diurnal and seasonal variation in fattening, and among species. However, fattening rate did not vary among years despite marked annual variation in water levels. Plasma glycerol and β-hydroxybutyrate also varied among years, but this was not consistently associated with high or low water levels.

P2.79 WAIN, A.R.*; MOORE, F.B.G.; The University of Akron; *awain@zips.uakron.edu*

Neurotransmitter-Induced Multicellularity?: The Effects of a Biogenic Amine (Serotonin) on Colony Formation and Gene Transcription in Salpingoeca rosetta

Past studies have demonstrated the ability of a chemical compound isolated from the bacterial species *Algoriphagus machipongonensis* to induce the formation of tightly packed rosette colonies in the choanoflagellate species *Salpingoeca rosetta*. Serotonin (5-hydroxytryptamine), which acts as a neurotransmitter in higher metazoans, has been shown to increase the frequency of colony formation in cultures containing *A. machipongonensis* (col+ cultures). In this study, the effects of serotonin addition on both col+ and col- (lacking *A. machipongonensis*) cultures of *S. rosetta* were investigated in order to remove the potentially confounding effects of the bacterial compound on the effect of serotonin. Serotonin was found to increase the frequency of colonies as well as cell density when added to either col+ or col- cultures of *Salpingoeca rosetta* at $5x10^{-6}$ and $5x10^{-5}$ M concentrations. In col- cultures, serotonin addition was also associated with increased average colony size. Transcription levels of several genes (PRCDH1, S. rosetta Cadherin, and Sphingosine 1 Phosphate Lyase 1) were shown to vary depending on culture type (col+ or col-) and, in some cases, the presence of serotonin.

P3.211 WALDRUP, C.L.; BERNER, N.J.*; Sewanee: University of the South; *nberner@sewanee.edu*

Environmental cues of seasonal acclimation in the Eastern red spotted newt (Notophthalmus viridescens viridescens)

Eastern red spotted newts are active in the winter. Our previous work shows that they acclimate enzyme activity, metabolic rate, behavioral thermoregulation, and membrane phospholipid fatty acid (FA) composition in skeletal muscle seasonally, in the field and in the laboratory. Here, we studied the relative influence of temperature and photoperiod on these seasonally plastic characteristics. While most studies of seasonal acclimation in ectothermic vertebrates have used fixed photoperiods, photoperiod influences physiology in our model species. The activity rhythm of *N. viridescens* is shifted by modified light cycles, and part of the seasonal variation in their critical thermal maximum is responsive to photoperiod (Hutchison, 1961; Demain and Taylor, 1977). We maintained newts (fed bloodworms *ad libitum*) in the laboratory in four acclimation groups: summer light/summer temperature (SL/ST); SL/winter temperature (WT); winter light (WL)/ST; and WL/WT. Photoperiods (WL = L:D 10:14 and SL = L:D 14:10) and acclimation temperatures (WT = 8°C and ST = 26°C) were based on local conditions. After maintaining the newts at these conditions for 12 weeks we determined their standard metabolic rates (SMR, measured as oxygen consumption after one week of food deprivation) at 26 and 8°C. We also measured enzyme activity (cytochrome c oxidase, CCO, and citrate synthase, CS) in liver and skeletal muscle tissue at 26 and 8°C and determined membrane FA composition of these tissues. The SL/WT acclimation group had the highest SMR ($p < 0.001$) at both 26 and 8°C, and the highest skeletal muscle membrane polyunsaturated FA content ($p < 0.001$) while SL/ST was lowest in both of these characteristics. While temperature was sufficient for acclimation of SMR, the interaction with photoperiod was significant.

P2.161 WALKER, R.A.*; DEAROLF, J.L.; RICHMOND, J.P.; Hendrix College, Conway, AR , Univ. of North Florida, Jacksonville, FL; *walker@hendrix.edu*

Assessment of the oxidative capacity of the rectus throracis muscle in betamethasone treated fetuses

Multiple doses of the prenatal steroid, betamethasone, accelerate the lung development of premature babies. However, the effects of betamethasone on the development of ventilatory muscles are unclear. Previous histochemical research in our laboratory indicated that a multi-course exposure to betamethasone did not affect the percentages of highly oxidative slow- and fast-twitch fibers in an accessory ventilatory muscle. However, our histochemical analyses did not allow us to compare the actual oxidative enzyme concentrations in the steroid-treated and control muscles. Thus, additional biochemical analyses that allow us to quantify oxidative enzyme concentrations are necessary to support our conclusion that betamethasone does not affect the oxidative capacity of ventilatory muscles. Samples of the rectus thoracis, an accessory ventilatory muscle, were collected from fetal guinea pigs that were exposed to multiple doses (2 injections per week at 65%, 75%, and 85% gestation) of betamethasone or sterile water prior to collection of muscle samples. Extracts of each fetal muscle were prepared and analyzed for their citrate synthase (CS) activities under the following conditions: 50 mM imidazole, 0.25 mM DTNB, 0.4 mM acetyl-CoA, and 0.5 mM oxaloacetate, pH 7.5 at 37°C. If the average CS activities of the control and treated rectus thoracis muscles are similar, these data would support our hypothesis that betamethasone does not have a significant effect on the oxidative capacities of the rectus thoracis muscle. Thus, premature babies treated with betamethasone will have similar oxidative capacities in their ventilatory muscles and will not be better prepared to sustain ventilation than babies who are not exposed to prenatal steroids.

P1.57 WALKER, J.F.*; MONTEIRO, A; Purdue University, Yale University; *jfwalker@purdue.edu*

Determining the putative source of a morphogen underlying black spot development in Pieris rapae butterflies

Presented here is the outcomes involved in disrupting putative sources of morphogen underlying black spot development in the pupal wings of the butterfly *Pieris rapae* and a protocol for methods of measuring alterations to the resulting adult color pattern. Morphogens are signaling molecules that once secreted by the producing cells typically travel through tissues to affect the regulation of genes in surrounding cells in a concentration-dependent manner. Eyespot patterns in lineages of nymphalid butterflies (one of the five major butterfly families) are induced by one or more morphogens produced by central cells, as disruption of these cells eliminates or reduces eyespots, and their transplantation to novel locations on the wing induces eyespot patterns. Little is known, however, about the developmental mechanisms underlying the differentiation of the simpler spot patterns in the earlier splitting lineage of pierid butterflies. This study examines the formation of wing spots in *P. rapae*, which we hypothesize to be the result of one central source of morphogen. We tested whether one or more sources of morphogen positioned at the center or just off-center to *P.rapae* slightly dumbbell shaped spots underlies their differentiation. To test this, wings at the spot location were pierced at several time points after pupation, and the resultant right and left (control) wing spot patterns were photographed. We performed comparative image analysis to determine whether the experimental spots have been altered in shape and size. Our results suggest that there is a single source of morphogen, located in the center of the future spot pattern, responsible for spot differentiation in *P. rapae*.

118.1 WALKER, J.F.*; ZANIS, M.J.; Purdue University; *jfwalker@purdue.edu*

The evolution of mononucleotide repeats and gene stability in eukaryotes

The signature of natural selection shaping genome sequences can be detected through the statistical analysis of the pattern and distribution of mutations in DNA. At times, they can have a positive effect and allow organisms to survive by adapting to their environment; however, more often mutations have a negative or deleterious effect. Because of the negative effects of mutations on cell machinery, and ultimately the fitness of the organisms, the mechanisms eukaryotic organisms use for efficient and reliable DNA replication have evolved for stability. In this study, we survey the presence and evolution of long mononucleotide repeats in coding DNA. Previous research has indicated that natural selection will act against runs of monomeric nucleotide repeats because of their increased likelihood of slippage and the introduction of frameshift mutations into gene sequences. In order to examine the structure of genes, we maintained the integrity of the amino acid sequence and created sequences with the expected number of mononucleotide repeats that were then compared to the number of mononucleotide repeats actually observed. We also examined the hypothesis that long runs of monomers lead to frameshift mutations. By comparing the genomes of closely related species, we were then able to determine whether the genes that have a long mononucleotide repeat in one species led to a frameshift mutation in the same gene of a closely related species. We found that almost all eukaryotic species have a strong resistance to long mononucleotide repeats; this remains true across the entire tree of life with the exception of two lineages. We present data with the following goals: 1) to expound on the role of monomers contributing to frameshift mutations and 2) to discuss how natural selection acts to maintain genome stability in most eukaryotic lineages.

P2.38 WALL, C.B.*; EDMUNDS, P.J.; California State Univ. Northridge; *cbw0047@gmail.com*

Elevated pCO$_2$ increases ammonium excretion in juvenile colonies of the scleractinian Seriatopora caliendrum

Abiotic stressors can affect organism performance through perturbed aerobic respiration, and are revealed by changes in oxygen consumption and by-products of the catabolism of respiratory substrates. When protein is used as a respiratory substrate, increased rates of nitrogenous excretion can result, and in aquatic invertebrates this corresponds to ammonium production. Elevated environmental pCO$_2$ (hypercapnia) has been shown to affect aerobic respiration and nitrogen excretion in terrestrial and marine invertebrates, and this effect has been hypothesized to reflect the effects of pCO$_2$ on acid-base regulation and protein metabolism. Thus, in the case of ocean acidification (OA) negatively affecting scleractinian corals, we reasoned it was timely to ask whether these effects might reflect changes in respiration and protein metabolism. To test the hypothesis that OA affects the respiration and excretion rates of juvenile *Seriatopora caliendrum*, corals were exposed for 14 d to 47 (ambient) versus 90 Pa (elevated) pCO$_2$ at 27.5°C and assessed for total protein content, O_2 consumption, NH_4^+ excretion, and the density of the coral's algal symbiont *Symbiodinium* spp. To block NH_4^+ recycling by *Symbiodinium*, the photosynthetic inhibitor DCMU was used in a contrast with uninhibited corals. Corals at 90 Pa pCO$_2$ exhibited elevated rates of NH_4^+ excretion, whereas corals at 47 Pa continued to absorb NH_4^+ from seawater. However, pCO$_2$ had no effect on respiration, protein content, or *Symbiodinium* density, and DCMU had no effects on any dependent variables. Our preliminary results suggest that OA might affect protein metabolism and nitrogen excretion in corals, however the mechanism remains equivocal.

P1.135 WALLACE, G.T.*; NEUFELD, C.J.; Whitman College, University of Washington; *wallacgt@whitman.edu*

Latitudinal variation in the cold tolerance of the intertidal copepod Tigriopus californicus

Broadly distributed species may adapt to local temperature conditions such that isolated populations have different thermal tolerance ranges than the species as a whole. Therefore, to accurately predict how species' ranges will be affected by global climate change, bioclimate models would benefit from knowing the thermal tolerance of different populations within latitudinally distributed species. In this study, the intertidal copepod *Tigriopus californicus* was used as a model system to study how local adaptation influences the cold resistance of isolated populations. Among five populations spanning 18 degrees in latitude, three metrics were used to compare cold tolerance: post-freezing recovery, chill coma recovery time (CCR), and the temperature of chill coma onset (CT_{min}). Recovery rates following freezing were faster in copepods from colder northern latitudes. Likewise, northern populations exhibited shorter chill coma recovery times and lower chill coma onset temperatures. Importantly, all three metrics showed a consistent latitudinal trend suggesting that any single metric could be used equivalently in future studies investigating latitudinal variation in cold tolerance. Our results provide evidence that populations within a single species can display strong local adaptation to spatially varying climatic conditions. Thus it would be valuable for bioclimate models to account for local adaptation when forecasting biological responses to climate change.

P1.15 WALLACE, B.P.*; WELCH, A.M.; College of Charleston, SC; *bpwallac@g.cofc.edu*

Habitat preference of southern toads (Anaxyrus terrestris) in response to substrate salinity

Selecting an appropriate habitat can be important for survival and reproductive success. Habitat selection is especially relevant for amphibians, a group that can be particularly sensitive to the environment due to their permeable skin. Human activities such as over-irrigation and road de-icing can lead to increased levels of salinity in the soil. These salinized habitats can be inhospitable to amphibians, because their permeable skin makes them subject to dehydration in hyperosmotic environments. We investigated whether female southern toads (*Anaxyrus terrestris*) can avoid slightly saline substrates by preferring non-saline substrates instead. Toads were individually placed in an arena in which the two sides differed only in substrate salinity. Salinity was manipulated by moistening the substrate on one side of the arena with brackish water and the other with freshwater. Time spent on each side and activity on each side, measured as the number of times the individual hopped or crawled, were monitored for two hours. At the lowest salinity level tested (4 parts per thousand), toads did not spend significantly more time on either side but did move significantly more when on the saline side. Toads may increase activity on the saline substrate in search of a more suitable, non-saline habitat. Tests using higher substrate salinities (6 and 8 ppt) will reveal whether toads show avoidance of salinity levels that pose a greater threat. The ability to detect and avoid saline soils may allow toads not only to find suitable terrestrial habitats, but also to locate appropriate low-salinity aquatic environments for reproduction.

P1.215 WALLACE, K/R*; CALLAGHAN, M; MURRAY, J; BELL, J; CSU East Bay, CSU Monterey Bay, CSU Maritime; *kelsey.r.wallace@gmail.com*

Exploration of the role of indoleamines in the cyclical behavior of Tritonia diomedea

Recent data have shown that *Tritonia diomedea*, an opisthobranch mollusc that is functionally blind, displays cyclical changes in crawling when entrained to a consistent photoperiod. The investigation involved exploring possible hormonal mediation of this activity rhythm. Hemolymph samples were obtained after 5, 10, 11, and 12 days of exposure to a strict 12 hour-light, 12 hour-dark schedule. Exogenous hormones in biological quantities were injected into the hemocoel of the animals at times that corresponded to low secretion levels in order to elicit a change in the rate of crawling, as measured by camera footage. An LC/MS protocol was developed against known biological standards using pure caffeine as a baseline marker. Overall standard purity ranged from 97-94%. The hemolymph samples were filtered using an Agilent filtration cartridge and concentrated under hydrogen. The limit of detection using fluorescence was 1.4 x10-9 M for melatonin and 4.54 x10-10 M for serotonin. The data suggests that melatonin is not in the hemolymph. Serotonin, on the other hand, is present in the hemolymph, implying an endocrine function. If melatonin and serotonin are involved in this animal's activity, the result could be a simpler biological model for studying the neuronal function of sleep. This may help us understand how sleep affects memory on a synaptic level. Understanding *Tritonia's* behavioral cycles could also have implications for understanding the ecology of their prey, soft corals.

S11-1.5 WALSH, M. R.; Univ. of Texas Arlington; *matthew.walsh@uta.edu*

Environmental influences on plasticity in sexual investment in Daphnia

Sex and dormancy are directly connected in organisms that engage in asexual and sexual reproduction. The transition between asexual and sexual reproduction typically results in a dormant stage that provides a mechanism to persist under harsh environmental conditions. For example, many species of *Daphnia* engage in sexual reproduction when environmental conditions deteriorate and produce resting eggs (ephippia) that remain viable for decades. It has long been assumed that observed variation in the timing and magnitude of sexual investment among populations or species reflects local environmental conditions. Yet, the importance of sex to the persistence of a given population of *Daphnia* can differ dramatically among habitats (i.e., permanent vs. seasonal ponds). As a result, environmental conditions have the potential to exert selection on sexual investment in *Daphnia*. In this presentation, I will highlight a growing body of research illustrating an important link between environmental conditions and divergent reproductive strategies in zooplankton. I will specifically: (1) discuss the environmental cues that initiate a transition between asexual and sexual reproduction in *Daphnia*, and (2) review recent work demonstrating an evolutionary consequence of ecological selective pressures, such as predation and competition, on plasticity in sexual investment in *Daphnia*.

P1.218 WALTI, K.A.*; SANDERS, K.E.; LEMA, S.C.; CalPoly, San Luis Obispo; *slema@calpoly.edu*

Multiple AVT receptors in teleost fish: Identification and tissue distribution of two distinct V2-type AVT receptor cDNAs in Amargosa pupfish

The neurohypophysial hormone arginine vasotocin (AVT) and its mammalian homolog arginine vasopressin (AVP) regulate hydromineral balance and social behaviors in vertebrates. In mammals, the actions of AVP are mediated by three types of receptors: V1a, V1b and V2. Previously, our laboratory identified multiple V1a-type receptors (V1a1 and V1a2) and the first teleost V2-type receptor from the Amargosa pupfish (*Cyprinodon nevadensis amargosae*). The evolution of these two V1a-type receptors and a V2-type AVT receptor has since been confirmed in other teleost species. Here, we used degenerate primer PCR to amplify and sequence a 551-bp nucleotide partial cDNA encoding a fourth AVT receptor from Amargosa pupfish. Alignment of the deduced amino acid sequence of this partial cDNA against previously described nonapeptide receptors revealed only 55.7% and 60.2% identity, respectively, to the V1a1 and V1a2 AVT receptors of Amargosa pupfish. Rather, this new cDNA encodes a deduced receptor with highest sequence identity to a clade of V2-type receptors comprised of avian V2-type receptors (63.4-63.6% identity) and a newly described V2-type receptor V2b from pufferfish (75.4%), stickleback (74.9%) and zebrafish (68.3%). RT-PCR showed that *v2b* mRNAs encoding this receptor are present at highest relative levels in the brain, heart and testis of pupfish. This contrasts with the distribution of *v2a* receptor gene transcripts, which are at greatest abundance in the pituitary gland, gills, heart, kidney and ovary. Although the functional role of this V2b V2-type AVT receptor remains unclear at present, the evolutionary diversity of AVT receptors in fishes suggests a high potential for the evolution of AVT action via receptor-specific function.

P1.3 WANG, DL*; PAPAJ, DR; The University of Arizona; *wangd2@email.arizona.edu*

The role of larval dietary carotenoids in an adult butterfly's vision and nectar-foraging behavior

Vision is a key sensory system for many animals. For vision to occur, light-detecting photopigments in the eye must trigger a downstream neurological cascade. Carotenoids such as beta-carotene are precursors to such photopigments. However, animals cannot synthesize carotenoids *de novo* and must obtain them from their diet. Due to drastically different mouthparts as larva and adult, holometabolous insects such as butterflies are restricted to obtaining dietary carotenoids in their larval life stage. As such, their adult vision is a product of their larval diet. Although some is known about the physiological effects of larval dietary carotenoids on adult vision, little is known about the effects on visually-mediated behaviors such as nectar-foraging. Here, we rear larvae of cabbage white butterflies, *Pieris rapae*, on standard and carotenoid-fortified diets to determine the effects of larval dietary carotenoids on adult visual carotenoid levels, visual sensitivity, and color preference in a nectar-foraging context.

P2.84 WARGELIN, LJ*; MASSEY, K; BOWLING, M; YOUNG, RS; BOUCHARD, SS; Otterbein University; *sbouchard@otterbein.edu*

Carryover effects of larval density on body composition, growth, and feeding in Gray Treefrogs, Hyla versicolor, post-metamorphosis.

