

Symposia and Oral Abstracts

37.5

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WHY DOES STRESS SUPPRESS IMMUNITY? A POSSIBLE ANSWER FROM INSECTS.

Both vertebrates and mollusks (e.g. oysters) become more susceptible to disease after exposure to a stressor, suggesting that stress-induced immunosuppression is an old and wide spread phenomenon. We found that insects are also immunosuppressed by stress. Physical exercise, restraint, flight, heat, agonistic behaviour and elevated levels of the fight-or-flight neurohormone octopamine reduced immune function (lysozyme-like activity) and disease resistance (resistance to the bacterium *Serratia marcescens*) in the cricket *Gryllus texensis*. However, a brief escape run, exposure to cold and a minor cut to the wing did not induce an increase in hemolymph octopamine titres nor did they reduce resistance to *S. marcescens*. These results suggest that a prolonged period of elevated metabolism coupled with neurohormonal octopamine release are required for immunosuppression. We found no evidence that immune resources are undergoing redistribution after stress. Wound infection was more likely after restraint stress than in controls. Preliminary evidence suggests that the decline in immune function after stress is due to a physiological constraint involving carrier molecules (lipophorins) that are required both for ferrying lipid energy compounds from fat body to muscle as well as for normal immune function.

14.11

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EVOLUTION OF TROPHIC SPECIALISATIONS IN NEOTROPICAL CATFISHES: MORE THAN A MOUTHFUL

In 1986, Schaefer and Lauder presented a case study on structural innovations in loricarioid catfishes, providing support for the so-called decoupling hypothesis. The observed innovations nicely fitted onto a phylogenetic framework, explaining a hierarchical addition of evolutionary steps towards an increased mobility of the feeding apparatus. It could also be considered as an example of a clear trend towards increased biomechanical independence of functional components, in this case towards a sucker mouth for scraping algae from the substrate (in loricariids) and for clinging against rocks (in astroblepids). Exactly 20 years after the publication of this paper, an update will be given based on new evidence on the microscopic anatomy of both ontogenetic and adult specimens in some loricarioid representatives, as well as some preliminary data on the kinematics of feeding in loricariids. A re-evaluation of the hypotheses formulated by Schaefer and Lauder (1986) is done, giving an overview to what degree they are still corroborated or not. *Schaefer, S.A. & G.V. Lauder (1986) Systematic Zoology 35(4):458-508*

S3-2.4

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LOCOMOTOR PERFORMANCE AND STRATEGIES IN FROGS: A SIMPLE MODELLING APPROACH

A simple mathematical model consisting of an ellipsoid body and telescopic limbs, driven by actuators with muscle-like properties, is used to assess locomotor performance and strategies in frogs. F_{max} and V_{max} of the actuators are tuned in such a way that, upon full activation, the model performs realistic jumps. These muscle characteristics are then used to mimic aquatic locomotion. The reliability of the approach is successfully tested by comparing maximal model performance (in terms of propulsive impulse) with the performance of animals stimulated to flee with maximal efforts. Obviously, the interaction between the physical properties of the environment and of the muscles suffices to explain the seemingly poor aquatic performance when compared to the jumping impulses. A sensitivity analysis indicates that adjusting intrinsic muscle speed offers the best option to improve maximal (aquatic) performance. Finally, the model is used to gain insight in coordination and control of submaximal swimming performance.

76.8

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METHIONINE BIOSYNTHESIS LIMITS ADAPTATION TO HIGH TEMPERATURE IN *ESCHERICHIA COLI*

In *Escherichia coli*, degradation of the first enzyme in the methionine biosynthesis pathway may be a critical limitation to growth at high temperatures. To determine if this pathway was subject to change by natural selection, we measured fitness and growth rate in 6 lines of *E. coli* that had evolved for 2000 generations at 41.5°C. In 3 of the 6 lines, fitness relative to their ancestor was significantly reduced with methionine supplementation compared to control. Thus, methionine partially restored the ability of the ancestor to compete by compensating for reduced methionine biosynthesis. In one line, methionine completely restored the fitness of the ancestor, suggesting that stabilizing the methionine pathway was a major adaptation to 41.5°C. In contrast, for those lines in which fitness was not significantly affected in methionine, adaptations to high temperature appear to be independent of methionine biosynthesis. If cultures were supplemented with alanine, fitness was unchanged or significantly increased, showing that changes in methionine are not a general amino acid effect. At 37°C, fitness changed significantly with addition of methionine in two lines, but in opposite directions. Lag time and maximal growth rate were measured at 41.5°C and at 37°C. Overall, lag time decreased and growth rate increased with methionine supplementation at 41.5°C, however no individual line changed significantly. Protecting methionine biosynthesis appears to be important during evolution at high temperatures, but the growth-phase in which it is critical isn't clear. (Supported by NSF-IBN9905980 and NASA-632731 to AFB and NIH-Bioinformatics Training grant to NMA.)

S3-2.3

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TRANSLATING A NEURAL SIGNAL INTO A MECHANICAL OUTPUT

The mechanical behavior of muscle during locomotion is often predicted from its anatomy, stimulation pattern, basic contractile properties, and joint kinematics. Cockroaches and frogs provide model systems to examine these assumptions. In the cockroach leg, two muscles operating at the same joint are innervated by a single motor neuron. Direct measurements under *in vivo* running conditions reveal that the same neural signal and joint kinematics can result in different mechanical behaviors from two anatomically similar muscles with the same contraction kinetics, force-length properties, and force-velocity properties. In the frog semimembranosus muscle (SM), *in vivo* segment length changes along the muscle's length were examined during hopping to link data addressing *in vitro* sarcomere behavior with *in vivo* muscle behavior. As expected, the proximal and mid segments of the SM shortened similarly during hopping. During the same hop, however, the strain of the distal segment was lower and more variable, often lengthening before shortening. These differences in strain amplitude and pattern imply that adjacent segments along a parallel-fibered muscle can operate on different regions of their force-length and force-velocity relationships. Moreover, these *in vivo* segment strain patterns differ from the patterns of sarcomere heterogeneity seen *in vitro* in single fibers. A single neural input to two muscles within group and to adjacent segments along a muscle can result in variable mechanical outputs during locomotion.

24.3

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INTEGRATION AND EVOLUTION OF THE TELEOST MANDIBLE: THE MOLECULAR BASIS OF ALTERNATE FEEDING STRATEGIES

The cichlid jaw is an icon of Darwinian evolution by natural selection. Highly specialized modes of feeding have evolved rapidly and repeatedly in various lineages resulting in impressive trophic diversity. The opening and closing lever mechanisms of the lower jaw have traditionally been used to describe the mechanics of feeding behavior in bony fishes. Here we explore the molecular basis of this biomechanical system. Quantitative genetic analyses demonstrate that the opening and closing mechanism of the cichlid jaw are genetically modular and therefore free to evolve independently. *Bmp4* is one of two loci that segregate with the mechanical advantage of closing, and account for over 30% of the phenotypic variance of this trait. Species-specific differences in jaw shape are obvious early in cichlid larval development and are correlated with alternate patterns of *bmp4* expression in the mandibular primordium. When *bmp4* is over expressed in the obligate suction feeder, *Danio rerio*, mechanical advantage increases, and mandibular morphology adopts a surprisingly specific biting design. This work demonstrates the potential of integrating studies in natural populations and model organisms to address questions relating to evolution and development. We conclude that patterns of morphological integration of the cichlid jaw reflect a balance struck among conflicting functional demands. Further, we demonstrate that *bmp4* has the potential to alter mandibular morphology in a way that mimics adaptive variation among fish species.

22.3

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INCREASED AMBIENT TEMPERATURES IN AN URBAN LANDSCAPE AFFECT HATCHING SUCCESS OF THE THREATENED FLORIDA SCRUB-JAY *APHELOCOMA COERULESCENS*

Ambient temperature has important physiological consequences on the viability of eggs. According to the egg viability hypothesis eggs exposed to ambient temperatures for prolonged periods prior to the onset of incubation have reduced hatchability. Data collected over two years show that daily ambient temperatures differ between a suburban and a wildland site in south central Florida. We studied the effects of these differences on the hatchability of eggs. We hypothesized that the suburban population would have decreased viability of earliest laid eggs within a clutch. We recorded clutch initiation date, number of laying days, clutch size, number of incubation days (days between last laid egg and first hatched egg), pre-incubation and total egg water loss, and pre-incubation embryonic development as potential factors affecting egg viability. Using logistic regression we found that the hatchability of entire clutches was affected only by site and the number of days of incubation. Specifically, first-laid eggs in the suburban population had lower viability than first-laid eggs in the wildlands, supporting the egg viability hypothesis. In addition, the mean number of incubation days was lower in the suburbs. Ambient daily temperature increased in both sites as the season progressed, and a negative relationship existed between the number of incubation days and the advancing season. This suggests that as ambient temperature increases, jays may respond by initiating incubation before the clutch is completed, thus decreasing the duration that un-incubated eggs are exposed to ambient temperatures. This may be a behavioral adaptation to reduce decreased viability of the first laid egg in warm environments.

8.3

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TESTING RATES OF PLANKTONIC VERSUS BENTHIC PREDATION IN THE FIELD

Predation is thought to be the most important source of embryonic and larval mortality for benthic marine invertebrates. However, few estimates of larval mortality exist and more precise estimates of larval mortality in the field are needed to improve our understanding of the evolution of complex life-cycles. Despite the importance of this information, field studies of mortality have been limited, with few comparisons across species or habitats. This has prevented comparison of the relative risks of development in different habitats. The planktonic environment is assumed to be a safe harbor for the developmental stages of marine invertebrates with rates of predation that are lower than on the benthos. However, no data currently exist comparing predation rates on equivalent developmental stages in these habitats. To determine relative risks of predation for eggs, embryos and larvae, we measured loss rates of agarose baits flavored with the eggs of the sand dollar *Dendraster excentricus* in planktonic and benthic habitats in Parks Bay, Washington. In addition, we measured loss rates on live, tethered megalopae of the crab, *Cancer magister* in the same habitats. For both agarose baits and tethered megalopae, predation rates were lower in planktonic than benthic habitats. Predation rates on tethered megalopae were three times greater on the benthos than in the plankton during the day, and loss rates were 18 times greater for benthic megalopae than for planktonic megalopae at night. These results suggest that diel migrations of larvae may significantly reduce mortality rates due to predation. These experiments also confirm a basic, yet untested, assumption of life-history theory, that rates of predation on developmental stages of marine invertebrates are greater on the benthos than in the plankton.

28.1

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EVO-DEVOS HARD PROBLEM: NATURAL SELECTION

Three broad problems faced evo-devo during the 20th century, and two have been solved. The problems were 1) To find a level of description of evolutionary processes that also expressed ontogeny. Heterochrony and allometry were unsuccessful candidates. 2) The dominance of transmission genetics, and its uncomfortable relations with developmental biology (née embryology). The transmission genetic basis of the Evolutionary Synthesis served as a kind of buffer between evolution and development. 3) The methodological accusation that developmental evolutionary theorists were typological, while proper evolutionists were population thinkers. Even though this seemed the most rhetorical, it is the problem that persists. The first two were solved when developmental genetics matured in the 1990s. Developmental genetics replaced the developmentally recalcitrant tradition of transmission genetics, and (when understood phylogenetically) it covers the ontogeny/phylogeny divide. It may seem that the third problem is solved also: the accusations of typological thinking have abated. But this is only an illusion born of the prestige of developmental genetics. The accusations of typological thinking were heavily rhetorical and historically inaccurate, but they contained a kernel of truth. I argued in *The Changing Role of the Embryo in Evolutionary Thought* that certain basic concepts of evo-devo indeed seem to violate the principles of population thinking. This does not make them unscientific (contrary to earlier rhetoric), but it poses a problem for the unification of evo-devo with standard views of the operation of natural selection. I will discuss some informal attempts made by evo-devo-ists to solve the problem, and how these attempts fail. In conclusion I will summarize as succinctly as possible what remains of the old challenge: typological thinking is inconsistent with natural selection.

73.8

ANDERSON, N.J., ANDERSON, C.W.; andenoah@isu.edu. Idaho State University
KINEMATICS OF AQUATIC FEEDING IN THE SOFTSHELL TURTLE, *APALONE SPINIFERA*, WITH COMMENTS ON THE ROLE OF SUCTION IN TURTLE FEEDING

Generation of negative buccal pressure is a necessary component of aquatic feeding for many vertebrates. While past studies found similar mechanics of the jaw and hyoid apparatus in several species of turtles, the role of suction feeding in this group is debated. Two components of suction feeding, compensatory and inertial suction feeding, have been proposed for this group. I studied the kinematics of feeding in the softshell turtle, *Apalone spinifer*, which are thought to feed using inertial suction. Kinematic analysis suggests that while jaw and hyoid mechanics are similar to other species of turtles, this species differs in several important aspects. First, static prey is contacted prior to initiation of the feeding sequence, hence any bow wave from head and/or the body has proceeded past the prey by the time feeding is initiated. Secondly, the lips occlude the corners of the mouth during the gape cycle, which may assist feeding and possibly eliminate the need for head rotation during feeding. Lastly, for some feeding sequences, the neck moves in reverse, rather than forward motion (i.e., striking) that is commonly reported in turtles. The kinematics of prey capture in *A. spinifer* will be compared to other species of aquatic feeding turtles.

18.1

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DEVELOPMENTAL MECHANISMS UNDERLYING DIVERGENT MORPHOLOGY IN THE ANTENNAE OF *TRIBOLIUM* FLOUR BEETLES (COLEOPTERA)

Describing the mechanisms through which animal morphology evolves is a fundamental goal of modern biology, unifying developmental and evolutionary disciplines. We have chosen to examine this issue in flour beetles of genus *Tribolium* (Coleoptera, Tenebrionidae). *Tribolium* includes 30 species, which have diverged within approximately the last 15 million years. Many of these species are significant pests of stored grain products, which has made *T. castaneum* a popular genetic system. Among the *T. castaneum*, *T. confusum*, and *T. brevicornis* species groups, the adult antennae differ in their structure and the number of segments organized into the distal club region. We have taken a comparative developmental genetic approach to analyze the roles of appendage-patterning genes in pupal antennal development in *Tribolium*. Insect appendage development is best understood in *Drosophila* (Cyclorrhapha) where adult limbs develop in a derived state, from imaginal discs during larval instars. In contrast, *Tribolium* appendages develop in the primitive insect state, from embryonic limb buds. Larval appendages are subsequently repatterned during metamorphosis: a process about which little is known. Using candidate genes from *Drosophila*, such as *bric-a-brac*, *arista-less* and others, as well as classical genetic mutations isolated in *Tribolium*, we have begun to characterize antennal patterning in *T. castaneum*. The complete genome sequence of *T. castaneum* has aided in the analysis in putative gene regulatory regions. Comparisons of gene expression and function have also been undertaken in congeners in order to explore differences in antenna developmental mechanisms and their potential influence on divergent morphologies.

4.3

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GEOMETRIC MORPHOMETRIC ANALYSIS OF PLASTRON SHAPE IN THE WESTERN POND TURTLE (*EMYS MARMORATA*): IMPLICATIONS FOR CONSERVATION AND PALEONTOLOGY

We present results of a geometric morphometric study of plastron shape in *Emys marmorata*. We digitized 19 landmarks on the sulci between the plastral scutes using photos of over 700 specimens. After archiving the data, we examined three sources of shape variation, ontogeny, sexual dimorphism, and phylogeography. We also tested whether two fossil shells from the Miocene (~10 mya) and Pleistocene (0.5-1.0 mya) fall within the range of variation displayed by extant members of the species. Multivariate regression shows that size and plastron shape are correlated. Sexual dimorphism also is apparent; males and females display subtle but significant shape differences. To test for a phylogeographic signal, we binned specimens into geographically delimited groups based on four clades recognized in a recent molecular phylogeny of *E. marmorata* populations. Comparisons between the groups suggest that each differs significantly in plastron shape. Finally, the Pleistocene fossil reliably fell within the extant range of variation, but the Miocene fossil did not, perhaps reflecting postmortem deformation. Our preliminary results show that significant morphologic variation exists that corresponds to molecular variation in *E. marmorata*. In this sense, our data are an independent line of evidence corroborating the distinct histories of the four mitochondrial clades. If the apparent distinctiveness of the clades withstands further testing, conservation plans for *E. marmorata* will need to be altered to account for this diversity. Finally, our results suggest that geometric morphometrics may be useful for rigorously comparing fossil *E. marmorata* specimens to the range of extant morphologies, even in the absence of discrete characters.

28.5

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CELL SIZE VS. CELL NUMBER. DOES IT MATTER?

Many environmental factors influence realized body size and, all else being equal, organismal size is determined by a combination of cell size and cell number. In some species, temperature is thought to affect body size primarily through cell size while food is thought to act primarily through cell number. It is, however, not known whether or not the cellular mechanism underlying variation in body size matters for whole organism performance. Here, I test this hypothesis by rearing tadpoles of the Western spadefoot toad at different temperatures and food levels. Performance is measured in terms of burst swimming speed and these correlated with cell size and number in the tail muscle. Tadpoles reared at warmer temperatures are slower swimmers, a pattern seen in other anuran species. Food level, however, does not influence swimming speed independent of its affect on overall body size. Differences in swimming speed are correlated with differences in muscle composition. Warm-reared tadpoles had many small muscle fibres in comparison to cold-reared tadpoles. Patterns of muscle development in these tadpoles and several teleosts suggest this is due to accelerated recruitment of new cells. As a result, warm-reared tadpoles have many, small, immature muscle fibres which may explain their slower swimming speeds. It appears that composition (cell size vs. cell number) matters for performance, at least in some tissues.

S6-2.3

ARONOWICZ, J., LOWE, C.J.; jochi@uchicago.edu. University of Chicago
THE MIDBRAIN-HINDBRAIN GENE EXPRESSION PROFILE IN
SACCOGLOSSUS KOWALEWSKII

The diffuse nervous system of the direct developing hemichordate *Saccoglossus kowalewskii* shares many of its remarkably complex anterior posterior patterns of developmental gene expression with vertebrates. Recent studies in larvaceans, tunicates and amphioxus indicate that the complex suite of signaling and transcriptional factors that give rise to the midbrain/hindbrain organizer in vertebrates (MHB) have either been partially lost in the cephalochordates and urochordates lineages, or evolved later in chordate evolution along the vertebrate lineage. Our results suggest that much of the genetic regulatory cassette responsible for patterning this critical region of vertebrate neural anatomy evolved very early in deuterostomes, and has been utilized for patterning very different elements of neural organization in vertebrates and hemichordates. The topology of expression of many conserved transcription factors involved in MHB patterning is almost identical between the two groups. Further similarities are found when comparing the expression of signaling molecules such as wnts fgfs and retinoic acid. It appears that the regulatory relationship of genes responsible for patterning the vertebrate MHB have a deep pre-chordate history and have been deployed in taxa with highly divergent neural organization.

40.1

ARONOWSKY, A., ANDERSON, L.C.; audrey@geol.lsu.edu. Louisiana State University
CORBULID BIVALVE PHYLOGENY AND THE FACILITATION OF ECOSYSTEM INVASION

The bivalve family Corbulidae includes about 35 nominal genera of which 15 are extant. Although corbulids are often overlooked in malacologic and paleontologic collections, in part because of their diminutive size, the family is of particular interest biologically and paleontologically because it contains two extant invasive species (*Potamocorbula amurensis* and *Varicorbula gibba*), and at least 20 fossil species that came to dominate the freshwater systems they colonized. Thus corbulid history is marked by both ancient natural and modern anthropogenically-mediated invasions, making it an ideal clade in which to examine the traits thought to facilitate invasion. However, a clear understanding of corbulid evolutionary history is hindered by a number of taxonomic and systematic issues. We explore the phylogeny of the Corbulidae using separate and combined analyses of corbulid soft anatomy and shell morphology. This study, which builds upon previous research, uses shell characters that describe external ornament, hinge features, pallial line and sinus, and adductor muscle scars. The analysis includes four genera (*Notocorbula*, *Potamocorbula*, *Anticorbula*, and *Lentidium*) previously uncoded for shell morphology, as well as new outgroups: *Mya* and *Lyonsia*. Soft anatomical characters describe all aspects of corbulid anatomy, but focus on more variable features such as the siphons, mantle, gills, muscles, and digestive system. This study presents the first full anatomical descriptions for several corbulid species including *P. amurensis*. The corbulid phylogeny will be used to test hypotheses related to the number of times corbulids have successfully invaded ecosystems and which ecologic and life history characters correlate with these invasions.

41.1

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FEARSOME FANGS AND FAST FEET: KINEMATICS OF PREY CAPTURE IN TARANTULAS

Tarantulas are large, predatory spiders of the family Theraphosidae. Adult sizes range from 4–10 inches across the outspread legs, and these spiders are capable of eating prey up to mice and birds in size, though much of their diet consists of insects. Unlike many derived spider families, tarantulas do not spin webs for prey capture; instead, the theraphosids strike and subdue prey using their appendages. We used high-speed video at 500 frames per second to record and analyze a minimum of five successful strikes on crickets of three species of tarantula: the Mexican Red-Knee (*Brachypelma smithi*), Chilean Rose-Hair (*Grammostola rosea*) and Guyana Pinktoe (*Avicularia avicularia*). Contrary to our initial expectations, the fangs are not used in the initial strike to contact the prey. Rather, the first two pairs of legs are typically reached over the cricket, and used to scoop the prey in toward the mouth. As soon as the prey comes within reach of the pedipalps, these shorter appendages are used to position the cricket under the fangs. The fangs then pierce the prey while the pedipalps and first two pairs of legs hold the prey stationary. Time taken from first movement of the legs to piercing the prey with the fangs is approximately 300 ms. Following initial mastication of the cricket with the chelicerae, the tarantulas often spin a diffuse mat of silk on the ground, drop the mashed-up prey onto the silk, spin more silk to cover the prey, and finally pick up the wrapped package for further mastication and ingestion. Though the basic sequence of events in prey capture and processing is stereotyped, tarantulas are capable of extensive modulation in the direction of the strike, and the amount and kind of post-capture processing.

72.10

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CLIMBING WITHOUT LIMBS: ARBOREAL LOCOMOTION OF SNAKES

Environmental variation commonly affects patterns of movement, muscle activity, and energetics of locomotion. Some of the functional challenges imposed by arboreal habitats include inclines, balancing, and fitting on surfaces of limited width which have been well studied for limbed vertebrates such as primates and lizards. Although several lineages of snakes have independently become specialized for arboreal habitats, data on the mechanisms and modes of arboreal locomotion of snakes are lacking. Thus, we videotaped five phylogenetically diverse species of snakes climbing on cylinders of varying diameter and incline to determine if perch attributes affect kinematics and performance within a species and if locomotor modes varied among species. Four species (*Python reticulatus*, *Corallus hortulanus*, *Morelia spilota*, *Elaphe guttata*) are obligate constrictors, and one species (*Boiga irregularis*) is mildly venomous and occasionally constricts prey. *Corallus hortulanus* and small individuals of *B. irregularis* are more attenuate and specialized for arboreal locomotion than the other species. We observed two major strategies for moving on cylindrical perches. *B. irregularis* performed a variant of lateral undulatory locomotion without grasping the perch, whereas the other species grasped the perch firmly during static contact while performing a variant of concertina locomotion. Species that grasped the perch varied in whether the body was wrapped helically or was looped alternately to the left and right. Quantitative differences among species included speed and forward progression per cycle of movement. Descent of steep inclines usually lacked the momentary static contact that occurred while ascending. Thus, despite the superficial similarity of an elongate limbless body plan, arboreal snakes displayed an unexpected diversity of locomotor modes.

72.4

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ANTI-ADHESIVE PROPERTIES OF GECKO SETAE

Gecko toe pads operate under perhaps the most severe conditions of any adhesive application. The adhesive setae on the toes of climbing geckos must adhere strongly yet detach rapidly and avoid fouling or attachment at inappropriate times. Gecko setae do not adhere spontaneously to surfaces, but instead require a mechanical program for attachment. Following preload and drag steps, a single seta on a hydrophobic Si MEMS cantilever can generate a very strong adhesive force of up to $40\mu\text{N}$ over approx. $43\mu\text{m}^2$ of area, or approx. 917 kPa (9 atm) of adhesive stress. Paradoxical as it may seem given that setae are so strongly adhesive, there is growing evidence that gecko setae are also strongly anti-adhesive. Unlike adhesive tapes, gecko setae do not self-adhere. Pushing the setal surfaces of a gecko's feet together does not result in strong adhesion. Unlike conventional adhesives, gecko setae do not stay dirty after particulate contamination. New results comparing water droplet contact angle (τ) of isolated setal arrays to the smooth surface of eye spectacle scales of tokays (*Gekko gekko*) suggest that gecko setae are strongly anti-adhesive in their unloaded default state. At equilibrium, τ was $98.3^\circ \pm 3.4$ in spectacle scales of live geckos and $93.3^\circ \pm 3.5$ in isolated spectacles. Isolated setal arrays were ultrahydrophobic, with τ of $160.6^\circ \pm 1.3$ (means \pm SD). By Cassie's law of surface wettability, the difference in τ of setal arrays and smooth spectacles indicates a very low contact fraction. Less than 6.6% of the surface of unloaded setae is solid and at least 93.4% is air space. The contact fraction must increase from 6% to 46%, or by approx. 7.5x, following preload and drag to yield 917 kPa of adhesive stress. Thus gecko setae may be nonsticky by default because only a very small contact fraction is possible without first mechanically deforming the setal array through preload and drag.

57.4

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FORTUNA DUBIA: BYSSAL FUNCTION IN MARINE MUSSEL ADAPTATION TO SEASONAL CHANGES IN WAVE ENERGY

Mussels are dominant space competitors on intertidal rocky shores. They occupy space on rock by attaching extra-cellular shock absorbing fibers to their surroundings. Continuous force records during mussel dislodgement from substratum demonstrate that low wave energy adapted animals have low attachment strength and piecewise failure of the byssal apparatus. High wave energy adapted mussels have high attachment strength and exhibit catastrophic failure of the byssus. The period of transition between seasons of low wave energy to seasons of high wave energy is predicted to have the greatest probability of individual dislodgment by hydrodynamic forces. Here we use forces measured on mussels in breaking waves in concert with the continuous force records of mussel extraction to explore the importance of byssus structure on seasonal wave force adaptation, and to estimate the seasonality of risk of dislodgement.

28.2

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ARE FLUCTUATING ASYMMETRY STUDIES ADEQUATELY SAMPLED? IMPLICATIONS OF A NEW MODEL FOR SIZE DISTRIBUTION

Previous work on fluctuating asymmetry (FA), a measure of developmental instability, has highlighted its controversial relationship with environmental stress and genetic architecture. While size-based measures of FA have long been assumed to be half-normally distributed within populations, recent studies that model developmental mechanisms have suggested other plausible distributions for FA. We investigated the distribution of FA in large empirical datasets of wing shape and wing size asymmetry from three species of insects (cotton aphid, *Aphis gossypii* Glover, honeybee, *Apis mellifera*, and long-legged flies, *Chrysosoma crinitus*). Regardless of method of measurement, FA was best described by a double Pareto lognormal distribution (DPLN), or one of its limiting functional forms. To investigate convergence of mean sample FA to the population mean at various sample sizes, we sampled repeatedly under a DPLN using parameter values that best fit our data. Sample variances are much larger, and hence convergence is slowed considerably, with univariate or multivariate size-based measures of FA in contrast to a multivariate shape-based measure of FA. We suggest that much of the past work in FA may be under-sampled and we recommend using multivariate shape-based approaches or collecting larger datasets in future studies. We also discuss the implications of the DPLN distribution for understanding the developmental mechanisms underlying FA.

74.2

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DRINKING OF FRESH WATER BY SEA SNAKES

Recent field observations at Orchid Island, Taiwan, suggest that sea snakes are more abundant at sites having near-shore sources of fresh water (springs or estuaries), compared with strictly marine sites. We quantified the relative abundance of sea snakes by means of nocturnal surveys when snakes were active in shallow coastal pools. The mean number of snakes observed hourly was 22 ± 19.0 at three marine sites with freshwater inflow, but only 1 ± 1.7 at three strictly seawater sites. No snakes were found at a coastal spring that was entirely fresh water. In the laboratory, we dehydrated three individuals each of the amphibious sea snakes *Laticauda laticaudata* (146.9 ± 1.9 g mean wet mass) and *L. semifasciata* (533.7 ± 38.2 g). Snakes were held in mesh bags outside of water for a period of 5 days. In spite of greater mass, individuals of *L. semifasciata* lost a larger percentage of body mass during the dehydration period than did those of *L. laticaudata* (6.27 ± 3.2 % vs. 5.63 ± 1.9 %). The three dehydrated *L. laticaudata* drank fresh water in amounts of 2.3, 2.7 and 7.4 % of initial body mass, respectively, whereas none of the *L. semifasciata* drank fresh water. Previous studies have documented freshwater drinking in two other species of marine snake (Guinea, 1991; Lillywhite & Ellis, 1994). Our studies at Orchid Island are part of ongoing investigations that incorporate direct observations as well as stable isotope analyses to evaluate the generality of freshwater use in marine snakes.

57.2

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THE EFFECTS OF HYDRODYNAMICS ON FERTILIZATION SUCCESS IN THE GREEN SEA URCHIN, *STRONGYLOCENTROTUS DROEBACHIENSIS*

Among free spawning invertebrates such as sea urchins, it is often assumed that sperm and eggs are advected away from the animals in a plume and rapidly dilute in the water column to ecologically irrelevant concentrations. However, urchin gametes are highly viscous and resist mixing. During spawning, gametes can be retained on or near the urchin and strands or clumps of gametes can remain intact for an appreciable length of time in the water column. Furthermore, local hydrodynamic conditions play a key role in determining rates at which eggs and sperm are advected away from the animals and mixed into the water column. The combination of these effects can greatly alter the amount of time that sperm and eggs interact in relatively high concentrations, thereby altering overall fertilization success. In this study, we quantified the percentage of eggs fertilized on or near the urchins and in the water column as a function of water velocity and bottom roughness in the green urchin, *Strongylocentrotus droebachiensis*. At low flow speeds, a significant number of eggs and sperm spent time entrained in local eddies or deposited on the substrate prior to being advected away from the animals. As flow speed increased, eggs were quickly mixed into the water column and there was little retention of eggs near the spawning animal. As a result, there was a transition from fertilization being a local process at lower flow speeds to being a water column process at higher flow speeds and overall more eggs were fertilized at slow relative to high flow speeds.

36.2

BAEZA, J.A.; jab9444@louisiana.edu. The University of Louisiana at Lafayette

THE EVOLUTION OF PROTANDRIC-SIMULTANEOUS HERMAPHRODITISM IN THE SHRIMP *LYSMATA WURDEMANNI* IS A CONSEQUENCE OF SEX-DEPENDENT TIME COMMITMENTS BUT NOT SEX-DEPENDENT MORTALITY RATES.

Protandric simultaneous hermaphroditism (PSH), as recently reported for shrimps in the genus *Lysmata*, is a novel sexual system in which individuals invariably reproduce as males first (MP individuals) and later in life as simultaneous hermaphrodites (SHP individuals). I test here two recently proposed models (i.e., sex-dependent time commitments and sex-dependent mortality rates) explaining the evolution of PSH in the shrimp *L. wurdemanni*. Specific predictions/assumptions of each model were evaluated in the laboratory using observational/manipulative experiments. I found no evidence that the sex-dependent mortality model explains PSH in the studied species because mortality suffered by SHPs due to predatory fishes was not greater but similar to that suffered by MPs, in contrast to that predicted by this model. On the other hand, the time SHPs required to replenish their sperm reservoir after mating as males was shorter than the time they required to produce and brood two consecutive eggs clutches. Small SHPs also experienced a heavier mortality rate by fish predators than large SHPs. This sex-dependent reproductive time commitment and size-dependent mortality agree with predictions of the sex-dependent time commitment model that additionally explain the evolution of PSH in *L. wurdemanni*. This study stresses the necessity of explaining the evolution of strict simultaneous and sequential hermaphroditism, as well as mixed sexual systems such as PSH with a single comprehensive theoretical model.

65.6

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ROLE OF THE ENVIRONMENT ON THE EVOLUTION OF SIGNAL TRANSDUCTION PROTEINS AND METAMORPHOSIS

Signal transduction proteins regulate differentiation and development, which are central to metamorphosis. We focus on the role of environmental factors (e.g. climate, chemicals) in the evolution of nuclear receptors and Mitogen-Activated Protein Kinases (MAPK), two classes of signal transduction proteins, which regulate developmental transitions in animals. Heat shock protein 90 (HSP90) chaperones proper folding of nuclear receptors and MAPKs into active structures. HSP90 also promotes folding of mutant nuclear receptors and MAPKs, which would be otherwise destabilized. Stress diverts HSP90 from stabilizing mutant signal transduction proteins and towards its role as a chaperone to promote proper folding of stress-damaged proteins and to prevent the aggregation of denatured proteins. Reduced HSP90 levels allow expression of cryptic mutations in signal transduction proteins and new developmental patterns. By affecting HSP90 levels, environmental stress in the form of extreme climate can influence the evolution of metamorphosis. We discuss how extreme cooling called snowball earth, which occurred in two periods from -760 to 700 myr ago and -620 to 580 myr ago, diverted HSP90 from chaperoning signal transduction proteins that regulate development in animals. As a result, pre-existing mutant signal transduction proteins were expressed in animals. Some of these mutations were a source for selectively advantageous developmental pathways in animals during the Cambrian. Similarly, chemicals (e.g. the antibiotic geldanamycin) inhibit HSP90, providing a mechanism for chemicals to influence metamorphosis evolution and a method to study how alterations of HSP90 affect the evolution of metamorphosis.

68.5

BAKKEN, G.S., KROCHMAL, A.R.; gbakken@indstate.edu. Indiana State University, University of Houston, Downtown
PITVIPER THERMAL VISION: AN OPTICAL ANALYSIS OF SPATIAL RESOLUTION AND SIGNAL STRENGTH

The long-standing belief that the facial pit of pitvipers is strictly a specialization for detecting and striking at warm prey has led studies of the pit organ to focus on a maximum detection range of the organ. However, demonstrations that the pit organ can direct thermoregulatory movements have supported earlier speculation that facial pits are used for general navigation. The imaging quality of the facial pit and associated neural processing centers is particularly relevant to navigation. But, optical studies of the pit are few and do not use standard optical analysis. Thus, the resolution of the thermal images formed by the facial pit is unknown. We therefore studied image formation in the facial pit with combined optical and heat transfer analysis techniques. We first recorded quantitative thermal images of typical prey items against laboratory and field backgrounds over a natural range of microclimate conditions. We then used MATLAB image processing routines to combine these images with optical point-spread functions to estimate the differential irradiance of the facial pit sensory membrane. We constructed the spread functions on the basis of approximate facial pit geometry and angular resolution from published neurological studies. Finally, we estimated the distribution of pit membrane temperatures resulting from the irradiance distribution using heat transfer analysis, and adjusted the range and contrast of the final digital image to reflect the published 0.001°C 0.003°C temperature sensitivity of the membrane. Preliminary results indicate a need for detailed studies of pit organ geometry, behavioral responses in complex environments, and the role of neurological image sharpening in order to resolve the difference between computed and observed capabilities.

60.2

BALTZLEY, M.J., LOHMANN, K.J.; baltzley@email.unc.edu. University of North Carolina at Chapel Hill
EVOLUTION OF A NEURAL CIRCUIT IN SEA SLUGS

Most nudibranch molluscs crawl using mucociliary locomotion. In *Tritonia diomedea* crawling behavior is controlled partly by two pairs of bilaterally symmetrical neurons located in the pedal ganglia. These cells, known as the Pd5 and Pd6 cells, produce a class of neuropeptides called TPeps. To investigate whether similar cells exist in other sea slugs, immunohistochemistry was used to identify TPep-like immunoreactive neurons in 11 additional nudibranch species. All species had at least one large, TPep-like immunoreactive cell on the dorsal surface of each pedal ganglia. Some species possessed only one large, TPep-like immunoreactive cell, while others had as many as six. Based on a current nudibranch phylogeny, the data indicate that the number of these cells has changed multiple times during nudibranch evolution. Between species, the number of cells in a given species was not correlated with the size of adults of that species. In other words, species with large individuals did not tend to have a greater number of cells. Similarly, the relative size of the largest TPep-like immunoreactive cell of a species was not correlated with the maximum body size of adults of that species. The presence of large, TPep-like immunoreactive cells in diverse nudibranchs is consistent with the hypothesis that part of the neural circuitry controlling mucociliary locomotion has been conserved, even though the size and number of cells is variable across species.

68.9

BARIMO, J.F., MCDONALD, M.D., WASLH, P.J.; jbarimo@rsmas.miami.edu. University of Miami
THE INFLUENCE OF PHOTOPERIOD ON PULSATILE UREA EXCRETION IN TOADFISH (*OPSANUS BETA*)

The gulf toadfish *Opsanus beta* (Batrachoididae) is one of the few teleosts to maintain a functional ornithine-urea cycle (O-UC) during adult life and possess the capability to change from ammonotelic to ureotelic within 24 hours in the laboratory. In the laboratory, *O. beta* excrete most nitrogenous waste across the gill membrane and urea is generally excreted in daily pulses of 1.5 hrs in duration while ammonia is eliminated continually. At present, the mechanism of O-UC activation is due to an elevation of plasma cortisol (stress response) which promotes the up regulation of the key O-UC enzyme glutamine synthetase. Furthermore, plasma cortisol levels drop prior to pulsatile urea elimination. This study examines the diel pattern of nitrogen excretion with individual toadfish in the laboratory and outdoor mesocosms. Under both experimental conditions toadfish were exposed to natural photoperiod, samples were collected hourly from toadfish in shelters fabricated with PVC pipe, and assayed for urea and ammonia with standard chemical techniques. In laboratory, conducted in 2 L containers with static seawater changed daily, urea pulses occurred at random with no apparent correlation to light or dark cycles. In mesocosm experiments, toadfish were unrestrained in 8000 L tanks with the seagrass *Thalassia testudinum* planted on carbonate substrate effectively simulating their natural habitat. Shelters were outfitted with an underwater IR camera connected to a time-lapse video recorder to document toadfish behavior. In preliminary results, urea and ammonia excretion in mesocosms occurred predominately during daylight hours with peak levels near dawn or dusk. Differing results between experimental regimes are believed to reflect the degree of stress encountered by toadfish.

66.7

BARTHELL, J.F., THORP, R.W., MASON, C., GARVIN, E., JOHNSON, E., WELLS, H., WENNER, A.M.; jbarthell@ucok.edu. University of Central Oklahoma, University of California, Davis, University of Tulsa, University of California, Santa Barbara
AN ISLAND ECOSYSTEM AFTER HONEY BEES: IS A NOXIOUS WEED NOW COMPETING FOR NATIVE POLLINATORS?

Feral honey bees, *Apis mellifera*, have steadily declined on Santa Cruz Island, California (USA), since the release of the varroa mite, *Varroa destructor*, in 1993. Indeed, no honey bees have been detected at flowers since 2004 and swarm traps designed to monitor for the presence of colonies on the island have remained empty since 1996. Before their decline, honey bees showed strong preference for visiting the invasive weed yellow star-thistle, *Centaurea solstitialis*. Conversely, native bees preferred a native gumplant, *Grindelia camporum*, that flowers at the same time and in the same location as yellow star-thistle. Since an obligate out-crossing species like yellow star-thistle must maintain pollen flow among plants to reproduce, we hypothesized that yellow star-thistle would competitively draw native pollinators from its native counterpart (gumplant) in the absence of honey bees. We simulated invasion in a patch of gumplant by removing all existing yellow star-thistle in the area and then re-introducing thistles next to designated gumplants. Visitation rates at the gumplants in gumplant-thistle pairs were compared with visitation of those in gumplant-gumplant (control) pairs. The results show that gumplants paired with yellow star-thistle had significant reductions in the number of native pollinators that visited them in comparison with the controls. Our observations are consistent with predictions that successfully invasive plant species, in the absence of co-evolved pollinators, compete for native pollinators that may, in turn, reduce fitness in native plant species.

BARTON, B.T., ROTH, J.D.; brandon.barton@yale.edu. Yale University, University of Central Florida
SEA TURTLE NEST PREDATORS: IMPLICATIONS FOR COMMUNITY ECOLOGY

All four species of marine turtle that nest in Florida are listed as threatened or endangered under the Endangered Species Act of 1973, requiring actions to protect and restore these species. Raccoon (*Procyon lotor*) predation is among the highest causes of egg mortality for marine turtles, and raccoon removal programs have been implemented on some Florida beaches for >25 years. We examined the cascading effects of raccoon removal on sea turtle nesting beach communities in east-central Florida. Interestingly, raccoons consume ghost crabs (*Ocypode quadrata*), the second most common marine turtle nest predator on these beaches. We compared the diet and demography of a raccoon population that had experienced two decades of raccoon removal to a previously unmanaged population. The sex ratio of the historically managed population was significantly male-biased (10.5:1) in comparison to the unmanaged population (1:1), which is probably due to male-biased natal dispersal. Stable isotope analysis of raccoon and ghost crab tissue suggests marine turtle eggs are not a critical aspect of either predators diet, a finding that has been speculated by other authors. We also compared the abundances of raccoons and ghost crabs at four study sites using passive tracking plots to determine the numerical relationship between these two species. Our data suggest intraguild predation by raccoons limits ghost crab abundance and that reduced raccoon abundance allowed ghost crab abundance to increase, resulting in a net increase in sea turtle egg predation. These results support our hypothesis that intraguild predation of ghost crabs by raccoons is an influential interaction on sea turtle nesting beach community dynamics.

51.11

BASCH, L.V.; lbasch@hawaii.edu. University of Hawai'i, Manoa, National Park Service
MARINE CONSERVATION SCIENCE: EXAMPLES IN A NETWORK OF NATIONAL PARKS AND MARINE PROTECTED AREAS IN HAWAII

The persistence of benthic ecosystems including coral reefs and their component species depends on natural processes affecting the replacement of adult individuals within populations by young life stages (animal larvae or algal spores). Recruitment is defined as the processes by which young individuals enter and inhabit the system. Recruitment of marine organisms typically varies naturally at different time and space scales. However, disturbances, resource exploitation and environmental impacts can limit recruitment and the persistence of species of key ecological, economic or cultural importance. A set of integrative studies in progress are described that address questions of recruitment limitation and connectivity for several marine populations in a network of National Parks and Marine Protected Areas on the Kona coast of the island of Hawai'i. Preliminary results will be presented based on complimentary approaches including basic ecological surveys, natural chemical or genetic tags, oceanographic current measurements, remote sensing and GIS, and Traditional Ecological Knowledge.

19.1

BASOLO, A.L.; basolo@cricket.unl.edu. University of Nebraska-Lincoln
THE EFFECT OF PREDATION ON THE EVOLUTION OF GENETICALLY LINKED LIFE HISTORY TRAITS

Adult size is often negatively correlated with the age at which an individual matures, and there are both benefits and costs associated with maturing earlier at a smaller size. Benefits to earlier maturation include a higher probability of surviving to maturation and a shorter generation time. However, if predation risk is greater for smaller individuals, delayed maturation may be favored. Few studies have examined how predation affects genetic variation in animal size, largely because the genetic basis of age and size of maturation is not well characterized for many animals. An exception is the southern platyfish, *Xiphophorus maculatus*, a livebearer in which allelic variation at the pituitary locus (P-locus) has a major effect on age and size at sexual maturation. In the field, a correlational study I conducted showed that adult platyfish from populations without piscivorous fish are smaller than platyfish from populations with piscivorous fish. To experimentally test the effect of predation on age and size at maturation, I have established eight populations in the laboratory with known P-allele frequencies. Four replicate populations have a predatory cichlid and four replicate populations do not. I am tracking changes in P-allele frequencies over time using genetically linked color markers. If larger size provides an advantage by lowering predation risk, the allele for later maturation is expected to increase in the predation replicates relative to the replicates without predators.

1.3

BASSETT, D.K., MONTGOMERY, J.C.; dk.bassett@auckland.ac.nz. University of Auckland, New Zealand
ECOLOGICAL IMPLICATIONS OF DIFFERENT SEARCH STRATEGIES IN NOCTURNAL TELEOST PREDATORS

Underwater diver transects and baited underwater video determined that the Dwarf Scorpionfish, *Scorpaena papillosus*, and the Southern Bastard Cod, *Pseudophycis barbata*, were the two dominant nocturnal teleost reef predators along the northeast coast of New Zealand. Laboratory based behavioural experiments investigated the search strategy of both species in response to live and dead prey. The Southern Bastard Cod is in constant motion when searching for prey and utilises more than one sensory system. It detects the respiratory currents of live crabs using its lateral line and detects dead crabs through the use of its barbels. In contrast, the Dwarf Scorpionfish exhibits a saltatory search strategy and detects the respiratory currents with its lateral line while motionless. Remaining motionless when searching for prey would eliminate any self generated noise and may explain the larger reactive distances for this species for hydrodynamic detection of prey. Non-visual predators that adopt a cruise search strategy would search a larger area than those species adopting a saltatory search strategy. However a saltatory searcher would search an area more thoroughly detecting both cryptic and conspicuous prey rather than only conspicuous prey as in the cruise searcher. This is reflected in the habitats that are utilised by these two species with the Dwarf Scorpionfish spending more time foraging in broken heterogenous parts of the reef while the Southern Bastard Cod spending more time in the uniform flat parts of the reef.

26.4

BATTIPROLU, P.K., RODNICK, K.J.*; battpava@isu.edu. Idaho State University

EVIDENCE FOR SEX DIFFERENCES IN GLUCOSE-MEDIATED CARDIAC CONTRACTILITY IN RAINBOW TROUT (*ONCORHYNCHUS MYKISS*)

The heart of the rainbow trout is hypoxia-intolerant, may experience variations in oxygen availability and is omnivorous in its preference for metabolic fuels. However, the importance of exogenous glucose, oxygen and sex differences for contractile performance has not been established. We determined whether extracellular glucose (5 mM) promotes cardiac contractility in male and female trout, and measured lactate release under oxygenated ($PO_2 = 640$ mm Hg) and hypoxic conditions ($PO_2 = 20$ mm Hg). METHODS: Ventricles from 10-12 month old immature males (n=8), and females (n=10) were excised. Four strips were cut, attached to isometric force transducers and electrically stimulated at 0.5 Hz under glucose-free/oxygenated conditions for 1 h at 14°C. Strips either 1) remained glucose-free/oxygenated; 2) were changed to hypoxia, or 3 and 4) were treated with glucose for 1 h (oxygenated or hypoxia). Percent original twitch force (F) and lactate release were calculated. RESULTS: Under glucose/oxygenated conditions, F was significantly higher in males compared with females ($145 \pm 3\%$ vs. $125 \pm 4\%$; $P < 0.05$). In contrast, glucose did not promote contractility in both sexes under hypoxic conditions. Lactate release (nmoles g⁻¹ min⁻¹) was higher in females under oxygenated (with glucose, 275 ± 18 ; without glucose, 180 ± 14 vs. males with glucose, 71 ± 20 ; males without glucose, 46 ± 15 ; $P < 0.05$) and hypoxic conditions (females with glucose, 401 ± 24 ; females without glucose, 421 ± 25 vs. males with glucose, 244 ± 20 ; males without glucose, 232 ± 21 ; $P < 0.05$). CONCLUSION: Glucose promoted contractility more in males and it appears that females may rely more on glycolysis for energy production under oxygenated and hypoxic conditions. Funded by NIH P20RR16454.

29.3

BEAUMAN, R.L., MENDONÇA, M.T.; beauml@auburn.edu. Auburn University

FACTORS AFFECTING DEGREE OF BURROW COLLAPSE AND RESULTING TORTOISE SELF EXCAVATION AND BEHAVIOR

The gopher tortoise is a federally listed species in the western portion of its range, and a species of concern elsewhere. Their burrows are often collapsed during human activity associated with logging activity and land use. Little is known to what extent burrows collapse, what factors contribute to the degree of collapse, how this impacts the tortoise's ability to self excavate after the collapse, and what effect this has on movement behavior. As part of a larger study to determine how physiologically detrimental this disturbance is to tortoises, we documented the physical factors that impact the degree of the collapse and monitored pre collapse and post excavation movement behavior. In the spring of 2004, we experimentally collapsed active burrows with tortoises in them using a JD 648 logging skidder (n = 22). We measured the collapse zone and monitored the number of days until each tortoise self excavated. The collapsed zone ranged from 0.66 to 2.21m and the amount of time to self excavation ranged from hours to 85 days. The majority of tortoises excavated within 20 days. The distance from the original mouth to the point of exit on self excavation ranged from 0 to 3.05m. There was a significant positive correlation between the amount of burrow collapse and the exit distance from the original mouth. There was no significant difference between the number of burrows used, the number of times moved or the size of the home range pre and post collapse. Upon self excavation, tortoises stayed in the collapse burrow (50%), moved to a previously used burrow (4.5%), or moved to a new burrow (45.5%). A follow up study was conducted in 2005 to look at the long term effects of burrow collapse on tortoise movement and home range size. This and other aspects of movement behavior will be discussed.

33.1

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GENE EXPRESSION OF HOUSE MICE ACCLIMATED TO CHRONIC HYPOXIA

Chronic hypoxia is a significant physiological challenge to mammals in high altitude environments (2500 m or more). To accommodate the decrease in O_2 partial pressure, mammals that acclimatize to high altitudes remodel their cardiovascular and other organ systems, change their blood chemistry, and adjust their metabolism to maintain O_2 homeostasis. These acclimatization responses likely require changes in gene expression. Gene expression responses of *in vitro* cell cultures (e.g., hepatocytes) have helped illuminate the molecular and cellular mechanisms of hypoxia responses. Likewise, studies on ischemic organs have illustrated how particular organs respond to hypoxia. However, the gene expression profiles associated with *in vivo*, whole animal exposure to hypoxia may be quite different than what is found in *in vitro* or ischemic studies. To better understand *in vivo* gene expression associated with acclimatization to chronic hypoxia, we subjected 36 male house mice to oxygen partial pressures corresponding to 1400 m, 3000 m, or 4500 m. After 32 days of exposure, tissue samples were taken from these mice for RNA analysis on GeneChip Mouse Genome Arrays (Affymetrix). We will present data on the effect of chronic hypoxia on gene expression in the liver. This study will complement further work that is being carried out on feral house mice living at high altitudes in South America. Not only do we hope to gain a better understanding of physiological responses to hypoxia, but to eventually determine which of these responses represent acclimatization versus which represent potential adaptations.

60.6

BELANGER, R.M., MCDOWELL, K.E., MOORE, P.A., ZIELINSKI, B.S.; belangr@bgsu.edu. Bowling Green State University, University of Windsor

REPRODUCTIVE SIGNIFICANCE AND SENSORY HAIR MORPHOLOGY OF THE MAJOR CHELAE OF MALE CRAYFISH *ORCONECTES RUSTICUS*

It has been shown that the major chelae of crayfish have both mechano- and chemosensory abilities (Bauer and Hatt 1980; Hatt and Bauer 1980; Altner et al. 1983). Our previous investigations have shown that reproductive male crayfish (*Orconectes rusticus*) use their major chelae and respond significantly with an increased handling time to a female conditioned water source when compared to those that have been sensory lesioned. We have also shown that reproductive males use their major chelae for handling a female odour source which differs from a food odour source, where they use their walking legs and maxillipeds. For this reason, it is important to investigate the morphology of the sensory hairs on the major chelae of male crayfish in order to identify which sensory hairs could be used for perception of female odours. Using scanning electron microscopy to visualize hair pockets on the dorsal surface of the chelae, we have shown an increase in sensory hair pockets and sensory hairs (simple and plumose setae) in reproductive males when compared to non-reproductive males. A permeability assay using crystal violet demonstrated that simple setae readily take-up and hold the dye after clearing with xylene, while plumose setae do not. Also, DiI and acetylated tubulin readily stain neural structures found within simple setae, suggesting that simple setae are putative chemoreceptors. To confirm this, transmission electron microscopy was used to determine the ultrastructure of simple and plumose setae. Overall we have found that simple setae on the chelae are putative chemoreceptors and thus may be used for perception of female odours. Future analysis will use electrophysiology to examine peripheral processing of female odours.