Amphibian larval environments can have important effects on individuals post-metamorphosis. We studied the effects of larval density on froglet condition, growth and feeding in Gray Treefrogs, *Hyla versicolor*. Larvae were reared at high, medium and low densities in 410 L mesocosms. Each mesocosm was supplied with the same amount of algal food, such that food availability varied with treatment. Larvae were photographed and measured with image analysis software to determine growth rates. Upon emergence from mesocosms, froglets were weighed and measured. They were either euthanized for percent dry matter and ash determinations or placed in individual aquaria where they were maintained on insects to investigate feeding and growth. Euthanized froglets were dried at 65 °C and then ashed at 500 °C. All feces were collected for two weeks from maintained froglets, and intake was determined by counting insect head capsules in feces. Larvae reared at high densities grew significantly slower and metamorphosed later than those reared at low densities. Froglets emerging from high larval densities were one third the mass of those emerging from low densities. Their bodies were also significantly lower in percent dry matter (11.5 vs. 14.3 %) and percent ash (78.3 vs. 83.8 %). High density froglets began producing feces 3.5 days later than low-density froglets (8.1 vs. 4.7 days). However, high-density froglets grew by 58% during the four weeks post-metamorphosis, whereas low-density froglets did not grow appreciably. These results suggest that while low larval food resources initially reduce froglet quality, froglets may maintain the capacity to compensate with accelerated growth post-metamorphosis.

70.5 WARNE, R. W.; KIRSCHMAN, L. J.*; CRESPI, E. J.; BRUNNER, J. L.; Southern Illinois University, Washington State University, Washington State University; *l.j.kirschman@siu.edu*

STRESS EFFECTS ON IMMUNE FUNCTION AND DISEASE EMERGENCE IN AMPHIBIANS

Environmentally induced stress is thought to be a key driver of emerging disease in wildlife populations, however, the mechanistic links between stress, vertebrate immune function and epidemic outbreaks are not well tested. The physiological stress response regulated by the hypothalamus-pituitary-interrenal (HPI) axis and the expression of glucocorticoid hormones is likely central to disease dynamics. While chronic stress and activation of the HPI axis is often immunosuppressive, acute stress can have a positive effect on immune function by stimulating the inflammatory response and lymphocyte production. In this experiment, we tested the effects of experimentally induced physiological stress on the immune response and susceptibility of wood frog larvae *(Lithobates [Rana] sylvaticus)* to *Ranavirus*. *Ranavirus* (family Iridoviridae) are directly transmitted, often lethal viruses of ectothermic vertebrates that cause mass die-offs and may contribute to the risk of extinction in amphibians throughout the United States and the globe. Through experimental acute or chronic exposure to exogenous corticosterone and immunohistochemistry staining for splenocyte proliferation we explore the effects of stress on amphibian immune responses, susceptibility and survival to ranavirus infection.

88.2 WARNER, S E*; HENRY, V; HUTCHINSON, J R; Royal Veterinary College; *swarner@rvc.ac.uk*

Regional pressure changes in the digital cushion under vertical load in elephants and horses.

It is difficult to determine how externally applied locomotor loads affect internal foot mechanics, however the digital cushion (DC) in terrestrial animals is commonly associated with distributing and thus reducing pressures as a result of locomotion. Considering that the DC of horses is relatively small and rigidly confined compared to the DC of elephants, we used these two extreme, specialized morphologies to compare regional changes in (DC) pressure under load, focusing on forefeet. We hypothesized that under similar loads, pressures would vary with location and be greater in horse feet. We used standard invasive blood pressure monitoring equipment to measure cadaveric DC pressure in four locations under vertical loads representing 0%, 30%, 60% and 100% body weight (BW) in 6 adult specimens of mix-breed horses and 6 Asian elephants. We found that internal pressures increased under load and varied with location ($p < 0.05$). Surprisingly, under similar “standing” loads (mean ± SD; 27.8 ± 8.4 % BW and 29.6 ± 5.9 % BW), pressures were higher in the elephant DC (median ± IQR; 4.3 ± 4.8 mmHg) than in the horse DC (3.8 ± 1.5 mmHg), although these differences were not statistically significant. Regardless, the heterogeneous internal pressures we observed support the inference that the DC acts more like a compressible solid than an incompressible fluid under vertical loading conditions. Considering that high pressures may be related to the development of pathology, determining how internal structures such as the DC respond to locomotor loading is essential to understanding foot health and pathology.

P3.8 WARRAICH, T.N.*; WYNEKEN, J; Florida Atlantic Univerisity, Florida Atlantic University; *tnwarraich@gmail.com*

feeding behavior of loggerhead (caretta caretta) and leatherback (dermochelys coriacea) sea turtles: a model to understand bycatch

Loggerhead (Caretta caretta) and leatherback (Dermochelys coriacea) turtles are two species of sea turtle caught most frequently as bycatch in longline fishing which uses many hooks baited with fish or squid. The leatherback feeds primarily on gelatinous zooplankton while the loggerhead is a carnivore. Hence, the attraction and capture of loggerheads is not surprising but the attraction and capture of leatherbacks is somewhat unexpected. We investigated the responses of these two species to bait odors in controlled laboratory experiments to better understand releasers of feeding behavior. We measured and compared the responses to olfactory cues. Previous studies quantified and compared feeding responses include increased diving, biting, gaping, accelerated or diminished swimming speed, and altered swimming behavior. The two species share some behavioral components but others were species specific. Our comparative study highlights the differences in the two species, unexpected similarities, and suggests aspects of their behavior that may predispose them to accidental capture in fisheries.

P1.73 WATERS, S P*; LEONARD, K; PORTER, M E; LONG, J H; LIEW, C W; ROOT, R G; Lafayette College, California State University, Channel Islands, Vassar College, Vassar College; *waterss@lafayette.edu*

Automated Shape Modeling for Undulatory Swimmers Using Blum’s Medial Axis

The swimming patterns of undulatory swimmers can be modeled by tracking changes in their medial axis. In the past, the process for extracting this axis from video consisted of time consuming manual analysis. Our research proposes to optimize collection of medial axis data via a mathematical model of the image. By identifying the outline of the swimmer in a video frame, we identify the medial axis through a series of computations based on the concept of a medial axis as first described by Blum. The algorithm depends upon two parameters, the rate at which outline points are chosen for inclusion in the computation, and the size of the contour ratio associated with each candidate medial axis point, and through these parameters, the algorithm can be applied flexibly in a wide array of video. To demonstrate the utility of the technique, we apply it to video clips of swimming fish of several species in a variety of situations.

19.3 WATERS, JS*; HARRISON, JF; Princeton University, Arizona State University; *jswaters@princeton.edu*

Metabolic and behavioral variation with colony size and age: a manipulative test of the size-dependence theory of metabolic allometry

The nonlinear relationship between animal metabolic rates and their body size is a “many-splendored thing” and the mechanistic basis for this relationship, if one exists, is highly controversial. One of the challenges in empirically testing the predictions of hypotheses regarding an organism’s size is that the necessary manipulations are likely destructive. Colonial organisms, including marine ascidians, encrusting bryozoans, and terrestrial social insects, are composed of functionally integrated modular subunits, making them ideal systems to study across a range of artificial sizes. We investigated the relationship between metabolic rate and colony size for a set of laboratory reared *Pogonomyrmex californicus* seed harvester ant colonies. Repeated measures of metabolic rates and patterns of behavior were conducted with minimal disruption to the social milieu of the nests by maintaining entire colonies within enclosures designed for flow-through respirometry and video analysis. Same-aged colonies ranging in mass from 0.32-1.7 grams were measured before and after a manipulation of their size to include only half of their workers, larvae, and pupae. Both sets of measurements, before and after manipulation, revealed metabolic hypometry and moreover, there was a significant increase in the mass specific metabolic rate of the manipulated colonies. Investigating the scaling of locomotory activity and interaction network structure among the workers within these colonies may help to identify the mechanistic basis for the size-dependence of their metabolic rates.

68.4 WATTS, H.E.*; VILGALYS, T.P.; Loyola Marymount University, Los Angeles, CA; *hwatts1@lmu.edu*

Shifts in reproductive timing in house finches in relation to temperature

Changes in phenology - the timing of seasonal activities of plants and animals - as a consequence of global climate change are now well documented. Among birds, advances in the timing of migration and advances in the initiation of reproduction have been reported across a range of species and geographic locales. In this study, we first use nest records to document advances in the timing of termination of reproduction among free-living house finches (*Carpodacus mexicanus*) in California over the past century, and find that this change in timing corresponds with increasing ambient temperatures in the area over the same period. We then test experimentally the hypothesis that warmer temperatures directly advance termination of breeding in house finches. Male house finches were captured in April and housed under two different temperature regimes, simulating cooler (mean max = 23.5°C) and warmer (mean max = 30.6°C) summer temperatures. We found that males in the warmer treatment transitioned from reproduction to molt earlier than did males in the cooler treatment. Our results suggest that observed changes in reproductive timing in free-living house finches may be due, at least in part, to warmer summer temperatures.

94.1 WEBB, JF*; GILLIS, JA; University of Rhode Island and MBL, Woods Hole, Dalhousie University and MBL, Woods Hole; *jacqueline_webb@mail.uri.edu*

Lateral Line Morphogenesis in Chondrichthyan vs. Osteichthyan Fishes: New Perspectives on an Old Problem

The morphology of the lateral line system (LL) differs significantly in chondrichthyan and osteichthyan fishes, so we hypothesized that the pattern of its development would also be distinct in these two gnathostome lineages. We have shown that in the little skate (*Leucoraja erinacea*), migration/elongation of LL placode-derived primordia, differentiation of neuromasts, and morphogenesis of LL canals are not discrete, sequential processes as in bony fishes. SEM revealed that the surface of the shallow grooves that define the paths of the migrating/elongating LL primordia on the head and trunk is characterized by small epithelial cells with dense apical microvilli. We used CM-DiI to trace the fate of LL placode-derived cells (from the anterodorsal and posterior placodes) to clarify the relationship between the LL primordium, microvillous epithelial cells, and the unique longitudinal pocket associated with LL development on the trunk (Johnson, 1917). DiI+ placode-derived cells were found below the microvillous epithelial cells found in the cranial grooves and rostral to the entrance to the pocket and below the epithelial cells that line the pocket on the trunk. Gillis et al. (2012) had shown that LL placode-derived cells contribute to neuromasts and canal walls in older embryos. Thus, we hypothesize that placode-derived cells found below the epithelium subsequently intercalate among the microvillous cells and differentiate into the hair cells of the canal neuromasts and the cells of the walls of the lateral line canals. An on-going analysis with finer temporal resolution will allow an accurate description of the processes of neuromast differentiation and canal morphogenesis in chondrichthyan fishes. Supported by URI (JFW) and a Allen/Bang/Colwin Summer Research Fellowship from the MBL, Woods Hole (JAG).

P1.124 WEBER, C.J.*; VON DASSOW, M; University of Washington, Seattle, Duke University Marine Lab, Beaufort, NC; *ceriw@uw.edu*

Environment and the mechanics of development: effects of salinity on the sand dollar blastula

Organisms can develop normally and thrive in dynamic environments. The interplay between the environment and the biomechanics of morphogenesis can help us understand how development operates in a changing world. Effects of salinity on blastula expansion in the sand dollar *Dendraster excentricus* were used to investigate interactions among the environment, development, and mechanics. Salinity fluctuations, which are common in *Dendraster*'s habitat, affect embryonic cell size. The hyaline layer, an extracellular matrix layer closely associated with the outside of the blastula, is hypothesized to resist blastula expansion. Four models describing how the hyaline layer responds to blastula expansion were compared. In three models the hyaline resists expansion as either an elastic, plastic, or viscous layer. In these models, salinity-driven changes in cell size were predicted to cause changes in the ratio of blastocoel volume to cell volume. In a fourth model, the hyaline is a perfectly accommodating layer that allows the embryo to expand freely as cells divide in a single layer. In this model, salinity changes were predicted not to affect the blastocoel-to-cell-volume ratio. To test these hypotheses, *Dendraster* embryos were placed in either 25‰ or 32‰ seawater wells and switched to wells of either the same or the other salinity. In a second experiment, *Dendraster* embryos were raised in 32‰ seawater until the 16-cell stage, at which point a subset of embryos were moved to 25‰ seawater for one cleavage stage and then moved back to 32‰ for the duration of the experiment. In both experiments blastocoel-to-cell-volume ratios were not affected by the salinity treatment. These results suggest that the hyaline layer does not resist blastula expansion in *Dendraster*, thereby maintaining a constant blastocoel-to-cell-volume ratio.

P3.20 WEHRLE, BA*; ESPINOZA, RE; California State Univ., Northridge; *bwehrle@uci.edu*

Lounging lizards and gut bugs: Testing the role of the social aggregations for transferring digestive microbes

Why sociality evolves is poorly understood, but both biotic and abiotic factors have been implicated. Sociality may have evolved in some herbivorous reptiles to aid the transfer of gut microbes. These endosymbionts are needed to digest plant fiber and the fermentation products contribute greatly to the host's energy budget, but this symbiosis is poorly understood. Green Iguanas (Iguana iguana) are herbivorous throughout life, yet hatch with sterile guts. So how do they acquire their gut microbes? Although rare in lizards, social interactions are a hypothesized route of microbe transfer via direct contact and/or eating conspecifics' feces. Early attempts to characterize this microbial community in iguanas provided crude measures of microbial turnover. Our study is the first to characterize the spatial, temporal, and social variation of these microbial communities using modern genomic techniques. We hypothesize that microbial communities will be more similar within sites, diversify over time, and will vary with social grouping. We observed and marked juvenile iguanas in social lounges at nine sites on and around Barro Colorado Island, Panamá over two reproductive seasons. Of the 540 focal observations, 38% were of social aggregations (mean = 2.9 lizards/group), yet very few were intergenerational interactions (0.7% of observations). Hatchlings in groups averaged 1.2 m from their nearest neighbor, although densities varied among sites. We collected hindgut microbe samples from iguanas over the first 60 days post-hatching. Microbe-specific DNA was isolated from samples and high-throughput sequenced to characterize the gut microbe communities of iguanas over space, time, and with respect to observed social interactions. We predict that microbial communities will be most similar among proximate hatchlings and will increase in diversity with lizard age.

P1.31 WEISS, A.K.*; PAKES, M.J.; LINDBERG, D.R.; Univ. of California, Berkeley; *ameliakw@berkeley.edu*

Abiotic influences on the distribution and abundance of tropical cave-dwelling Macrobrachium spp.

Our understanding of factors controlling species distributions within tropical cave ecosystems is limited. This study is the first to investigate aquatic macrofauna distributions and abundances in a Panamanian cave system. We surveyed the abundances of varying size classes of shrimp, *Macrobrachium* spp., as well as their vertebrate and invertebrate predators, along an 864m cave passage. Changes in abiotic characteristics, such as current velocity, water depth, salinity, dissolved oxygen content and substrate type, as well as human traffic, were examined along this transect. Correlations were found between changes in community composition and changes in the physical environment.

90.1 WELCH, A.M.; College of Charleston, SC; *welcha@cofc.edu*

Anthropogenic stressors and the evolutionary potential of amphibian populations

Virtually all habitats on Earth have been affected by human activities. Understanding and mitigating the ecological consequences of anthropogenic habitat modification require addressing how multiple stressors interact to affect the long-term viability of populations. In addition to diminishing population numbers, exposure to anthropogenic stressors can lead to the evolution of increased tolerance via natural selection. However, the evolution of tolerance to one stressor may compromise a population's ability to tolerate or adapt to different stressors in the future. To address how natural selection imposed by different stressors may impact a population's evolutionary potential, I investigated genetic variation in tolerance to two different stressors as well as the genetic correlations between tolerances to these different stress regimes. Southern toad, *Anaxyrus terrestris*, tadpoles from a series of half-sibships were subjected to increased salinity, the common insecticide carbaryl, both, or neither, and genetic variances and covariances were estimated. If tolerance to different stressors is genetically correlated, adaptation to one stressor should lead to improved tolerance to the other stressor. On the other hand, if tolerance to one stress regime is not genetically correlated with tolerance to another, then the reduction in genetic variation that occurs as a population adapts to one stressor would make it more difficult to evolve tolerance to future stressors, putting the population at further risk. Because anthropogenic stressors are and will continue to be an important part of many habitats, the long-term persistence of populations will depend on how these stressors influence not only population sizes but also a population's ability to respond adaptively to future stressors.

P1.4 WELKLIN, J.F.*; REICHARD, D.G.; KETTERSON, E.D.; Indiana Univ.; *jwelklin@indiana.edu*

Low-amplitude song: a meta-analysis of its prevalence and functions in North American birds

Research on birdsong has focused primarily on species' high amplitude, long-range songs. Yet, the vocal repertoires of many avian taxa extend beyond those signals that are easily recognized from a distance by the human ear, and attention has recently turned to more enigmatic, low-amplitude vocalizations. Researchers studying the functions of these songs and calls have largely interpreted them as mediating aggression between males. However, males also produce low-amplitude vocalizations while interacting with females, raising the possibility that these songs may serve multiple functions including courtship, depending on the species sampled. Using the Birds of North America Online Archive, we performed a systematic search for evidence and presumed functions of low-amplitude vocalizations in the accounts of 749 bird species known to breed in North America. Using keywords such as: soft, quiet, low-amplitude, whispered, and strangled, we discovered 122 species that sing low-amplitude songs, and 301 species that produce low-amplitude calls. Of these 423 species, presumed courtship or territorial functions were reported for 138. Further, we found that more than twice as many species produce low-amplitude songs in male-female contexts (31 species) as compared to male-male contexts (12 species). These data suggest an important role for low amplitude vocalizations in courtship. Given how few low-amplitude vocalizations have a known function, and how even fewer of these functions are supported by experimental evidence, our survey highlights the need for future work investigating the occurrence and function of low-amplitude vocalizations. It also suggests that contrary to the current view favoring an aggressive function for low-amplitude songs, their role in courtship merits more attention.

P2.133 WELSH, C.*; BESS, F.; CATAPANE, E.J.; CARROLL, M.A.; Medgar Evers College; *catapane@mec.cuny.edu*

Presence of Octopamine and Octopamine Receptors in Ganglia and Tissues of Crassoatrea virginica

Octopamine (OA) biogenic amine first identified in octopus has been well studied in arthropods and gastropods being a neurotransmitter and hormone. OA has rarely been reported in bivalves. Using HPLC and ELISA we showed it present in ganglia and tissues of the oyster *Crassostrea virginica*, the mussel *Mytilus edulis*, and the clam *Mercenaria mercenaria*. We found it cardio-excitatory in oyster and mussel, but cardio-inhibitory in clam. To localize OA and OA receptors in tissues we used immunohistofluorescence. We used pan TAAR 1° antibodies, which are reactive to OA, beta-phenylethylamine, p-tyramine and tryptamine receptors, but not to classical biogenic amines and histamine receptors, and visualized with FITC conjugated 2° antibodies. Tissues were fixed with paraformaldehyde, treated with 1° and 2° antibodies, paraffin embedded, sectioned and viewed with a Zeiss epilume fluorescence microscope. To detect OA we used anti-OA 1° antibody (OA conjugated to KLH), and visulaized with FITC conjugated 2° antibodies. Tissues were fixed with EDAC (1-ethyl-3(3-dimethlyaminopropyl) carbodiimide), treated with 1° and 2° antibodies, and either paraffin embedded and sectioned, or frozen, cryostat sectioned and viewed. The TAAR antibodies revealed OA receptors in cerebral and visceral ganglia, heart, gill, adductor muscle and digestive tract. OA antibodies revealed OA in cerebral and visceral ganglia, heart and blood cells in the gill blood channels. The study demonstrates the presence of OA receptors and OA in ganglia and organs of the oyster. The distribution of the OA fluorescence as well as previous HPLC data suggests it may be a hormone in the animal as it appears to be very wide-spread.