17.2

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PHYLOGEOGRAPHY OF OPHIUROIDS FROM SOUTH AMERICAN AND ANTARCTIC WATERS USING MTDNA

The isolation of the Antarctic continent has been a driving evolutionary force for Antarctic fauna for ~25 million years. The separation of the Antarctic and South American continents and the onset of the Antarctic Circumpolar Current are presumed to have acted as primary forces driving the speciation of many marine taxa. Despite this geographic and thermal isolation, some benthic marine taxa exhibit surprising levels of non-endemism. We therefore wanted to examine evolutionary relationships existing between Antarctic/ subantarctic and South American benthic marine invertebrates due to the variety of potential isolating factors existing between these geographic localities. We looked at relationships among three ophiuroid species, two Antarctic species from the genus *Ophiurolepis* and one South American species questionably assigned to the genus *Homalophiura*. Two mitochondrial genes were used to answer questions regarding levels of divergence, morphological relationships and endemism. Our sequence data did not uphold traditional relationships based on morphology for the three species. It was found that the two sympatric *Ophiurolepis* species from within Antarctica were less closely related and more genetically divergent than one of the *Ophiurolepis* species was with the South American *Homalophiura* species. The assignment of the South American species to a separate genus has been debated in the taxonomic literature thus showing how molecular data can help to resolve existing taxonomic problems. These results indicate either that the two Antarctic species diverged prior to the separation of Antarctica and South America or that the two more closely related Antarctic and South American species maintained gene flow for some period of time after separation.

66.11

BELDEN, L.K.; belden@vt.edu. Virginia Tech

IMPACT OF EUTHROPHICATION ON WOOD FROG TADPOLES INFECTED WITH TREMATODE CERCARIAE

Global environmental changes are likely to have profound impacts on disease dynamics in natural systems. To make predictions about what specific impacts are expected, one thing we need is a solid understanding of how the environmental context of host-parasite interactions can impact disease systems. I am examining the role of environmental context in a natural host-parasite system consisting of the parasitic trematode *Echinostoma trivolvis*, the first intermediate host snail, *Helisoma trivolvis*, and a second intermediate host, larval wood frogs, *Rana sylvatica*. In spring 2005, I examined the potential effect of eutrophication on larval wood frogs infected with *E. trivolvis* trematode cercariae collected from naturally infected *H. trivolvis* snails. Individual tadpoles were batch color marked with visible implant elastomer by treatment (no infection, 20 cercariae, 80 cercariae) and reared in mixed infection groups, 45 tadpoles/tank in outdoor 1000 L mesocosms that were either pre-treated with 20-25-5 fertilizer to create a eutrophic environment or were untreated controls. Survival to metamorphosis of the individuals in the highest infection treatment was reduced regardless of eutrophication treatment. For the surviving infected individuals, no impact on mass at metamorphosis was documented, although individuals were larger in the eutrophic tanks. These data demonstrate that infection with *E. trivolvis* can impact *R. sylvatica* survivorship and that eutrophication may have minimal impacts on hosts once infection has occurred.

62.4

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DIFFERENCES AMONG ASCENDING, LEVEL, AND DESCENDING FLAPPING FLIGHT

Rock pigeons (*Columba livia*) flew along paths of varying angles of ascent and descent. Flights at angles of 60, 30, 0, -30, and -60 degrees were recorded with high-speed video. Kinematic marks were then digitized. During ascending flight, pigeons exhibited greater angles of excursion and greater wingbeat frequency relative to level flight. Flight velocity and angle of attack did not change with increasing ascent angle. When the birds descended, they showed lower angles of excursion and lower angles of attack during most of downstroke. Pigeons flew faster when descending, though wingbeat frequency did not differ from level flight. Kinematic patterns suggest that pigeons use wingbeats with tip reversal during ascending flight and wingbeats with feathered upstrokes during descending flight.

72.1

BERGMANN, P.J., IRSCHICK, D.J.; pbergman@tulane.edu. Tulane University

THE TEMPERATURE-DEPENDENCE OF CLINGING AND SPRINTING ABILITY IN DAY GECKOS.

We studied the clinging ability and sprinting velocity, acceleration, deceleration, and power output between 15°C and 35°C in the diurnal gecko, *Phelsuma dubia*. We measured clinging performance of the front limbs by dragging lizards across a force plate, and unsteady-state, accelerating sprinting performance using high speed video recordings of lizards running up a vertical race track. Our findings indicate that temperature does not affect these performance measures uniformly. Clinging ability is highly variable across temperatures and unaffected by temperature. In contrast, all velocity, acceleration, deceleration, and power output during unsteady-state sprinting are all enhanced by increases in temperature across the range studied. Power output is more sensitive to temperature than the other sprinting performance measures, increasing almost 4 fold between 15°C and 35°C. Increases in running speed are modulated by both increases in stride length and frequency. However, duty factor is unchanged across the temperature range. Our findings for sprinting parameters match those expected from the literature. However, a lack of temperature-dependence in clinging ability is surprising, and suggests that maximal clinging ability, as measured, is primarily dependent on passive processes, such as Van Der Waals forces.

19.2

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DO ENERGY-MORTALITY TRADEOFFS DRIVE SEXUAL DIMORPHISM IN A CRABS DECORATION? (*OREGONIA GRACILIS*, BRACHYURA: MAJIDAE)

Decorator crabs camouflage themselves by attaching sessile organisms to their carapace and legs. This behavior reduces predation risk, but incurs significant energetic costs. We asked whether this energy-mortality tradeoff might drive sexual dimorphism in the decorator crab *Oregonia gracilis*. Sexually mature *O. gracilis* females decorate extensively, as do juveniles of both sexes. Mature males, however, decorate very little. This variance is largely driven by differences in setal morphology. All decorating Majids use velcro-like hooked setae to attach decoration. Many species also have straight, bristled setae, which can work in concert with hooked setae to facilitate decoration. The density of bristled setae and consequently the amount of decoration carried varies sexually and over ontogeny in *O. gracilis*. Mature females have numerous bristled setae, as do juveniles of both sexes. In males, however, setosity decreases with each molt as they approach maturity. At the same time, males claws grow larger relative to body size. We asked whether this inverse relationship results from energetic tradeoffs between decorating and having large claws. We measured degrowth during starvation for males having artificial decoration, artificially enlarged chelae, or both. Artificial decoration alone causes degrowth similar to artificial chelae alone. A combination of decoration and chelae causes increased degrowth relative to either treatment alone and controls. These data suggest that male sexual maturity accompanies energy re-allocation from decorating into chelar growth, perhaps because large chelae increase mating success. Since females have small claws and brood their eggs for long time-periods, females might experience greater selective pressure to avoid predation, making it advantageous to decorate throughout their lives.

51.2

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CREATINE AND ARGININE KINASES ARE WIDESPREAD IN THE PORIFERA

Creatine kinase (CK) and arginine kinase (AK) are expressed in cells that display high and variable rates of ATP turnover and belong to a highly conserved family of phosphoryl transferases called phosphagen kinases. Recently, mitochondrial (MtCK) and protoflagellar (protoflgCK) CK cDNAs from the demosponge *Tethya aurantia* have been cloned and sequenced (Sona et al., *BBRC* 317: 1207-1214 [2004]) and an AK cDNA from another demosponge *Suberites domuncula* has been cloned and sequenced (Perovic-Ottstadt et al., *JEB* 208: 737-646 [2005]). We have surveyed for the presence of CK and AK activities in two sponge classes by spectrophotometric enzyme assays of tissue extracts. Class *Calcarea* (three species) had AK activity only. Out of >30 members of Class *Demospongiae*, a small number had CK activity only while roughly equal numbers had either AK activity only or both AK and CK activity. RTPCR of RNA from two of these demospogones showed that this CK activity consists of both Mt- and protoflgCKs. Total RNA was isolated from three hexactinellid (glass) sponges collected by submersible. RTPCR amplifications of these RNAs showed that all three express MtCK and protoflgCK; an AK was amplified from the RNA from one species. Hexactinellids appear to have diverged first in the sponge lineage followed by demospogones and then calcareans. Our results show that AK is widespread in all three sponge classes and that the two CK isoforms (Mt- and protoflg-) evolved prior to the divergence of the hexactinellids. The physiological role of both CK and AK in poriferans remains to be elucidated, although it seems likely that these reactions mitigate spatial ATP supply-demand mismatches in cells. (Supported by NSF grant IOB-0130024 to WRE)

36.3

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PARASITE-MEDIATED SEXUAL SELECTION IN AN INTERMEDIATE HOST, CAECIDOTEA INTERMEDIUS (ISOPODA): EFFECTS OF SPERM PRODUCTION AND MALE-MALE COMPETITION

The acanthocephalan parasite *Acanthocephalus dirus* infects the aquatic isopod *Caecidotea intermedius* (intermediate host) and one of several freshwater fishes (e.g., sunfish) as a definitive host. Inside *C. intermedius*, the parasite develops through non-infective stages before reaching the cystacanth stage, which is infective to definitive hosts. Previous work has shown that development into the cystacanth stage correlates with a decrease in male pairing success and that this effect can be explained by cystacanth-related changes in male mating behavior. Specifically, infected males are less likely to initiate mating attempts with females than uninfected males. Here, we examined whether this effect could be explained by either cystacanth-related variation in male sperm production or cystacanth-related changes in the dynamics of male-male competition. Using a laboratory-based experiment, we showed that variation in sperm production could not explain the effect because cystacanth-infected males contained viable sperm and could fertilize a females entire clutch. Using a field-based experiment, we showed that male-male competition was also unlikely to explain the effect because cystacanth-infected males showed the same behavioral response to females in non-competitive situations that they had shown previously in competitive situations. We conclude that variation in both sperm production and male-male competition were unlikely to explain the cystacanth-related decrease in male mating success observed in nature and propose alternative mechanisms to explain parasite-mediated sexual selection in *C. intermedius*.

S3-2.2

BIEWENER, A.A.; biewener@fas.harvard.edu. Harvard University
NEUROMUSCULAR DYNAMICS: PASSIVE VERSUS ACTIVE CONTROL OF LOCOMOTION AND STABILITY

Neuromuscular control of movement depends on matching neural commands to the time-varying requirements of muscle force generation and length change of multiple muscle groups within an animals limbs and body. In addition to motor unit characteristics, muscle-tendon architecture is likely key to the roles that particular muscle groups play in the support and movement of the body. Direct recordings of muscle force, length change, and activation (EMG) enable the in vivo dynamics of muscles to be examined while animals perform a range of motor tasks. Recent studies show that whereas more distal muscles may favor economical force generation with minimal length change and little net work output, more proximal muscles shorten or lengthen to modulate overall limb work. Current work examines how regional patterns of work modulation are achieved with respect to differing motor tasks (grade vs level, steady vs acceleration) and how these are controlled by the pattern of neural activation. Perturbations to an animals stability (maintenance of center of mass trajectory) require rapid, dynamic adjustments to correct and control the motion of limb segments and the body. While intrinsic biomechanical properties of muscle-tendon units (force-length and force-velocity), sometimes referred to as preflexes, may facilitate neuromuscular control, rapid neuromuscular feedback via muscle-tendon afferents is also likely to be important, and integrated with the animals passive dynamics, to stabilize movement at faster speeds. (Supported by NIH AR047679).

24.2

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ORIGIN OF COMPLEX STRUCTURES: ZEBRAFISH AS THE NEW MODEL ORGANISM FOR INVESTIGATING MORPHOLOGICAL INNOVATION

For the last decade the zebrafish has played an increasingly important role in biomedical research. Such research, exploiting conserved developmental processes among vertebrates in order to better extrapolate to humans, has by necessity concentrated on embryonic and early larval development. We are interested in morphological evolution, thus are more interested in later developmental events leading to the elaboration of those features that set zebrafish apart from related species. We propose that the zebrafish, long considered the lab rat of the piscine world, is exceptionally well suited as a model organism for investigating the developmental mechanisms underlying morphological novelty. Specifically, we are interested in the generation of morphological novelty in the vertebral column of fishes. The zebrafish, like other otophysan fishes, is characterized by the presence of the Weberian apparatus, a unique adaptation of the first four vertebrae that, when paired with adaptations in the swim bladder and the ear, confer increased hearing abilities to these fishes. These vertebral adaptations include significant morphological changes to neural arches, ribs, and parapophyses leading to increased regional complexity and specialization, something generally associated only with higher vertebrates. Immunohistochemistry, using a number of important markers, has allowed us to characterize differences between the developmental cascades leading to typical fish vertebrae found posteriorly, as compared with the greatly modified anterior vertebrae. Moreover, by examining expression patterns of genes both upstream and downstream of chondrogenic and osteogenic pathways, we have gained a better understanding of when during development morphological innovations become apparent.

43.4

BISHOP, K.L.; Kristin_Bishop@brown.edu. Brown University
KINEMATICS AND PERFORMANCE IN TWO SPECIES OF MAMMALIAN GLIDERS, *GLAUCOMYS VOLANS* AND *PETAURUS BREVICEPS*

Gliding has evolved independently in at least six lineages of mammals, all resulting in similar morphology and behavior. Investigations of the relationship between kinematics and gliding performance can provide insight into the mechanics of mammalian gliding. In addition, a comparison of gliding performance as it relates to kinematics between distantly related groups of mammals can reveal possible functional constraints on gliding behavior within mammals. In this study I compare the 3D kinematics and performance of two distantly related, but similarly sized gliding mammals: the placental southern flying squirrel (*Glaucomys volans*) and the marsupial sugar glider (*Petaurus breviceps*). The animals were trained to perform short glides along a known trajectory and were filmed from below during mid-glide using two high-speed digital cameras. Reflective markers were used to identify anatomical landmarks and the 3D coordinates of these points were computed using direct linear transformation (DLT). From the 3D position data I computed aerodynamically significant kinematic features such as angle of attack, camber, and instantaneous projected area of the wing and related them to performance measures such as glide angle, velocity, and body rotations. I also used the position data to compute the vertical acceleration during mid-glide, allowing me to estimate the lift and drag generated by the animal and examine how differences in body position coincide with differences in aerodynamic force. Comparison between the results of this study and predictions based on aerodynamic theory highlight the differences between the aerodynamics of low aspect ratio, flexible, extensible wings operating at a moderate Reynolds number and the wings of large, fast moving, rigid-winged aircraft.

S7-1.1

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METAMORPHOSIS: UNDER STIMULATORY OR INHIBITORY CONTROL?

Environmentally dependent metamorphosis of marine invertebrate larvae is a dynamic process that integrates ontogeny with habitat selection. The capacity of many marine invertebrate larvae to survive and maintain metamorphic competence in the absence of environmental cues has been proposed as an adaptive convergence (Hadfield et al., 2000). Juvenile ecology is assumed to shape how selection acts on the capacity of larvae to maintain the larval state, but knowledge of this relationship is not understood in any detail. Comparative studies of metamorphosis in marine invertebrates reveal both similarities and differences in metamorphic sensory and control pathways. For the species studied to date, nitric oxide/cyclic guanosine monophosphate (NO/cGMP) signaling serves as an inhibitory mechanism to control the timing of life-history transformations. In most cases, pharmacological reduction in concentrations of NO or cGMP is sufficient to induce metamorphosis in the absence of external cues. Recent studies with the nudibranch *Phestilla sibogae*, a specialist predator of the coral *Porites compressa*, indicate that NO/cGMP signaling also inhibits metamorphosis, but with an important difference: inhibition of NO/cGMP signaling only potentiates responses to external metamorphic cues. A reduction of internal concentrations of NO or cGMP does not induce metamorphosis. We will present data on NO/cGMP signaling in a sea urchin *Lytechinus pictus*, the gastropods *Phestilla sibogae* and *Crepidula fornicata* and propose that this subtle but potentially important difference in the dynamics of NO/cGMP signaling relative to metamorphic induction reflects differences in juvenile/adult habitat specificity.

61.4

BLACKBURN, D.C.; dblackburn@oeb.harvard.edu. Harvard University
THE EFFECT OF MINIATURIZATION ON SKELETAL MORPHOLOGY WITHIN THE AFRICAN FROG FAMILY ARTHROLEPTIDAE

Miniaturization the evolution of extremely small body size has broad implications for many aspects of vertebrate evolution. Its dramatic effects include novel morphologies, increased morphological variation, and changes in proportions and anatomical organization. Within the frog family Arthroleptidae, which is endemic to sub-Saharan Africa, miniaturization is associated with a suite of skeletal morphologies. The similarities among small-sized species were proposed by Laurent (1979) to be derived characters of a single miniaturized lineage (genus *Schoutedenella*). Long-standing taxonomic difficulties in arthroleptid systematics suggest that miniature species do not necessarily form a monophyletic lineage. This raises the possibility that different arthroleptid lineages have converged on similar skeletal morphology via independent miniaturization, possibly through paedomorphosis. My research reveals that many, but not all, small-sized species (<25 mm snout-vent length) are characterized by carpal fusions, loss of a tarsal, novel sesamoids associated with the mesopodials, and proportions of the skull and pectoral girdle that differ from those of larger arthroleptid species. Interestingly, two miniature arthroleptid species appear to be polymorphic for fusion of carpal elements and may also exhibit left-right asymmetries in carpal fusions. This pattern is reminiscent of that found by Hanken (1985) in the miniature plethodontid salamander *Thorius*. Based on ontogenetic data from both large and miniature arthroleptid species, the skulls of miniature species do not appear to be strictly paedomorphic with respect to larger species. Phylogenetic hypotheses constructed using data independent of morphology (i.e., mitochondrial DNA sequence) will be necessary to evaluate the monophyly of miniature species and to determine the extent to which the skeletal morphologies associated with miniaturized species represent derived characteristics of miniature lineages. Supported by NSF EF-0334846 (AmphibiaTree) and the Museum of Comparative Zoology (Harvard University).

23.5

BLANK, J.M., FARWELL, C.J., MORRISSETTE, J.M., SCHALLERT, R.J., BLOCK, B.A.; jblank@stanford.edu. Stanford University, Monterey Bay Aquarium
EFFECTS OF TEMPERATURE ON METABOLIC RATES OF PACIFIC BLUEFIN TUNA, *THUNNUS ORIENTALIS*

Tunas are remarkable among teleosts for systemic endothermy, high metabolic rates and exceptional cardiac performance. Among tunas, the 3 bluefin species attain the largest body sizes, inhabit the broadest thermal niches, and maintain the highest body temperatures. We measured oxygen consumption of 7 to 10 kg Pacific bluefin tuna as the animals swam in an 870 L swim tunnel respirometer for up to 6 days at temperatures of 6 to 25 C. Routine metabolic rates of bluefin at 20 C (222 ± 24 mgO₂/kg/hr) were higher than those of yellowfin tuna in this study (162 ± 19 mgO₂/kg/hr). VO₂ was minimized at higher speeds in bluefin than in yellowfin. At a given speed, bluefin swam with higher tailbeat frequencies and shorter stride lengths than yellowfin tuna. This difference may be related to interspecific differences in internal temperature. VO₂ of bluefin swimming at 1 BL/s was minimized at temperatures of 15 to 20 C and increased at ambient temperatures of 8 to 10 C and at 25 C. Yellowfin tuna showed a similar pattern, but were unable to tolerate temperatures below 10 C. Archival tag data indicate that visceral thermal excess remained constant as ambient temperature in the swim tunnel changed. The cold-induced increase in VO₂ may be related to endothermy, muscle mechanics, or behavior. Interspecific differences in metabolic rate and thermal tolerance correspond to differences in cardiac performance and biochemistry. Funded by NSF and Monterey Bay Aquarium.

38.3

BLOMQUIST, C.H., LIMA, P.H., ATKINSON, S.; blomq007@umn.edu. University of Minnesota, Alaska SeaLife Center/University of Alaska Fairbanks
ACTIVITY OF STEROIDOGENIC ENZYMES IN PLACENTA AND IN LUNG, FAT AND SKIN OF THE STELLER SEA LION PUP (*EUMETOPIAS JUBATUS*)

Steroidogenic enzymes that regulate levels of estrogens and androgens in mammalian tissues may be targets for endocrine disruptors. As a basis for assessing their role in regulating hormone levels and their potential as biomarkers of endocrine disruption in the Steller sea lion, 17 β -hydroxysteroid dehydrogenase (17 β -HSD), 3 β -hydroxysteroid dehydrogenase/5-ene-3-ketosteroid isomerase (3 β -HSD) and 3 α -hydroxysteroid dehydrogenase (3 α -HSD) were assayed in homogenates of placenta (n=13) as well as lung, subcutaneous fat and skin from one female and five male pups (1-4 weeks). 17 β -HSD activity with estradiol (E2) and testosterone (T) was detected in the placenta samples as was 3 α -HSD activity with 5 α -DHT. 3 β -HSD activity with DHEA was not detected. With regard to 17 β -HSD activity in pup tissues, lung samples had the lowest activity and skin the highest. The ratio of 17 β -HSD activity with E2 and T varied from 0.1 to 1.1 for skin and 0.1 to 2.3 for fat. For male pup skin samples, the 17 β -HSD/3 α -HSD activity ratio varied from 0.27 to 7.2. For subcutaneous fat the range was 0.16-5.1. No 3 α -HSD activity was detected in the female pup skin sample. The marked variations in activity levels and ratios are consistent with the presence of multiple isoforms of 17 β -HSD. They are also suggestive of differential regulation of 17 β -HSD, 3 α -HSD and 3 β -HSD in skin and fat, tissues in which the levels of these enzymes are known to be regulated in other species by gonadal steroids. Although the basis for the marked differences between samples remains to be clarified, our findings suggest activity patterns and ratios may be sensitive markers of endocrine status and endocrine disruption in sea lion pups.

15.8

BOBACK, S.M., GUYER, C.; bobacsm@auburn.edu. Auburn University
A TEST OF REPRODUCTIVE POWER IN SNAKES

Reproductive power is a contentious concept among ecologists and the model has been heavily criticized on theoretical and empirical grounds. Despite these criticisms, this model has successfully predicted the modal (optimal) size in three large taxonomic groups and shape of the body size distribution in two of these three groups. Here, we test the reproductive power model on a group that differs from the endothermic groups (upon which the model was derived) in both physiology and shape of the body size distribution. We derived snake-specific constants for the model using allometric relationships of energy in clutches or litters and relative population productivity. The relationships used to derive these constants were surprisingly similar between snakes and endotherms. Using snake-specific constants, the model accurately predicted the modal size in the snake size distribution; maximum reproductive power is achieved for a snake that is 408 g. However the model predicted a right-skew rather the log-normal shape of the empirical size distribution for snakes. If the model is correct, then snake diversity is limited especially in the largest size classes. Possible explanations for this limitation include biomechanics of locomotion and energetic constraints on foraging for the large prey. We briefly discuss how the relationships used to derive constants could limit the predictive power of the model.

14.3

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COMPARATIVE TIME-LAPSE STUDIES OF TWO DIFFERENT SPONGE DESIGNS

Most time-lapse microscopy studies on sponges have been done on those with leuconoid canal architecture (seen in a majority of sponges). This present study has initiated time-lapse examinations of live asconoid sponges. It was hoped that recording asconoid sponges, with their simpler architecture, would provide valuable insight into motile phenomena seen in more complex sponges. Time-lapse videos of intact asconoid sponges (*Leucosolenia* sp.) show motile behaviors, such as locomotion and contractile waves, that are similar (in appearance and speed) to those seen in leuconoid sponges (e.g.: *Aphysilla longispina*). In asconoids, contractile waves propagated at speeds of 30- 50 μ m/minute, and they involved systemic constriction then dilation of the slender canal-body tubes. Apparent locomotion of the asconoid tubes was an outward movement away from the central conglomeration, this movement was always accompanied by spicule rearrangements. Time-lapse videos of the margins of the leuconoid sponges confirmed earlier reports of several features: such as crawling amoeboid cells at the leading edge, and contractile waves in both canals and in cortical tissues. Further comparisons between the two sponge designs will be discussed.

70.3

BONIER, F., MARTIN, P.R., JENSEN, J.P., FOLTZ, S., WINGFIELD, J.C.; fb2@u.washington.edu. University of Washington
STRESS IN URBAN SONGBIRDS: ADAPTATION TO LIFE IN THE CITY?

The vast majority of species are excluded from human-dominated landscapes, but some species persist and appear to thrive. By studying species that are established in urban habitat, we may gain insight into the traits that have allowed them to coexist with us. Here we present data on variation in basal and stress-induced corticosteroid levels within six populations of a Passerine bird breeding in both urban and rural habitats. Male *Zonotrichia leucophrys* had significantly higher basal and stress-induced corticosterone levels in urban habitat than birds in rural sites, but female birds did not differ. We discuss potential causes of this pattern, and present preliminary estimates of the associated fitness costs and benefits.

29.5

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VARIATION BETWEEN SUBURBAN AND WILDLAND POPULATIONS IN NESTLING IMMUNE RESPONSE OF FLORIDA SCRUB-JAYS *APHELOCOMA COERULESCENS*

In past years, a suburban population of Florida Scrub-Jays has produced fewer fledglings and fledglings of lighter mass per breeding pair than a nearby wildland population. Suburban young may be in poor condition relative to wildland young because their diet includes anthropogenic foods, which may be of lower quality than natural foods. Although brood sizes at hatching are similar at both sites, if the quality of food available for rearing young is lower in the suburbs, the optimal brood size may be smaller than the mean brood size, thus affecting the physiological condition of suburban birds in larger broods. We hypothesized that the specific response of nestlings to an immunological mitogen would differ by site and brood size. We used a phytohemagglutinin (PHA) assay to estimate cell-mediated immune response as an index of nestling physiological condition. We measured PHA immune responses during the 2004 and 2005 breeding seasons in 287 nestlings from 108 broods (39 suburbs, 69 wildlands) ranging from 1-5 nestlings. Immune response varied among brood sizes and between suburbs and wildlands. Nestlings in broods of 1 or 2 tended to have a lower immune response in wildlands than in the suburbs; however, immune response did not differ statistically in broods of 1-3 nestlings between the sites. The immune response of nestlings in broods of 4 was significantly lower in the suburbs than in the wildlands. This supports our hypothesis that the physiological condition of suburban nestlings is reduced in larger broods, likely due to improper anthropogenic foods and possibly reduced availability of natural nestling food resources to birds in the suburban site.