130.2 WEN, L*; LAUDER, G.V.; WEAVER, J.C.; KOVAC, M; WOOD, R.J.; Harvard University; *liwen@oeb.harvard.edu*

Hydrodynamics of Self-propelling Flexible Synthetic Shark Skin Membranes

Through the studies of man-made materials, considerable effort has been made to understand how the morphological features of shark skin may reduce static hydrodynamic drag. However, no study has yet quantitatively examined the hydrodynamics of micro-fabricated synthetic shark skin with controllable denticle morphology and mechanical properties, especially under conditions of dynamic deformation. We present the first study of the design, fabrication, and hydrodynamics of a synthetic, flexible shark-skin membrane which is capable of bending like the skin of a swimming shark. The 3-D model of the denticles was based on micro-CT reconstruction of the skin of the shortfin mako (Isurus oxyrinchus). Using 3-D printing, thousands of rigid synthetic shark denticles were placed on flexible membranes in a controlled, non-random pattern. These skin-model membranes were actuated at the leading edge in a heave and/or pitch motion using a robotic device, allowing the undulating membranes to swim at their self-propelled speed. Additionally, digital particle image velocimetry (DPIV) was used to understand how flow modification occurs in the near-surface region and the surrounding area of the undulating membranes. Hydrodynamic results, including self-propelled swimming speed, power consumption and wake flow, were quantitatively compared with those of a smooth membrane without surface denticles. Beyond broadening our understanding of the biomechanics of shark skin, the results of this study may be employed to optimize designs of human swimsuits, gas-transmission lines, and the propulsive performance of biomimetic swimming robot etc.

53.4 WERNING, S; Univ California, Berkeley; *swerning@berkeley.edu*

Osteohistological differences between marsupials and placental mammals reflect both growth rates and life history strategies

Bone microstructure is influenced by many factors, including body size, growth rate, and phylogeny. The literature acknowledges no great differences between marsupial and placental bone histology, leading some to infer a common histological signature for therian mammals. Histological similarity is reasonable for small marsupials and placentals (< ~40g), which have similar growth rates and durations, but larger marsupials grow at lower rates and delay epiphyseal fusion for several years compared to placentals of similar body size and ecology. Given these growth differences, larger marsupials should show histological evidence of extended slow growth, contrasting the fast-growing bone tissues described for placentals. However, the mammalian osteohistological sample is biased toward placentals of economic importance, and only two marsupials have been usefully described. I sampled the mid-diaphyseal femora of 42 extant and extinct marsupial species, as well as afrotherian, xenarthran, and laurasiatherian placentals. My marsupial sample encompasses all extant orders, spans a 10g-2500kg size range, and comprises mainly wild-caught animals. Small therians do show a common histology of nearly avascular lamellar bone. Marsupials >50g typically produce well-vascularized woven bone early in life, but after 1-2 years deposit poorly vascularized lamellar bone for several years. This pattern also occurs in afrotheres (except elephants), xenarthrans, *Solenodon*, and bats; but differs from those of the large-bodied ungulates (exclusively well-vascularized woven bone) and primates (heavily remodeled bone) that dominate the literature. I propose that the first condition is plesiomorphic for therians, and that sampling biases have obscured both size and phylogenetic signals in the distribution of mammalian bone growth patterns.

S4-1.4 WHEAT, Christopher W; Univ. of Helsinki, Finland; *chris@christopherwheat.net*

RNA-seq for ecologists - fundamentals and practicalities

Recent advances in DNA sequencing now provide unprecedented access to the transcriptome of any species. However, extracting informative quantitative expression insights is challenging, especially for the ecological researcher. Why? 1) The studied organism is not likely to have a well assembled genome or the gene models needed by many software programs for mapping RNA seq reads. Although the transcriptome can be assembled and used as a scaffold for mapping, generating a high quality transcritpome is a very challenging endeavor. 2) Researchers are likely to be focused upon complex phenotypes arising from expression variation that is much weaker than disease phenotypes such as cancer, etc., necessitating statistical approaches that leverage functional information. 3) Obtaining functional annotation is challenging, especially in the context of gene family dynamics and alternative splicing. During my presentation I will address each of the 3 issues, using data from butterflies to humans to illustrate these points and how steps can be taken to circumvent them.

P2.158 WHEELER, J.D.*; ANDERSON, E.J.; HELFRICH, K.R.; MCGANN, B.J.; MULLINEAUX, L.S.; Woods Hole Oceanographic Institution (WHOI), Grove City College, WHOI, WHOI; *jwheeler@whoi.edu*

Vertical swimming and diving behaviour of competent larval oysters (Crassostrea virginica) in turbulence

Investigating settlement responses in the transitory period between planktonic and benthic stages of invertebrates helps shape our understanding of larval dispersal and supply, as well as early adult survival in seafloor habitats. Turbulence is a physical cue which has been shown to induce sinking and potentially settlement responses in mollusc larvae. In this study, we observed swimming behavior in competent larval eastern oysters (*Crassostrea virginica*) in a grid-stirred turbulence tank, with the following objectives: 1) to isolate and quantify the behavioural component of larval vertical velocity (relative to the surrounding flow) using particle image velocimetry, 2) to determine if larval vertical velocity varies with turbulence level, and 3) to identify a dive response and determine if it increased in frequency in highly turbulent flow. Interestingly, we found that oyster larvae continue to swim upwards even in levels of turbulent flow comparable to estuarine and coastal surf zone habitats. The dive response decreased significantly in frequency with increasing turbulence. We determined that it was critical to track larvae and flow simultaneously, and subtract the local flow, in order to quantify accurately the population-level responses in larval vertical velocity.

P3.18 WHITE, M.; ANDREWS, K.*; TIERNEY, A.J.; Colgate University; *atierney@colgate.edu*

Dear Enemies and Nasty Neighbors in the Crayfish Procambarus clarkii

The dear enemy effect predicts that territorial animals will respond less aggressively to neighbors compared to strangers. In contrast, there is also a proposed nasty neighbor effect in which familiar conspecifics pose a greater threat than strangers and are hence treated more aggressively. The dear enemy effect has recently been reported in crayfish and used as a measure of individual recognition. Our experiment explored if the crayfish *Procambarus clarkii* demonstrates dear enemy or nasty neighbor effects, and the role of social status and sex in either behavior. Pairs of size and sex matched crayfish fought to establish social status and the resulting dominant and subordinate crayfish then participated in a choice phase in which they interacted with two conspecifics tethered in an arena. Both choice conspecifics had the same social status and sex, but one was familiar (the focal animal's previous opponent) and the other was novel. We found that subordinate focal animals of both sexes spent significantly more time in proximity to the unfamiliar choice animal, behavior inconsistent with the dear enemy and nasty neighbor hypotheses. In contrast, male and female dominant focals differed significantly: females spent more time close to and fighting with the familiar choice animal while male dominants responded equivalently to the two choice animals. Thus the response of crayfish toward familiar and unfamiliar conspecifics was complex and not explained by a single hypothesis. We suggest that, in addition to familiarity and unfamiliarity, the perceived threat-level of opponents influences the behavior of crayfish toward conspecifics.

S9-2.3 WHITEHEAD, A.*; PILCHER, W.; MAYER, G.; DUBANSKY, B.; GALVEZ, F.; University of California Davis, Louisiana State University, Texas Tech University; *awhitehead@ucdavis.edu*

Integrative biological footprint of the Deepwater Horizon oil spill in the laboratory and field

Large populations of killifish inhabit Gulf-exposed marsh habitats that are at high risk of contamination from oil spilled from the Deepwater Horizon disaster, and are strategic models for assessing contaminating oil impacts. We conducted a field study spanning the year following the spill, integrated with controlled laboratory exposures, to characterize oil spill impacts by integrating genomic and physiological indicators of biological effects. In field studies genome expression in livers and gills of resident fish was tracked across space and time. Genome expression was most distinct at the only field site out of six that was clearly impacted by oil, and at the peak of oil contamination documented by satellite imagery and analytical chemistry, showing a clear genomic footprint of oil exposure. Divergence in genome expression that coincided with contaminating oil is consistent with genome responses that are predictive of exposure to hydrocarbon-like chemicals and suggestive of physiological and reproductive impairment, and coincide with significant impacts on tissue morphology. Genome expression responses following exposures to oil in the laboratory were predictive of the responses observed in the field, and coincided with damage to the DNA molecule. These data confirm that marsh fish were exposed to the toxic components of contaminating oil in the field, highlight mechanisms underlying exposure responses, and contribute to forming hypotheses about how other natural estuarine stressors may interact with oil to affect organismal resilience in nature.

96.5 WHITEHILL, E.A.G.*; MORAN, A.L.; Clemson Univ.; *whitehi@clemson.edu*

Using energetics of sea urchin development to examine the temperature-size rule

Temperature is one of the most important environmental parameters that organisms experience. Physiological processes such as metabolism are strongly affected by temperature, and temperature-driven changes in metabolic processes can affect how an organism expends and stores energy. Most ectotherms grow to larger sizes when reared at lower temperatures, an effect known as the temperature-size rule (TSR); the TSR may be driven by differential effects of temperature on energy utilization and acquisition. To investigate this hypothesis, we reared larvae of the sea urchin *Lytechinus variegatus* through metamorphosis at 23, 27, and 30°C and measured size (body length), energy consumption (algal cells consumed), energy expenditure (respiration, ammonia excretion), and energy accumulation (changes in biochemical content) at multiple developmental stages. We found that larvae and juveniles reared at 23°C were larger and had more protein, lipid, and carbohydrate than larvae reared at higher temperatures. Animals reared at 23°C also had greater food intake and reduced energy expenditure. Together these data suggest that the TSR may be driven by increased food intake and decreased energy expenditure at lower temperatures. Also, juveniles which metamorphosed from larvae reared at 23°C had lower mortality rates; this suggests that increases in sea temperature may negatively affect marine invertebrates by lowering the quality of both larvae and juveniles, which in turn could affect recruitment into adult populations.

P2.157 WHITEHILL, E.A.G.*; MORAN, A.L.; Clemson Univ.; *whitehi@clemson.edu*

Energy utilization by nonfeeding larvae is affected by rearing temperature

Temperature can have a strong effect on many physiological processes. For ectotherms, environmental temperature is positively correlated with both metabolic rate and energetic output and is negatively correlated with developmental rate. Many marine taxa have lecithotrophic larvae that do not feed, and we do not know if temperature will affect energy utilization in these taxa, therefore affecting larval and juvenile quality. To determine how rearing temperature affects the energetics of nonfeeding larvae, we reared larvae of the facultative planktotroph *Clypeaster rosaceus* through metamorphosis without food at 23, 27, and 30°C. At multiple developmental stages we measured size, oxygen consumption, protein, lipid, and carbohydrate content, and ammonia excretion. Temperature affected both metabolic rate and larval duration, thus affecting the total amount of energy required to develop from egg to juvenile both directly and indirectly. Larvae and juveniles reared at 27°C were larger and contained more protein and lipid than larvae reared at 30°C. Energy expenditure was lowest at 27°C when summed over development. Larvae reared at 23°C took much longer (2x) to reach metamorphosis, and so despite lower (1-3x) metabolic rates, they consumed more egg energy over development and contained less protein and lipid after metamorphosis. Together these data suggest that the effect of temperature on lecithotrophic larval and juvenile quality will depend on the relative temperature-sensitivities of metabolism and developmental rate over the range of temperatures an organism experiences. At the lower end of a species' temperature range, development of nonfeeding organisms may be extended to the point where net energy expenditure increases and juvenile quality is compromised; however, in the optimum temperature range, juvenile quality may be enhanced.

P2.50 WHITENACK, LB*; RYERSON, W; Allegheny College, University of Connecticut; *lwhitena@allegheny.edu*
Thermal effects on jumping kinematics in plethodontid salamanders
Many plethodontid salamanders must endure a wide range of environmental temperatures, yet still be able to escape and feed despite the strong effects of temperature on muscle function and performance. On the other hand, ballistic movements, which rely more on elastic recoil of structures, have been found to be thermally independent. Jumping is typically described as a ballistic movement powered by elastic recoil of structures loaded by muscle contractions, and is used by plethodontid salamanders as a means of escape. We examined jumping behavior in *Plethodon cinerus* and *Desmognathus ochrophaeus* across a temperature range of 5-25°C in order to understand how the jump is affected by temperature and to elucidate muscular versus elastic contributions to jump mechanics. Salamanders were filmed at 500 fps jumping over a 5 cm gap, with five trials per temperature (5, 15, 25°C) per individual. Q10 (or R10) values were calculated for bending and unbending angular change, durations, and angular velocities. Preliminary results indicate that the while the much of the bending kinematics were unaffected by changes in temperature, unbending duration and velocity were significantly higher than 1 (Q10 = 1.6 and 1.4 respectively), suggesting that jumping in plethodontids may not be powered by elastic recoil as it is in other organisms.

103.1 WHITENACK, LB*; HERBERT, GH; BERT, T; Allegheny College, Univ. of South Florida, Florida Fish and Wildlife Conservation Commission; *lwhitena@allegheny.edu*
Handedness and predation success in the stone crab Menippe mercenaria-adina
The stone crab *Menippe mercenaria* possesses dimorphic claws, typically with a large, molar-tooth bearing, right crusher claw for breaking shelled prey and a smaller, left pincer or cutter claw for holding and stabilizing prey . While the majority of *M. mercenaria* hatch this way, molting errors, limb autotomization, and removal of crushing claws by fisheries can lead to reversed handedness after a number of subsequent molts. A major food source for *M. mercenaria* is the gastropod *Strombus alatus*, which has a right-handed or clockwise coiling direction. To investigate whether and how fisheries-induced handedness changes in stone crabs mightinfluence feeding interactions with right-handed coiling gastropod prey, we assessed experimentally whether right versus left-handed *M. mercenaria-adina* hybrids differed in prey handling behaviors and predation success on *S. alatus*. Preliminary results indicate that left-handed crabs had similar feeding success than right-handed crabs as estimated by numbers of prey “kills,” but their attacks resulted in less damage to *S. alatus* shells and less access to prey tissues . Energy gain per successful attack may, therefore, be less in left-handed stone crabs relative to their right-handed counterparts. The prevalence of certain types of damage differed as well; right-handed crabs tended to damage the shell ornamentation and siphonal canal more often, while left-handed crabs clipped the spire more often.

P3.197 WHITNEY, M*; CURRY ROGERS, K; BAGLEY, B; Macalester College, University of MInnesota; *rogersk@macalester.edu*
Bone Histology and Primary Growth Rates in Hatchling Titanosaurs from Madagascar: New Insights from Micro-Computed Tomography
The smallest post-hatching juvenile sauropods are only a little less than half of known adult size and leave details of the earliest stages of sauropod ontogeny poorly understood. Here we report on two partial skeletons of hatchling *Rapetosaurus krausei*, a titanosaur from the Upper Cretaceous Maevarano Formation of Madagascar, that provide new data on primary early stage growth rates in sauropods. The skeletons come from two localities and greatest length ratios for appendicular elements confirm that there are only two individuals present, that there is no significant allometry in *Rapetosaurus* postcranial ontogeny, and that each individual is less than 15% adult size. The smaller specimen includes sacral and caudal vertebrae, pubis, femur, tibia (12.7 cm long), fibulae, metatarsal I, humeri, metacarpal III, and a phalanx. The larger specimen includes caudal vertebrae, tibia (17.9 cm long), and metacarpals I and IV. We employed an X5000 high-resolution dual-head 225kV microfocus X-ray CT system located in the Department of Earth Sciences, University of Minnesota to garner bone histological data on earliest stage growth rates in these juveniles. We achieved an effective pixel pitch of 36 – 48 microns for the larger samples and 14 – 28 microns for sub-volumes. We collected 2-D radiographs and reconstructed these data to produce a 3-D volume for visual analysis and slices of the 3-D volume for quantitative analysis. Primary bone growth in *Rapetosaurus* is highly vascularized woven and fibrolamellar bone with mid-diaphyseal remodeling. These results support the hypothesis that intensive remodeling observed in the bones of older juvenile *Rapetosaurus* may be dictated, at least in part, by resource limitations during periods of drought/ecological stress recorded in the Maevarano Formation.

P2.160 WHITTEMORE, SB*; MORRIS, K; MEDLER, S; SUNY Fredonia, University at Buffalo; *scott.medler@fredonia.edu*
Stride Frequency and Body Size in Running Ghost Crabs
Body size has a major impact on the skeletal muscles that power locomotion. Smaller animals operate with higher frequencies of limb and body movements, and the muscles driving these movements have correspondingly faster contractile properties. In mammals, interspecific comparisons show that smaller species possess myosin heavy chain isoforms with faster shortening velocities than their orthologs in larger species. Ghost crabs exhibit similar shifts in stride frequency as they grow from small crabs into larger animals. Does the slowing of contractile kinetics reflect a fundamental shift in muscle organization, similar to that observed among mammalian species? Or, do changes in relative body proportions that accompany increases in scale drive the slowing of stride frequency? We studied ghost crab running performance in animals representing a 50-fold range in body mass, and related this performance to changes in body dimensions and relative mass. As we have found previously, stride frequency systematically declines in larger crabs, with frequency being proportional to mass$^{-0.15}$. Another consequence of changes in scale is that the relative load of the crabs increases as they grow larger. This stems from the fact that mass increases more rapidly than the cross section area of muscles as crabs grow larger. We tested the hypothesis that increases in relative load cause a slowing of stride frequency by attaching weights to crabs and measuring their stride frequencies. Crabs carrying an extra 15% of their body mass showed no slowing of stride frequency, indicating that the relative load carried by the crabs during running does not limit their performance. Although body dimensions have an important impact running performance, we predict that size-related changes in stride frequency are affected by reorganization of the muscles at the cellular and molecular levels.

P2.53 WIGTON, R/A*; BARTOL, I/K; Old Dominion University; *rachelwigton@gmail.com*
Hydrodynamic and kinematic turning performance of brief squid Lolliguncula brevis
Squid locomotion is complex and involves integration of a pulsed jet and paired fins. While fin and jet propulsion have been studied in squids during steady rectilinear swimming, little is known about how these systems are used during unsteady maneuvering, such as turning. Unsteady maneuvers are ecologically important for squids, playing roles in prey capture, predator avoidance, and navigation in complex habitats. To better understand turning performance capabilities in cephalopods, brief squid *Lolliguncula brevis* swimming in a viewing chamber and water tunnel were studied using high speed video and defocusing digital particle tracking velocimetry (DDPTV). Kinematic variables, such as swimming speed, center of rotation of turns, angular velocity, mantle angle, fin beat frequency, and funnel diameter and direction were recorded. Using DDPTV, 3D flows produced by the fins and jet during turns were also visualized and quantified. Complex fin oscillations, funnel positioning, and body orientation emerged as important factors driving tight and rapid turns, and fin flows were generally stronger than jet flows, though both the jet and fins played critical roles during maneuvering.

125.1 WILCOXEN, TE*; HORN, DJ; FLAMM, JC; GUERRA, DF; HOGAN, BM; HUBBLE, CN; HUBER, SJ; KNOTT, MH; SALIK, F; WASSENHOVE, SJ; Millikin University; *twilcoxen@millikin.edu*
Physiological and ecological impacts of bird feeding activities.
Bird feeding is a popular hobby for many Americans, with more than 55 million individuals participating in feeding annually. Though bird feeding remains a largely unregulated practice, the true value of commercial bird seed to the health of free-living birds remains unknown, although some studies have indirectly examined the influence of feeding on avian populations. Over an 18-month period, we completed a comprehensive study examining community dynamics, body condition, nutritional condition and measures of immune, reproductive, and stress physiology in twelve songbird species before, during, and after addition of bird feeders at feeder naïve sites. Comparisons were made to similar sites without feeders that were monitored simultaneously to address potential seasonal changes independent of the presence of supplemental food. Our results demonstrate that bird feeding greatly influences community dynamics and the general health state of birds, however, not all influences are positive

P3.39 WILDER, A.E.*; WELCH, A.M.; College of Charleston, SC; *aewilder@g.cofc.edu*
Effects of pesticide and salinity on sperm activity in the green tree frog (Hyla cinerea)
Increased salinity in freshwater habitats can result from anthropogenic factors such as climate change and sea level rise, use of road salts, over-irrigation and groundwater depletion. This emerging threat can affect freshwater species in both coastal and inland environments. Pesticides have also been found in freshwater environments around the globe, and can be harmful to many different aquatic organisms. Amphibians are highly sensitive to changes in their surroundings, making them good indicators of environmental quality, especially in freshwater habitats. This study examined the effects of increased salinity and a common insecticide, carbaryl, on sperm activity in the green tree frog (*Hyla cinerea*). Because amphibians have external fertilization, sperm must be able to move effectively in the water source in which breeding occurs to ensure successful fertilization. To test effects of salinity on sperm activity, we subjected *H. cinerea* sperm to levels of salinity ranging from freshwater to moderately brackish and analyzed activity using computer assisted sperm analysis (CASA). Effects of carbaryl on sperm activity were measured in a similar fashion, using concentrations ranging from zero to a dose that is beyond the expected field concentration. Mean sperm motility and velocity were both found to decrease as salinity increased. The effect of carbaryl on sperm activity appears to be less deleterious than that of salinity. These findings suggest that increased salinity in freshwater habitats could negatively affect reproductive success of *H. cinerea*. This disruption of the life cycle could lead to population declines, unless individuals are able to find more suitable breeding sites.

79.4 WILGA, C*; SAKAI, S; Univ Rhode Island; *cwilga@uri.edu*
Strain in the Hyomandibular Cartilage of Elasmobranchs
The main jaw suspensory element, the hyomandibula, determines jaw mobility in elasmobranchs and ranges from slender and posteriorly directed in wide gaped bite feeders, to block-like and laterally directed in smaller mouthed suction feeders, to slender and anteriorly directed in skates and rays, which have ventrally oriented mouths. This diversity in jaw suspension morphology and feeding style will impose different levels and type of mechanical strain in the hyomandibula when feeding. Here we measure biological load in vivo with the goal of understanding the performance of cartilaginous elements with clear morphological and kinematic differences. Sonomicrometry uses ultrasound to measure distance and is used to quantify applied biological load and function. Strain in spiny dogfish and little skates was quantified using sonometric transducers firmly glued to the ventral surface of the hyomandibular cartilage. Another transducer was sutured to cranium adjacent to the hyomandibula to record hyoid movements. Results show that strain is tensile in the hyomandibula of dogfish and increases with mouth opening during suction feeding and ventilation. Strain is lowest in normal ventilation, intermediate in heavy ventilation, and highest in suction capture. Strain during processing can be as high as that during capture. In contrast, strain is compressive in the hyomandibula of skates during biting and ventilation, with greater strain when biting. It appears that major morphological shifts in the evolution of the jaw suspension and associated changes in kinematic patterns of the feeding apparatus also show related transformations in mechanical performance and feeding style. This also supports the theory that the jaw and hyoid arches evolved from branchial arches to increase ventilation performance and then became preadapted for feeding. This technique for measuring strain can be used on many biological structures for the broadest possible comparative content.

103.3 WILLIAMS, T.M.*; LINDBERG, D.R.; Univ. of California, Santa Cruz, Univ. of California, Berkeley; *williams@biology.ucsc.edu*

Gut Instinct: Digestive Capacity and the Evolution of Extreme Carnivory in Marine Mammals

Reinvasion of the oceans by mammalian predators 30-50 MYA required fundamental changes in physiological processes and organs originally intended for terrestrial living. Such changes appear so formidable that land-to-sea transitions by mammals seem nearly impossible. To determine how ancestral mammals might have overcome these evolutionary barriers, we examined energy demand (field and resting metabolic rates) and assimilation capacity (small intestine length) along the evolutionary paths leading to land-sea transitions in carnivorous mammals. Based on daily energetic costs of 49 extant mammalian species, we find that marine living exacts a high energetic toll on carnivores. Field metabolic rate of marine mammals averaged 1.8 times that of similarly-sized terrestrial mammals and is attributed to elevated resting rates required for counterbalancing the high thermal conductivity and heat capacity of water. A pivotal characteristic for land-to-sea transitions was exceptionally long digestive tracts that resolved conflicting physiological demands for digestion, thermoregulation and diving. Intestine length to body length ratio averaged 2.6 $\pm$ 0.4 S.E. (n = 10 species) for terrestrial carnivores, 4.6 $\pm$ 0.6 S.E (n = 16) for omnivores and herbivores, and 13.2 $\pm$ 1.3 S.E. (n = 25) for marine carnivores. This trait explains the intriguing phylogenetic link between carnivorous marine mammals and terrestrial omnivores and herbivores, and how marine mammals evolved into comparatively voracious predators. This study also demonstrates that what was once an evolutionary springboard for mammalian radiations into colder, highly productive waters may now prove disadvantageous as their appetites exceed currently available oceanic resources.

45.1 WILLIAMS, T.D.; Simon Fraser Uni.; *tdwillia@sfu.ca*

Mid-winter temperatures, not Spring temperatures, predict breeding phenology and fecundity in the European starling

The current working model for control of timing of breeding suggests that day length provides reliable 'initial predictive information' for general seasonal breeding but that 'supplemental factors', especially ambient temperature (Ta), fine-tune the actual timing of egg-laying. Furthermore, theory suggests that the greater the time-lag between an organism's perception of a cue and the fitness consequences of their response, the less informative cues are likely to be. To date, most studies of timing of breeding in temperate avian species are fully consistent with this model: the time period where Ta is most highly correlated with onset of egg-laying is relatively close (< 1 month) to the population mean egg-laying date. Here I use an 11-year dataset on European starlings (Sturnus vulgaris) to show that mid-winter Ta, not Spring Ta, strongly predicts both breeding phenology and fecundity. Mean laying date was 10 April (range 5-13 April), and 80% of all nests were initiated over 2-8 days within-years. Despite this high degree of synchrony clutch size decreased significantly with date in most years. Sliding window analysis showed that a time period of 22 days from the 9 - 31 January provided the highest correlation between Ta and laying date ($r = -0.87$). Analysis of average monthly Ta data and mean laying date confirmed that laying date was independent of temperatures in February, March or April. However, January Ta was highly negatively correlated both with laying date and clutch size, i.e. when mean January Ta was colder starlings laid later, and laid larger clutches. Despite high synchrony of breeding starlings are exquisitely attuned to "date', and they appear to use supplemental environmental cues, but in a very different way than predicted by our current models.

P3.154 WILLIAMS, P.*; AKANDE, P.; CATAPANE, E.J.; CARROLL, M.A.; Medgar Evers College; *catapane@mec.cuny.edu*

Further Studies on the Sensory Motor Integration of Gill Lateral Cilia in the Bivalve Mollusc Crassostrea virginica

Lateral cilia of gill of *Crassostrea virginica* are controlled by serotonergic-dopaminergic innervation. The motor aspects have been well studied, but the sensory side has not. Here we studied effects of sensory stimulations to mantle on beating of gill cilia of *C. virginica*. Cilia beating was measured by stroboscopic microscopy. Applying Isochrysis, a food source, to mantle rim increased beating rates, whereas crab extract reduced beating rates. The response to crab extract was abolished by disrupting nervous innervation to gill by cutting the branchial nerve or detaching the mantle rim. Cutting the cerebrovisceral connective lowered basal cilia rates but crab extract still slowed beating. Stimulating mantle nerves with suction electrodes increased beating, which was not observed when the circumpallial nerve from mantle was cut. Histamine, which does not alter beating when applied to gill, decreased beating when applied to mantle. This was not seen when nervous innervation to gill or mantle rim was transected suggesting histamine maybe a neurotransmitter of mantle receptor cells that synapse with afferents going to the VG. The neurotransmitters/neuroactive substances: serotonin, dopamine, acetylcholine, GABA and FMRFamide had no effect on rates when applied to mantle rim. The study demonstrates sensory-motor integration of beating of lateral cilia that involves the sensory mantle rim and VG and cerebral ganglia. It appears animals can sense harmful cues and food, and adjust gill cilia beating appropriately. The results also suggest the sensory apparatus involved are sensory nerves that send axons to the VG, and sensory receptor cells that synapse in the mantle rim with afferent neurons.

60.6 WILLIAMS, L.E.*; DEFUR, P.L.; Virginia Commonwealth University; *lewgirl4@yahoo.com*

The Effects of River Sediment Contaminants and Moderate Hypoxia on the Blue Crab (Callinectes sapidus) in the Tidal Freshwater James River

Juvenile male blue crabs move into the freshwater James River during warmer months to feed and grow by undergoing molting. In crustaceans, growth and molting are hormonally controlled and the juvenile molting crab is a life stage sensitive to chemicals found in the James River benthos. This set of experiments looks at the effects of multiple stressors, including moderate hypoxia and sediment contaminants. The physiological effects of a multiple stressor environment are determined by comparing the blue crab's basal oxygen uptake to the oxygen uptake after exposure to pure sand, James River sediment, or Endosulfan-spiked sediments. The effect of these multiple stressors on molting is measured by activity of an enzyme in the epidermal tissue important to molting: N-acetyl-&beta-glucosaminidase.

20.3 WILLIAMS, C.D.*; BIEWENER, A.A.; Harvard Univ., Boston; *charleswilliams@fas.harvard.edu*

Squeezing through: strategies for navigating tight spaces in flight

Navigating through confined spaces is one of the more impressive tasks flying animals can accomplish. We presented pigeons (*C. livia*) trained to navigate through a field of vertical obstacles with an evenly spaced array of vertical bars. The spacing between these bars was altered in successive trials; pigeons successfully navigated through gaps between 2 and 6 body widths (13 and 31 cm). At wider spacings body roll was used to pass between the obstacles. However, at spacings below 26 cm, one of two strategies was employed, the wings were either: 1) held at the top of the upstroke for the time required to pass through the gap, or 2) folded back at the wrist just before passing through the gap. This first strategy was employed in 71% of the trials (n=52 runs) and may provide greater control authority upon reaching the unobstructed space, as a new wingstroke may be immediately initiated. The second strategy was employed in the other 29% of trials, and may be a backup for when the timing of the wingstroke cycle relative to the approaching obstacles did not permit pausing at the top of the upstroke. (ONR N0014-10-1-0951)

123.2 WILLIAMS, CM*; WATANABE, M; MORGAN, T; EDISON, AS; BOROUJERDI, A; HAHN, DA; University of Florida, Gainesville, Claflin University, Orangeburg, Kansas State University, Manhattan; *carolinewilliams@ufl.edu*

Selection for cold tolerance alters the maintenance of metabolic homeostasis during cold exposure in Drosophila melanogaster.

Low temperatures induce in insects a state of paralysis (chill coma), which is reversible following the return of favourable conditions, although the time taken to recover varies widely both inter- and intra-specifically. This variation may result from differences in the degree to which insects can maintain metabolic homeostasis during cold exposure. We selected replicate lines of *Drosophila melanogaster* for either fast or slow recovery from chill coma (cold-tolerant or -susceptible lines), then profiled and compared the polar metabolome before, during and after cold exposure using nuclear magnetic resonance spectroscopy. We found that the cold tolerant lines were smaller, and maintained a higher degree of metabolic homeostasis during cold exposure. Pathways that responded differently to the cold exposure between cold-tolerant and –susceptible lines included amino-acyl tRNA biosynthesis (indicating differential levels of translation during cold stress), proline and alanine metabolism, starch and sucrose metabolism, and the TCA cycle. Our results suggest that adaptation to cold environments results in evolution towards energetic pathways that function better in the cold. These lines are fully genotyped, allowing us to look for genetic divergence in implicated pathways among the selected lines.

1.11 WILLIAMS, J.B.*; OSTROWSKI, S.; Ohio State University, National Wildlife Research Station; *williams.1020@osu.edu*

Energy Expenditure and Water flux of Free-living Sand Gazelles in Saudi Arabia

Arabian sand gazelles (*Gazella subgutturosa marica*; 12–20 kg) occur naturally in the northern deserts of Saudi Arabia, and in the Rub' al-Khali, one of the driest regions in the world. In 1990, they were reintroduced into Mahazat as-Sayd, a protected area 160 km north-east of Taif, Saudi Arabia. Gazelles have no access to drinking water apart from ephemeral pools that occur in the desert landscape after infrequent rains. We have studied the foraging time, energy expenditure, and water turnover rate of this desert ungulate in central Saudi Arabia. Using doubly labeled water we showed that for 7 gazelles daily energy expenditure was 5,432 kJ/day and water turnover was 596 mL/day. In the laboratory these same gazelles had a resting metabolic rate of 1666kJ/day and a total evaporative water loss of 132 g/day.

44.3 WILLIAMS, CT*; SHERIFF, MJ; BARNES, BM; BUCK, CL; University of Alaska Anchorage, University of Alaska Fairbanks; *ctwilliams07@yahoo.ca*

Phenology of hibernation and reproduction in free-living arctic ground squirrels

Climate warming is predicted to lengthen the growing season, particularly at high latitudes, which provides increased foraging opportunities, although biological interactions can also be disrupted due to intra- and inter-specific variability in the response to climate forcing. We developed a method of using patterns of core body temperature in free-living arctic ground squirrels to precisely determine the timing of key seasonal events including hibernation, mating and parturition, and immergence and emergence from the hibernacula. Long-term data collected from two arctic ground squirrel populations living 20 km apart in northern Alaska indicate that individuals respond plastically to environmental conditions with earlier reproduction at the site characterized by earlier snow melt. The timing of parturition was tightly linked to the termination of heterothermy and subsequent emergence from the hibernacula at both sites, whereas timing of entrance into hibernation was only weakly correlated with date of parturition. Females ended heterothermy in spring coincident with rising soil temperatures from winter minima, but since average soil temperatures did not differ between the two sites, a single threshold in warming cannot explain the differences in timing of spring emergence and reproduction between the two populations.

57.4 WILLIAMS-SIEG, K. A.*; MILES, D. B.; Ohio University; *kw114105@ohio.edu*

Behavioral plasticity mediates life history trade-offs in response to habitat disturbance

Environmental variation is known to induce trade-offs, which requires shifts in energy allocation among behaviors involved in reproduction, parental care and self-maintenance, thereby affecting reproductive success and survival. We examined behavioral plasticity in hooded warblers (*Setophaga citrina*) in response to alteration of habitat structure due to commercial logging and linked plasticity in behavior to reproductive success. A seven state Markov model was used to describe how birds move through the habitat, how they attack prey, prey handling behaviors, and reproductive behaviors. We found significant differences in the transition probabilities among males in the undisturbed stand compared to the disturbed stand including how they searched for and attacked prey. Males in the disturbed stand had higher transition probabilities from short flight to aerial attack while males in the undisturbed stand were more likely to transition from hop to surface attack. Males in the disturbed stand were more likely to transition from non feeding behaviors to short flight consistent with observations of opportunistic foraging while singing. This suite of behaviors suggests that aerial attacks may ameliorate time budget trade-offs. Significantly fewer young were fledged per nest in the disturbed stand compared to the undisturbed stand. In 2010, individuals that were more plastic also fledged more young. In 2011 this trend was reversed; however, the pattern may be driven by the high levels of brown headed cowbird nest parasitism in the disturbed stand which reduced brood size. This study demonstrates that behavioral plasticity varies between years and in relation to habitat disturbance. In addition, plasticity is associated with reproductive success thus providing support for the hypothesis that plasticity is adaptive.

P2.196 WILLIS, K L*; CARR, C E; Univ of Maryland; *kwillis@umd.edu*

Turtle hindbrain auditory circuits

Tract tracing techniques were used to describe the connections of the turtle hindbrain auditory nuclei. Dye was injected into the auditory nerve brainstem or midbrain auditory nuclei; brains were maintained in cold, oxygenated ACSF for dye transport (3-5 days). Brains were sectioned and labeled using an ABC followed by SG reaction (Vector Labs). Labeled neurons were reconstructed using Neurolucida (MBF Bioscience). The auditory nerve terminated in both Nucleus Magnocellularis (NM) and Nucleus Angularis (NA). Single auditory nerve fibers bifurcate to NM and NA. In NM, auditory nerve terminals formed dense bouton terminals on the soma and neuropil. Nerve terminals in NA were varicose, and formed both boutons and complex endings. They were also less dense, although their mean area was comparable to terminals in NM. In the brainstem, NM contained relatively large, round cells. It was located at the medial edge of the dorsal brainstem, and extended from caudal to and overlapping with the VIII nerve root. NM cells were morphologically variable, and projected to both the ipsilateral nucleus lamiaris (NL) and across the dorsal midline to the contralateral NL. NL was located ventral to NM, and contained vertically-oriented bitufted cells arranged in a mediolaterally oriented lamina, as well as horizontally-oriented bitufted cells dorsal to the lamina. The vertical NL cells were more round than the horizontal NL cells. NL projects to torus semicircularis (TS). NA neurons were heterogeneous, and fell into two broad categories on the basis of dendritic morphology: multipolar and stubby. NA neurons did not otherwise vary significantly in soma size or form factor. NA extended further rostral than NM. NA, NL and the superior olive projected to TS, with input from NL and NA being largely contralateral. NA also received descending projections back from TS.