15.3

BOWDEN, R.M., JANZEN, F.J.; rmbowde@ilstu.edu. Illinois State University, Iowa State University
GROWTH AND REPRODUCTION DURING A TRANSITIONAL LIFE HISTORY STAGE

Ontogenetic changes in reproductive characters can impact organismal life history. A variety of factors including reproductive frequency, clutch size, and egg size have been shown to increase with female age or body size in turtles. Previous research has also found age-related and seasonal variation in steroid hormone content in yolk. We performed a multiyear study to investigate longitudinal changes in reproductive parameters in a marked population of the painted turtle, *Chrysemys picta*. Females were classified at the outset of the study as having either high nesting experience (HNE) with at least 6 years prior experience, or low nesting experience (LNE) with 0-2 years prior experience. Nesting was monitored from 2002-2005 and we recorded a number of parameters including linear measures of female body size, clutch size, egg size, nest overstory cover, and nest location relative to shore. Eggs were also collected to determine testosterone and estradiol concentrations in yolk. Preliminary analyses indicate that LNE females grew faster and produced fewer clutches than HNE females during the course of the study. Restricting the analysis to females that nested multiply (2-3 clutches/year) in more than one year of the study, we found that LNE females still had a significantly higher growth rate than HNE females, suggesting that some LNE females are capable of both rapid growth and high reproductive frequency. Hormone analyses indicate that eggs from LNE females contain higher levels of testosterone than those from HNE females, while estradiol levels vary between first and second clutches. These data suggest that LNE females are experiencing a transitional period of maturation during which they must balance allocation to individual growth and to reproductive effort.

27.1

BOYER, S.L., GIRIBET, G.; boyer@oeb.harvard.edu. Harvard University
VICARIANCE IN THE HARVESTMAN FAMILY PETTALIDAE (ARACHNIDA, OPILIONES, CYPHOPHTHALMI) DURING THE BREAKUP OF GONDWANA

The theory of plate tectonics has generated many hypotheses concerning the historical causes of global distributions of organisms. The former supercontinent Gondwana has become the textbook system for historical biogeography, and the role of vicariance vs. dispersal across Gondwanan fragments has been studied in such groups as *Nothofagus*, chironomid midges, and *Araucaria* beetle herbivores. An ideal candidate for a study of vicariance across Gondwana is found in the family Pettalidae (Arachnida, Opiliones, Cyphophthalmi), a group of tiny, leaf-litter dwelling harvestmen. These cryptic arachnids are found in Chile, South Africa, Madagascar, Sri Lanka, Australia, and New Zealand. The small species ranges within this group, and the absence of these animals on any islands formed de novo by volcanoes, suggest that these organisms have very limited dispersal ability. Therefore, their Gondwanan distribution may be due solely to vicariance. We present a phylogenetic study of this family and interpret it in light of the geological history of the breakup of Gondwana.

39.3

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MOSQUITOES RESPIRE USING THE DISCONTINUOUS GAS EXCHANGE CYCLE

Larval stages of the mosquito *Culiseta inornata* were collected and reared in the laboratory at 20°C and 12:12 L:D. Adult female mosquitoes aged between 2 and 6 days post-emergence and with access to 10% sucrose were used for the experiments. Measurements of respiratory patterns were performed using flow-through respirometry in a temperature-controlled room. The respirometry equipment consisted of an 8-channel multiplexor, a LiCor CO₂ infrared gas analyzer (LiCor 6251, Lincoln, NB) and a computer running the program Expedata (Sable Systems software) which simultaneously, via a UI-2, controls the multiplexor and acquires data from the gas analyzer. We performed measurements at a variety of flow rates between 20 and 1000 ml/min. Each series of measurements consisted of recording the respiratory pattern of a mosquito at multiple flow rates. We performed the experiments at different temperatures in order to affect the metabolic rate of the mosquitoes. The temperatures chosen for the measurements were 10, 20 and 30°C. Between each series of experiments we changed the temperature and waited 12 hours for the room and equipment to adjust to the new temperature before performing another series of experiments. We found that under the experimental conditions in which insects are normally examined, the mosquitoes appeared to use a cyclic respiratory pattern. Lowering the temperature and/or increasing the rate of air flow revealed that the mosquitoes were actually using the discontinuous gas exchange cycle (DGC). The importance of the rate of air flow in respirometry of small insects will be discussed. The DGC has profound implications for the water conservation and avoidance of oxygen toxicity in these insects.

2.2

BREELAND, T.B., STRAUSS, R.E.; tarabb@juno.com. Texas Tech University, Lubbock

SCHOOL AND SHOAL DISTRIBUTIONS IN A FRESHWATER CATFISH SPECIES, *CORYDORAS PALEATUS* (CALLICHTHYIDAE)

The South American armored catfish *Corydoras paleatus* has been observed to occur in nature in large schools, in smaller shoals, and individually or in pairs. These catfishes are advantageous for laboratory study because they are easily bred and raised, they spend large amounts of time resting between bouts of swimming and foraging, and their resting behavior in particular is easily quantified. In these experiments, we explore (1) how individuals allocate their time among foraging/shoaling, schooling, aeration, and resting; (2) how much time individuals spend in available aggregations; (3) distributions of nearest-neighbor distance; (4) numbers of groups as a function of density; (5) activity patterns; and (6) how these factors change with density. We examine the implications of this research.

70.6

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ANDROGENS AND ARRIVAL BIOLOGY IN A MIGRATORY SONGBIRD

Seasonal breeders rely on photoperiod to initiate breeding. However, local conditions can modulate the timing of nesting onset. One important component of reproductive development affected by local conditions is androgen secretion in males. We examined patterns of androgen secretion during the arrival phase of the breeding season in a moderately long-distance migrant, the mountain white-crowned sparrow (*Zonotrichia leucophrys oriantha*). Our study population breeds just outside Yosemite Park (~3000 m elevation). Males may begin defending territories immediately upon arrival (early May) or as late as mid June (depending on residual snow pack, weather). During unsettled weather in May, sparrows may be up at the breeding site or at lower elevation staging areas nearby. In 2005, early May snow-pack was 150% of the long-term average, and onset of nesting was late. We collected plasma samples from three groups of males: 1) sparrows at low elevation staging areas, 2) high-elevation sparrows caught on or near their eventual breeding territories, and 3) high-elevation sparrows that were transients at the capture site. Samples from the same time window for all three groups show that low elevation sparrows have significantly lower androgen levels than high-elevation sparrows on their breeding territories. However, transient males at high elevation had intermediate levels between the two groups (and not significantly different from either). Mountain white-crowned sparrows do not modulate androgens in response to male-male interactions; as such, these data suggest that the breeding site itself, not elevation, temperature, or the presence of competing males is one of the more important local cues. We are currently measuring corticosterone and corticosteroid binding globulin levels from the same samples to estimate free testosterone levels.

10.5

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INTERANNUAL VARIATION IN ADRENAL RESPONSIVENESS OF BLACK-LEGGED KITTIWAKE CHICKS: AN INDICATOR OF FORAGE AVAILABILITY?

Productivity (fledglings/nest attempt) of black-legged kittiwakes (*Rissa tridactyla*) is strongly influenced by local foraging conditions. Recent studies demonstrate that corticosterone levels of breeding kittiwakes correlate inversely with both productivity and forage availability. Increased plasma concentration of corticosterone in kittiwake chicks is known to promote begging behavior and facilitate increased metabolism of lean tissue; however, the relationship between adrenal responsiveness of chicks and foraging conditions experienced by their parents has not been previously explored. We set out to test the hypothesis that adrenal responsiveness of kittiwake chicks is sensitive to local forage availability as reflected by productivity. In 2002-2005, we monitored productivity at 21 colonies in Chiniak Bay, Alaska and sampled chicks for blood at <3, 10, 30, and 50 minutes post-capture. Corticosterone concentrations were subsequently determined by radioimmunoassay. Productivity was greatest in 2002, then progressively decreased in 2003 and 2004 before improving slightly in 2005. Baseline levels (<3 minutes post-capture) of corticosterone did not significantly differ among years; however, adrenal responsiveness was inversely related to productivity. Chicks in low productivity years exhibited both a greater and more protracted increase in plasma corticosterone levels, features indicative of chronic stress. These results suggest that corticosterone concentration in black-legged kittiwake chicks may be a reliable indicator of foraging conditions experienced by their parents.

62.5

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ALTITUDINAL VARIATION OF WING SHAPE IN THE ANDEAN PASSERINE *ZONOTRICHIA CAPENSIS*

A challenge common to both engineered and biological volant forms is flight at high altitudes, where the density of air is low relative to that at sea level and thus compromises the lift capacity of airfoils. However, little is known about the role of high altitudes/hypodense atmospheres as selective forces shaping the morphology or aerodynamic properties of biological flyers. This research focuses on population-level variation in flight-related morphology of the passerine *Zonotrichia capensis* sampled over a relatively large altitudinal gradient along the Western Peruvian Andes. Collections were made at three elevational zones: low (0-1800 m), mid (2100-2400 m) and high (3000-4200 m). Body mass, wing loading, and aspect ratio did not differ significantly among the altitudinal groups. Low elevation birds had significantly shorter wingspans than either medium or high elevation birds. Thin-plate Spline/Relative Warp Analysis was used to compare wing planform shape independently of size. Relative warp 1 showed variation in the distal half of the wing and in the trailing edge at the wing base. High and low elevation birds were not significantly different from each other, yet mid elevation birds were significantly different than those from both high and low elevations. The leading edges of wings from mid elevation birds possessed greater aft sweep and a relatively less elliptical wing tip. Furthermore, wings from mid elevation birds showed an increased curvature at the transition of the trailing edge and the wing root. These findings suggest that, for this species, selective pressures on flight morphology maybe more strongly influenced by habitat type, and possibly predation risk, than by atmospheric pressure.

50.4

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THE ENERGETIC CONSEQUENCES OF PREY SPECIALIST AND GENERALIST POPULATIONS OF THREE SPECIES OF GARTER SNAKE (*THAMNOPHIS ELEGANS*, *T. COUCHII* AND *T. ORDINOIDES*).

North American garter snakes (*Thamnophis* spp.) represent a unique study system because of their diverse diets and habitats, both within and among species. For example, the Western Terrestrial garter snake, *T. elegans*, exists in two geographically isolated populations in northern California: a coastal population with a specialized diet of slugs and an inland population with a generalized diet of fish, anurans, mice and leeches. The difference in prey preferences between the two populations is congenital, heritable, and ontogenetically stable. To test whether or not the coastal slug eaters have an energetic advantage over the inland generalists when digesting slugs, we have shown that the snakes from the specialized coastal populations assimilate more energy from a slug diet than do the generalist snakes. Recently, we have included an interspecific comparison between garter snake species considered to be dietary specialists on slugs (*T. ordinoides*) and fish (*T. couchii*). We have designed similar feeding experiments with these species as for the two populations of *T. elegans*. Using the inland population of *T. elegans* as the dietary generalist, we tested the hypothesis that dietary specialization of garter snakes is accompanied by increased assimilation efficiency when digesting specialized prey types compared to that of generalist garter snakes. This study was supported by NSF grant IBN 9727762 to A.F.B and J.W.H. and by NSF grant IOB 0445680 to J.W.H.

76.1

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PHYSIOLOGICAL EVOLUTION AND AGING IN GARTER SNAKES

A primary theory on the evolution of senescence purports that different rates of aging may have evolved as part of a suite of co-evolved life-history traits involving trade-offs in energy allocation. Specifically, energy allocated to early growth and reproduction results in less energy for somatic maintenance and repair. Thus response to stresses, whether external or internally derived is less efficient in organisms that divert energy to other functions. Natural populations of garter snakes are the study subjects for this evolutionary ecological study of aging as it relates to oxidative stress. The garter snakes in this study are either fast growers or slow growers; this difference in growth phenotype is due to genetic differences between the two phenotypes. Slow growers have resultant long lifespan (median lifespan = 8 years); fast growers have shortened lifespan (median = 3 years). Mitochondrial oxygen consumption, P:O ratios, and H₂O₂ production are compared between the two phenotypes to test the hypothesis that differences in metabolism and free radical production result from different mitochondrial efficiency between the two genotypes.

S9-1.4

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THE PHYSIOLOGICAL ECOLOGY OF OVERWINTERING MONARCH BUTTERFLIES

Monarch butterflies (*Danaus plexippus* L.) are extreme specialists in their selection of overwintering sites in Mexico. Up to a billion butterflies, produced in a breeding range covering 87 million hectares in eastern North America, converge into massive aggregations on a handful of hectares high in Mexico's transvolcanic range. Energetics and thermal constraints interact to restrict the butterflies winter habitat selection. Although in the tropics, monarch colonies form at elevations of 3000m and higher, where nectar availability is greatly limited and where they are subject to winter storms from the north. The butterflies, therefore, must rely on lipid reserves accumulated during their migration for their metabolic requirements, and they must avoid freezing or chill injury during and after storms. We are combining ecophysiology, climatology, GIS and remote sensing to increase our understanding of the monarch butterfly overwintering requirements and the characteristics of the habitats they select. Potential habitat varies in suitability: sites that are too warm will cause the butterflies to burn their lipid reserves, and other sites will increase risks of freezing. We are comparing the microclimate in sites where butterflies do and do not form colonies, and comparing rates of lipid depletion and risks of freezing in colony sites with different microclimates. We are using GIS models to integrate these data. Both illegal logging and climate change are diminishing the amount of suitable wintering habitat for the monarch butterfly. The spectacular migration is at great risk.

64.2

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GERM CELLS AND *VASA* EXPRESSION IN ASCIDIANS

Several evolutionary transitions between solitary and colonial lifestyles have been identified in the tunicates. These transitions are accompanied by dramatic morphological, developmental, and reproductive changes. We are studying whether stem cells involved in blastogenesis (asexual reproduction) of a colonial ascidian are able to generate both germline and soma. We compare the expression of *vasa*, a DEAD box RNA helicase found in germ cells across the metazoans, in the solitary ascidian *Boltenia villosa* and the closely related colonial ascidian *Botrylloides violaceus*. In *B. villosa*, *in situ* hybridization studies show expression of *vasa* in the posterior lineage of cells during embryogenesis and in germ cells of the adult gonad. *Boltenia vasa* mRNA is strongly expressed in the cytoplasm and nuclei of small oocytes, and expression decreases qualitatively in larger oocytes, where it is observed perinuclearly. In contrast, in colonies of the adult ascidian *B. violaceus*, *vasa* mRNA is expressed in the presumptive germ cells and oocytes in the gonads, and in certain isolated cells in the differentiating zooid. The timing of specification of the germline in colonial ascidians and the functionality of *vasa* positive cells in adult colonies is being investigated. Additionally we have conducted a phylogenetic analysis of the conserved DEAD box of *Vasa* in 22 highly divergent species of Metazoans, including *Boltenia* and *Botrylloides*. Our reconstruction shows that the *vasa* gene tree corroborates with known phylogenetic trees.

76.5

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ANATOMIC AND MOLECULAR CORRELATES OF DIVERGENT SELECTION FOR BASAL METABOLIC RATE IN LABORATORY MICE

The question about the mechanisms of evolution of high level of basal metabolic rate (BMR) in endotherms is one of the most intriguing in evolutionary physiology. Since BMR mostly reflects metabolic activity of internal organs, evolutionary increase in BMR could have been realized by an increase in a relative organ size and/or in their mass-specific cellular metabolic rate. The latter may be mediated e.g. by an increase in the abundance of polyunsaturated fatty acids in cell membrane lipids, which determines the activity of many metabolically-important enzymes. We investigated the effect of divergent artificial selection for low (L-BMR) and high (H-BMR) BMR in laboratory mice (*Mus musculus*) on the size of internal organs and acyl composition of cell membranes. H-BMR mice had considerably higher body-mass specific mass of liver, kidney, heart and intestines. In contrast, both lines differed little in the acyl composition of total phospholipids from liver cell membranes. Contrary to the expectations, L-BMR mice showed significantly higher content of 20:3 and 22:6 polyunsaturated fatty acids. Residual variation in BMR, not explained by the liver mass, was negatively correlated with the abundance of 20:3 fatty acid. Thus, divergent selection for BMR did not affect the acyl composition of liver phospholipids in the direction, which may explain the observed variation in BMR. We conclude that a significant intra-specific variation in BMR may rapidly arise solely due to the changes in size of internal organs, without simultaneous modification of their mass-specific metabolic rate, related to the changes in cell membrane composition.

53.6

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GENE-SPECIFIC CHANGES IN PROMOTER OCCUPANCY BY THYROID HORMONE RECEPTOR DURING FROG METAMORPHOSIS: IMPLICATIONS FOR DEVELOPMENTAL GENE REGULATION

In all vertebrates, thyroid hormones (TH) affect post-embryonic developmental processes. The role of TH receptor (TR) in mediating the TH signal during development is complex as evidenced by divergent phenotypes in mice lacking TH compared to TR knockout mice. We have proposed a dual function model for the role of TR during development based on studies of frog metamorphosis, where TR functions as a transcriptional repressor or activator during premetamorphosis and metamorphic climax, respectively. Here, we examined an important assumption of this dual function model using the chromatin immunoprecipitation (ChIP) assay, namely constitutive TR binding to promoters *in vivo* throughout development. We examined two TH direct response genes with TH response elements (TRE) in their promoters, TR β itself and TH/bZIP (TH-responsive basic leucine zipper transcription factor). Using an antibody that recognizes both TR β and TR α in the ChIP assay, we found that TR binding to the TR β promoter is indeed constitutive, whereas TR binding to the TH/bZIP promoter increases 5- to 10-fold from near background levels after TH treatment of premetamorphic tadpoles and at metamorphic climax. Using an antibody specific to TR β , TR β binding increases at both TR β and TH/bZIP promoters in response to TH. *In-vitro* biochemical studies showed that TRs bind the TH/bZIP TRE with 4-fold lower affinity than to the TR β TRE. Our data, suggesting that only high affinity TR β TREs are occupied by limiting levels of TR during premetamorphosis and that lower affinity TH/bZIP TRE becomes occupied only when overall TR expression is higher during metamorphosis, have broad implications for developmental gene regulation.

67.10

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EVOLUTION OF VIVIPARITY AND SPECIATION PATTERNS IN VERTEBRATES

The evolution of viviparity (here defined as development through metamorphosis of offspring within the mother with maternal nourishment) in vertebrate lineages has been traditionally studied from ecological, physiological, and developmental points of view. More recently, it has been argued that the evolution of viviparity can be better understood under a tug-of-war scenario between mothers and their developing offspring. Hypotheses such as the viviparity-driven conflict, parent-offspring conflict, or genetic incompatibility avoidance stress the conflict of interest between parental investment and offspring demand in the evolution of this derived reproductive strategy. These hypotheses predict, among other things, that the tug-of-war conflict will rapidly select for postzygotic isolation mechanisms, leading to an increase of speciation rates and a decrease of hybridization in viviparous lineages. We gather data on recently published vertebrate phylogenetic hypotheses to compare rates and modes of speciation and levels of hybridization between pairs of viviparous and non-viviparous sister groups. We analyze those data in a phylogenetic framework to test for correlation of traits or morphological and physiological constraint among lineages, shedding more light on the features that are related to the evolution of viviparity in the different vertebrate clades. We argue that the study of the evolution of an adaptive trait such as reproductive modes may be improved when approached from a historical (phylogenetic) and internalist (mechanistic) point of view rather than from a purely externalist or adaptationist point of view.

4.2

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Tulane University, Harvey Mudd College
PERSISTENCE OF INCUBATION EFFECTS ON THE PHENOTYPES OF HATCHLING WESTERN FENCE LIZARDS, *SCOLOPORUS OCCIDENTALIS*

The conditions under which an organism develops can have profound effects on its phenotype and subsequent evolution. Recently, incubation temperatures and their effects on offspring phenotypes have received increased attention in the evolutionary literature, and a wealth of empirical data reveals substantial physiological effects of the incubation environment on offspring performance and behavior. Many empirical studies assume that the effects of incubation temperature are adaptive. To date, however, few studies have determined whether these effects persist (i.e. remain adaptive) throughout an animal's lifetime. Other factors, including the rearing environment, may prove more important to a young organism than its incubation temperature. To test this prediction, we incubated eggs of the western fence lizard, *Sceloporus occidentalis*, from two different populations (1370 and 2230m elevation, respectively) under temperature conditions representative of both sites. A split-clutch design allowed us to separate the effects of population of origin from incubation environment. These hatchlings were then raised under identical thermal conditions. We measured the hatchlings' morphology, sprint speed and thermal preference immediately following hatching, and every two weeks for up to 11 weeks after. As predicted, incubation temperature had a significant effect on incubation timing and hatchling morphology. Here we discuss the persistence of these effects into the life of a juvenile lizard.

62.3

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POWER REQUIREMENTS OF BIRD FLIGHT WITH ADDITIONAL MASS

In the wild, birds routinely fly appreciable distances supporting the weight of prey items, nest material, water, and short-term fat stores. Under experimental conditions, subject animals are often encumbered with recording equipment (e.g. satellite transmitters, data loggers, etc) that artificially alters their body mass, and may also change the drag they experience at intermediate and fast flight speeds. From previous work we know that some birds are capable of takeoff and climbing flight while weighted with 150% of their bodyweight and can support 200% of their body weight during level flight. Yet surprisingly we have very little data documenting how this extra weight might alter the power required to remain airborne, and no empirical information addressing how these requirements may change with flight speed. To address these questions we trained three species of birds (*Pica hudsonia*, *Falco sparverius* and *Nymphicus hollandicus*) to fly in a variable speed windtunnel. We used *in vivo* sonomicrometry and measures of delto-pectoral strain to determine the pectoralis power output during free and encumbered flights across a wide range of speeds. During encumbered flights the birds supported the extra mass (approx. 0.1 M_b) and drag of a mask and tube that had previously been used to determine their metabolic power curves. For all three species, we found no difference in power requirements between free and encumbered flights at the minimum power speed. However at the fastest and slowest flight speeds from which measurements were possible, the power requirements were $38 \pm 9\%$ (\pm SE) and $26 \pm 5\%$ greater for encumbered *vs.* free flights. We discuss the physiological and ecological implications of these results.

S5-1.2

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AN ENDODERMAL ORIGIN OF MESODERM

Mesoderm played a critical role in the radiation of triploblastic bilaterians, allowing the evolution of more complex body plans than their diploblastic predecessors. The diploblastic phylum Cnidaria represents the likely sister group to triploblasts. Members of this phylum possess two distinct tissue layers separated by mesoglea consisting primarily of extracellular matrix. In some cnidarians, including the starlet sea anemone, *Nematostella vectensis*, the mesoglea also contains a limited number of cells. These cells are endodermal in origin. We investigated the expression of eight genes from *Nematostella* whose triploblast homologs are implicated in mesodermal specification and the differentiation of mesodermal cell types (*twist*, *snail-a*, *snail-b*, *otx*, *forkhead*, *mef2*, a *GATA* transcription factor and a *LIM* transcription factor). Expression of these genes is largely restricted to the endoderm, suggesting that (1) these genes play a role in endoderm specification and patterning and (2) the mesoderm and endoderm of triploblastic animals are derived from the endoderm of diploblastic animals. In *Nematostella*, as in other Cnidaria, an individual adult animal may be formed through three distinct processes. With respect to germ layer specification, regeneration and asexual fission are quite distinct from embryogenesis, as both the endoderm and ectoderm exist at the outset. Comparing expression of developmental genes across all three developmental contexts can provide insight into their developmental role. For example, *forkhead* and *otx* expression during fission and regeneration suggests that this gene plays a role in endodermal patterning, not just endodermal specification.

70.5

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REPRODUCTIVE ENDOCRINOLOGY OF THE SONG WREN (*CYPHORHINUS PHAEOCEPHALUS*), A RESIDENT BIRD OF THE LOWLAND TROPICS

In male tropical birds, levels of testosterone (T) are low and are often not as closely linked with breeding physiology and behavior as they are in temperate and arctic-breeding species. We explored the hormonal controls of reproduction in the song wren (*Cyphorhinus phaeocephalus*) during its breeding season (May-October) in the Republic of Panama (9°N, 79°W). Luteinizing hormone (LH), T, dehydroepiandrosterone, estradiol, and progesterone concentrations in males show no clear seasonal pattern at the population level. Mean T levels for male birds during the breeding season were low compared to species breeding in the temperate and arctic zones (mean=0.43 ng/ml, SE=0.06, N=26). To test the activity of the hypothalamo-pituitary-gonad axis, we injected male birds with gonadotropin releasing hormone (chicken 1). LH levels increased significantly 2-4 min after injection ($p < 0.001$, $N_{\text{control}}=14$, $N_{\text{GnRH}}=13$), but T levels did not change 30 min after injection ($p=0.50$). In many avian species, using conspecific playback to simulate a territorial intrusion results in an increase in LH and T in the territorial male. We saw no relationship between T (N=26) or LH (N=65) and duration of conspecific playback with playback times ranging from 1-97 min. Our results show that the control of T release and potential role of plasma T levels in this species do not fit the paradigms developed with temperate and arctic-breeding species and are more in line with the results from studies on other lowland tropical species.