114.2 WILSHIN, SD*; DALEY, MA; Royal Veterinary College; *swilshin@rvc.ac.uk*

Continuous metrics for classification of bipedal gaits and predictions of gait transition fine structure in turkeys

An accurate method for differentiating walking and running bipedal gaits is presented and applied to experimental data from turkeys. It is known that bipedal walking and running gaits can be distinguished based on the phase difference of the kinetic and potential energy of the center of mass. It has also been suggested that the energy stored in the legs may also differentiate these gaits. It is, however, conventional to use a discrete estimate of these phase differences (such as the relative timing of peaks in these energies). Such estimates are prone to error, especially during non-steady locomotion, and are of limited utility when examining gait transitions which typically occur over short time scales (one or two strides). It is the short time scale of transitions that makes them interesting, as it is likely that energy cost is of diminished importance. Other factors such as stability and robustness may play a greater role in the form of transitions than in ordinary locomotion. To investigate these issues, we need a continuous-in-time classification of gait. We present and discuss a continuous-in-time classification of the gait of turkeys (n=5) on a treadmill. Gait classification was constructed by applying continuous-time phase extraction techniques to kinematic data. We show that the resulting gait classifier has a high performance, average 93% correct from a testing set with at least 16 strides per bird, and can correctly classify partial strides. We will discuss the potential application of this classifier to investigating locomotor dynamics and transition fine structure. Funding: HFSP:RGY0062/2010

112.1 WILSON, R S*; CARTER, A J; The University of Queensland, University of Cambridge; *r.wilson@uq.edu.au*

Optimal Performance Theory: developing a framework for understanding whole-animal performance in the wild

Should an animal run as fast as it can when trying to escape a predator? What about when running to catch food or whilst displaying to a female? The simple answer should be no, of course not. After all, we would never run at full pace down a steep set of stairs or across an icy sidewalk, no matter how many predators were chasing us. It is surprising then that much of our focus on animal performance is concerned with quantifying an individual's maximal capabilities. In fact, when biologists have quantified whole-animal performance levels used in the wild, most species seem to rarely perform at speeds that approach maximal capacities, even when executing fitness-relevant tasks. This should not be surprising - whether it's running on a slippery surface or on a thin branch, the actual performance used by an animal should be optimized to the prevailing environmental conditions. In this talk, we will explore the idea of optimal performance theory and attempt to develop a theoretical approach for studying whole-animal performance in nature. We believe that the concept of optimal performance will help shift the focus away from studies of only maximal capacity towards a more comprehensive understanding of the evolution of physical performance tasks. To do this, we will present a simple model of optimal performance and provide a discussion of the type of empirical studies that may help move this framework forward.

_113.5_ WILSON, J.K.*; WOODS, H.A.; University of Montana; *keatonwilson@me.com*

Abiotic noise in volatile signaling by plants

Plants have developed a multitude of ways to defend themselves from insect herbivores. One recently discovered strategy is the release of airborne chemicals that signal the type of herbivore attacking the plant. In some systems, this information is used by predators and parasitoids to find their prey or host – that is, the plant defends itself by calling in a third trophic-level. However, we still know little about these communication systems, and the ecological ramifications they have. Any type of communication system can be corrupted by noise. Here, we propose that variation in environmental factors can act as a source of noise in plant volatile communication systems. We focus on abiotic noise affecting the plant-transmitter, *Datura wrightii* after herbivory by larvae of the hawkmoth *Manduca sexta* based on field measurements from a population in southeastern Arizona. Among potential sources of noise in the natural world, temperature is likely to be particularly powerful, because it modifies the underlying biochemistry of signal reception and transmission, and is one of the few abiotic factors that can affect plants and insects simultaneously. However, air humidity and soil moisture vary widely (both spatially and temporally) in many habitats, including the desert southwest, and may also be important in modifying communication between plants and insect defenders. If environmental noise causes significant signal degradation, the effects of varying abiotic conditions on both transmitters (plants) and receivers (insect predators and parasitoids) may drive broad patterns of evolution and ecology in both parties.

_5.1_ WILSON, BA; University of Baltimore; *bawilson13@gmail.com*

Utilizing algal communities as bioindicators for PPCP contamination

There is growing concern over the increased presence of personal and pharmaceutical care products (PPCPs) in the environment. Freshwater algal productivity and diversity are often used as bioindicators for freshwater systems under stress. A series of assays were performed to determine the individual impacts of Triclosan, Estradiol, Loratadine, and Ciprofloxacin on a natural algal community. Toxicological effects were measured as total productivity (chlorophyll *a*), total protein production (genera production), and relative genera abundance (biovolume). Total productivity was significantly reduced in the presence of and Loratadine ($p < 0.05$), however, productivity was not significantly reduced by the presence of Triclosan, Estradiol or Ciprofloxacin ($p > 0.05$). The relative genera abundance was significantly reduced ($p < 0.05$) in communities exposed to Triclosan and Ciprofloxacin, including the loss of at least one genus. In both cases, the dominant genera present shifted from a high protein producing organism to one of lower protein content. Individual genera produce varying amounts of available protein ranging from 20-60% dry mass. For both Triclosan and Ciprofloxacin there was also a significant loss ($p < 0.05$) in total protein available due to the change in dominant genera. There was no significant loss in either relative genera abundance or protein content in the algal community exposed to Loratadine or Estradiol ($p > 0.05$). Productivity may not be a sufficient indicator for potentially compromised ecosystems; other measures of diversity and protein content may be required. Changes within the overall algal community not only represent a loss in potential food sources for preferentially grazing herbivores in freshwater systems, but may also result in herbivorous grazing on less valuable protein sources due to PPCP exposure.

_S3-1.6_ WILSON, JM*; CHEW, SF; IP, YK; CIMAR, Porto, Portugal, Nanyang Tech. Univ., Singapore, National Univ. Singapore, Singapore; *wilson.jm.cimar@gmail.com*

Metabolic and osmoregulatory challenges of emersion in fishes.

The climbing perch (*Anabas testudineus*), combtooth blenny *Lipophrys pholis*, and weatherloach *Misgurnus anguillicaudatus* are three examples of teleost fishes that have adapted to terrestrial conditions. The gill in fishes, which is generally the main organ for aquatic respiration, is also the site of ion-regulation and excretion of metabolic (nitrogenous) waste primarily as ammonia. However, the typical teleost fish gill is designed to function in water and collapses in air and with the loss of ventilatory water flow to maintain favorable diffusion gradients combine to challenge metabolic waste elimination and osmoregulation. The climbing perch is a euryhaline, freshwater fish that is capable of surviving days out of water. It has a specialized labyrinth organ in the suprabranchial chamber that facilitates aerial gas exchange. The climbing perch is capable of maintaining aquatic rates of ammonia excretion while emersed in contrast to most other fishes, although we have made a similar observation in the intertidal blenny. As an indicator of iono regulatory status, plasma Na^+ and Cl^- levels fell 10 and 5%, respectively, after 5d emersion. The expression levels of two key branchial ion pumps, Na^++/K^+-ATPase (NKA) and H^+-ATPase, were found not to be modulated under these conditions. This can be contrasted with the intertidal *L. pholis* in which branchial NKA activity increased during emersion. The facultative intestinal air-breathing weather loach has adapted to long periods of emersion during the dry season by volatilizing ammonia through its intestine using facilitated NH_4^+ excretion while in the gill NH_3 excretion by a different Rhcg-H^+-ATPase coupled mechanism is up regulated. This work was partially supported by FCT grant POCTI/BSE/47585.

_89.2_ WILSON, AM*; ROSKILLY, K; LOWE, J; HUDSON, P; GOLABEK, K; MCNUTT, J; RVC, London, BPCT, Botswana; *awilson@rvc.ac.uk*

Dynamics of high speed locomotion and hunting in free ranging cheetah

Studies of maximum performance are limited by subject motivation and attempts by ourselves and others to measure domestic cheetah performance show limited straight line and manoeuvring performance. We set out to describe the speed, acceleration and manoeuvring of wild cheetahs when hunting. We developed a collar powered by a combination of rechargeable, non rechargeable batteries and solar panels. Sensors comprise a 5Hz L1 pseudorange Doppler data GPS receiver, 3-axis MEMS accelerometer, 3 axis MEMS gyroscope, and a 3 axis magnetometer. Data were off loaded via a wireless link to an aircraft or vehicle. The sensors provide, at 300 Hz, acceleration (force) and with integration velocity and position, angular velocity and with integration heading and orientation of the collar and (approximately) the cheetah. GPS and IMU data are fused using our own Kalman filtering optimised for sensor characteristics and animal dynamics to provide the data we require. The collar adapts its operation (and hence power consumption) across six states depending on the time of day, the animal's activity level and battery voltage. This allows collection of fine grained behaviour and movement data and therefore unbiased records of hunting behaviour data. Collars were attached to five cheetahs in the Okavango Delta area of Botswana. To date we have collected data for 169 runs from these five cheetah and data collection is ongoing. Successful hunts involve rapid acceleration and deceleration indicating high muscle powers, relatively high speed galloping and a period of manoeuvring with high lateral accelerations. We have also deployed similar collars on other predators in the study area.

101.2 WINDSOR, S.P.*; TAYLOR, G.K.; Univ. of Oxford; *shane.windsor@zoo.ox.ac.uk*

The role of head stabilization in the flight control system of hawkmoths

During flight many insects actively stabilize their head relative to their surroundings. Gaze stabilization acts to significantly simplify the processing and extraction of relevant visual information but in addition to this the act of stabilizing the head may also play a significant role in the flight control system of flying insects. Using a virtual reality flight simulator we measured the head motions of the hawkmoth *Hyles lineata* in response to complete wide-field visual motion. The moths responded strongly to visual motion, moving their heads to greatly reduce the dynamic range of the visual stimuli seen by the eyes. In addition to stabilizing the visual field the orientation of the head relative to the body potentially gives the insect information about the angular orientation of its body relative to the world around it. Using mathematical models the advantages and limitations of head stabilization and its role in the flight control system of a flying insect were investigated. These models indicate that head stabilization may play an important role in insect flight control.

71.5 WINDSOR, P.J.*; LEYS, S.P.; Univ. Alberta; *pwindsor@ualberta.ca*

Tracing cell identity through metamorphosis in a freshwater sponge larva

Sponges, like other animals, show anterior-posterior polarity especially in their larval stages. However whether larval polarity is carried over to the adult is not yet known, nor is the fate of any of the cells from the larva. We used diI injection coupled with cell labelling using CMFDA and bisection experiments to determine the fates of different regions of the larva of the freshwater sponge, *Eunapius fragilis*. This larva has a distinct anterior end with a large larval cavity, and a posterior end that contains amoeboid cells, feeding chambers and spicules; the entire outer surface consists of columnar ciliated cells. We cultured anterior and posterior halves separately to determine the fates of each half. The anterior half of the larva settles and flattens into a thin sheet, but lacks adult structures such as canals and an osculum. Without the anterior half, the posterior half is not competent to settle. We tattooed the anterior and posterior poles with diI to define specific cells that arose from these regions. The anterior pole largely gives rise to basopinacocytes that adhere to the substrate during settling, while sclerocytes derive from the posterior pole. Interestingly, the osculum, the terminus of the aquiferous system axis in the adult, is also derived from posterior cells. We dyed the outer layer of columnar ciliated cells in swimming larvae with CMFDA. At metamorphosis these cells appear to be resorbed. Choanocyte chambers of the juvenile sponge arise from multinucleated cells very soon after settlement. Importantly, we show larval polarity is reversed in the adult – the posterior pole gives rise distinctly to cells that form the osculum – confirming a long held concept that sponge polarity is inverted relative to other metazoa.

S6-1.1 WINGFIELD, JC; University of California, Davis; *jcwingfield@gmail.com*

Allostasis, resilience and coping with a changing world

A potentially serious outcome of global climate change is the increase in frequency and intensity of extreme weather events. Additionally, environmental perturbations such as human disturbance, invasive species, social disruption and pollution indicate that bird populations world wide face major challenges in coping with stress. Responses to one or more environmental perturbations incur energetic costs in addition to those of the normal life cycle such as breeding, migrating etc. The concept of allostasis provides a framework to integrate energetic demand and wear and tear of daily and seasonal routines (the predictable life cycle) with perturbations of the environment including disease, aging and social status. The concept is particularly attractive because it allows a framework to assess the challenges faced in changing social and physical environments at the individual level because no single organism experiences the environment in exactly the same way as another. The reactive scope of the mediators of coping mechanisms, such as the adrenocortical response to acute stress, also vary on seasonal, daily, habitat and individual bases. Understanding these regulatory mechanisms will be critical to ameliorating the effects of global change in general.

P3.77 WINTERS, G.C.*; KOHN, A.B.; CITARELLA, M.R.; BOSTWICK, C.J.; DABE, E.C.; BOBKOVA, Y.; KOCOT, K.M.; SWALLA, B.J.; MOROZ, L.L.; University of Florida Whitney Lab, St Augustine, Auburn University, Alabama, University of Washington, Seattle; *gabrielle.winters@gmail.com*

Conserved expression patterns of Nanos in the ctenophore Pleurobrachia bachei: Implications for germ line specification in basal metazoans.

The pelagic ctenophore *Pleurobrachia bachei* is a representative of one of the most basally branching lineages of metazoans. Here, we take advantage of the sequenced *Pleurobrachia* genome to characterize the complement of molecular “toolkits” potentially implemented in development and cell fate specification. We began by investigating the gene for the maternal effect factor, *nanos*. *Nanos* contains a nucleotide sequence coding for a zinc finger domain that is highly conserved across metazoan taxa including ctenophores. We found a single copy of a *nanos* gene in *P. bachei*. This corresponds with the single *nanos* found in sponges, and does not correspond with the two copies found in the remaining non-bilaterian metazoans - the cnidarians. Next, we performed *in-situ* hybridization using DIG-labeled antisense mRNA probes to localize expression of *nanos* mRNA in adult *P. bachei*. *Nanos* expression was observed in the gonads, suggesting a role for *nanos* in germ cell maintenance in *P. bachei*. Further expression was observed in the aboral organ, and in potential stem cell niches throughout the adult organism. Finally using RT-PCR, we found that *nanos* is expressed constitutively during embryonic development. Thus, *nanos* likely plays a role in ctenophore development and can be considered a conserved component of the developmental toolkit for basal metazoans.

S8-2.3 WOERHEIDE, G; Ludwig-Maximilians-Universitaet Muenchen; *woerheide@lmu.de*

Phylogenomics of non-bilaterian animals: pitfalls and challenges

Deep-level metazoan relationships have long been controversial issues. Especially a well resolved and supported phylogeny of non-bilaterian animals is needed to provide a robust framework for reconstructing early metazoan evolution. Expanding molecular (phylogenomic) datasets are increasingly being used to unravel these relationships. However, important nodes remain notoriously difficult to resolve. For example, some recent large-scale metazoan phylogenomic analyses – contrary to classical conceptions – found ctenophores to be the sister-group to the remaining Metazoa and favored a sister-group relationship between sponges and cnidarians, while other analyses suggest that the Placozoa are the sister-group to the remaining Metazoa or that sponges are a paraphyletic assemblage that share a grade of construction rather than common ancestry. From these hypotheses, many claims have been made with far reaching implications for the early evolution of animals. An overview about the current state of the debate will be given, especially with respect to the mono- vs. paraphyly of sponges and their position in the animal tree of life. Several (novel) phylogenomic analyses of non-bilaterians will be used to address the underlying causes of the incongruences observed among deep-level metazoan phylogenies. However, even using large phylogenomic datasets, some non-bilaterian relationships remain difficult to resolve as they are highly dependent on taxon- and gene sampling, evolutionary model selection and outgroup choice. Additional sequence-independent data might be required to unequivocally resolve the branching order of all non-bilaterian groups.

95.3 WOFFORD, SJ*; MOORE, PA; Bowling Green State University; *sjwofford1@gmail.com*

Sex and fighting: Male and female crayfish use different assessment strategies during agonistic behavior

Agonistic behavior is an important social aspect of animal behavior, and the outcome of agonistic interactions is critical to the acquisition of resources such as food, shelter, and mating opportunities. During agonistic interactions, individual participants make behavioral decisions based on energy and time investment such as escalating the intensity of the interaction and whether to end the interaction by retreating. Each of these decisions can be informed through self-assessment (i.e. energy reserves, fight capability, size) or through some form of mutual assessment (i.e. comparative energy reserve, size differential). Crayfish are ideal model organisms for the study of such behavior due to ritualized fighting and a well –established ethogram. In this study, we are examining the assessment strategies that crayfish employ during same and mixed sex fights. After a brief acclimation, two individuals (male-male, female-female, or male-female) were allowed to interact for 15 minutes. Video analysis was used to calculate fight duration and times spent at various intensity levels. Analysis indicates that males and females appear to be using two different assessment strategies. In male-male fights, agonistic decisions are based on a self-assessment strategy whereas in female-female fights, decisions are based on a mutual assessment strategy. In mixed sex bouts, a mixed strategy appears to underlie a crayfish's decision.

52.6 WOLCOTT, T G*; DEAN, A G; SICHITIU, M L; NC State Univ; *tom.wolcott1@gmail.com*

A networked "Citizen Science" monitoring system for estuarine environment and biota.

The Coastal and Estuarine Monitoring System (CEMS) addresses the spatial and temporal heterogeneity in estuaries, where events can be fully described only by dense monitoring arrays. Changes in many estuarine variables are large, and useful information can be obtained from instruments with modest accuracy. These cost far less than precision units and can be affordably deployed in large numbers. Our prototype system sits offshore in Chesapeake Bay but data uploading and control are via the Web. It logs solar panel and battery status; water depth; temperature, salinity, water clarity in four color bands at two depths; and biological observations correlated with the physical data (gape of 16 oysters). The datalogging module will be expanded to log currents, surge and waves, and can accommodate other sensors that provide serial data or voltage output. The same electronics could go into a mobile housing and be towed along transects by a small boat, when they would log the vessel's GPS positions and compass headings as well. Logged data are stored in non-volatile memory. In fixed arrays, the datalogging module is polled by a single-board computer on a piling or buoy, which periodically uploads data via Wi-Fi to an on-shore access point and server. The data appear on the project website in nearly real time. We also are developing apps to allow the data and graphs to be downloaded by nearby visitors with "smart phones." The sensors are simple and their housings, mainly of PVC and pipe fittings, are designed for easy assembly and maintenance. Citizen groups (e.g., high school classes) would be capable of "taking ownership" of an array, and seeing "their data" online as contributions to a national database.

P3.16 WOLF, MG*; MARTIN III, AL; Saginaw Valley State University; *mgwolf@svsu.edu*

Urine as a Signal of Dominance

Social relationships can be obtained through agonistic interactions between two or more conspecifics. These encounters can result in the development of a status that signifies the animal as being a dominant or subordinate individual. The establishment of dominance can influence the outcome of future bouts which in turn can influence the availability and access to resources such as food, shelter, and mates. Aggressive bouts between conspecifics can include both physical and non-physical behaviors. Chemical signals, such as odors, have been shown to be a common mechanism for non-physical communication. It is proposed that urine released during agonistic bouts is the odor that influences the outcome of agonistic interactions in the model crayfish. Dominant and subordinant status in male crayfish, *Orconectus rusticus*, will be established through agonistic encounters. Once social status has been established, urine will be collected from each individual for a 24 hour period and stored fresh. Playback experiments will be conducted to test the affect of the urine on naïve crayfish and also both dominant and subordinate crayfish. The crayfish's agonistic response to the urine will be video recorded and analyzed according to known algorithms for aggression. This will assess whether urine is the signal of dominance and also lead to further research into the chemicals that compose the urine to better understand the mechanism which elicits aggressive responses. There are interesting questions that will need to be addressed in the chemical composition and the behavioral response that status specific urine elicits.

82.1 WONG, W.L.*; MICHELS, J.; GORB, S.N.; Zoological Institute, Christian-Albrechts-Universität zu Kiel, Germany; *wlwong@zoologie.uni-kiel.de*

Attachment ability of a clamp-bearing fish gill parasite, Diplozoon paradoxum (Monogenea)

An effective attachment system is crucial for the survival of monogeneans, which are mainly fish ectoparasites. Monogeneans use various types of haptoral (posterior) attachment devices to attach themselves onto their hosts. However, there is no study done to assess the efficiency of their attachment devices. The present study aimed to determine (1) the attachment forces of a paired adult *Diplozoon paradoxum* from the fish gills, (2) the contribution of muscles action to the clamp movements and (3) the distribution of a resilin-like protein in clamp sclerites. An average force of 6.1 ± 2.7 mN (about 246 times of the animals' weight) is required to dislodge a paired *D. paradoxum* vertically from the gills of the fish *Abramis brama*. When the monogeneans were treated in three different solutions, the widths of the clamp openings differ significantly in each treatment. The widest clamp openings were observed in the monogeneans treated in 2.5 % glutaraldehyde (74.52 ± 28.31 µm), followed by the those treated in 20 mM $MgCl_2$ (37.91 ± 7.58 µm), and in filtered lake water (20.16 ± 8.63 µm). Results from the toluidine blue staining and spectral analyses of the blue autofluorescence, exhibited by the clamp sclerites, indicated that the sclerites contain a rubber-like protein similar to resilin of Arthropods. Our results suggest that the closing of the clamps is not due to the continuous contraction action of muscles, but rather due to the elasticity of the clamp material. The presence of the resilin-like protein likely improves the attachment efficiency and the lifespan of the clamp sclerites.

13.10 WOODS, H.A.*; WILSON, J.K.; Univ. of Montana; *art.woods@mso.umt.edu*

Information theory illuminates the evolution of homeostasis

A common view among physiologists is that homeostasis evolves to protect organisms from the damaging extremes of variation in physiological factors. Here we propose that homeostasis also evolves to minimize noise in physiological channels. Fluctuations in physiological factors constitute inescapable or global noise that corrupts the transfer of information through physiological systems. We apply information theory to homeostasis to develop three related ideas. First, because fluctuations of physiological factors are systemic and affect such basic cellular components, many common modes of noise cancellation (filtering, private channels) won't work. Homeostasis and signal redundancy are the only options. Second, homeostatic regulation creates quiet physiological backgrounds for the transmission of all kinds of physiological information. Third, because homeostatic systems act as coupled pairs of transmitters and receivers, the performance of any one homeostatic system influences information processing in all other homeostatic systems. This dependence implies that multiple homeostatic systems, embedded within individual organisms, should show strongly synergistic or emergent effects. This new view emphasizes that selection may work on subtle dysfunctions arising from disturbance to communication networks at all levels of sub-organismal organization, and it frames death as a kind of runaway physiological noise.

22.4 WRIGHT, ML*; CALDWELL, RL; UC Berkeley; *wrightml@berkeley.edu*

Are two parents better than one? Examining the effects of biparental care in a stomatopod crustacean

Although social monogamy and biparental care have been extensively studied in birds, mammals, and fish, few studies have been conducted on invertebrate species. Social monogamy is characteristic of several marine crustaceans, while biparental care is only known in a single genus of monogamous stomatopod crustaceans, Pullosquilla. In Pullosquilla litoralis, males and females spend statistically equal amounts of time aerating eggs with their pleopods and removing fouled eggs from clutches. Under certain conditions, P. litoralis is also capable of double-clutching. Based on laboratory observations, we suspected that biparental care also occurs in Pullosquilla thomassini, a congener with very similar ecology and behaviors. Through observational studies and experiments conducted at Lizard Island Research Station, Queensland, Australia, we characterized parental care in P.thomassini and examined the effects of uni- and biparental care on the survival and development of egg clutches and weight gain in parents. We found that parental care behaviors in P. thomassini are similar to those of P. litoralis and that males and females provide similar amounts and types of care. We observed two double-clutches in the field. We found that there were no clear benefits of biparental care over uniparental care, but that any form of parental care decreases the amount of weight lost by developing egg clutches. There were also no significant differences in the survival of egg clutches between care provided by males or females. These results suggest that biparental care is not evolutionarily maintained simply by short-term fitness gains in egg development and survival in P. thomassini. Instead, it may be selected for with other life history traits, such as double-clutching, that increase lifetime reproductive success, but do not affect the size or developmental outcome of individual clutches.

116.6 WULFF, J/L; Florida State University; *wulff@bio.fsu.edu*

Sponge recovery after extreme mortality events: Taxonomic and morphological patterns in regeneration vs. recruitment

Sponge mortality associated with a dense phytoplankton bloom on the southern portions of the Belize Barrier Reef in late summer 2011 was extreme, with 70% of the sponge biomass abruptly lost. Context for this mortality event was provided by detailed records of community dynamics for the previous five years. Beginning in 2006, all sponges on a set of shallow patch reefs were mapped, identified, and measured for volume at yearly intervals, allowing sponge dynamics to be quantified with respect to biomass, number of individuals, and species. These data revealed an earlier mortality event and documented the early stages of recovery, both on the community level and also for every individual sponge. Differences in the degree to which the 54 sponge species suffered mortality ranged from complete loss to no effect, resulting in immediate significant alterations in community composition. Groups of species defined by higher taxa or by morphology not only experienced mortality very differently, but also recovered differently, with some showing efficient regeneration after partial mortality, others adding small individuals by recruitment, and still others not recovering at all. And because each taxonomically or morphologically defined group of sponge species also contributes differently to ecosystem services, such as water column filtration, hosoting inquilines, feeding spongivores, stabilization of broken corals, and improved coral survival, differential mortality and recovery has caused shifts in how adequately these functional roles are played. Rapid changes in representation of taxonomically-defined groups, at levels from species to order, provide additional strong impetus for continuing efforts aimed at thorough understanding of sponge systematics.

P3.195 WUNDERLICH, RE*; MILLER, CE; WILHELM , BA; GARDINER, J; TONGEN, A; SCHMITT, D; James Madison University, Duke University; *wunderre@jmu.edu*

Characterizing the mechanics of free-ranging leaping behavior in sifakas Propithecus verrauxi using accelerometers.

Laboratory-based studies of animal locomotion provide critical insights into biomechanics and form-function relationships. However, connecting biomechanical data to detailed aspects of naturalistic behavior is a challenge, and represents a critical gap in our knowledge of locomotor biomechanics. To refine such techniques and test hypotheses about locomotor ontogeny, we developed a method to identify leaping behavior from accelerometer data in sifakas (*Propithecus verreauxi*). Accelerometers (Humotion, Muenster) collecting linear accelerations in three directions at 100 Hz were mounted close to the COM on three adult and two juvenile sifakas. Trials were conducted with simultaneous video in restrictive enclosures with leaps of known distance, and also in large free-ranging areas. Data were analyzed using custom code written in Matlab applying an 8 Hz filter to distinguish patterns of vertical leaping including cyclic and single leaps, bipedal galloping, and climbing. Animals were released into the large free-ranging enclosures, and data were collected for multi-hour periods where documentation of locomotor behavior was validated with simultaneous locomotor bout sampling. 94% of leaps were identified correctly. Cyclic leaping and bipedal galloping exhibit similar COM acceleration patterns; both can be distinguished from single leaps and climbing. For single leaps, take-off and landing components exhibit characteristically high accelerations. During cyclic leaps, the intermediate leap exhibits only a single acceleration peak, suggesting that cyclic leaping may be selectively advantageous where it is important to reduce the number of impacts.

P3.171 WYNEKEN, J*; SALMON, M; GUTHRIE, K; Florida Atlantic University; *jwyneken@fau.edu*

Facial Pits in a Gelatinivore Sea Turtle

Leatherback turtles (*Dermochelys coriacea*) have many unique morphological characteristics that reflect their specialized behavior and trophic ecology. These sea turtles feed exclusively upon pelagic gelatinous zooplankton. They possess unique mouth and throat morphology for capturing, ingesting and processing gelatinous prey. In this study, we investigated multiple pits in the jaws, located along in the outer surfaces of the anterolateral maxillae and the anterior mandible. The function of these pits is unknown. Behavioral studies of feeding leatherbacks indicate that these turtles locate prey using visual and chemical cues. There is no evidence that the turtles sample sections of jellyfish before initiating feeding. Both neonates and adults tend to slice out the central gonadal and gut sections of jellyfishes, leaving the bell behind. These central parts contain more concentrated nutrients. To determine if specialized receptors are present in the pits, we preserved and sectioned the heads of hatchlings that died while emerging from the nest. We stained the tissues with H&E and Sudan Black B for tryglycerides to identify peripheral nerves and neurons. We found highly branched neurons in the pits scattered along the anterolateral jaws and in rostral cartilaginous foramina. We hypothesize that the pits house specialized neurons that may aid in assessing food quality.

139.6 YANCEY, P.H.*; GERRINGER, M.E.; CAMERON, J.; HARDY, K.; CHASTAIN, R.; BARTLETT, D.H.; Whitman College, DEEPSEA CHALLENGE, Scripps Institution of Oceanography; *yancey@whitman.edu*

High contents of methylamines and scyllo-inositol as potential piezolytes (pressure counteractants) in muscles of amphipods from the Mariana Trench

One hypothesis to explain how life adapts to the deep sea involves piezolytes, small organic solutes (first discovered as osmolytes) that counteract perturbations of proteins by hydrostatic pressure. Trimethylamine oxide (TMAO) is a prime candidate. 1) It counteracts pressure effects on protein activity and stability in vitro, better than other osmolytes. 2) Muscle TMAO contents increase with depth in marine bony fishes (analyzed to 7 km depth). 3) In marine decapods (osmoconformers with a fixed osmolyte total), muscles in shallow species are dominated by the non-piezolyte glycine, but TMAO increases and glycine decreases with depth in species down to 3 km. 4) Muscle TMAO contents increase with depth (to 1.4 km) in freshwater Lake Baikal amphipods, which do not need osmolytes. Here we report organic osmolytes in amphipods (*Hirondellea* sp.) from 10.9 km in the Mariana Trench. They were caught with a lander with bait (tuna, chicken) inside a 30 L Niskin sampler that rested on the seafloor. On the ship, animals were deep-frozen and later shipped on dry ice to Whitman College, where metasomal muscles (n=5) were analyzed for osmolyte-type solutes. We found no glycine but instead a predominance of the methylamines TMAO, glycerophosphocholine and dimethylglycine, plus the polyol scyllo-inositol (SI). Though only TMAO has been tested with pressure, all are potential piezolytes as each is a protein stabilizer (e.g., SI stabilizes the non-toxic form of beta amyloid). These results represent a record depth for such analyses of animals and support the piezolyte hypothesis. Funding by the National Science and Blue Planet Marine Research Foundations.

40.3 YANIV, S; ELAD, D; HOLZMAN, R*; Tel Aviv University; *holzman@post.tau.ac.il*

Computational model of aquatic feeding: Scaling of suction feeding dynamics from larval to adult fish

To capture prey, larval fishes swim towards their target while rapidly opening their mouth to generate a flow of water external to the mouth. This feeding mode, termed “suction feeding”, is thought to be the universal feeding mode in larval fishes. The suction flow is key to feeding success, because it draws the prey into the predator’s mouth, countering possible escape response of the prey. Because of the difficulties inherent in making direct measurements and observations on small animals such as larval fishes, very little is known about these flows, how they translate to prey capture, and whether those flows change during early development. In this study, we used a Computational Fluid Dynamics model (CFD) to elucidate the flow dynamics inside and outside the mouth, from the scale of first feeding larvae to adult fish. Our simulations reveal that size has strong effects on the patterns of flow inside and outside the mouth. Peak flow speed and Reynolds numbers increased with increasing mouth size. The radial symmetry that characterises suction flows in adult fishes dissipated as mouth length decreased. In adult fish, flow decays rapidly outside the mouth, and suction flows have a negligible effect on particles movement at a distance of ~2 mouth widths. However in larval fish flow decayed much slower, and significant flows were observed at a distance of ~5 mouth widths. While invicid models are generally suitable to describe the flow in large mouth sizes, they fail at the size range that characterizes larval fish. The different flow regime in larval fish likely changes larval feeding performance, including their ability to exert forces on the prey, and lead to size-related changes in feeding efficiencies.

64.6 YANOVIAK, S. P.*; DUDLEY, R.; University of Louisville, University of California, Berkeley;
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Aerial behaviors in wingless canopy arthropods

Gliding flight occurs in a wide range of vertebrate taxa, but was unknown for wingless terrestrial arthropods until it was reported for ants of the tropical rainforest canopy in 2005. Here we show that tropical arboreal bristletails (Archaeognatha) glide to tree trunks in approximately 90% of falls. Experimental manipulation of the caudal filaments reduced gliding success (percent of individuals landing on a tree trunk) and performance (glide index) relative to controls. We quantified similar gliding behavior in selenopid spiders of Peru and Panama. In contrast, baetid mayfly larvae showed no aerodynamic control during voluntary jumps from vertical substrates. The existence of aerial control in the ancestrally wingless bristletails, and its habitat association with an arboreal lifestyle, are consistent with the hypothesis of a terrestrial origin for winged flight in insects.

85.4 YOUNG, V.KH.*; GIFFORD, M.E.; Clemson Univ., Univ. Arkansas, Little Rock; *vkhilli@clemson.edu*

Limited thermal acclimation capacity in a salamander, Desmognathus brimleyorum

Temperature is a critical factor impacting the fitness of ectotherms. Previous studies have indicated that many ectotherms have the ability to adjust their physiological capabilities to cope with variation in their thermal environment. Theories of optimal acclimation predict that individuals experiencing thermal conditions that fluctuate widely will exhibit physiological traits that are less sensitive to temperature than those individuals experiencing stable thermal conditions. We tested this prediction by studying acclimation of swimming performance, metabolic rate, and critical thermal maximum in the salamander *Desmognathus brimleyorum*. Salamanders from each of five populations across the species range in Arkansas, USA were assigned to either a constant or variable temperature treatment in the lab. Following a two-month period of acclimation, each salamander was subjected to swimming speed trials at each of seven temperatures between 2 and 30°C. Each trial was recorded using a high-speed camera and velocity data were collected via video analysis. Metabolic rates for individuals were measured using flow-through respirometry and recorded over four temperatures between 5 and 20°C. Our results indicate that adult *D. brimleyorum* do not acclimate swimming performance to alternate thermal environments. However, limited capacity for thermal acclimation of metabolism and thermal tolerance was evident in this study. Interestingly, the majority of variance detected in this experiment resulted from differences among populations. We also discuss interpopulation variation in physiological traits and possible sources of this variation.

P1.42 YOUNG, R. C.*; KITAYSKY, A. S.; SCHULTNER, J.; WELCKER, J.; Univ. of Alaska Fairbanks, Norwegian Univ. of Science and Technology, Norwegian Polar Institute;
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: Environmental determination of life-expectancy in long-lived seabirds: an inter-ocean comparison of kittiwake chicks' responses to stress

Black-legged kittiwakes (*Rissa tridactyla*) breeding in the Pacific and Atlantic oceans have different life history parameters. In the Pacific, adults invest in self-maintenance, have lower reproductive output and higher adult survival, indicating a slow-track investment strategy. The opposite is true in the Atlantic: productivity is higher and adults have lower survival: a fast-track strategy. Atlantic kittiwakes are smaller bodied as well, a trait which allometrically aligns with a faster-track life history. We compared chick physiology in the nest to address how physiological patterns early in life might determine differences in adult life history strategies. Chicks were sampled from colonies in both oceans as part of a larger comparative project addressing kittiwake physiology and behavior. Telomeres provide a proximate physiological measure that may establish adult life history patterns at the chick stage by acting as an estimator of lifespan. Telomere lengths early and late in the nestling phase differ by ocean, a potential explanation for differences observed in adult survivals and projected lifespan. The link between cellular markers, like telomeres, and life histories of populations relies on the linking mechanism of physiological stress. We assessed nutritional stress, using corticosterone, and oxidative stress, using several measures. If established, the causal relationship between stress and telomere dynamics will elucidate how life history trajectories are determined and the factors involved. Regional responses to climate change can be predicted more precisely when mechanisms driving individual differences are better understood.

P2.81 YOUNG, N.M.; University of California, San Francisco;
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Macroevolutionary diversity of amniote limb proportions is congruent with predictions from developmental interactions

Mammals, birds, and reptiles exhibit remarkable diversity in limb proportions. These evolved differences are thought to principally reflect selection on variation in fetal and postnatal segmental growth. However, early conserved developmental events also have the potential to impact the generation of interspecific variation. Experimental evidence indicates that proximo-distal patterning of the limb into segments occurs through a balance between activating signals at the flank and inhibitory signals from the tip. Modeling of this mechanism further predicts that the initial proportions of the developing limb should exhibit tradeoffs between stylopod and autopod and invariance of the zeugopod. To test whether this patterning signal exists and whether it varies over ontogeny, amniote limb proportions were analyzed at both early fetal and adult developmental time points. Results demonstrate that macroevolutionary limb diversity is congruent with predictions of activation-inhibition despite subsequent variation in segmental growth or differences in phylogenetic history and functional adaptation. Ontogeny within species exhibits a similar conservation. These results suggest that developmental mechanisms limit initial zeugopodial proportions while selection on higher order design principles may act to further dampen variation in a wide range of functional limb adaptations, resulting in a persistent developmental signal. Limb diversity therefore reflects selection on variation in a range of developmental processes that combine to generate observed macroevolutionary patterns.

P2.28 YU, P. C.*; KAPSENBERG, L.; HOFMANN, G. E.; University of California, Santa Barbara; *pyu@lifesci.ucsb.edu*

Ocean acidification and thermal stress in a polar ectotherm—physiological responses of the larvae of Sterechinus neumayeri to a potential future ocean

Polar ectotherms of coastal Antarctica experience the most thermostable environment of all shallow marine environments, and they have evolved in these stable conditions for 22 million years. This cold seawater also is rich in dissolved CO_2, and as a result presents a challenge to calcifying invertebrate fauna for biomineralization; future atmospheric loads of CO_2 will intensify this effect, resulting in overall acidification and calcium carbonate undersaturation. We tested the developmental stability of invertebrate development to simultaneous warming and acidification stresses: larvae of *Sterechinus neumayeri* were raised at -0.6 (control) and +2 °C under present day carbonate conditions, and at two elevated pCO_2 levels (650 and 1050 µatm). Developmental schedules overall were unaffected by elevated pCO_2 at control temperatures, and were accelerated by elevated temperatures. Respiration rates at control temperatures were largely unaffected by elevated pCO_2. In thermal stress trials, tolerance of acute heat stress (1hr exposures) was surprisingly high (up to 20 °C), and unaffected by CO_2 treatment, with high recovery and survival at several early developmental stages. While it has been hypothesized that warming effects may counteract potential depressive effects of higher CO_2, the climate changes occurring in Antarctica may be decoupled between rates of warming and rates of seawater CO_2 increase in different regions of the continent. The undersaturation of calcium carbonate in Antarctica will likely occur sooner than large changes in temperature, and calcifying larvae in the Earth's southernmost marine ecosystem may not experience metabolic tradeoffs in the same way as temperate or tropical species.