13.9

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WORK AND POWER CHARACTERISTICS OF SKINNED FIBERS FROM THE DEEP AND SUPERFICIAL DIGITAL FLEXOR MUSCLES IN THE FORELIMBS OF HORSES

The objective involved making measurements of mechanical work and power on permeabilized fibers from the deep (DDF) and superficial (SDF) digital flexors as well as soleus (SOL) for a slow muscle control. Individual fibers underwent sinusoidal oscillations over a range of physiological frequencies (0.5-16Hz) and strain amplitudes (0.01-0.07 ML) under relaxing conditions (pCa 9), maximum activation (pCa 5) and rigor conditions at both 10°C and 30°C. Work and power were analyzed by both the workloop technique and a Nyquist technique of determining the elastic and viscous moduli of fibers to evaluate the real and imaginary components following correction for phase differences measured in rigor. Results from the workloop analysis on activated fibers (pCa 5) showed a general trend of increased mean work and power absorption with increasing strain and cycling frequency for all three muscle fiber types at each temperature. At 30°C only, work and power were actively generated (avg. 0.002-0.05 Wkg⁻¹) at 0.01 ML strain for all three fiber types although at differing cycling frequencies: DDF (4-7 Hz), SDF (4-5Hz) and SOL (1Hz). Workloop results were corroborated by Nyquist analysis (30°C only) on a subset of fibers which showed mean cross-bridge work being done against the apparatus by DDF, SDF and SOL fibers at 0.01 ML strain and further a marginal mean capacity for cross-bridge work to be done by DDF fibers at 0.02 ML strain between 4-6Hz. On average, work done by cross-bridges peaked at 1Hz for SOL, 4Hz for SDF and 6Hz for DDF fibers. Physiological findings contribute to an integrative model of digital flexor function in equine locomotion.

67.7

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OUCH! AN IMPROVED METHOD FOR PHYLOGENETIC TESTS OF ADAPTIVE EVOLUTION

The comparative method is a central tool for investigating the adaptive significance of traits. Using interspecific data, biologists seek to identify and study the factors which have been important in producing the diversity of life that we see today. The use of phylogenies to rigorously investigate character evolution has become standard practice in modern evolutionary biology. However, all existing "phylogenetic comparative" methods share the significant shortcoming that they use a completely neutral model of evolution. That is, they fail to account for natural selection, despite the fact that it is the central feature of interest. Using the Ornstein-Uhlenbeck model, we have been able to simultaneously account for genetic drift, common ancestry, and natural selection under multiple adaptive regimes. The truly novel feature of this approach is the modelling of multiple evolutionary optima or adaptive regimes, which can be painted on the phylogeny to represent alternative evolutionary hypotheses (models). We can then use model selection techniques to identify the best supported models. By explicitly modeling the causal factors of interest, scientists will be able to identify which aspects of the evolutionary process are most important, describe the relative strengths and directions of these forces, and understand how they have influenced the tempo and mode of evolution. We will illustrate use of the software and the method using new empirical examples.

43.6

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CORRELATIONS BETWEEN FLIGHT DEMANDS AND THE STRUCTURE OF CONTOUR FEATHERS IN SMALL BIRDS

Many studies have illustrated adaptations in birds to reduce the large aerodynamic and metabolic costs of flight, but no study has examined the relationship between flight demands and the morphology of the body feathers that form the plumage surface. We performed two phylogenetically-controlled comparisons between flight and the macro-structure of individual contour feathers. We measured variation in the number and arrangement of the barbs, and we compared that variation to flight demands in small birds. We compared feather structure in two ways: 1) between 21 pairs of congeners in which one species is resident and the other species is migratory, and 2) among 28 resident species that differ in the importance of sustained flight for foraging, such as aerial foragers and bark-probers. Based on those categories, greater flight demands were significantly correlated with barbs that were shorter, packed more tightly together, and oriented in a more streamwise (anterior to posterior) direction. Body feather structure could be related to aerodynamic drag, thermoregulation during sustained flight, or another function that is correlated with the flight differences among the species in our sample.

S6-2.1B

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DISTRIBUTION OF NOS-LIKE IMMUNOREACTIVITY WITHIN THE NUDIBRANCHIA

Within the invertebrates, the gaseous neurotransmitter nitric oxide (NO) has been shown to mediate a variety of behavioral pathways. Although there is evidence that NO functions in some sensory systems, the majority of studies have linked NO signaling to motor patterns governing feeding or locomotion. Indeed, most of the pathways in which NO has been implicated, including non-motor pathways, involve rhythmically active neurons or neuronal circuits. The primary effect of NO within these cells and circuits is to modulate the output of the system, thereby changing the duration or frequency of the rhythm or the phase relationship of the neural components underlying the rhythm or oscillations. Previously, attempts were made to identify the distribution patterns of NO producing neurons in a number of molluscan species (Moroz and Gillette, 1995). This and subsequent work has shown variability in the number and location of NO producing cells throughout the nervous system that correlated with habitat and/or feeding characteristics. In this study we investigated the distribution of putative NO producing cells in 13 species of nudibranchs representing all 4 suborders (Arminacea, Doridacea, Dendronotacea, and Aeolidacea) of this molluscan group. Using a universal NOS antibody, we found that the number and locations of immunopositive cells varied greatly across this monophyletic group. Interestingly, one set of apparently homologous neurons consistently labeled within the pleural ganglia in all 13 species investigated. Our results suggest that, with the exception of this one group of neurons (whose location suggest that they function in either feeding or locomotion), the use of NO as a neurotransmitter/neuromodulator can change rapidly within a closely related group of species.

13.3

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MODELLING ARBOREAL LOCOMOTION: THE EFFECT OF LIMB ABDUCTION ON SUBSTRATE REACTION FORCES DURING LEMURID QUADRUPEDAL LOCOMOTION

Arboreal locomotion requires movement through three-dimensional settings in which substrates and superstrates are irregularly positioned. As a consequence, animals adopt a variety of limb postures during locomotion, often abducting limbs at proximal joints. Studies of external forces during simulated arboreal locomotion, however, typically examine a limited subset of locomotor diversity observed among free-ranging animals. While comparisons of arboreal and terrestrial linear locomotion have shown lower external forces during arboreal locomotion, likely due to compliant gait, the mediolateral (ML) component of the substrate reaction force (SRF) may reflect degree of limb abduction (i.e., greater during terrestrial linear locomotion). To investigate this, SRFs and degree of limb abduction at shoulder and hip joints were recorded for 390 limb contacts of lemurs (*Eulemur rubriventer*). Individuals traveled along a wooden runway or linear pole, each with an instrumented segment, and the same pole, but with the instrumented section offset from the longitudinal axis of the pole. As offset increased, ML peak force magnitude increased. At the greatest offset, magnitudes and directions of ML peak forces were similar to those observed during runway locomotion, despite slower average speed. When the instrumented segment was offset to any degree, the SRF usually switched to medially-directed, unlike the laterally-directed force usually observed during simulated arboreal locomotion on the linear pole. Mediobasilar peak force magnitudes experienced during arboreal locomotion can be high, even exceeding those experienced during terrestrial locomotion. Supported by NSF BCS 0411489.

13.1

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LUCYS DIMINUTIVE LEGS

Australopithecines had short legs. Relatively short hindlimbs characterize most large bodied primates (Jungers, 1984). The short legs of australopithecines are generally thought to represent arboreal specialization. There are reasons, however, to suspect that the evolution of relatively short legs may also be due to specialization for physical aggression. Fighting is a behavior in which short legs can be expected to improve performance, by lowering the center of mass and reducing the length of the ground reaction force moment arm. Fighting, associated with male-male competition, is prevalent in all extant great ape species. To address whether the evolution of short legs is associated with aggression, I examined the relationship between limb length and body size sexual dimorphism (SSD) in Hominoidea (i.e., Hylobatidae and Pongidae). Among anthropoid primates, SSD is strongly correlated with levels of male-male competition (Plavcan and Van Scaik, 1997), which allows SSD to be used as an index of male-male aggression. Relative leg length is strongly correlated with SSD ($R^2 = 0.825$, P -value = 0.0018). Ape species with the shortest legs for their body mass tend to be the most dimorphic. Independent contrast analysis also indicates a negative correlation ($R^2 = 0.940$, P -value = 0.0003). This negative correlation remains significant after the effect of body size is removed ($R^2 = 0.665$, P -value = 0.025). In contrast, the evolution of relative hindlimb length is not significantly correlated with the evolution of relative forelimb length ($R^2 = 0.274$, P -value = 0.228). Although australopithecines possessed a striding bipedal gait, they retained relatively short legs for over 2 million years. The observed negative correlation between evolution of leg length and evolution of sexual dimorphism in apes is consistent with specialization for high levels of physical aggression in australopithecines.

44.1

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MUSCLE FUNCTION AND MUSCULAR POWER OUTPUT DURING SUCTION FEEDING

Muscle power output is thought to limit suction feeding performance, yet it has never been directly measured. In this study, epaxial activation and strain, hyoid depression, and intra-oral pressure were simultaneously measured in the largemouth bass (*Micropterus salmoides*) feeding on elusive prey. A mechanical model of muscle force transmission between the neurocranium and oral cavity was used to estimate muscle stress, work, and power based on buccal pressure and morphological measures. The epaxials shortened from rest an average of 9% of their length, with the highest efforts producing greater than 20% strain. Onset of shortening was simultaneous with or shortly after (<10 ms) onset of activation. Maximal net power for individual fish ranged from 17 to 137 W kg⁻¹. Muscle power was significantly correlated with rectified EMG area ($r=0.80$; $p<0.0001$). The power required for cranial expansion was significantly correlated with epaxial power ($r=0.81$; $p<0.0001$), and the power exponent of this relationship (-1 for 3 of the 4 fish) implies that epaxial power accounts for most of the power of cranial expansion. The limitations imposed by the kinematic requirements and loading environment of suction feeding (short delay between activation and strain, maximal stress occurring after shortening, operation at lengths shorter than resting length) may reduce muscular power production. This study marks the first comprehensive simultaneous measurement of all aspects of muscle function (activation, strain, and force), the first direct measurement of muscular power, and the first direct measurement of the power cost of cranial expansion during suction feeding.

63.1

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USING MORPHOLOGY TO PREDICT FEEDING BEHAVIOR: A PRELIMINARY STUDY OF JUVENILE RED SNAPPER (*LUTJANUS CAMPECHANUS*) FEEDING

Red snapper are an important commercial species in the Gulf of Mexico. However, their biology and feeding mechanics are virtually unknown. The goals of this study were to, (1) characterize the feeding biomechanics of juvenile red snapper and, (2) to test the hypothesis that the jaw biomechanics differ between subjects from different size classes and habitats. Juvenile red snapper from three size classes (<49 mm, 50-69 mm, and >70 mm SL) and two habitats (on-ridge & off-ridge) were collected from the northwestern Gulf of Mexico off the coast of Texas. Fourteen morphometric measurements of the lower jaw and main closing adductor muscles, A2 and A3, were recorded. These data were used in the biomechanical model MandibLever 3.0 (M.W. Westneat), which provided dynamic outputs of predicted jaw function, such as effective mechanical advantage (EMA) and jaw velocity (VR). Outputs from the model were used to predict and characterize the feeding biomechanics from the three size classes and two habitats. Overall, the model reported a low EMA and high VR, suggesting that juvenile red snapper are primarily suction feeders. This suggestion is supported by kinematic feeding trials of live juvenile red snapper. No significant differences among size classes ($p > 0.05$) or between habitats ($p > 0.05$) were observed in EMA or VR. However, as body size increased, VR tended to decrease, and EMA tended to increase. Although our data is for juveniles only, the trends in EMA and VR suggest a shift from primarily suction feeding as juveniles to primarily biting as adults. This trend is supported by kinematic feeding trials of juvenile red snapper, modeling data from a few adult red snapper, as well as observations of feeding behavior in adults.

69.4

CASPER, A.F., JOHNSON, L.E.; afcasper@stpt.usf.edu. University of South Florida, St. Petersburg
PATTERNS OF MICROEVOLUTION AND DISPLACEMENT IN A RAPIDLY EXPANDING SPECIES: INSIGHTS FROM COMPARATIVE PHYSIOLOGICAL ECOLOGY OF ZEBRA AND QUAGGA MUSSELS

This research explores whether a contiguous population of adult zebra and quagga mussels (*Dreissena polymorpha* and *D. bugensis*) in a stable, divergent mosaic of river environments has developed localized physiological differences and, if so, whether these are plastic or irreversible responses. Previous field and laboratory experiments show that the riverine zebra mussel distributions are constrained by salinity. However zebra mussels from the estuarine transition zone of the St. Lawrence were in better condition (biomass, RNA/DNA ratio, glycogen content) than those from upriver. To explore whether this represents plasticity or alternatively local differentiation, reciprocal transplants of adult mussels from the estuarine transition zone and the river were conducted. Results indicate that shell growth depends on source population, independent of the environment (river source mussels > estuary source mussels). In contrast, RNA/DNA ratio, a short-term measure of tissue condition and growth, was significantly higher for estuary mussels in their source environment. Methodologically this confirms that shell growth is not always an accurately accurate proxy for changes in biomass. Evolutionarily it suggests the differentiation in shell growth and strength in zebra mussels has a clear source population component. Ecologically the second species of dreissenid to arrive, the quagga mussel, appears to have a physiological advantage and is displacing the zebra mussel in river environments. However this is not true in the estuarine transition zone where zebra mussels appear to have made an irreversible physiological adjustment that currently allows them to maintain their dominance.

66.3

CATENAZZI, A.; acaten01@fiu.edu. Florida International University
THE *ULVA* CONNECTION: MARINE RESOURCES SUBSIDIZE TERRESTRIAL CONSUMERS IN COASTAL PERU

How can terrestrial animals survive in a desert with scant primary productivity? The Peruvian coastal desert is hyper-arid, but faces one of the most productive marine ecosystems, the Peru-Chile cold current. Given the stark difference in productivity between these two adjacent ecosystems, I expected to find strong linkages connecting the terrestrial and marine food web. I investigated how marine resources are incorporated in the diet and influence the distribution of terrestrial consumers. Stomach contents from geckos (*Phyllodactylus angustidigitus*) and carbon and nitrogen isotopic values of geckos and other terrestrial consumers suggest that marine green algae of the genus *Ulva* provide energy and nutrients to the terrestrial food web. Isotopic values suggest that amphipods of the genus *Orchestoidea*, which feed on stranded *Ulva*, make marine resources available to terrestrial consumers by moving between the intertidal and supratidal zones. *Orchestoidea* is the most common prey item in the stomachs of geckos. The spatial distribution of geckos indicates that they depend on marine resources. Geckos are 25 times more abundant between 0 and 9 m away from shore than they are between 50 and 59 m away from shore. This study describes a unique community found at the juxtaposition of one of the richest ocean currents and one of the driest deserts in the world. It shows that it is not possible to understand the structure and dynamics of the terrestrial food web without including the effects of marine energy and nutrients.

S1.5

CATTADORI, I.M.; imc3@psu.edu. Penn State University
THE EFFECT OF IMMUNITY AND SEASONALITY ON PATTERN OF INFECTION

Insight into the dynamics of parasite-host relationships of higher vertebrates requires an understanding of two important features: the nature of transmission and the development of acquired immunity in the host. We have examined the dynamics of infection of two gastrointestinal nematodes, *Trichostrongylus retortaeformis* and *Graphidium strigosum*, and the poxvirus myxoma within a natural population of rabbits sampled monthly for 26 years. Rabbit age was re-constructed using body mass, and parasites intensity and virus prevalence were recorded. The rabbit age-nematode intensity curves were examined seasonally and with and without myxoma co-infection. We found that a decrease in immunity with host age associated with seasonality in host reproduction and parasite force of infection increased the number of heavily parasitized rabbits. These heavily infected hosts also had a significant higher net parasite transmission rate. We concluded that specific groups of rabbits that became immunosuppressed during part of the year are responsible for parasites persistence and transmission.

55.1

CHADWELL, B.A., STANDEN, E.M., LAUDER, G.V.; chadba1@wfu.edu. Wake Forest University, Harvard University
DORSAL AND ANAL FIN FUNCTION DURING THE C-START ESCAPE RESPONSE IN BLUEGILL SUNFISH.

Axial kinematics during the fish C-start have been studied extensively and the pattern of body and caudal fin movement is well understood. However, there are effectively no detailed kinematic data on median fins such as the dorsal and anal fins during C-starts. We filmed the escape response of bluegill sunfish simultaneously with three high-speed, high-resolution cameras at 500 fps for a 3-dimensional kinematic study of median fins, in particular the soft dorsal (sfD) & anal (An) fins. Individual fin rays in the sfD & An fins were digitized to determine detailed movements in relation to the body and to each other throughout the escape maneuver. We also measured the degree of elevation & curvature of the rays. Fin movement occurred simultaneously with onset of Stage 1 (S1), increasing fin surface area by the elevation of anterior rays and depression of posterior rays. During S1, trailing edges of both fins were displaced from the midline contralateral to the direction of movement. Curvature of the trailing edges increased rapidly and maximum curvature occurred within 15-21 msec, just prior to maximum lateral displacement of the tail. At the start of the return stroke, i.e. Stage 2 (S2), the trailing edges were again displaced to the contralateral side and maximum curvature occurred within 2-4 msec. Unlike S1, fin curvature & displacement remained fairly consistent throughout S2 and maximum curvature & displacement were less. While fin kinematics differed between S1 and S2, the sfD & An fins showed coordinated movements and curvature throughout the maneuver. We suggest that the synchronicity of sfD & An fin kinematics functions 1) to resist rolling during the escape maneuver and 2) to possibly increase acceleration performance over that obtainable with collapsed median fins.

30.1

CHAN, S.-M.; chansm@hkucc.hku.hk. The University of Hong Kong
VITELLOGENIN AND VITELLOGENESIS IN DECAPOD CRUSTACEANS: KNOWLEDGE FROM PROTEOMIC AND MOLECULAR STUDIES

Vitellogenin (Vg) is the precursor for one of the major yolk proteins that supplies the embryos and larvae with nutrients for development and growth. During ovarian maturation of decapod crustaceans, vitellogenins are synthesized and transported to the ovary for oocyte uptake by receptor-mediated endocytosis. Although the biochemical characterization of vitellin and vitellogenin has been the major research focus in the past decades, there are still controversial issues regarding the synthesis sites, number of vitellogenin gene, sizes of transcripts and the processing mechanisms for the vitellogenin subunits. By proteomic approaches, amino acid sequencing of hepatopancreas and ovary proteins extracted from reproductive females have confirmed the presence of vitellogenin subunits in both tissues. However, the results from proteomic study suggested that the hepatopancreas may contribute to the production of small vitellogenin subunits. By molecular approach, the gene for several decapods vitellogenin had been cloned. Results from genomic Southern blot, genomic PCR and RT-PCR analyses confirmed the presence of multiple Vg genes in a single species. The Vg gene organization of different decapods is highly similar which suggests that the Vg gene organization is highly conserved during evolution. When we compared the Vg sequence among different decapods (i.e. lobster vs shrimp), they shared much lower sequence identities. Both the hepatopancreas and the ovary of females express Vg during gonad maturation. Although the 7.8 kb RNA Vg transcript was reported, smaller transcript specific to the Vg had also been detected in Northern blot. These smaller transcripts may contribute to the production of smaller Vg subunits by the hepatopancreas and ovary. Both post-transcriptional and post-translational modifications may be involved in the final production of vitellin in the ovary. (Supported by HKSAR Government RGC Grant # HKU7214/02M)

S8-1.1

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SCDNR/MRRI, Medical University of South Carolina/MBES
ECOGENOMICS: ANALYSIS OF COMPLEX SYSTEMS

Ecogenomics is a convenient descriptor for the application of advanced molecular technologies to studies of organismal responses to environmental challenges in their natural settings. The development of molecular tools to survey changes in the transcript profile of thousands of genes has presented scientist with enormous analytical challenges. In the main, these center about the reduction of massively paralleled data to statistics or indices comprehensible to the human mind. Historically, scientists have used linear statistics such as ANOVA to accomplish this task, but the sheer volume of information available from microarrays severely limits this approach. In addition, important information in microarrays may not reside solely in the up or down regulation of individual genes, but rather in their dynamic, and probably non-linear, interactions. In this presentation we will explore alternative approaches to extracting of these signals using artificial neural networks and fractal geometry. The goal is to produce predictive models of gene dynamics in individuals and populations under environmental stress and reduce the number of genes that must be surveyed in order to recover transcript profile patterns of environmental challenges.

3.2

CHAPPELL, M.A., RUSSELL, G.A., HAMMOND, K.A.;
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BMR IS NOT REPEATABLE OVER EXTENDED PERIODS IN DEER MICE

Basal metabolic rate (BMR) is probably the most thoroughly investigated aspect of energy metabolism in vertebrate endotherms. Hundreds of studies have explored its mass allometry, phylogenetic and ecological relationships, ontogeny, mechanistic underpinnings, and so forth. Implicit in many of these studies, (and explicit in a few) is the view that BMR responds to selection, either direct selection on metabolism or energy economy, or indirect selection on correlated traits. Selection on any trait presumes repeatability and heritability but BMR is known to be highly plastic, responding to circadian cycles, altitude hypoxia, acclimation to temperature, and numerous other physiological, environmental, or life history factors. Given all the attention it has received, especially in the context of evolution, there have been surprisingly few studies of BMR repeatability, especially in mammals. We studied BMR repeatability in captive deer mice (*Peromyscus maniculatus*) across intervals of 33-88 days, and also examined the role of birth altitude (3800 versus 340 m) and cold acclimation (8 weeks at -4°C) on BMR, and relationships between BMR and organ size. BMR was not affected by birth altitude but significantly increased in response to cold acclimation. Organ masses were not correlated with BMR, and BMR was not repeatable. Absence of consistent relationships between organ size and BMR suggests that no single organ or organ system (either central or peripheral) controls variation in BMR. Lack of repeatability although in sharp contrast to a recent report of high BMR repeatability in bank voles indicates little potential for selection to act on BMR in deer mice.

S3-1.2

CHIEL, H.J.; hjc@case.edu. Case Western Reserve University
NEUROMECHANICS OF MULTIFUNCTIONALITY

How do animals deploy a group of muscles and neurons to generate qualitatively different behaviors? In engineered devices, different functions are cleanly assigned to different sub-components. In contrast, in biological systems, fluid and rapid reconfiguration of both the periphery and nervous system are utilized to generate qualitatively different behaviors. We have studied this phenomenon in the feeding system of the marine mollusk *Aplysia californica*, which is capable of generating at least three qualitatively different behaviors: biting, swallowing and rejection. The same muscles and motor neurons mediate each of these three behaviors. Changing the timing and phasing of activation of different muscles, which also alters the function of identified motor neurons, mediates the expression of the different behaviors. We are beginning to analyze the interneuronal control that generates multifunctionality by altering the activity of single identified neurons in intact, behaving animals. These results have led to the design of novel, multifunctional biologically-inspired robots.

53.9

CHRISTIANS, J.K., HOEFLICH, A., KEIGHTLEY, P.D.; julian.christians@ed.ac.uk. Simon Fraser University, Ludwig-Maximilians Universitaet, University of Edinburgh

INVESTIGATION OF THE CAUSAL GENE UNDERLYING A QUANTITATIVE TRAIT LOCUS (QTL) CONTRIBUTING TO GENETIC VARIATION IN GROWTH

Within all species, many traits show continuous variation between individuals, with phenotype determined by both the environment and a potentially large number of genes. Understanding the genetic basis of intraspecific variation is of fundamental importance to medicine, evolutionary biology and agriculture. In the past decade, enormous effort has focused on identifying genes underlying quantitative trait loci (QTL), i.e., naturally occurring genetic variation that contributes to normal variation within species. Our recent work has focused on a QTL with a general effect on size in mice; the QTL affects the length of the tail and various bones, and has a weaker effect on mass. We have refined the location of this QTL to a chromosomal region containing only four genes, one of which is a strong candidate: the mouse orthologue of the human *PAPPA2* gene. The protein product of this gene is known to cleave insulin-like growth factor-binding protein 5 (IGFBP-5) *in vitro*, but its physiological role is poorly understood. To evaluate whether this candidate gene is responsible for the effect of the QTL, we have examined coding sequence variation between QTL alleles and found a number of amino-acid changing differences. We are also examining the tissue expression profile of this gene, and whether its expression levels differ between QTL genotypes. Furthermore, effects on potential downstream pathways (e.g., IGFBP-5) are also being investigated. This system promises a powerful model for exploring the physiological pathways by which genetic variation leads to phenotypic variation.

59.1

CHRISTY, J.H., RISSANEN, J.R., BACKWELL, P.R.Y.; christyj@si.edu. Smithsonian Tropical Research Institute, Australian National University
A ONE-DAY PAUSE IN THE BIWEEKLY COURTSHIP CYCLE OF A TROPICAL FIDDLER CRAB ALLOWS FEMALES TO AVOID RELEASING LARVAE DURING TWILIGHT

Predation on adults or young in the intertidal zone may vary predictably with the daylight, tidal height and tidal amplitude cycles and favor reproductive timing for predator avoidance. A novel pattern in the reproductive cycle of the fiddler crab *Uca terpsichores* supports this idea. Fiddler crab larvae are vulnerable to predation by diurnally feeding planktivorous fish that abound in shallow habitats where adults live. Estuarine fiddler crabs usually release larvae at night near the time of the evening high tides on the few consecutive days every two weeks with larger amplitude nocturnal ebb tides. Consequently, newly released larvae move rapidly seaward on ebbing tides under the cover of darkness and thus avoid falling prey to diurnal planktivores. Daily monitoring for 20 months of the intensity of courtship by *U. terpsichores*, which lives on protected sand beaches in the tropical Eastern Pacific, shows they have a typical biweekly courtship and mating cycle but with two modes split by a day when reproductive activity is greatly reduced. Given that embryonic development takes about two weeks, this mid-day pause predicts a decline in larval release two weeks later on the days with crepuscular high tides. Plankton sampling showed that larvae are released throughout the night up until dawn. As predicted, there was a decline in the density of newly hatched larvae on days with twilight high tides and also on days with moonlit high tides. Avoiding light-dependent visual predators at the time of larval release is paramount for this species. Apparently less important is extensive seaward dispersal at night perhaps because this species lives relatively close to deeper, safer waters.