P1.53 YUE, J.*; HOLLAND, L.Z.; YU, J.; PUTNAM, N.H.; Rice University, Univ. of California, San Diego, Academia Sinica; *yjx@rice.edu*

Functional Characterization of the Asymmetron lucayanum Genome

The tropical lancelet *Asymmetron lucayanum* is a representative species of cephalochordates. The study of it, together with the comparison with the other cephalochordate species, *Branchiostoma floridae*, can shed important light on our understanding about the evolution of cephalochordates. Here, we report a whole genome analysis on individuals collected from the wild. Using the published genome draft of B. floridae as the reference, we are able to capture a considerable amount of genomic information with regard to their coding sequences and some conserved non-coding sequences, although these two species have diverged for a long time. Besides, the transcriptomes of *Asymmetron lucayanum* genome at two different developmental stages were characterized by RNA-seq technique. The assembly of these transcripts, together with the whole genome sequencing data, revealed valuable information with regard to *A. lucayanum*'s genomic evolution in both of its coding and regulatory regions. For coding regions, the joint comparison with those from *B. floridae*, urochordates and vertebrates helped to identify genes under strong positive selection in Branchiostoma, Asymmetron or on the cephalochordate stem lineage. For the noncoding regions, a collection of putative conserved noncoding regions were identified, among which the top candidates are under further experimental examinations to assess their regulatory activities.

13.5 YUGE, S*; HONEYFIELD, D.C.; SALOKA, S.K.; LI, W.; Michigan State Univ., E. Lansing , USGS-NARL, Wellsboro; *shinya.yuge@gmail.com*

Characterization and functional analyses of three thiamin related transporters and a thiamin pyrophosphokinase in rainbow trout, and examination of their expression alteration in thiamin deficiency

Thiamin (Th, vitamin B_1) is a micronutrient essential for metabolism. Th deficiency (TD) has caused a lethal disease in salmonids. However, little is known about molecular mechanisms of the salmonid TD. In the rainbow trout, we identified Th metabolism related genes, two *th transporters* (*thtr1*, *thtr2*), a *th derivative transporter* (*thde-tr*/*rfc*) and *th pyrophosphokinase* with its seven splice variants (*tpk_tv1-7*). The transporters are critical for cellular and body Th uptake, and the enzyme generates the active Th. Thtr1 and Thtr2, but not Thde-tr, expressed in HEK cells exhibited ^{3}H-Th uptake. mRNA expression of *thtr1*, *thde-tr* and *tpk_tv1* with two-three *tpk_tv* was found in all examined tissues, while *thtr2* transcripts were observed only in intestine and kidney. During embryonic development, total *tpk_tv* transcripts increased to a peak before hatch, *thtr1* and *thde-tr* transcripts peaked in yolk-sac fry stage, while *thtr2* transcripts gradually increased toward the swim-up stage. Notably, *tpk_tv5* mRNA expression was abundant in ovary and in most of the embryonic stages. In trout with TD, the mRNA expression was reduced in the following tissues: *thtr2*, upper and lower intestine; *thde-tr*, all tissues examined; total *tpk_tv*, gill, liver, upper intestine and muscle. In contrast, no such changes occurred in *thtr1* in any of those tissues. In summary, in rainbow trout, 1) *thtr1*, *thde-tr* and *tpk* are active genes within all tissues and most of embryonic stages, while *thtr2* may be specific for intestinal and renal Th absorption; 2) *tpk_tv5* mRNA expression might be important in ovary and in embryogenesis; and 3) in TD, *thtr2*, *thde-tr* and *tpk* appear to be down-regulated.

62.5 YUND, P.O.*; MCCARTNEY, M.A.; TILBURG, C.E.; The Downeast Institute, University of North Carolina - Wilmington, University of New England; *pyund@downeastinstitute.org*

Is the southern range boundary of the northern blue mussel, Mytilus trossulus, determined by constraints on larval dispersal or thermal tolerance?

The northern blue mussel, *Mytilus trossulus,* co-occurs with its congener, *M. edulis,* throughout the Canadian maritime provinces but decreases in abundance south of the Bay of Fundy. The Eastern Maine Coastal Current (EMCC) flows from northeast to southwest along the Maine coast, so upstream source populations should be plentiful and larval abundance high. However, the EMCC diverges from shore where *M. trossulus* abundance decreases, suggesting that limited mixing between the EMCC and inshore waters may prevent larvae from returning to the coast. Alternatively, larvae or adults may suffer mortality from exposure to higher temperature water inshore of the EMCC. We tested these alternative hypotheses through a combination of field surveys and field and lab manipulative experiments. Hydrographic data collected along three transects extending from the nearshore waters out into the EMCC indicated limited wind-driven across-shelf mixing in the northeast portion of our study region, but virtually no mixing to the southwest. Mussel larval densities at the same stations were largely consistent with predictions from the hydrographic study, suggesting that a diverging coastal current can limit across-shelf larval dispersal. Field transplant experiments with juvenile mussels indicated no increase in mortality on the relevant spatial scale. However, lab experiments suggest higher mortality of *M. trossulus* larvae at a temperature attained by inshore waters, albeit only late in the dispersal season. Consequently, constraints on larval dispersal appear to be the primary determinant of the range boundary, though we cannot completely exclude larval thermal tolerance issues.

S11-1.4 YUSA, Yoichi*; SAWADA, Kota; YAMAGUCHI, Sachi; Nara Women's University, The Graduate University for Advanced Studies, Kyushu University; *yusa@cc.nara-wu.ac.jp*

Diverse and plastic sexual systems in barnacles

Barnacles (Crustacea: Thoracica) show diverse sexual systems, including simultaneous hermaphroditism, androdioecy (hermaphrodites + males), and dioecy (females + males). When males occur, they are always smaller than conspecific hermaphrodites or females (called “dwarf males”). Since Darwin found this, many scientists have been fascinated by the diversity. While most barnacles are hermaphroditic, females and dwarf males tend to occur in symbiotic or deep-sea species. We hypothesized that dwarf males had evolved in response to low sperm competition among hermaphrodites in small mating groups. Females might have evolved in very small groups, where large individuals have little chance to fertilize conspecifics. Using a phylogenetic comparative method, the data from 48 species of barnacles supported the hypothesis that dwarf males and females evolved when group size was small. In some hermaphroditic species, we observed that small individuals were attached to a specific site of large conspecifics. To test if the small individuals act as dwarf males, we investigated their reproductive state in *Octolasmis warwickii*. The small individuals on large conspecifics had a well-developed testis and a longer penis as compared with others of the same body size. Thus, these conspecific-attached individuals act as “dwarf males”. A transplanting experiment using small individuals of *O. lowei* suggested that those transplanted on conspecifics emphasized male function than those on plastic plates. Overall, our study shows that the distinction between hermaphrodites and dwarf males is sometimes obscure. We suggest that sexual expression of barnacles is more continuous and plastic than previously considered.

96.6 ZAKAS, C*; ROCKMAN, M.V.; New York University; *christinazakas@gmail.com*

Identifying genomic regions responsible for offspring dimorphism in Streblospio benedicti

Major transitions between development modes are a nearly ubiquitous feature in the evolutionary history of most animal phyla, with profound micro- and macroevolutionary consequences. However, the genetic changes that govern such transitions have yet to be characterized, impairing our understanding of how such shifts occur and shape metazoan evolution. Poecilogonous species, such as the marine polychaete *Streblospio benedicti*, produce two distinct offspring types and are ideal systems to study the evolutionary consequences of offspring dimorphism within a single species. Here, we use transcriptomic data to investigate how intraspecific genetic differences can produce morphologically distinct offspring modes. We compare expression and sequence differences between adults with contrasting developmental modes to establish markers for future genomic studies. Preliminary investigation of the *S. benedicti* transcriptome has revealed little differentiation between the two developmental modes in neutral SNP markers, suggesting that only a small portion of the genome underlies developmental differences. By using a comparative transcriptomic approach, we expect to identify a small number of key gene regions that are responsible for driving the distinct morphological differences in development mode that occurs in *S. benedicti*.

17.5 ZAMORE, S*; LAMARCA, E; DANIEL, TL; University of Washington, Roosevelt High School; *sharri@uw.edu*

Mosquitoes do not track warm plumes in the absence of CO2

Mosquitoes track host prey at large distances using windborne signals such as CO_2 and odor emission. They are also equipped with a pair of thermosensory organs on the distal end of each antenna. The calculated radiative sensitivity and unbiased landing on surfaces of varying radiative emissivity suggest they are not sensitive to radiative (black body) heat, making convective (windborne) heat a likely navigation signal. Experiments suggest that thermosensation is gated by CO_2 detection, suggesting convective tracking may require the presence of CO_2. We seek to determine if mosquitoes can track a convective thermal signal, and how this behavior is modulated by a CO_2 background. To test mosquitoes’ ability to navigate using convective heat in the absence of CO_2, we flew female mosquitoes (*Aedes aegypti*) in a darkened wind tunnel (1 m long, 0.33 m wide) in clean air. Two gold-leafed stainless steel heating rods were placed upwind as a convective heat source with low radiative emissivity. Small changes in temperature (+2 C) were detectible in thermographic images. For all trials, one heater was kept at 40 ± 0.1 C. We used 200 fps video to track the flight path and landing selectivity between two heat sources. Our data suggest that, in the absence of CO2, *A. aegypti* do not exhibit bias toward the heated element. Of the animals flights analyzed, 5 of 9 of the mosquitoes flew predominantly downwind of the heated element, while 2 trials showed no side preference. All exhibited search behaviors, but none landed on the heated rods. Given the low radiation of the heat source and the falloff of radiant heat, it remains unlikely that the mosquitoes detect radiant heat at these distances. Our observations suggest thermal tracking requires CO_2 detection.

54.3 ZAMUDIO, S*; BRAMANTI, L; EDMUNDS, PJ; California State University, Northridge; *sylvia.zamudio.69@my.csun.edu*

Temperature-induced maternal effects on the phenotype of larvae released by the brooding coral Pocillopora damicornis

Maternal effects on offspring facilitated though environmental factors can provide insight to the response of organisms to global climate change. A maternal effect occurs when environmental factors affecting mothers influence offspring phenotype, independent of their genotype or the environment into which they are released. Such effects are referred to as transgenerational phenotypic plasticity. In this study we examined maternal effects induced by temperature on the larvae of the scleractinian coral *Pocillopora damicornis* in Nanwan Bay, Taiwan. Specifically we tested the hypothesis that colonies exposed to high temperature displayed different reproductive traits and released dissimilar larvae compared to colonies at a lower temperature. Eight colonies were incubated for 16 d at ambient (27.13˚C) and elevated (29.65˚C) temperature and the outcome assessed as colony-level fecundity, timing of larval release, and energy content of larvae. Colony-level fecundity was affected significantly by temperature, with fecundity increasing 52 % at high compared to ambient temperature, and colonies in warmer conditions releasing larvae earlier (1 d) than colonies at ambient temperature. The energy content of larvae also was affected by the temperatures under which the parents were retained, with energy content 34 % lower in larvae released from colonies held at 29.65˚C. Our results show for *P. damicornis* that the thermal environment affecting maternal colonies can influence reproduction and larval phenotypes in ways that could affect offspring success.

P2.139 ZANDER, I. A.*; ABUHAGR, A. M.; CHANG, E. S.; CHANG, S. A.; MYKLES, D. L. ; Colorado State University ; *iazander@rams.colostate.edu*

Expression of molt-inhibiting hormone in brain and thoracic ganglion of green shore crab, Carcinus maenas

Molt inhibiting hormone (MIH), a neuropeptide hormone produced in the eyestalks of decapod crustaceans, regulates molting by suppressing the synthesis of ecdysteriods (molting hormones) by the Y-organ. Typically, molting can be induced by eyestalk ablation (ESA). However, adult green shore crab (*Carcinus maenas*) is refractory to ESA. ESA causes a small increase in hemolymph ecdysteroid titers, but animals do not immediately enter premolt. Some ES-ablated animals molt after many months, but most fail to molt at all. We therefore hypothesized that other regions of the nervous system, specifically brain and/or thoracic ganglion, were secondary source(s) of MIH. Nested endpoint RT-PCR showed that MIH transcript is present in brain and thoracic ganglion of intermolt crabs. Sequencing of the PCR product confirmed its identity as MIH. Quantitative PCR was used to determine the effects of ESA on MIH expression. Both green and red color morphs were ES-ablated and brain and thoracic ganglion were harvested at 7 days and 14 days post-ESA. Tissues from intact animals served as controls. MIH expression was similar between the color morphs and ESA had little effect on MIH transcript levels, indicating that the MIH gene was not regulated transcriptionally by the loss of the eyestalks. The data suggest that MIH secreted by neurons in the brain and thoracic ganglion is sufficient to prevent molt induction when the primary source of MIH is removed by ESA. Supported by NSF (IOS-0745224).

P1.82 ZANI, P.A.; BECICH, N.B. *; University of Wisconsin, Stephens Point, Pomona College ; *ncb02009@mymail.pomona.edu*

Color-morph-specific predation on clay models of side-blotch lizards, Uta stansburiana

The mechanisms behind the microevolution of color morphs of side-blotched lizard *Uta stansburiana*, in their western U.S. range are largely unstudied. Previous studies suggested that higher latitude populations of *U.stansburiana* tend to be more color-monomorphic, while populations farther south exhibit a greater range of color polymorphisms. It is unknown whether these color morphs experience different predation pressures within populations. Well-documented populations of orange morph *U.stansburiana* near Burns-Hines, OR are subjected to predation by mammals, birds, and snakes. We used clay models to measure predation rates for orange, yellow, and blue color morphs. Each color of clay model was exposed for approximately 3500 model hours during biologically relevant activity times for lizards. Blue models were nearly three times as likely to be attacked as either orange or yellow models. Differing predation rates across color morphs may indicate selection pressures against certain morphs and suggest possible explanations for morph-frequency differences between northern and southern populations of *U.stansburiana*.

P2.221 ZAPPE, ME*; THACKER, RW; Univ. of Alabama at Birmingham; *mzappe@uab.edu*

Symbiotic Microbial Communities Associated with Haplosclerid Sponges: Stability Across Space and Time

Marine sponges can host a diverse set of symbiotic microbes, many of which may provide nutrients or critical physiological functions to the sponge in exchange for shelter and some of the sponge's metabolites. Some of these interactions are obligate while others are facultative, raising questions about the evolution and maintenance of these interactions. For example, some sponge species may have co-evolved with a particular set of microbial symbionts; alternatively, the symbionts might simply be a representative sample of microbes found in the water column at the sponge's location. We examined the bacterial communities associated with haplosclerid sponges collected from different locations in different years. Multiple samples of each of 15 species were examined, including: *Haliclona manglaris*, *Haliclona maravillosa*, *Haliclona tubifera*, *Neopetrosia carbonaria*, *Neopetrosia rosariensis*, *Neopetrosia subtriangularis*, *Xestospongia bocatorensis*, *Xestospongia deweerdtae*, *Xestospongia muta*, *Xestospongia proxima*, *Xestospongia sp.1*, and *Xestospongia sp. 2*. We used terminal restriction fragment length polymorphisms (T-RFLPs) to compare community fingerprints of the most abundant bacterial symbionts within and among species. Most sponges showed high community similarity within species, even when collected in different locations and in different years. This pattern supports a potential co-evolutionary relationship between sponges and their symbiotic bacterial communities.

72.1 ZARROUK, D.; PULLIN, A.*; FEARING, R.; UC Berkeley; *david.zarrouk@gmail.com*

Locomotion Analysis of Dynamic in-Plane Hexapod

This research focuses on the velocity of in-plane dynamic hexapedal robots. The velocity of the robot and the thrust forces are calculated as a function of robot geometry, leg compliance, static and dynamic friction coefficients, stride rate. In our model, the body of the robot is rigid and each of the legs has two compliant degrees of freedom, one along its length and the other, rotational, at the hip. We first formulate the velocity of the robot for the rigid legs case and then compare the influence of the leg compliance on the locomotion using a dynamic multi-body numeric simulation and analyze the influence of the kinetic coefficient of friction on the locomotion speed. During a stride, the robot experiences a varying thrust which results in decelerating at the beginning and the end of each step while accelerating through the middle. The velocity decreases with surface incline and the advance ratio on inclined surfaces is a function of the step angle only. For experimental validation, a purpose built robot with high, nearly flat, sprawl angle, was developed to examine the in-plane mechanics model and simulation. The experimental robot was run on two different surfaces using rigid and flexible legs while changing the slope. For rigid legs, the running stall angle was ultimately limited by the minimum of the range of the kinetic COF values. For flexible legs, the advance ratio of the locomotion was reduced due to bending, but in certain cases such as running over acrylic, the stall angle was the maximum of the kinetic COF. The static COF was practically irrelevant to the locomotion for both rigid and compliant legs because the locomotion is dominated by slip. The results of the simulation, analysis and experiments were compared and found to be in excellent agreement.

P2.37 ZAVALA, N. A.*; RANK, N. E.; DAHLHOFF, E. P.; Santa Clara University, Sonoma State University; *nzavala@scu.edu*
Effects of variation at mitochondrial and nuclear genes on mitochondrial enzyme function and locomotor performance of a leaf beetle
Organisms experiencing stressful thermal conditions can experience reduced performance and reproductive success. Genetic differences at loci associated with temperature adaptation may mitigate these effects, and metabolic enzyme function may mediate the relationship between genetic variation and performance. Sierra Nevada populations of the leaf beetle *Chrysomela aeneicollis* are distributed along elevation and latitudinal temperature gradients and are polymorphic at the glycolytic enzyme locus *phosphoglucose isomerase* (*pgi*) and mitochondrial gene cytochrome oxidase II (*COII*); latitudinal variation at *pgi* and *COII* are concordant. Prior studies have shown that effects of temperature on thermal tolerance, performance and reproduction differ among (*pgi*) genotypes; however, Cytochrome c Oxidase (CytOx), an enzyme partially coded for by *COII* critical for aerobic metabolism, has not been investigated. To quantify the relationship between genotype, CytOx function, and performance, beetles were collected along elevation gradients in drainages differing in thermal regime; *COII* haplotype and *pgi* genotype was determined. In nature, CytOx activity differs between sites and drainages, being highest in coolest drainages and at high elevation. To investigate this further, beetles were collected from genetically intermediate localities, acclimated to common garden conditions in the laboratory, and effects of heat stress (36°C, 3 h) versus controls (20°C) on running speed between *pgi* genotypes/*COII* haplotypes was measured. Beetles exposed to 36°C ran faster than controls, males faster than females. Genetic analyses are underway. Variability at enzymes critical for metabolism may contribute to enhanced performance in the face of environmental change.