31.2

CHUNG, J.S., ZMORA, N., ZOHAR, Y.; chung@umbi.umd.edu. COMB, UMBI, Baltimore

CLONING AND EXPRESSION PROFILE OF NON-EYESTALK CRUSTACEAN HYPERGLYCEMIC HORMONE (CHH) NEUROPEPTIDES FROM THE BLUE CRAB, *CALLINECTES SAPIDUS*

Since the first structural characterization of crustacean hyperglycemic hormone (CHH) from sinus gland of *Carcinus maenas*, other CHHs, showing with a high structural similarity, have been identified from non-eyestalk tissues (pericardial organs= PO and fore-and hindguts) of this crab species.¹⁻³ Using immunohistochemistry, HPLC and cDNA cloning, we have identified and characterized non-eyestalk CHHs from PO and guts of the blue crab. These non-eyestalk CHHs show high resemblance in their structure to eyestalk CHH (AAS 45136). The results obtained from the testing biological activity of PO-CHH indicate that PO-CHH does not involve in the modulation of glucose or lactate level in hemolymph. It was, however, noted that the expression of CHH gene in PO and eyestalk was sensitive to stress. Yet the regulatory mechanism governing the expression of PO-CHH and eyestalk CHH appears to be different. 1. Kegel et al., (1989) FEBS Letters 255, 10-14. 2. Chung et al., (1999) PNAS, 96, 13103-13107. 3. Dirksen et al., (2001) Biochem J 356, 159-170.

61.3

CLAESON, K.M., LUNDBERG, J.G.; kclaeson@mail.utexas.edu. Amherst College, Academy of Natural Sciences, University of Texas, Austin
MICRO CATFISH MICRO CATSCANS

Tendencies toward extremely small body size occurred several times during the course of teleost evolution. The catfishes (Siluriformes) are a group of fishes in which miniaturization occurred multiple times. We present new information on two distantly related miniaturized catfishes from South America, *Micromyzon akamai* (Aspredinidae) and *Sarcoglanis simplex* (Trichomycteridae). Data were collected with the classical technique of clearing and staining (C&S) and the more contemporary approach of microfocus computed tomography (CT). CT was developed in the mid 1970s and used to examine humans and other vertebrates in veterinary sciences. Around 20 years ago, CT was adapted for examining paleontological specimens. Microfocus CT (conducted at Amherst College), is similar to traditional CT scanning but allows for significantly greater resolution on small specimens. The remarkably small size of these fishes (<20mm, SL) and the sparse number of specimens raise difficulties for detailed examination of the skeletal anatomy in comparative morphological and phylogenetic research. Results of this study demonstrate fundamental differences between these techniques, warranting discussion of the benefits of C&S and CT as separate entities and in combination. CT images are ready at once for illustration, are non-destructive, and results are easy to distribute for study by others. C&S is inexpensive, cartilage can be counterstained, and improved digital imaging such as automontage for depth of field produces sharp illustrations. Additionally, when a small sample set is available, using both CT and C&S on the same specimen greatly reduces the need to dissect, disarticulate, and otherwise modify rare specimens.

47.1

CLAMP, J.C.; jclamp@ncsu.edu. North Carolina Central University
THE PHYLOGENETIC POSITION OF *LAGENOPHRYS*
(PROTISTA, CILIOPHORA, PERITRICHIA) INFERRED FROM
THE SEQUENCE OF THE GENE FOR 18S SMALL SUBUNIT
RRNA

Lagenophrys is a genus of peritrich ciliates in which the cell body and life cycle are highly modified to accommodate existence as ectosymbionts of a wide variety of crustaceans. On one hand, the morphology of the peristome (expanded oral area) of *Lagenophrys* suggests a phylogenetic relationship to the family Operculariidae; however, *Lagenophrys* is so different from operculariids with respect to other morphological characteristics that this relationship cannot be supported well on those grounds alone. On the other hand, sequencing genes of *Lagenophrys* spp. to obtain molecular data for phylogenetic analysis presents special challenges because the organisms are surrounded by a protective lorica that is cemented firmly to the exoskeleton of the crustacean host, making separation from the host almost impossible. Moreover, the cell body of *Lagenophrys* is extremely flat, which adds to this difficulty. Normally, *Lagenophrys* spp. abandon a host before its ecdysis by undergoing binary fission and then exiting their loricae, but individuals occasionally fail to react to the hosts impending molt and remain behind. A sample of the common grass shrimp *Palaemonetes pugio*, a frequent host of *Lagenophrys eupagurus*, was collected from the Pamlico River in eastern North Carolina during December, when they are heavily infested with the ciliates. This created a greater possibility that each freshly molted exoskeleton would harbor at least a few individuals of *L. eupagurus*. DNA was extracted from specimens of *L. eupagurus* on fresh molts of *P. pugio* and the 18S small subunit rRNA gene was sequenced successfully. The molecular evidence suggests that *Lagenophrys* is indeed most closely related to operculariid peritrichs, confirming morphological results.

44.3

CLARK, A.J., SUMMERS, A.P.; aclark@uci.edu. University of California, Irvine
FUNCTIONAL MORPHOLOGY AND KINEMATICS OF THE
HAGFISH FEEDING APPARATUS

Hagfish are basal craniates that lack jaws. Instead of jaws, hagfish possess a cartilaginous dental plate with two rows of cusps that resemble grasping dentition. A series of ventrally situated cartilaginous elements (the basal plate) support the dental plate and feeding muscles. During feeding, a network of protractor and retractor muscles pull on the dental plate resulting in a protraction-retraction movement. The protractor and retractor muscles behave in a manner analogous to gnathostome jaw abductor and jaw adductor muscles, respectively. Hagfish (*Myxine glutinosa* and *Eptatretus stoutii*) were housed in a glass aquarium with circulating ASW at 10°C. Feeding kinematics were recorded with a digital camera (30 fps) and analyzed with Adobe Premiere 6.0 and Image J. We measured bite cycle times and compared our results with those from several elasmobranch species. Hagfish bite cycle times were longer than previously recorded elasmobranch bite cycle times. Bite cycle times re-scaled to body length of the hagfish were longer than eight re-scaled elasmobranch bite cycle times. The longer bite cycle times of hagfish indicate a disadvantage of lacking jaws.

43.5

CLARK, C.J., DUDLEY, R.; cclark@berkeley.edu. University of California, Berkeley
EFFECTS OF TAIL LENGTH ON HUMMINGBIRD TOP SPEED,
POWER CURVE, AND PARASITE DRAG

Hummingbirds (Trochilidae) exhibit enormous variation in their tail morphology and this variation is largely driven by sexual selection. One aerodynamic effect of an elongated tail may be to increase parasite (body) drag, by increasing the surface area of the bird that is in contact with air. To test this hypothesis, we measured top speed, metabolic rate, and parasite drag on Annas hummingbirds (*Calypte anna*) with their natural tail and with a tail elongated by 15 cm. With the elongated tail, top speed decreases by approximately 2.5%, while metabolic rate increases by up to 8% at high speeds. Parasite drag, as measured with a live bird perched on a force transducer, also increases. These independent measurements of body drag all indicate that elongating the tail by 15 cm increases overall drag by about 7% at high speeds. This measurement is almost twice as high as predicted by surface area alone; we hypothesize that the difference between our measures and theory arises from fluttering of the tail feathers caused by their low flexural stiffness.

27.5

CLOUSE, R.M., GIRIBET, G.; clouse@fas.harvard.edu. Harvard University
THE SYSTEMATICS AND BIOGEOGRAPHY OF THE STYLOCCELLIDAE,
A SOUTHEAST ASIAN FAMILY OF CYPHOPHTHALMI
(OPILIONES)

Here we present our current understanding of the systematics of the Stylocellidae, a Southeast Asian family of the opilione suborder Cyphophthalmi. These animals are small (1-6 mm), cryptic, slow-moving arachnids that live in wet leaf litter around the world, and they are excellent subjects for biogeographic studies. The Stylocellidae live in Southeast Asia, Indonesia, Palawan, and New Guinea, and they await an extensive, systematic, collecting effort. We have done a preliminary study of specimens borrowed from museums worldwide, and we have found that this family contains a large number of novel species, especially on Sumatra. From the more recent collections, we have generated sequence data and have thus been able to include stylocellidae species in a comprehensive cyphophthalmid phylogeny and begin to understand relationships within the family. Relationships within the Stylocellidae are especially interesting in such a geologically complex region.

S1.3

COHEN, C.S., TIRINDELLI, J., GOMEZ-CHIARRI, M., GAUGER, E., NACCI, D.; sarahcoh@sfsu.edu. San Francisco State University, Harvard University

MAJOR HISTOCOMPATIBILITY COMPLEX (MHC) VARIATION AT THE POPULATION LEVEL: MAKING THE MOST OF FUNCTIONAL AND STRUCTURAL MODELS, WITH AN EXAMPLE USING ESTUARINE FISH

Structural models of the MHC antigen-binding cleft offer the opportunity to test for functional differences in substitution patterns at the population level. The mammalian crystal model for the antigen-binding receptor has been used successfully across vertebrates to infer binding areas and test hypotheses of positive selection at broad taxonomic levels. More recently, MHC researchers have found additional ways to test for shorter term, local effects of selection on the MHC. Some species with relatively low genetic diversity or under strong directional pathogen selection have revealed fascinating cases of MHC allelic disease linkage. But, more generally in genetically diverse species, these linkages may be hard to find. We are taking an alternative approach using the structural model to produce a population composite of antigen-binding region variation by mapping population-specific substitutions onto functional regions of the molecule. This population level approach is related to the strong differences in parasite load observed in highly disturbed, chemically contaminated estuaries, in comparison to reference sites. This approach will be illustrated with examples from EPA Superfund sites such as the one in New Bedford Harbor where resident killifish, *Fundulus heteroclitus*, show evolved resistance to chemical contaminants and have highly unusual parasite loads in comparison to fish from reference populations. Laboratory *Vibrio* challenges confirm functional aspects of the immune system in Superfund site fish. Population-specific patterns of antigen-binding region variation are a new tool for inferring functional changes in MHC. Funding for this included grants from the NRC, US EPA, Hudson River Foundation, NSF, Harvard University, and San Francisco State.

S8-1.2

COLBOURNE, J.K., LINDQUIST, E., BAUER, D., BROKSTEIN, P., THOMAS, W.K., ANDREWS, J.; jcolbour@cgb.indiana.edu. Center for Genomics and Bioinformatics, Indiana University, US Department of Energy, Joint Genome Institute, Hubbard Center for Genome Studies, University of New Hampshire

GENE DISCOVERY IN *DAPHNIA* BY EXPRESSED SEQUENCE TAG SEQUENCING

The *Daphnia* genome project is a consortium based endeavor to characterize the genome and transcriptome of a crustacean and to generate resources for genomic studies in the fields of ecology, toxicology and evolution. To facilitate the annotation of the genome sequence and to accelerate the production of a full transcriptome microarray, we created unidirectional cDNA libraries from *Daphnia* exposed to 12 distinct ecological stressors ranging from toxic metals and UV radiation to hypoxia, starvation and predation. We are sequencing 5 and 3 EST sequence reads from randomly selected clones from each library. At the mid-point in the project, we identified over 12,600 unique genes from 71,000 high quality ESTs. These gene sequences were queried, using a variety of homology searches, against those from other arthropod genomes to discover their evolutionary conservation with respect to putative gene functions. This genome-wide comparative analysis of *Daphnia* genes with the functionally well characterized genes of model insects provides important findings into similarities / differences between these two classes of Arthropoda and provides clues into the biology of a fascinating sentinel species within freshwater habitats.

52.3

COLLAR, D.C.; dccollar@ucdavis.edu. University of California, Davis
TESTING THE BASS FISHERMANS HYPOTHESIS: DOES REACHING AN ADAPTIVE PEAK LIMIT DIVERSIFICATION OF THE FEEDING APPARATUS IN *MICROPTERUS* (TELEOSTEI: CENTRARCHIDAE)?

The potential for a lineage to diversify morphologically might be limited if it sits atop an adaptive peak. If the common ancestor of a lineage possesses structures and performance capacities that confer optimal fitness, then selection will act to limit the diversity of those structures in descendent lineages. Inspired by the observations of many bass fishermen that the black basses (*Micropterus*) are the ultimate fish predators, I tested the hypothesis that, with respect to the feeding mechanism, the position of *Micropterus* atop an adaptive peak has limited its diversity. *Micropterus* is a clade of eight freshwater fish species belonging to the North American radiation, Centrarchidae. The diets of all *Micropterus* species contain fish, and the diversity of diet items within this group is lower than that of its sister clade, *Lepomis* (sunfishes), and the sister clade to these two groups. Among prey items available to freshwater carnivores, fish contain the most protein and yield the highest growth rates. Thus, the *Micropterus* diet can plausibly be considered optimal among freshwater fishes. With respect to characters of the feeding apparatus, I found that *Micropterus* exhibits significantly lower within-clade variance on the first two principal components than the other two centrarchid clades. My hypothesis also predicts that attainment of an adaptive peak in a common ancestor of *Micropterus* is associated with a decrease in the rate of morphological evolution. I found that the first two principal components evolve more slowly in *Micropterus* than in the other two clades of the Centrarchidae. These results support the hypothesis that diversification of the *Micropterus* feeding mechanism has been restricted by its position at an adaptive peak.

19.3

COLLIN, R.; collinr@naos.si.edu. STRI
SEX RATIO AND PATTERNS OF SEX CHANGE IN CALYPTRAEID GASTROPODS

The size advantage hypothesis predicts that the optimal size at which an individual should change sex is a function of its size and the size and sex of its potential mates. In species that form small mating groups, variation in group composition may result in more variation in size at sex change across the population than in species that do not form mating groups. I use data on the size, sex, and grouping of individuals of 27 populations of 19 species of calyptraeids, a family of protandrous marine gastropods including *Crepidula*. These data are used to test the following hypotheses about variation in size at sex change: (1) Sex ratio is biased toward the first sex, (2) The ratio of the size at sex change to the maximum size is a life history invariant, (3) Species that form groups or stacks have more variation in size at sex change than species that stack less frequently. There was substantial variation in sex ratio across the different species with sex ratio being related to mode of development, skewed size distribution, and frequency of stacking, but not with maximum body size. Sex ratios were male biased more often than they were female-biased but there were several female biased populations. There was little evidence that the ratio of size at sex change and maximum size is invariant and there is evidence that at least one of the assumptions of this theory is invalid for calyptraeids and probably for other animals. Species that form larger stacks or mating groups had more variation in size at sex change within a population than species that were generally solitary. These results suggest that incorporating information about individual groupings could help refine predictions of life-history theory.

34.11

COLLIN, M.A., SWANSON, B.O., HAYASHI, C.Y.; mcoll002@student.ucr.edu. University of California, Riverside, Pacific University, Oregon
MECHANICAL PROPERTIES OF EMBIOPTERA SILK

Arthropods produce and use silk for a variety of purposes. Silk from a few types of arthropods have been mechanically tested and some of these silks were found to be exceptionally strong, lightweight, and extensible. Embioptera (webspinners) are an order of paurometabolous, subsocial insects that has been little studied. Other investigations of insect silks have focused on orders that are distantly related to Embioptera, namely Lepidoptera (moths), Diptera (flies), and Trichoptera (caddisflies). Embiids are unique because they produce silk throughout their lifetime, unlike other insects, which use silk during just one developmental stage. The primary function of embiid silk is for the construction of silken galleries and foraging tubes. We mechanically tested embiid silk from 15 individuals of *Haploembia solieri*. The mean diameter of the silk fibers was 0.86 ± 0.31 micrometers. The tensile strength of the silk measured $159 \text{ MPa} \pm 70$. Compared to other arthropod silks, this is one of the weakest fibers tested to date. While individual *Haploembia* silk fibers are small and weak, embiids make sheets from these fibers and layer the sheets to construct sturdy galleries. Our future studies will include comparative mechanical analyses of silks spun by phylogenetically and ecologically divergent embiids. We will also characterize the silk protein coding genes from these insects. The comparison of molecular sequences and material properties of embiid silks, which are spun from tarsal glands, to lepidopteran and dipteran silks (spun from modified salivary glands) and spider silks (spun from abdominal glands), will improve our understanding of the multiple evolutions of arthropod silks.

62.2

COMBES, S.A., DUDLEY, R.; scombes@berkeley.edu. University of California, Berkeley
LIMITS TO MAXIMUM FLIGHT VELOCITY: PITCH CONTROL AND ROLL INSTABILITY IN ORCHID BEES DURING FAST, FORWARD FLIGHT

Maximum velocity is a critical component of flight performance, but observing or eliciting maximum flight speeds is difficult in most flying animals. Flight velocity is thought to be limited by either energetic constraints, such as maximum power output, or by aerodynamic constraints, such as maximum stroke amplitude or wingbeat frequency. We measured maximum flight velocity in several species of euglossine bees by placing aromatic oils, which bees are highly motivated to collect, in the mouth of an outdoor, open-ended wind tunnel in Panama. Bees were filmed with two high-speed cameras, and wind tunnel velocity was increased until bees were unable to maintain a stable flight position. We also collected the bees and measured parasite drag using a one-axis force beam mounted in front of the outdoor wind tunnel. We measured maximum flight speeds up to 7 m/s (over 500 body lengths/s), and found that flight speed is highly correlated with body and stroke plane angle. Surprisingly, bees extend their enlarged hindlegs below their body as they fly faster, although this increases parasite drag by 25% or more. However, this increased drag force located below and behind the center of mass produces a torque that tilts the body and stroke plane angle forward, allowing bees to increase their forward speed. At the highest flight velocities, orchid bees with fully extended hindlegs were unable to maintain stable flight, due to rolling moments caused by asymmetric forces on the two legs. These results suggest that pitch control and flight stability may play a role in limiting maximum flight velocity in some insects.

74.3

CONTRERAS, H., TALBOT, C.; hydikins23@msn.com. California State University, San Bernardino
OSMOREGULATORY BEHAVIORS IN PACIFIC AND CALIFORNIA TREE FROGS: DIFFERENCES IN ABILITY TO FIND WATER AND SPECIES SALT CONCENTRATION PREFERENCES

Amphibians are frequently faced with excessive dehydration through evaporative water loss across the skin. To counteract the effects of quick dehydration, many species have developed behavioral adaptations for proper water balance such as the water absorption response (WR). Before inducing WR, amphibians must be able to detect a water source and its solute concentration in order to ensure rehydration. This study aimed to examine the proficiency of *Pseudacris cadaverina* and *Pseudacris regilla* in detecting available water sources and also in determining the species preference in salt concentration before inducing WR. Frogs were dehydrated to 15% (*P. regilla*) and 22% (*P. cadaverina*) of their initial hydrated mass before being placed in the observation tank. In the detection of water source experiment, the tank was divided into four equal quadrants; one quadrant containing a wet tissue, the other a dry tissue, and two empty. We measured time to find wet tissue, time in each quadrant, and direction of movements. In the salt preference experiment the observation tank was divided into six sections, each containing a specific NaCl concentration: 1, 50, 100, 150, 200, 250mM. We then measured time in each section, time in each dish and time in WR. There was no difference in the proficiency of Pacific or California Tree Frogs in finding a water source and movement occurred randomly. There was also no difference in salt preference between the two species. Dehydrated *P. regilla* found a source of water less frequently and showed WR less than when fully hydrated. The opposite trend was shown for *P. cadaverina*. These results continue to support the idea presented in previous studies (Contreras and Talbot, 2004) suggesting that Pacific Tree Frogs drink opportunistically unlike California Tree Frogs which drink only when "thirsty".

S2-1.2

COOPER, M.S., VIRTA, V.M.; mscooper@u.washington.edu. University of Washington
EVOLUTION OF GASTRULATION IN THE ACTINOPTERYGIAN (RAY-FINNED) FISHES

This presentation reviews evolutionary changes in the gastrulation of ancient lineages of Actinopterygian fish. Cellular features of zebrafish gastrulation will be interpreted from an evolutionary perspective, focusing on the ontogenetic innovations that resulted in the derivation of Teleostean gastrulation. The most ancestral form of Actinopterygian gastrulation is preserved in Chondrosteian fish (sturgeons and paddlefish). Chondrosteians gastrulate in a manner similar to many amphibians and agnathans, suggesting that this conserved mode of gastrulation stems from an archaic ancestor that predates the Devonian. Bony ganoid fish (basal Neopterygians), such as the bowfin (*Amia calva*) and gar-pike (*Lepidosteus*), whose lineages first appeared in the early Mesozoic, represent a transitional group between Chondrosteian and Teleostean (advanced Neopterygian) fish. Although the gar-pike is the most basal Neopterygian to develop a syncytial endodermal yolk cell, more prominent proto-features of Teleostean gastrulation are exemplified in the bowfin gastrula. Comparisons between the bowfin Organizer and zebrafish Organizer reveal striking similarities in the morphogenesis of their presumptive germ layers. In particular, the bowfin gastrula possesses a prominent group of enlarged cells (Cushion Cells of Ballard) in the superficial Organizer epithelium. Similar to homologous cells in the zebrafish Organizer (which later become Kupffer's vesicle), bowfin Cushion Cells fail to involute during gastrulation, and come to lie beneath the chondoneural hinge. Evolution of several other prominent morphogenetic domains within the teleostean Organizer region will be discussed. A putative evolutionary sequence of gastrulative mechanics within the Neopterygian fishes will then be summarized.

44.4

COOPER, W.J.; wjcooper@uchicago.edu. University of Chicago & Field Museum

THE EVOLUTION OF FEEDING BIOMECHANICS IN DAMSELFISHES

The damselfishes (Perciformes; Pomacentridae) comprise one of the dominant groups of fishes on all coral reefs and are a major component of the trophic ecology within these systems. This study examined the evolution of damselfish feeding mechanisms by combining morphological, biomechanical and phylogenetic analyses of all damselfish genera. Digital images of dissected specimens were used to generate coordinate data for the location of morphological landmarks important for feeding. Thin plate spline, principal components, and procrustes superimposition techniques were then used to determine relative differences in the location of these landmarks among pomacentrid species and to describe the distribution of their skulls in shape space. These same coordinates were also used to make functional predictions of damselfish trophic capabilities (e.g. maximum jaw protrusion, mechanical advantage employed during biting). Both the morphological and functional data were then plotted on a pomacentrid phylogeny generated by Bayesian analyses of DNA sequences from 3 nuclear genes (RAG1, RAG2 and Bmp-4) and 3 mitochondrial genes (12S, 16S and ND3) extracted from over 100 species in all 29 damselfish genera. This comprehensive approach has yielded detailed information about the diversification of feeding mechanisms within the Pomacentridae. The more stalwart skulls of the primarily benthic feeding, basal damselfishes have repeatedly given rise to gracile forms and there is also a general trend away from the habitation of rocky reefs towards coral reefs. Such transitions are associated with increased planktivory, a trophic habit that has evolved multiple times from different morphological starting points within this lineage.

14.7

CORNETT, A.D.; sharkdivmstr@yahoo.com. Florida Atlantic University

ECOMORPHOLOGY OF SHARK ELECTRORECEPTORS

Sharks are morphologically very diverse and are found in nearly every marine environment. In addition, all sharks possess an electrosensory system that enables them to detect environmental electric fields. However, how this sensory system varies among taxa and in different environments remains unexplored. I studied the ecomorphology of shark electroreception to test whether the electrosensory system is constrained by phylogeny or varies with habitat. To accomplish this, I examined representative species of i) the same taxa (family and order levels) found in different environments (pelagic, shallow coastal, deepwater) and ii) different taxa found in the same environment to determine the effect of phylogenetic constraint and evolutionary convergence on shark electroreceptors. Sharks found in a pelagic environment possess between 4501400 electrosensory pores and the majority of these species have greater than 60% of these pores on the ventral surface of the head. Shallow coastal species possess the greatest number of pores, between 4303000 pores, and show mixed dorsal/ventral ratios with ventral pore distribution varying between 4366%. Species found in deepwater habitats possess the fewest electrosensory pores, between 2501150 pores, with 4859% distributed on the ventral surface. Members of the most speciose shark order, Carcharhiniformes, generally have an approximately even distribution of pores on the dorsal and ventral surfaces. This taxonomic group has greater pore counts overall, with a majority of species having over 1800 electrosensory pores. The results implicate evolutionary convergence as the primary factor responsible for the number of electroreceptive pores, while phylogenetic constraint is the dominant influence on pore distribution.

73.1

COUGHLIN, D.J., CARROLL, A.M.;

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IN VITRO ESTIMATES OF POWER OUTPUT BY EPAXIAL MUSCLE DURING FEEDING IN BASS

Recent work has employed video and sonometric analysis combined with hydrodynamic modeling to estimate power output by the feeding musculature of largemouth bass in feeding trials. The result was an estimate of -69 W kg^{-1} of power by the epaxial muscle during maximal feeding strikes. This study employed *in vitro* measurements of force, work and power output by fast-twitch epaxial muscle bundles stimulated under activation conditions measured *in vivo* to evaluate the power output results of the feeding experiments. Isolated muscle bundles from the epaxial muscle, the sternohyoideus and the lateral red or slow-twitch muscle were tied into a muscle mechanics apparatus, and contractile properties during tetanic contractions and maximum shortening velocity (V_{\max}) were determined. For the epaxial muscles, work and power output during feeding events was determined by employing mean stimulation conditions derived from a select set of maximal feeding trials: 17% muscle shortening at 3.6 ML sec^{-1} , with stimulation occurring 5 msec before the onset of shortening. Epaxial and sternohyoideus muscle displayed similar contractile properties, and both were considerably faster ($V_{\max} \sim 11\text{-}13 \text{ ML s}^{-1}$) than red muscle ($V_{\max} \sim 5 \text{ ML s}^{-1}$). Epaxial muscle stimulated under *in vivo* activation conditions generated -33 W kg^{-1} with a 17% strain and $-45\text{-}50 \text{ W kg}^{-1}$ with a 10% strain. The short lag time (5 msec) between muscle activation and muscle shortening is apparently a limiting parameter during feeding strikes, with maximum power found at an offset of 15-20 msec. Further, feeding strikes employing a faster shortening velocity generated significantly higher power output. Power production during feeding strikes appears to be limited by the need for fast onset of movement and the hydrodynamic resistance to buccal expansion.

51.4

COWART, J.D., PAWLIK, J.R; jdc1234@uncw.edu. University of North Carolina Wilmington

IS THERE A TRADE-OFF BETWEEN REPRODUCTION AND GROWTH FORM FOR TWO CLOSELY RELATED FLORIDA REEF SPONGES?