103.6 ZELDITCH, M. L.*; SWIDERSKI, D. L.; Univ. of Michigan, Ann Arbor; *zelditch@umich.edu*
Plasticity of a complex, integrated structure: The impact of diet on mandibular form
Plasticity may play a critical role in the persistence of populations threatened by climate change and even populations that track their thermal habitat are likely to be challenged by extreme or novel biotic environments. Phenotypes responsive to the biotic environment may be under intense selection, and, in the case of complex morphologies such as the mammalian jaw, adaptive evolution may be impeded by the (co)variance structure. If plasticity can produce a large enough change, in a direction specific to the environmental change, plasticity can circumvent both demographic and quantitative-genetic constraints. But large changes may incur other costs, e.g., disrupted developmental homeostasis. As a model system, we use mandibles of deer mouse, *Peromyscus maniculatus bairdii*, fed pellets, powder or gruel, to examine the impact of dietary consistency on size and shape. We find that plasticity has a moderate impact on size, shifting the mean of the gruel-fed mice by 0.6 standard deviations, but it has a large impact shape, shifting the means by 7.5 Mahalanobis distance units and in significantly different directions depending on diet. Despite those large changes, jaw development is not decanalized, destabilized or distintegrated. The covariance structure does change, however. Our results suggest that plasticity can modify trophic morphologies by more than is feasible by natural selection over by 10-100 generations at the maximal sustainable rate, incurring neither demographic nor developmental costs.

P3.83 ZELDITCH, M. L.*; SWIDERSKI, D. L.; Univ. of Michigan, Ann Arbor; *dlswider@umich.edu*
Contrasting responses to 100 years of climate change: Jaw morphology of two montane chipmunks
Global warming has had pronounced effects on species' ranges and timing of reproductive events, but its effects on phenotypes are not yet well documented. Morphological traits might show temperature-related trends, but they could instead show more idiosyncratic temporal patterns due to the fact that whole communities do not track the environments in concert nor do all interacting species change their phenologies concordantly. Consequently, species now may inhabit novel biotic environments, and their phenotypic changes these may be unpredictable from any single abiotic or biotic environmental variable. We compare phenotypic changes in two species of chipmunks, the alpine chipmunk (*Tamias alpinus*) and lodgepole chipmunk (*T. speciosus*) from the Sierra Nevada mountains. The samples comprise individuals that were collected by Grinnell and colleagues in 1915 and those collected by the Grinnell Resurvey Project in 2004-2007. Over that century, the alpine chipmunk has undergone a severe range contraction and exhibits increased genetic subdivision; in contrast, the lodgepole chipmunk's range has been stable and it exhibits no increased genetic subdivision. Both species have changed their jaw size and shape significantly over the past 100 years; jaw shape has changed more than jaw size in both species. Despite that commonality, jaw shapes of these species evolve in nearly perpendicular directions: the angle between evolutionary trajectories is greater than 70°. Although phenotypic change appears to be quite rapid in both species that may be due, in part to plasticity, which can produce more change within a single generation than we find within these populations over a 100 years of environmental change.

P3.96 ZELLMER, N.*; BERTA, A.; San Diego State Univ.; *ntzellmer@gmail.com*
Open Wide! An Analysis of Interspecific Variation in Baleen Ultrastructure
Baleen whales (Cetacea: Mysticeti), some of the largest animals to have ever existed, reach their colossal size through the exploitation of a novel ecological niche using a unique adaptation: baleen. A rack of baleen consists of serially placed, horn-like plates that are fringed with bristles on the lingual side. The bristles act as a sieve allowing the whales to capture large batches of prey during a single feeding event. Despite our increased understanding of baleen whales, relatively little is known about the ultrastructure of baleen and how baleen differs between species. The objectives of this study were to 1) describe the interspecies variation in plate and bristle ultrastructure, and 2) describe interspecific variation in calcium salt deposition within the tissues of the baleen plate. Histological samples were taken from the labial side of plates from members of each of the major mysticete families. These samples were analyzed using an optical microscope and transmission electron microscopy. The Von Kossa staining method was used to show the deposition of calcium salts within the baleen plates. Basic structure and patterns were described for each species and interspecies variation was contrasted. Preliminary results show striking interspecific differences in the ultrastructure of the baleen plates. The tubules of the sei whale are a uniform, circular shape while they are variably sized and rectangular in humpback whale plates. There are also differences in the organization and thickness of the horny matrix; the sei whale has a thick, outer horny wall, which is completely absent in the minke whale. The patterns of calcium salt deposition within the tissues of the plates also showed interspecific variation. Further analysis of the patterns found in baleen ultrastructure will elucidate evolutionary and ecological relationships among these unique organisms.

P2.59 ZENG, Y*; TANG, J; SINGHAL, S; GONZALES, C; RAHIM, F; NAING, G; AZIZ, A; DUDLEY, R; Univ. of California, Berkeley, Universiti Kebangsaan Malaysia; *dreavoniz@berkeley.edu*

Stepwise Flight Reduction Evolved Along Ecological Gradient

Progressive wing reduction associated with altitudinal gradient is found in different populations of a single species of stick insect native to Malay Peninsula. We used integrative approaches to investigate the functional consequence, ecological correlates and evolutionary process of this scenario. Morphometric analysis showed a disproportional reduction of wing size and flight musculature, in addition to overall body size reduction towards higher altitudes. Using high-speed filming, motion reconstruction and mechanical models, we discovered that different sized wings serve distinctive aerodynamic functions, leading to various flight performances with different adaptive significance. The morphological and functional transitions of wings are correlated with the gradient of several environmental factors, as revealed by our ecological niche modeling based on distribution of each flight morph. Furthermore, our phylogenetic analyses based on molecular data suggested a stepwise model of wing reduction during diversification toward high altitudes.

64.4 ZENG, Y*; NUNNS, H; DUDLEY, H; Univ. of California, Berkeley; *dreavoniz@berkeley.edu*

Flight with Winglets in Stick Insects

The stick insects (Insecta: Phasmatodea) exhibit remarkable variation in wing size and flapping kinematics across a wide spectrum of aerial performance, from flapping flight to complete flightlessness. How species with intermediate-sized wings fly is thus key for understanding the transition between flapping flight and flightlessness in nature. We compared different forward flights in both transport efficiency and details of wing and body kinematics, and used conservative models to address the aerodynamic output of different wings. Our analyses showed that the average wing force production with respect to body weight is important for determining the incline angle of equilibrium flight. Incipient flapping in intermediate-sized wings show reduced lift generation and power efficiency than flapping of fully developed wings. Furthermore, we modeled the distribution of material properties on wings based on experimental measurements from wings of selected species, and used computational simulation to explain the major types of dynamic deformation observed in flight performances characteristic of different sized wings.

P2.177 ZHANG, Y.*; KING, M.O.; SWANSON, D.L.; University of South Dakota; *yufeng.zhang@usd.edu*

Flight muscle size but not cellular aerobic capacity is correlated with thermogenic capacity in American goldfinches Spinus tristis .

Concurrent seasonal variation in thermogenic capacity (= summit metabolic rate, M_{sum}) and flight muscle size in small birds suggests that seasonal changes in flight muscle size are a major contributor to seasonal changes in M_{sum}. In addition, seasonal variation in cellular aerobic capacity may also contribute to seasonal variation in M_{sum}. However, few studies have directly addressed the relationship between flight muscle size, cellular aerobic capacity and M_{sum} in individual birds, so whether they are consistently correlated among individuals remains uncertain. In this study, we measured flight muscle size by ultrasonography, pectoralis and supracoracoideus masses, and activities of key catabolic enzymes, and correlated these measurements with M_{sum} for individual American goldfinches (*Spinus tristis*). Ultrasonographic measures of flight muscle width were significantly positively correlated with flight muscle mass, demonstrating that ultrasonographic measures of muscle size accurately track flight muscle mass. Flight muscle mass was significantly positively correlated with M_{sum} and ultrasonographic muscle width was also correlated with M_{sum}, although not quite significantly so (P = 0.054). Allometric residuals of flight muscle mass were also significantly positively correlated with allometric residuals of M_{sum}. In contrast, mass-specific activities for citrate synthase, beta-hydroxyacyl CoA dehydrogenase and carnitine palmitoyl tranferase in pectoralis muscle were not significantly correlated with M_{sum}. These data suggest that flight muscle size, but not cellular aerobic capacity, is a primary driver of variation in thermogenic capacity in goldfinches. This is consistent with phenotypic flexibility of flight muscle size serving as a general mechanism by which birds can alter metabolic capacities to meet changing energy demands throughout the annual cycle.

147.5 ZHANG, T*; LI, C; GOLDMAN, DI; Georgia Institute of Technology, University of California, Berkeley; *tingnan1986@gatech.edu*

Using Terradynamics to Understand the Role of Limb Morphology in Legged Locomotion on Granular Media

The theories of aero- and hydrodynamics form the bases for prediction of animal movement and device design in flowing air and water. For example, they allow computation of lift, thrust, and drag on wings and fins of a diversity of shapes and kinematics in a variety of flying and swimming animals. In contrast, we know little about how limb morphology and kinematics affect legged locomotion on natural substrates like sand and gravel which also flow in response to movement. This is largely because predictive models for such flowing ground have been unavailable. Our recently developed "terradynamics" (*Li et al*, in review)—predictive force laws for legged locomotion on granular media (sand)—allow us to begin to investigate the role of limb morphology in locomotor performance on granular media. Using terradynamics, we develop a multi-body dynamic simulation of a small six-legged robot (13 cm, 150 g) moving on granular media, and predict the speed of the robot for c-shaped legs of a range of curvatures ($-1/R < 1/r < 1/R$, where $2R = 4.1$ cm is maximal leg length) and a range of stride frequencies ($0 < f < 5$ Hz). Our simulation reveals that the robot moves faster using positive curvature legs than negative curvature legs, because the former's leg elements can access larger stresses and penetrate less deeply but generate larger thrust given the same average lift (robot weight). Further, our model predicts that using an optimal c-shaped leg of curvature $1/r = 0.86/R$, the robot can achieve maximal speed of ~70 cm/s (~5 BL/s) at 5 Hz. Our study demonstrates the power of terradynamics in the design of bio-inspired devices and promises to aid understanding of the functional morphology of sand-dwelling organisms.

P3.153 ZIMMERMAN, K.L.*; SATTERLIE, R.A. ; University of North Carolina at Wilmington; *klz2540@uncw.edu*
Muscular Organization of a Scyphozoan Jellyfish: Aurelia aurita
The musculature of the Scyphozoan jellyfish *Aurelia aurita* was studied and observed, specifically within the subumbrella. Previous studies have concluded that the subumbrella of *Aurelia aurita* is comprised of a uniform sheet of circular, striated muscle. Recently, radial distortions have been found in the musculature, and these irregularities appear randomly throughout the sheet of circular muscle. A radial distortion is defined as a band of muscle fibers that run in apparently random directions, including a radial component. We provide observations on the distribution, size and orientation of the radial distortions. We also describe a region at the edge of the subumbrella that lacks circular muscle fibers. A developmental series from the ephyra to the adult medusa has been examined to determine how the radial distortions in the musculature of the subumbrella develop throughout growth and maturation of the jellyfish. The width of the marginal muscle-free band has also been measured throughout a developmental series. This work has implications for understanding the kinematics of swim contractions, particularly with reference to the rowing movements of the bell margin and the asymmetrical contractions seen during turning and righting behaviors.

P3.119 ZIMMERMAN, L.M.*; VOGEL, L.A.; BOWDEN, R.M.; Il. St. Univ.; *lmzimme@ilstu.edu*
Effect of age and temperature on antibody production in a long-lived ectotherm
Immunosenescence, a decrease in immune function with age, is a common finding in both endothermic and ectothermic vertebrates. However, because of the effect of temperature on basic biological processes of ectotherms, temperature can also influence the immune responses of ectotherms. In general, ectothermic vertebrates can mount immune responses over a wide range of temperatures, and often there is a species-specific temperature at which responses are strongest, with impaired responses above and below this threshold. Little is known, though, about how the long-term effects of age may influence the response to short-term temperature changes. This study examined humoral immune responses in a long-lived reptile, the red-eared slider turtle, *Trachemys scripta*. Sliders can produce both natural antibodies in the absence of antigen stimulation and specific antibodies in response to stimulation. Adult turtles were trapped and blood samples taken. Because sliders grow throughout their lifetime, plastron length was measured as a proxy for age. Leukocytes were isolated and their ability to produce antibodies at different temperatures was measured using an ELISpot assay. Cells were cultured in media alone to examine spontaneous antibody (Ab) production or in the presence of lipopolysaccharide (LPS) to examine stimulated Ab production. The assay was conducted at 27, 29, 33, and 37°C. We found a significant plastron by temperature interaction on spontaneous Ab production, and a similar trend for stimulated Ab production. Our results suggest that the negative effects of aging may only manifest themselves at higher temperatures, which could lead to differences in basking behavior for young and old individuals.

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Do heating rates matter for measurement of cardiac output in intertidal mussels?
Most controlled laboratory experiments examining the effects of temperature on the performance of intertidal organisms rely on air temperature as a proxy for body temperature, or conduct measurements in water to simulate aerial temperatures. In such experiments, body temperatures can deviate from air temperatures inside the experimental chamber based on heating method, organism size and behavior, and heating rate. Q_{10} and other metabolic rate calculations, such as Arrhenius temperature, tend to be based on changes in ambient air temperature and therefore may not correspond to the true changes in the body temperature of the organism. Understanding the metabolic responses of organisms to changes in body temperature provides a better index for comparing climate effects within and among species, especially among intertidal organisms, which experience large fluctuations in body temperature that commonly approach their upper lethal limits. In the present study, we used a non-invasive sensor to measure the cardiac responses of a rocky intertidal bivalve *Mytilus californianus* and a salt marsh bivalve *Geukensia demissa* to elevated body temperatures. These intertidal bivalves experience a wide spectrum of heating rates during every low tide. Our preliminary data, suggest that rates of heating have differential effects on cardiac output of experimental organisms of different sizes and species. Since many physiological assessments often overlook realistic heating rates, this index of thermal stress could be more important than previously thought (i.e. magnitude and duration) and should be considered when investigating future climate change impacts on intertidal organisms.

57.1 ZOHDY, S*; KEMP, A.D.; TECOT, S; WRIGHT, P.C. ; JERNVALL, J; Emory University, University of Texas, Austin, University of Arizona, Stony Brook University, University of Helsinki; *sarah.zohdy@emory.edu*
Of Lice and Lemurs: Personality Traits and Parasite Dynamics in Wild Brown Mouse Lemurs Microcebus rufus
Animal personality traits have the potential to influence exposure and susceptibility to parasites. Bold individuals may experience increased contact rates with conspecifics and aggressive behaviors which make them more vulnerable to parasites with direct transmission routes. To better understand whether bold individuals are at a higher risk of ectoparasite infestation than their shy conspecifics, we performed behavioral assays to qualitatively determine degrees of boldness and shyness, measured fecal testosterone levels, quantified louse infestations, and documented the exchange of lice between known individuals in a population of wild brown mouse lemurs (*Microcebus rufus*) in the eastern rainforests of Madagascar. We hypothesize that 1) bold individuals will have higher testosterone levels than shy individuals, 2) bold individuals will harbor more lice than shy individuals, and 3) bold individuals will play a larger role in spreading lice in the population than shy individuals. While we did find that bold individuals had the highest testosterone levels, we found no evidence to support the idea that bold individuals had more lice than shy individuals. However, when examining the patterns of louse exchange between individual lemurs, our results show that bold individuals act as superspreaders and are responsible for the widespread movement of lice in the population, while shy individuals act as supercollectors harboring higher louse infestations. Taken together, these results suggest that personality traits may underlie differences in host-parasite dynamics. Meanwhile, parasites also impact host condition, and thus may also play a role in the evolution of host personality traits such as boldness and shyness.

P1.162 ZUZOW, M*; CHILTON, H; FANGUE, N; TODGHAM, A; TOMANEK, L; Cal Poly, San Luis Obispo; *mzuzow@calpoly.edu*

Proteomic responses of Sebastes melanops to ocean acidification associated stress

Global climate change has implications for coastal marine ecosystems. Increasing CO_2 levels could have negative effects on physiological processes in numerous taxa including rockfishes (genus Sebastes). We chose the pelagic Black Rockfish (S. melanops) for our investigations for several reasons, including their economic and ecological importance in Pacific marine ecosystems, the availability of the species, its life history traits that make populations particularly sensitive to negative impacts, and the relative ease of collection and maintenance of its young life stages for laboratory experimentation. Among several goals of this experiment, we wanted to investigate the metabolic costs associated with developing under elevated CO_2 in juvenile fishes. Rockfish were exposed to 3 different CO_2 concentrations (400ppm, 1000ppm, and 2000ppm) over 7 d, 14 d, 21 d, 24 d, and 96d to monitor effects on development. We extracted protein from gill and liver tissues and separated their proteins with 2D gel electrophoresis. To identify protein expression patterns, we analyzed gels with Delta 2D (Decodon) and performed a 2-way permutation ANOVA to compare CO_2 concentrations and exposure times ($p<0.02$). Roughly a third of the proteins showed a time-dependent response to different CO_2 levels in both gill and liver tissues. Differing slightly, gill showed more of a time-independent response to increasing CO_2. The results suggest that there are broad similarities in the responses of the two tissue types. Proteins identified with tandem mass spectrometry in both tissues include proteins involved in the proteasome, oxidative stress proteins and proteins involved in energy metabolism.

P3.3 ZYLBERBERG, M*; KLASING, KC; HAHN, TP; University of California, Davis; California Academy of Sciences, University of California, Davis; *mzylberberg@ucdavis.edu*

House finches (Carpodacus mexicanus) balance investment in behavioral and immunological defenses against pathogens

Infection with parasites and pathogens is costly for hosts, causing loss of nutritional resources, reproductive potential, tissue integrity, and even life. In response, animals have evolved behavioral and immunological strategies to avoid infection with pathogens and infestation with parasites. Scientists generally study these strategies in isolation from each other; however, since these defenses entail costs, host individuals should benefit from balancing investment in these strategies, and knowing their relationship would inform our understanding of infectious disease dynamics. Here, we test the hypothesis that investment in immune function is inversely related to investment in behaviors that potentially decrease pathogen exposure. We show that *Carpodacus mexicanus* (house finches) alter their behavior in response to social partner health status, avoiding sick individuals. Moreover, we show that individuals investing less in behavioral pathogen defenses invest more in innate immune defenses. This individual variation in pathogen defense strategies is expected to affect the dynamics of pathogen spread through populations, and ultimately the course of epidemics. A deeper understanding of individual and population level disease defense strategies will improve our ability to understand, model, and predict the outcomes of pathogen spread in wildlife.

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