Sponges are prominent members of coral reef communities, where they often rival scleractinian and alcyonarian corals in both diversity and abundance. Nevertheless, little is known about the reproductive biology of coral reef sponges. The purpose of this study is to determine if a trade-off exists between reproduction and growth form for two prominent and closely related Florida reef sponges, *Calyspongia vaginalis* and *C. armigera*. *Calyspongia vaginalis* commonly grows as clusters of erect tubes and will not survive dislodgement, while *C. armigera* grows as a branching, often interconnected rope-form and easily reattaches to the substratum after dislodgement. Both species brood larvae in broodchambers and recent evidence suggests that larvae are released year round. Larval traps were placed over a single tube of 10 *C. vaginalis* and over 10 *C. armigera* for 5 days in June and August 2005. The total number of larvae released was counted daily. At the end of each trial the sponges were collected and volume recorded. Results showed that 70% of *C. vaginalis* and 20% of *C. armigera* released larvae in June and 90% of *C. vaginalis* and 50% of *C. armigera* released larvae in August. The total number of larvae released over the 5-day period ranged from 2-153 for *C. vaginalis* and 22-53 for *C. armigera* in June and 2-191 for *C. vaginalis* and 1-20 for *C. armigera* in August. There was no correlation between the size of the sponge and the number of larvae released. These data support the hypothesis that rope-form sponges are morphologically adapted to exploit asexual reproduction by fragmentation as their major propagative process and resource allocation to sexual reproduction is consequently reduced relative to vase-form sponges.

15.4

COX, R., BARRETT, M., ZILBERMAN, V., JOHN-ALDER, H.; cox.541@osu.edu. The Ohio State University, Rutgers University
EFFECTS OF SEX AND CASTRATION ON GROWTH OF YARROWS SPINY LIZARDS (*SCELOPORUS JARROVII*) ARE REDUCED OR ABSENT IN LABORATORY COMMON-GARDEN EXPERIMENTS

Adult males average about 10% larger (longer in snout-vent length) than adult females in natural populations of Yarrows Spiny Lizard (*Sceloporus jarrovi*). In two previous studies of free-living animals, we found that (1) sexual size dimorphism (SSD) develops because males grow more quickly than females as yearlings, and (2) growth of yearling males is inhibited by castration and restored to the rate of intact controls by exogenous testosterone (T). Here, we show that these effects of sex and castration on growth are reduced or absent under common-garden conditions. In a series of laboratory studies, growth was rapid under ad lib food availability, such that males grew only slightly more quickly than females. Food restriction reduced growth rate by about 50%, but this reduction was observed in both sexes, such that SSD was subdued (relative to natural expression) under either diet. At both high and low food levels, wet mass of abdominal fat pads was greater in females than in males, suggesting a sex difference in allocation to storage that could account for the minor sex difference in growth. Although castration inhibited the growth of free-living males, growth in captivity under ad lib food availability was rapid and did not differ among castrated males, intact controls, and castrated males treated with T. Collectively, our results show that sex differences in growth and effects of sex steroids on growth are subject to strong proximate environmental control in *S. jarrovi*. Our results also provide a cautionary example of the limitations of laboratory experiments in studies of endocrine growth regulation. Supported by NSF 0135167.

65.5

CRESPI, E.J., DENVER, R.J.; ercrespi@vassar.edu. University of Michigan, Ann Arbor
CONSERVED AND NOVEL FUNCTIONS OF LEPTIN IN THE SOUTH AFRICAN CLAWED FROG (*XENOPUS LAEVIS*)

Leptin, the protein product of the *obese (ob)* gene, is a type-I cytokine hormone secreted by fat that is integral to food intake regulation and influences almost every physiological system in juvenile and adult mammals. As a first step in studying the physiological roles of leptin in amphibians, we cloned the *ob* gene and a cDNA fragment of the leptin receptor gene in *Xenopus laevis*. The distribution of mRNA expression of leptin and its receptor in juvenile *X. laevis* suggests that leptin may have autocrine, paracrine, and hemocrine functions in amphibians. We also produced and purified recombinant *X. laevis* leptin (rxLeptin) in *E. coli*, and showed that intracerebroventricular injection of rxLeptin inhibited food intake in late-staged tadpoles and frogs as shown in mammals. rxLeptin treatment did not affect food intake in early prometamorphic tadpoles; however, repeated rxleptin i.p. injections induced growth and development of the hind limb. This effect was specific to the hind limb, as tail length, tailfin height, body length, and body weight were not affected by rxleptin treatment. We found that leptin receptor mRNA, but not leptin mRNA, is expressed in the hind limb of early prometamorphic tadpoles. Furthermore, leptin treatment increased [³H]-thymidine uptake by cultured hind limbs, suggesting that rxleptin can directly stimulate cell proliferation in this tissue. These findings suggest that the function of leptin in the regulation of appetite and energy balance evolved prior to the divergence of amniotes in the vertebrate lineage. In addition, we show for the first time that leptin influences limb growth and differentiation during early development (supported by NSF grant IBN 0235401 to R.J.D.)

24.5

CROLL, R.P., ROBERTSON, G.N., MCGEE, C.A.S., SMITH, F.M.; roger.croll@dal.ca. Dalhousie University
DEVELOPMENT OF THE SWIMBLADDER AND ITS INNERVATION IN THE ZEBRAFISH (*DANIO RERIO*)

Gas-filled swimbladders play essential roles in buoyancy control of many teleosts, yet little is known of how these organs and their innervation develop to meet changing demands through ontogeny. Here, we examined the development and time course of innervation of the zebrafish swimbladder. This organ originates as a single chamber from an evagination of the dorsal esophagus and is inflated to a prolate ellipsoid shape by 3-5 days post fertilization (dpf). Acetylcholinesterase histochemistry and zn12 immunoreactivity revealed that the earliest innervation of this organ, occurring at 4-5 dpf, consisted of two bundles of axons extending along the lateral margins. By around 20 dpf the swimbladder developed a second chamber anterior to the first, thus assuming the adult configuration; anterior and posterior chambers were connected through the ductus communicans, while the posterior chamber retained its connection to the esophagus via the pneumatic duct. By this time innervation to the posterior chamber became both more extensive and neurochemically complex. Fibres exhibiting tyrosine hydroxylase immunoreactivity were detected by 20 dpf, and within another 7 d, a mesh of fine vasointestinal polypeptide immunoreactive nerve fibers surrounded the anterior chamber. The basic features of the adult swimbladder morphology and patterns of its innervation were therefore present within the first 30 dpf. Morphometric data demonstrate volumetric contributions of the swimbladder to buoyancy of the developing zebrafish. Together these studies provide insight into how the swimbladder develops and contributes functionally to buoyancy control as the zebrafish matures from its larval to adult form. (Funded by Canadian Space Agency contract No. 9F007-046016/001/ST to RPC and FMS.)

46.1

CROTWELL, P.L., MABEE, P.M.; pcrotwel@usd.edu. University of South Dakota, Vermillion
A COMPARATIVE ANALYSIS OF GENE EXPRESSION PATTERNS CONSERVED IN SEGMENTATION OF FISH AND TETRAPOD SKELETONS

Much skeletogenesis in zebrafish occurs at late stages for which there are few tools to test gene function. The study of mutants, for example, is limited because many of the important skeletogenic genes (e.g. *shh*, *bmp2b*, *chordin*) are so critical to early stages that mutants do not survive, with few exceptions, to the fin development stage. Those that do (e.g. a few *chordin* mutants) exhibit significant skeletal malformations (Fisher & Halpern, 1999). Morpholino technology has not been adapted for delivery to specific tissue at later stages. The standard chick and mouse technique of protein-soaked bead implantation has yielded no significant data in late stage zebrafish. Thus, though patterns of association of gene expression can be analyzed, and such data can be highly suggestive, definitive conclusions regarding the role of skeletogenic genes in older larvae must await the development of new functional and bioinformatic tools. We focused our study of the evolution of skeletal joints in vertebrates on the gene expression of 10 genes or gene pairs (including *wnt9a* and *b*, *bmp2a* and *b*, *bmp4*, *gdf5*, *noggin*, *chordin*, *sox 9a* and *b*, *shh*, *bapx1*, and *collagen II*) in the axial and appendicular skeleton of the zebrafish in relation to those patterns in tetrapod vertebrates. Overall similarity in expression patterns in conjunction with phylogenetic history and the fossil record suggests a pattern of inheritance and co-option in the deployment of these genes. We conclude that there is a unity in the mechanisms of skeletal development and patterning that has been conserved over 500 million years of vertebrate evolution.

74.1

CUNNINGHAM, A., WATTS, S.A.; adelec@uab.edu. University of Alabama at Birmingham
DO OOCYTES OF THE SEA URCHIN *LYTECHINUS VARIEGATUS* COMPETE FOR NUTRIENTS?

Adult *Lytechinus variegatus* were collected over a period of 28 months (three reproductive seasons; $n = 16$ urchins per month) and H&E slides were made from gonad sections. Histology indicates that oocytes develop asynchronously over a period of months before major spring and minor summer spawns. However, some oocytes are apparently reabsorbed by somatic cells of the gonad, the nutritive phagocytes. Failure to discriminate different stages for phagocytosis would result in a sterile gonad; therefore, some system by which nutritive phagocytes recognize different stages of oocyte development has been hypothesized. Recent work on endocytosis by oocytes indicates that endocytosis increases greatly at about 50 μm . Other studies on acid phosphatase activity of oocytes indicate oocytes sometimes become autocatalytic. Which oocytes will mature and which will be reabsorbed? Do oocytes compete for nutrients? Competition may explain how nutritive phagocytes selectively reabsorb some oocytes. Histology of *L. variegatus* further indicates that some spawning events, especially summer spawns, are relatively minor and occur with many immature oocytes present in the gonad. Inadequate nutrient allocation to the gonad at high summer temperatures may limit the number of oocytes that can reach maturity synchronously. Supported by the Mississippi Alabama Sea Grant Consortium.

50.2

CURTIS, D.L., MCGAW, I.J.; curtisd4@unlv.nevada.edu. University of Nevada, Las Vegas, Bamfield Marine Sciences Centre
FEEDING AND DIGESTION IN RESPONSE TO LOW SALINITY IN THE DUNGENESS CRAB, *CANCER MAGISTER*

The Dungeness crab, *Cancer magister*, is classified as a weak osmoregulator. Nevertheless, this species often forages in estuaries where it may encounter episodes of low salinity. We hypothesized that the energy required for osmoregulation in estuarine conditions may limit that available for feeding and digestion. In the present study, changes in the feeding behaviour of crabs exposed to decreased salinity were examined as a function of acclimation time and starvation time. The likelihood of feeding decreased with salinity, but increased with starvation time, suggesting a trade-off between starvation time and osmoregulation when feeding in low salinity conditions. In 50% seawater, the number of crabs feeding increased with acclimation time. Crabs did not feed in salinities below 30% seawater. Changes in digestive processes were examined by following the passage of a radio opaque meal through the gut system with a fluoroscope. Exposure to low salinity following feeding resulted in a decreased rate of foregut contraction, leading to an overall increase in gastric evacuation time. The results of this study suggest that there is a prioritization during low salinity exposure, whereby osmoregulatory processes may limit the amount of energy available for feeding and digestion.

18.4

DAHAN, R.D., DAVIS, M.C., SHUBIN, N.H.; akaky@uchicago.edu. University of Chicago
CONSERVED *SHH* FUNCTION AND REGULATION IN GNATHOSTOME APPENDAGE PATTERNING

The developmental mechanisms patterning the gnathostome appendage endoskeleton exhibit surprising molecular conservation considering the diverse spectrum of anatomical variation achieved. However, phylogenetic differences fundamental signaling pathways have been reported, rendering construction of a general appendage developmental bauplan problematic. One such gene is *Sonic hedgehog* (*Shh*), which controls the anteroposterior (A/P) polarity of developing osteichthyan appendages via asymmetric expression along the posterior fin/limb border. Two critical elements of *Shh* regulation are conserved across osteichthyes: (1) appendage-specific *Shh* expression is controlled by a DNA regulatory element located 1 Mb from the *Shh* locus; (2) treatment with retinoic acid (RA) results in ectopic anterior *Shh* expression, and results in mirror-image duplications of endoskeletal elements. Chondrichthyan have been reported to lack both *Shh* expression in developing appendages, and the appendage-specific DNA regulatory element, suggesting that *Shh* signaling is dispensible for normal fin development. We have re-examined the role of *Shh* in developing skate and shark appendages, and report that *Shh* is expressed along the posterior border of both paired and unpaired fins. We have identified appendage-specific DNA regulatory elements in the genomes of several chondrichthyan species, which exhibit striking conservation with tetrapod and actinopterygian orthologs. We further report RA treatment results in both ectopic *Shh* expression in the anterior fin border, and mirror-image endoskeletal duplications. Conserved *Shh* expression, regulation, and function in developing gnathostome fins/limbs confirms its fundamental role in appendage patterning, and has important implications for understanding the evolution of appendage pattern.

S3-1.3

DANIEL, T., HEDRICK, T.; danielt@u.washington.edu. University of Washington, Seattle
INVERSE ANALYSIS OF FLIGHT CONTROL OF HAWKMOTHS

The three dimensional flight paths of insects are the result of complex temporal patterns of muscle activation which, coupled to the exoskeleton, create particular kinematic patterns of wing motion. These kinematic patterns result in aerodynamic forces that drive the animal through a particular spatial path. Most prior research has focused on how such kinematics lead to the forces that underlie the observed motions. However, using only the observed kinematics may not reveal the range of wing motions that might lead to similar or even identical body trajectories. The possibility that many kinematic patterns can result in a given flight trajectory has not been considered in any formal sense and may be important to understanding the diversity of motor patterns observed in freely behaving animals. We approached this issue as an inverse problem, asking what kinematics could give rise to the forces required to follow a predetermined flight path. We use genetic algorithms to evolve a suite of control parameters that define wing kinematics and thus flight kinetics in a simulated hawkmoth. These parameters include three angular amplitudes of wing motion (sweep, elevation and pitch), their mean values and relative phases. We find that there are indeed many possible kinematic patterns that can be used to hover or to track a moving flower, a subset of which approximately correspond to those observed in freely flying hawkmoths. These simulations also show that the diversity of feasible control parameters is sensitive to the speed with which controls may change and the number of controls employed. Reducing the number of controls reduces the number of available kinematic patterns while increasing the temporal variation in the controls

55.4

DANOS, N., BRAINERD, E.L.; ndanos@fas.harvard.edu. Harvard University, Brown University
BIOMECHANICS OF THE SKIN DURING SWIMMING IN THE AMERICAN EEL, *ANGUILLA ROSTRATA*

We are interested in the functional morphology of the dermis because it has a highly organized arrangement of collagen fibers, an arrangement that appears in all vertebrates that locomote by axial undulations. In this study we measure the *in vivo* mechanical behavior of the skin of the American eel, *Anguilla rostrata*, and use these data to conduct uniaxial tensile tests *in vitro* at realistic strain rates and magnitudes. Using sonomicrometry, we measured *in vivo* strains along the longitudinal direction to be 0.21 ± 0.0059 and strains along the hoop direction to be 0.061 ± 0.0031 . When *in vivo* strain rates were applied to uniaxial *in vitro* materials tests, we found a tendency for the material to become stiffer at higher strain rates demonstrating the effect of viscoelastic elements in the skin. The dermal collagen fiber angle of 45° led to a prediction of isotropic mechanical behavior along the longitudinal and hoop directions. Stiffness of the skin was similar, 28.21 MPa, 30.07 MPa and 30.21 MPa when stretched along the hoop, longitudinal and on-fiber directions respectively. However, the strain at which the skin began experiencing stress, a result of fiber reorientation, differed between the three directions. We interpreted this to be the result of higher density of vertical collagen bundles traversing the dermal lamellae on the skin lateral to myoseptal attachments. We also measured subcutaneous pressure and found subambient pressure on the convex side of the body simultaneous with superambient pressure on the concave side. We conclude that, given the absence of a constant pressure on the body walls, modeling of the eel body as a pressurized thin-walled cylinder is inappropriate.

15.1

DAVIDOWITZ, G., ROFF, D.A., NIJHOUT, H.F.; goggy@email.arizona.edu. University of Arizona, University of California, Riverside, Duke University
THE PHYSIOLOGICAL REGULATION OF SIMULTANEOUSLY SELECTED LIFE HISTORY TRAITS

Integrating physiology and selection experiments can be a powerful tool when asking one of the central questions of evolutionary biology: why do traits respond to selection the way that they do? We present such an approach in a simultaneous selection experiment on body size and development time in the tobacco hornworm *Manduca sexta*. Three physiological factors control body size and development time in the tobacco hornworm: growth rate (GR), the critical weight (CW) that measures the timing of the onset of the cessation of juvenile hormone secretion (which initiates the processes leading to pupation), and the time interval between attainment of the critical weight and secretion of the molting hormone 20-hydroxyecdysteroid (the interval to cessation of growth, ICG). These three physiological factors explain over 95% of the variation in these two life history traits. Knowledge of the physiological mechanism allow us to make explicit predictions, based on physiological first principles, as to how these life history traits should respond to simultaneous selection. Selection lines in each of the four combinations of body size and development time differed significantly from the initial population and from the control after ten generations of selection. Initial results support our predictions and show that the response to selection of the BIG/SLOW line was mainly due to an increase in CW and ICG, of the SMALL/FAST line to a decrease in CW and ICG, of the BIG/FAST line to an increase in GR, and of the SMALL/SLOW line to a decrease in GR. These results demonstrate the power of a combined physiological and selection approach to the study of life history evolution.

S5-2.3

DAVIDSON, B.; bandl@berkeley.edu. University of California, Berkeley
ASCIDIAN MESODERM SPECIFICATION AND THE EMERGENCE OF THE CHORDATE BODY PLAN

Ascidians occupy a crucial evolutionary position at the base of the chordates. Intensive research into early ascidian development has begun to illuminate the evolutionary relationship between mesoderm development in ascidians and higher chordates. It appears that aspects of mesoderm specification and patterning are highly conserved but include modifications related to a rapid embryogenesis. In particular, early maternal determination of ascidian tail muscle, through the cytoplasmic determinant Macho-1, overlays a more regulative and ancestral function of T-box mediated specification. However comparisons are complicated due to the ascidians bi-phasic life history (rapid embryogenesis of a larval form followed by prolonged differentiation of adult structures after metamorphosis). Tail muscle is the only mesodermal tissue that rapidly differentiates during embryogenesis. The remaining mesodermal tissues, including blood, heart, gonad and adult musculature, develop over a much longer time-span, through metamorphosis. This review will provide an in-depth comparison between mesoderm development in ascidians and higher chordates taking into account the distortions caused by major shifts in life-history patterns.

1.6

DAVIS, E.C.; edavis@colum.edu. Columbia College Chicago
NO DIFFERENCES IN MUCUS-TRAIL FOLLOWING WAS DETECTED IN *EUGLANDINA ROSEA* PREDATION ON LOCAL VERSUS NON-LOCAL GASTROPODS

Carnivorous snails, such as *Euglandina rosea*, have been used unsuccessfully as biocontrol agents in Hawaii and other Pacific islands in attempts to limit the spread of the giant African land snail, *Achatina fulica*. *Euglandina rosea* is native to the southeastern United States, and is able to follow the mucus trails of its prey. Although experiments have examined food choice, it is unknown if the ability of *E. rosea* to follow mucus trails differs with prey snail species. This study compared the ability of *E. rosea* to follow trails of two groups of gastropods: those found within its local habitat (southeastern USA) and those found outside its native range (Kansas). Each predator (n = 10) was tested against a total of 24 individuals from eight species of gastropods (four species from each area) and three individuals of each species. Unlike previous studies, *E. rosea* followed trails in the direction that they were laid. The results of the study indicate that prey gastropods from Florida and Kansas were followed at almost identical frequency by all ten predators tested. In addition, there were differences in the predators inter-tentacle angle when following or not-following a trail.

16.5

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THE RESPONSES OF MARINE INVERTEBRATE LARVAE TO PREDATOR CHEMICAL CUES IN THE LABORATORY

We are exposing marine invertebrate larvae to water-borne signals from planktonic and benthic predators as the larvae approach metamorphic competence. In predator treatments, living predators are included in larval containers, but kept separate in plankton mesh pens. Settlement substratum is available from the surface to the bottom of the experimental columns. The vertical location of settlement is being monitored along with time to settlement. Control treatments allow larvae to metamorphose and settle in the absence of predators. We hypothesize that the detection of benthic predators will delay metamorphosis and settlement. By the same reasoning, the presence of planktonic predators should force metamorphosis and settlement. Both habitats predators should influence the location of settlement within the experimental columns.

18.3

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GENE EXPRESSION AND FUNCTION IN THE PAIRED FINS OF BASAL ACTINOPTERYGIANS

Comparative studies of fins and limbs reveal a high degree of conservation in the genetic pathways present. However, there are significant differences in the patterns of gene expression observed that may underlie the fundamentally different appendage skeletons found in tetrapods and zebrafish. At issue is whether the characteristic ways in which tetrapod and teleost appendages develop represent derived conditions specific to each group or are the result of retention of ancient and generalized appendage patterning mechanisms. To address this question, we examined the expression patterns of key appendage patterning genes in the phylogenetically basal actinopterygians *Polyodon spathula* and *Lepisosteus osseus*, which retain the primitive vertebrate paired fin pattern and, thus, possess skeletal elements homologous to both zebrafish fin radials and tetrapod limb bones. Genes examined in this study include a number of genes that have been identified as important regulators of appendage patterning in vertebrate model systems, yet exhibit significant differences in their expression in tetrapods and teleosts. To further understand the regulation of appendage patterning in basal actinopterygians, we also examined the functional roles of several genes that play a role in appendage patterning using pharmacological mutagens. In particular, exposure to the posterior agent retinoic acid provided a number of insights into the regulation of the anterior-posterior axis in developing paired and unpaired fins.

63.4

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THE RELATION OF SUCTION PRESSURE AND FLUID SPEED DURING FEEDING IN LARGEMOUTH BASS

The suction feeding fish simultaneously generates negative pressure within the mouth and a flow field external to its head that draws prey towards the mouth. In the literature, both pressure within the mouth and fluid speed in front of the fish have been alternatively modeled and/or measured and used as indicators of performance. Conflicting arguments have been made about the relationship between pressure and fluid speed and whether one can serve as a proxy for the other. Can this relationship be explained by the Bernoulli equation or is this model invalidated by unsteady effects and complexity of the flow? We have attempted to address this question directly by simultaneously measuring fluid speed, using particle image velocimetry, and buccal cavity pressure in a largemouth bass (*Micropterus salmoides*) eating evasive ghost shrimp. For each feeding, we calculated an expected pressure in the mouth as a function of time by applying both steady and unsteady forms of the Bernoulli equation to the measured velocity field. Measured peak buccal pressures always occurred before peak fluid speed, and therefore earlier than peak pressures predicted by the steady form of the Bernoulli equation. Predictions of pressure that include the unsteady terms in the Bernoulli equation resolve this discrepancy and lead to good agreement in the time of peak fluid speed. Measured pressures have a considerably larger magnitude (approximately two times) than those predicted by either form of the Bernoulli equation during the expansive phase of the gape, but agree fairly well during peak gape and closing. This indicates that some amount of generated pressure is not related to fluid velocity or acceleration, but energy dissipated by fluid mechanical losses. Supported by NSF IOB-0444554

34.5

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CRANIAL MORPHOLOGICAL SPECIALIZATIONS RELATED TO BURROWING: A CASE STUDY OF HEAD- AND TAIL-FIRST BURROWING *PISODONOPHIS BORO*.

The order Anguilliformes forms a natural group of eel-like species. Life styles of these representatives cover the entire spectrum from non-burrowing to burrowing but wedging through small openings is assumed to be the plesiomorphic mode of life. This study focuses on burrowing anguilliform species in general with *Pisodonophis boro* (Ophichthidae) as a case study. Ophichthidae are known in literature to burrow tail-first. However aquarium observations of living specimens of *Pisodonophis boro* reveal them to burrow both head-first and tail-first. Furthermore, these specimens are predators, using rotational feeding. A detailed osteological and myological examination of the head of *Pisodonophis boro* reveals striking morphological convergence with *Moringua edwardsi*, a specialized burrowing moringuid with predacious feeding habits. In *Pisodonophis boro* the adductor mandibulae complex is hypertrophied and the anterior fibres of the A2 are anteriorly directed; the shape of the skull is elongated, tapering to the snout; the cranial bones are highly reinforced and their sutures show a high amount of overlap; the eyes are small; the coronoid process of the dentary is high and the quadrate and hyomandibula of the suspensorium form a strong entity, while the palatopterygoid is loosely connected; the opercular and suspensorial muscles are small. However, these features are more extreme in the head-first burrowing species *Moringua edwardsi* but appear to a lesser extent in the tail-first burrowing congrid species *Heteroconger luteolus*. The differences in morphology can be considered as specializations for this burrowing behaviour as well as to differences in feeding.

16.6

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THE EFFECTS OF FOOD LEVEL AND TROPHIC COPPER ON THE DEVELOPMENT AND METAMORPHOSIS OF *LYTECHINUS VARIEGATUS* LARVAE

Pluteus larvae of the sea urchin *Lytechinus variegatus* were raised on algae contaminated by a range of toxic copper concentrations (free Cu^{2+}). The microalga *Rhodomonas lens*, after being cultured in the presence of 0, 3, 12, 48, 100, 200 and 500 $\mu\text{g l}^{-1}$ of toxic copper, was separated from the contaminated growth medium and fed to pluteus larvae. This approach delivers trophically transferred copper, but reduces larval exposure to soluble toxic copper in surrounding water. Growth, survival, and metamorphosis of larvae were measured, but there were no observable morphological or developmental effects and toxic copper does not appear to transfer from phytoplankton to zooplankton via the trophic pathway. Aside from the question of copper effects, starvation elicited plasticity in development (metamorphosis) and larval morphology (arm length). This plasticity is similar to that observed in a number of urchin species when subjected to low food conditions.

S5-1.1

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PRE-MESODERM: THE EXPRESSION OF WNTS DURING SPONGE GASTRULATION AND THEIR ANCESTRAL ROLE IN METAZOAN DEVELOPMENT

While the original body plan from which all living metazoans evolved remains obscure, recent insights into the genome and development of basal animals, such as cnidarians, ctenophores and sponges, suggest that the metazoan ancestor (last common ancestor) was complex, employing many of the developmental mechanisms used by extant bilaterians. The demosponge *Reniera* is a representative of the most basal metazoan lineage and uses asymmetric cell divisions and morphogen gradients to specify and pattern cells during embryogenesis. Cell movements at gastrulation lead to the formation of a trilayered larva with a variety of cell types patterned along the anterior-posterior axis. While a blastopore is not obvious in *Reniera*, a number of cell types migrate to the (larval) posterior pole during gastrulation. Upon reaching the pole, some (i.e. primary sclerocytes) ingress into the inner cell mass. Wnt is expressed at this pole during and prior to the initiation of cell movements at gastrulation. Other components of the canonical Wnt pathway also are developmentally expressed in *Reniera*, suggesting this pathway is playing a key role in organising sponge embryonic cells in a manner akin to that observed in eumetazoans. From these and other observations, we can infer that the cells of the metazoan ancestor had the capacity to secrete long- and short-range signalling molecules that could induce different responses in other cells. Expansion and co-option of Wnt and other metazoan-specific signalling pathways and transcription factors in the eumetazoan lineage allowed for the invention and elaboration of new cell types, germ layers and tissues, including the mesoderm.

S7-1.2

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THE ORIGIN OF THE METAZOAN BIPHASIC LIFE CYCLE: NEW INSIGHTS FROM AN ANCIENT PHYLUM

The biphasic life cycle, characterised by metamorphosis from a pelagic larva to a benthic adult, is found throughout the Metazoa. So is sexual reproduction via eggs and sperm. Amidst a tangled web of hypotheses on the origin of metazoan biphasy, current weight of opinion lies with a simple, larva-like holopelagic ancestor that independently settled multiple times to incorporate a benthic phase into the life cycle. This school of thought derives from Haeckel's interpretation of the gastrula as the recapitulation of a gastreaan ancestor that evolved via selection on a simple, planktonic hollow ball-of-cells to develop the capacity to feed. We suggest that a paradigm shift is required to accommodate accumulating evidence of the genomic and developmental complexity of the metazoan last common ancestor, which was likely to have already possessed a biphasic lifecycle. Here we incorporate recent evidence from basal metazoans, in particular poriferans, to argue that a more parsimonious theory of the origin of biphasy is as a direct consequence of sexual reproduction in an ancestral benthic adult form. The metazoan embryo can itself be considered the precursor to a biphasic life cycle, wherein the embryo represents one phase and the adult another. Embryos in the water column are subject to natural selection for longevity and dispersal, which sets them on the evolutionary trajectory towards the crown metazoan planktonic larvae. This alternate view considers the conserved use of regulatory genes in disparate metazoans as a reflection of both the complexity of the LCA and the antiquity of the biphasic life cycle. It does not require that extant embryogenesis, including gastrulation, recapitulates evolution.

10.4

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PERCEPTION OF FOOD AVAILABILITY AFFECTS THE ADRENOCORTICAL STRESS RESPONSE OF NORTHERN SHOVELERS

In birds, corticosterone (CORT) secretion increases in response to nutritional deficits. In this study, we examined whether the *perception* of food availability also affects adrenocortical function. We tested the adrenocortical response of captive male Northern Shovelers (*Anas chlypeata*) to a short-term (48 hr) fasting. During the experiment, food was either present but inaccessible to drakes or completely removed from the aviary. We collected baseline and acute stress-induced blood samples during *ad libitum* feeding and fasting periods. We found that the drakes responded to fasting by increasing CORT secretion. Perception of food availability ameliorated these effects - baseline and acute stress-induced levels of CORT were dampened during the treatment when food was present but inaccessible. These results support the hypothesis that the adrenocortical response to stress depends on the intensity of a stressor. We conclude that the perception of food availability and nutritional condition are both determinants of adrenocortical function in this species which relies on visual cues during foraging.

S7-2.4

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HORMONES TRANSLATE ENVIRONMENTAL INFORMATION TO TIME AMPHIBIAN METAMORPHOSIS

Metamorphic timing in amphibians is highly dependent on environmental conditions. Hormones, in particular those of the neuroendocrine stress axis, play central roles in linking sensory information about the external environment with changes in development and growth. Neuropeptides of the corticotropin-releasing factor (CRF) family play critical roles in behavioral, physiological and developmental responses to stress. Hypothalamic corticotropin-releasing factor (CRF) neurons respond to environmental stressors, and CRF peptides stimulate the secretion of both thyroid hormone and corticosterone, two hormones that control metamorphosis. Also, CRF peptides are potent anorexigens, and the reduced foraging seen in tadpoles after exposure to an acute stressor and just prior to metamorphic climax is mediated, at least in part, by these peptides. Thus, in response to adverse environmental conditions, the stress neurohormone CRF simultaneously reduces growth rate through a central anorectic action, and induces morphological changes associated with metamorphosis through its hypophysiotropic actions. Resource restriction of late prometamorphic tadpoles accelerates metamorphosis, elevates brain CRF content, and whole body corticosterone and thyroid hormone content, suggesting that CRF production is influenced by energy balance in tadpoles. In mammals the activation of the neuroendocrine stress axis in the fetus or neonate leads to long term phenotypic changes in the adult; e.g., profound effects on growth, behavior and the basal activity and reactivity of the stress axis. Our recent findings show that, in addition to playing an essential role in timing metamorphosis, exposure to stress hormones during early development can have important organizing effects in the amphibian, leading to long-term, permanent alterations in phenotypic expression. (supported by NSF grant IBN 0235401 to R.J.D.)

21.2

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CHEMICAL DEFENSES OF SEA HARES: NOVEL AND ADAPTIVE STRATEGIES FOR ESCAPE AND DEFENSE VIA INKING

Defensive secretions are usually complex mixtures of chemicals that can be distasteful, harmful, or toxic. We have investigated inking by sea hares (*Aplysia*) to examine, within an ecological perspective, neural and molecular mechanisms of chemical defense, including identifying active compounds and how they interact with the predators chemosensory systems. We have found an impressive array of defensive mechanisms, including novel ones, which vary according to the attacking species. These include the following. 1) Phagomimetics a novel mechanism whereby chemicals in ink mimic food of spiny lobsters (*Panulirus*) and in so doing distract lobsters to attend to the secretion and thereby allow sea hares to escape. 2) Sensory disruptors produced in high concentration and in a viscous matrix that massively stimulate the chemosensory pathway of the predator, disrupting the subsequent reception capabilities of that predator. 3) Aversive or toxic substances functioning against spiny lobsters and sea anemones (*Anthopleura*). This is the most prominent mechanism for sea anemone predators, but it also operates against spiny lobsters. 4) Alarm cues produced by attacked conspecifics and which evoke escape. 5) Chemicals that protect sea hares against bacterial infections but which may also protect against unidentified predators; these include an enzyme escapin, an L-amino acid oxidase and its substrates lysine and arginine. Several principles are emerging from our work. First, several mechanisms can operate against a single species of predator. Second, one chemical can mediate different mechanisms. Third, a given mechanism acts through different compounds for different predators. Supported by NSF IBN-0324435, IBN-9876754, IBN-0322773

54.1

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ESTRADIOL, STRAIN, AND PERIOSTEAL BONE GROWTH

Recently we showed that estradiol (E_2) increases osteogenic responses to loading, so that the same mechanical loading produces more periosteal bone growth in individuals with higher E_2 levels. This hypothesis was supported in sheep (*Ovis aries*, $N=32$) exposed to either low or high E_2 levels and either sedentary or high activity levels. Periosteal growth in exercised animals was 25-75% greater in high than in low E_2 animals, but only 15-20% greater in sedentary high vs. low E_2 animals. Although E_2 clearly stimulates bone growth, it is unknown whether this growth improves resistance to deformation. This study tests the hypothesis that E_2 -induced periosteal growth coincides with areas of peak tensile strain at midstance. We calculated midshaft cross-sectional properties (polar moment of area, J_N ; section moduli of tension and compression, Z_{Nt} , Z_{Nc}) in the tibia and metatarsal using the experimentally determined neutral axis (Lieberman et al., 2004) and compared them to areas of bone growth during the experiment. Results indicate little variation in J_N , although it is greatest in high- E_2 animals. In the tibia, section moduli are similar in the low- E_2 and high- E_2 sedentary groups. However, Z_{Nt} and Z_{Nc} are 17-20% greater in high- E_2 vs. low- E_2 exercised animals, corresponding to periosteal deposition on the anterior and posterior surfaces of the bone. In the metatarsal, Z_{Nt} and Z_{Nc} are 13-24% greater in the high- E_2 exercised vs. the sedentary groups, corresponding to deposition on the posterior surface. These results support the hypothesis that E_2 -induced periosteal growth is concentrated in areas of highest tensile strain, improving bones resistance to bending.

44.5

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THE EFFECTS OF ACUTE TEMPERATURE CHANGE ON PREY CAPTURE KINEMATICS IN LARGEMOUTH BASS, *MICROPTERUS SALMOIDES*

A common relationship in ectothermic vertebrates is that as temperature decreases, the rate of muscle contraction decreases. Animals moving in cooler water must also contend with the increasing viscosity of their medium which occurs with decreasing temperature. We examined the effects of acute temperature changes on prey capture kinematics in Largemouth Bass, *Micropterus salmoides* expecting a considerable influence, given the dual effects of temperature on muscle performance and water viscosity. We acclimated five individuals to 22°C and then acutely exposed them to 15°C, 20°C, 25°C and 30°C. We video-recorded feeding events at each temperature at 500 frames s⁻¹. Although we found a significant overall effect of temperature on the time taken by *M. salmoides* to open the mouth during prey capture the Q10 value between 15-25°C was only 1.28, well below the minimum expected value 2.0. Thus, we suggest the possibility that *M. salmoides* recruit additional motor units at lower temperatures in order to partially compensate for the effects of acute temperature change. The capacity of *M. salmoides* to mitigate the impact of acute temperature change on muscle physiology and the physical properties of water may represent an adaptation to a predatory lifestyle in a thermally variable environment.

43.3

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WAIR FLOW: ONTOGENY OF WING AERODYNAMICS DURING INCLINE RUNNING IN BIRDS

A survey of diverse avian clades (e.g. Tinamiformes, Galliformes, Columbiformes, and Passeriformes), shows wing-assisted incline running (WAIR) to be a plesiomorphic locomotor behavior. This includes Australian brush turkey chicks that are capable of aerial flight the day they hatch but preferentially perform WAIR and are more proficient and effective at it than adults. To further our understanding as to how incipient and fully developed wings function during WAIR, we present preliminary data from digital particle imagery velocimetry (DPIV) for three age-classes of chukar partridge: 5 day (23 g), 42 day (200 g) and adult (600 g). We measured circulation in the wake of the birds as they ran up inclines varying from 65–90 degrees above horizontal, and we estimated lift production using the measured circulation coupled with 3D kinematic analyses of wing movement. All three age classes produced lift during downstroke, but lift scaled proportional to $M^{1.8}$, representing only 30% of body weight in the youngest birds and 3.5 times body weight in the adults. Impulse per downstroke revealed that lift was directed 12–34 degrees into the substrate. This is consistent with the hypothesis that wings function to increase traction during WAIR. Peak vorticity and circulation scaled positively with body mass ($M^{0.26}$ and $M^{0.72}$, respectively). These patterns reveal, for the first time, the effects of wing ontogeny on forelimb aerodynamic function during incline running in birds. NSF IBN-0327380 and IBN-0417176.

72.3

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WHY GECKOS DON'T FALL OFF CEILINGS

Directional arrays of branched microscopic setae constitute a dry adhesive on the toes of pad-bearing geckos. Geckos are able to easily and rapidly detach their sticky toes as they run on smooth vertical or inverted surfaces. There are two known mechanisms of detachment: 1) on the microscale, the seta detaches when the shaft reaches a critical angle with the substrate, and 2) on the macroscale, geckos digitally hyperextend their toes, apparently peeling like tape. This raises the question of how geckos prevent detachment while inverted on the ceiling, where body weight should cause toes to peel and setal angles to increase. Geckos use opposing feet and toes while inverted, possibly to maintain shear forces that prevent detachment of setae or peeling of toes. If detachment occurs by macroscale peeling of toes, the peel angle should monotonically decrease with applied force. In contrast if adhesive force is limited by microscale detachment of setae at a critical angle, the toe detachment angle should be independent of applied force. We tested the hypothesis that adhesion is increased by shear force in isolated setal arrays and live gecko toes. We also tested the corollary hypotheses that 1) adhesion in toes and arrays is limited as on the microscale by a critical angle, or 2) on the macroscale by adhesive strength as predicted for adhesive tapes. We found that adhesion depended directly on shear force, and was independent of detachment angle. Therefore we reject the hypothesis that gecko toes peel like tape. The linear relation between adhesion and shear force is consistent with a critical angle of release in live gecko toes and isolated setal arrays, and also with our prior observations of single setae. Inverted locomotion of geckos requires opposing shear forces at the level of toes or feet to maintain adhesion and support the weight of the animal. Support: DARPA N66001-03-C-8045, NSF-NIRT 0304730, and J.S. Rogers.

32.4

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CLUTCH-SPECIFIC SENSITIVITY TO ESTROGEN IN A TURTLE WITH TEMPERATURE-DEPENDENT SEX DETERMINATION

Most turtles exhibit temperature-dependent sex determination in which the incubation temperature of the egg determines the sex of the embryo. Previous studies have revealed clutch-specific variation in the pivotal temperature of sex determination in the red-eared slider turtle. For example, experiments in our laboratory indicate that clutch sex ratio can vary from all male to all female at near-pivotal temperatures. In the current study, we investigate whether this clutch-specific variation also extends to steroid hormone sensitivity. Many previous studies have shown that application of estrogen to eggs incubated at male-producing temperatures will cause sex reversal of the embryos. In the current study, eighteen clutches were incubated at male-producing temperature. These eggs were treated with a relatively low dosage of estrogen during the thermosensitive period. For a control, a separate group of eggs were incubated at male-producing temperature and treated with an ethanol solution. The control group of eggs produced all males. The sex ratios of the estrogen-treated clutches varied significantly and ranged from all male to all female clutches. The results indicate a clutch-specific sensitivity to estrogen. Thus, temperature-dependent sex determination in the red-eared slider turtle shows clutch-specific sensitivity to both temperature and exogenous estrogen.

73.6

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GILL SLIT KINEMATICS IN SUCTION AND RAM VENTILATING SHARKS

The movement of the gill slits during suction and ram ventilation in elasmobranchs differs mechanistically. The gill slits remain open during continuous swimming in ram ventilation. In suction ventilation, the gill slits open for the compression pump phase and close for the suction pump phase. The slits are generally considered to be one functional unit, regardless of ventilation mode. Individual gill slit kinematics of suction and ram ventilators have not been compared previously to evaluate these mechanistic differences. In this study, we quantify the gill slit kinematics at rest in white spotted bamboo sharks, *Chiloscyllium plagiosum*, a suction ventilator, and bonnethead sharks, *Sphyrna tiburo*, a ram ventilator. The peak opening width of each slit and time to peak opening was quantified using high speed video. During ram ventilation in bonnethead sharks, no difference in opening width among the gill slits was found. Furthermore, the slits are continuously held open while swimming. During suction ventilation in bamboo sharks, the peak opening width of slits one and two was smaller than the peak opening widths of slits three through five ($p < 0.05$). Slits three through five reached their peak opening width at least 20 milliseconds earlier than slits one and two. Larger opening widths and shorter time to peak opening in gill slits three through five could imply those slits pass more water than slits one and two. These data suggest that the gill slits and arches of suction ventilators may be separated into at least two functional units that play different roles in ventilation. Future studies will investigate the presence of multiple functional units of the gill arches and slits for other suction ventilators and compare the mechanics of suction ventilation to the mechanics of ram ventilation.

23.1

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TEMPERATURE, SAMPLING BIAS, AND SCALING OF BMR IN
ENDOTHERMS

The basal metabolic rate (B) for an organism can be scaled to body mass (M) using the allometric equation, $B = cM^b$, where c is the normalizing constant and b is the scaling exponent. Whether b should be approximately 0.75 or 0.67 is contentiously debated, however metabolism certainly is not related solely to body mass, and different values of the scaling constant may reflect the effect of other (unspecified) variables. We fit a multiple regression to scale B , body temperature (T), and M for birds, for mammals, and for birds and mammals combined. Residuals for the regression of $\log(B)$ and $\log(M)$ were not normally distributed, but the addition of t as a predictor yielded normally distributed residuals. We regressed M and T onto B for all three data sets using the basic model $B = cM^bT_g^t$ where T_g is either 10^T or $10^{1/T}$. Both T_g variables contributed significantly to the explained variance in B , and both yielded normally distributed residuals for all three data sets. Regressions for all three data sets produced 0.67 as the scaling exponent for body mass, and taxonomic group was not significant when body temperature was included in the model, suggesting T can account for the differences between metabolic rates of mammals and birds. We also tested whether or not sampling biases in the body masses of mammals included in allometric studies of B could result in a scaling exponent of 0.67 for M . We randomly sampled mammals with known metabolic rates in proportion to the body size distribution of all extant mammals. This random sampling was repeated 500 times, and the range of scaling exponents for M never included 0.75, but always included 0.67. We conclude that (1) T is important when scaling B with M , and (2) that $B \propto M^{0.67}$.

42.1

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COULD FEMALE RINGTAILED LEMURS BE MASCULINIZED BY
MATERNAL ANDROGENS?

To examine the broader application of hormonal mechanisms of behavioral and morphological masculinization described for the female spotted hyena (*Crocuta crocuta*), the present study explored a similar, but less extreme, phenomenon in the ringtailed lemur (*Lemur catta*), a Malagaszy primate in which the female socially dominates males, is size monomorphic with males, and exhibits a pendulous clitoris. Consideration of these masculine traits has focused attention on the role of androgens in female development. To characterize the extent of female morphological masculinization, experiment 1 measured the external genitalia of 18 intact adult lemurs (9 F; 9 M) at the Duke University Primate Center. Females displayed a shorter anogenital distance and larger urethral meatus than did males, but total clitoral width and length were comparable to those of the extruded male glans. Experiment 2 examined seasonal fluctuations in serum testosterone (T), androstenedione (A4), and estradiol (E2) in 22 intact adult lemurs (10 F; 12 M) over the course of 4 annual cycles, and assessed hormonal correlates of prenatal development by charting these same steroids throughout 16 pregnancies. Adults of both sexes showed a significant breeding season peak in steroid production. Whereas male T concentrations exceeded those of females, both sexes showed comparable A4 concentrations. Pregnancies that produced singleton males, twin males, or mixed sex twins showed higher concentrations of all three steroids than did pregnancies that produced singleton or twin females, especially in the third trimester, but steroid levels in female-producing pregnancies consistently exceeded preconception and postpartum values. These data are consistent with the hypothesis that female lemurs may be partially masculinized through exposure to maternal androgens. Funded by NSF grant BCS-0409367.

S5-2.1

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ROLE OF NODAL IN ESTABLISHMENT OF SEA URCHIN LARVA
BODY PLAN

Nodal factors play crucial roles during embryogenesis of chordates. They have been implicated in a number of developmental processes, including mesoderm and endoderm formation and patterning of the embryo along the anterior-posterior and left-right axes. We have recently isolated the first *nodal* gene from a non-chordate organism, the sea urchin. We have found that while Nodal signalling does not appear critical for the establishment of mesodermal and endodermal germ layers, it plays a crucial role during axis specification. Sea urchin *nodal* starts to be expressed in the presumptive oral ectoderm and controls the formation of the oral-aboral axis. The sea urchin *nodal* gene acts upstream of several transcription factors and secreted factors implicated in formation of the oral and aboral territories including *gooseoid*, *brachyury* and BMP2/4. The oral ectoderm territory of the sea urchin embryo seems to behave very much like the organizer of vertebrates by emitting signals that pattern the embryo along the oral-aboral axis. A second conserved role for *nodal* signaling during deuterostome evolution is its involvement in the establishment of left-right asymmetries. Sea urchin larvae exhibit profound left-right asymmetry with the formation of the adult rudiment from the left coelomic pouch. We have shown that a *nodal/lefty/pitx2* gene cassette regulates left-right asymmetry in the sea urchin but that intriguingly, the expression of these genes is reversed compared to vertebrates. We show that Nodal signals emitted from the right ectoderm of the larva regulate the asymmetrical morphogenesis of the coelomic pouches by inhibiting rudiment formation on the right side of the larva. Our results show that the mechanisms responsible for patterning the left-right axis are conserved in echinoderms. Altogether, it appears that the role of Nodal during axis specification is conserved in basal deuterostomes.

11.5

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University of California, Berkeley
RAPID RECOVERY FROM AN IMPULSE PERTURBATION TO A
LEG IN RUNNING INSECTS

Insects frequently run across unstructured environments, such as leaf litter, with little degradation in performance. Cockroaches rapidly traverse rough terrain with obstacles up to three times their hip height with no detectable change in motor output to major leg muscles when compared to running over smooth, level ground. Previously, we found that the isolated hind leg of a cockroach begins to recover within 5 ms to a vertically directed impulse perturbation. The isolated leg returns to within 99% of its original position within the swing phase duration (< 45 ms). With its vertically oriented joint axes, the response is primarily due to the legs passive material properties. To test the response in intact animals, we subjected the hind leg of running cockroaches, *Blaberus discoidalis*, to vertically directed impulse perturbations during the swing phase by tethering the animal above a Styrofoam ball floating on an air bearing. A beam, actuated by a diaphragm, first slid under the swinging leg and was then lifted upward by a servo-motor to perturb the leg. A point at the distal end of the tibia was tracked at 1000 fps in two views to track the response. As in the isolated leg, the intact leg begins to recover in less than 5 ms, and returns to within the 95% confidence intervals of the original swing trajectory within 40 ms with minimal overshoot. Leg placement at the end of swing was unaffected by the perturbation. Response times improved as perturbations occurred later in swing, recovering in as little as 9 ms. Spring-damping properties of the hind leg may act to simplify control of rapid running over unstructured environments by passively attaining quick settling times with minor overshoot.

54.2

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APPLYING MUSCLE FORCES TO FINITE ELEMENT MODELS OF BONE: HOW MUCH MODELING PRECISION IS NECESSARY?

Finite element analysis (FEA) is a powerful tool for understanding the mechanics of physical systems. Existing FEA tools were developed to enable engineers to predict the physical behavior of engineered products and manufacturing processes. The material properties, loading conditions, and especially geometries of these systems are fully specified by design engineers and easily defined in computer aided design (CAD) and/or FEA tools. In part due to the relatively simple shapes of the physical systems they study, engineers often use simple models to represent complex physical systems and place a high degree of confidence in analyses of those simplified models. FE modeling and analysis of biological structures is a much more complicated task. Organic structures inevitably contain complicated, irregular shapes and are often subjected to complex loading regimes. The extent to which models of biological structures can be simplified often is not clear and researchers invest a great deal of energy in creating true-to-life models. To begin to understand how FE models of biomechanical systems can be simplified without losing valuable information, we studied the effect of simple and complex models of muscle loads on the transmission of biting forces through the facial skeleton of a mammal. Using the same FE model, we conducted a series of analyses in which the major jaw adductors were modeled with increasing precision as point loads, evenly distributed tangential loads, tangential loads that changed in magnitude along a gradient, and tangential + normal loads that changed in magnitude along a gradient. Results indicate that all methods of modeling muscle loads return similar results and suggest that simple models of muscle loads can, in many cases, return reliable results.

69.2

DUNBAR, M.B., TOMASI, T.E.*; tomtomasi@missouristate.edu. University of Regina, Missouri State University
HIBERNATION ENERGETICS OF EASTERN RED BATS (*LASIURUS BOREALIS*)

Many bats use torpor to conserve energy during daily or seasonal periods of inactivity. Seasonal torpor (hibernation) allows bats to avoid thermoregulatory costs of extreme conditions. Unlike other temperate hibernating bats, eastern red bats (*Lasiurus borealis*) do not utilize the typical hibernacula (e.g., caves). Instead, red bats move into leaf litter during cold bouts of winter months. Because temperatures fluctuate widely at these winter roosts, our first goal was to determine whether there was a correlation between winter arousals and ambient temperature (T_a). Additionally, we measured changes in metabolism and body temperature (T_b) during hibernation and arousals at various T_a . Using these data, we estimated winter energy budgets within selected temperature profiles. Bats were captured during fall of 2003 and 2004 in southwestern Missouri and kept in environmental chambers simulating natural conditions. We assessed torpor durations using temperature-sensitive data-loggers within environmental chambers maintained at 2, 5, 10 and 15° C. Metabolism during torpor (MR_t; measured as oxygen consumption rates) was assessed within metabolic chambers maintained at -5, 1, 5, 10 and 15° C. These data were evaluated for differences between gender and T_a . Our data suggest that torpor bout duration was not affected by gender and it was negatively correlated with T_a . Likewise, MR_t was not affected by gender but it did vary with T_a . T_b of hibernating bats approximated T_a and the difference between these temperatures was greatest at 1° C.

48.1

DUNN, C.W., WAGNER, G.P.; cdunn@hawaii.edu. University of Hawaii, Yale University
THE EVOLUTION AND DEVELOPMENT OF COLONY-LEVEL ORGANIZATION IN THE SIPHONOPHORA (CNIDARIA, HYDROZOA)

The siphonophores (Cnidaria, Hydrozoa), like other colonial animals, are made up of many multicellular zooids, each of which is homologous to a free-living solitary animal. Each colony arises from a single zygote, but the zooids are produced asexually and remain physiologically integrated. Siphonophore zooids are functionally specialized to a greater degree than are those of any other colonial animal, and are arranged in precise, species-specific patterns. Little is known about the diversity of colony-level organization and development of these superorganisms, even though they include the longest animals in the world and are among the most abundant predators in the open ocean. This is because they are extremely fragile and difficult to collect intact. Colony level development has previously been described in detail for only two species. We have described the colony-level organization and development of 6 additional siphonophores that have been strategically sampled across the phylogeny. Intact specimens in pristine condition were collected for 3 of these species by remotely operated underwater vehicles and by SCUBA diving from ships in the open ocean; observations for the remaining taxa were made using preserved material that had been previously collected by manned submersible. These new data indicate that pro-bud subdivision, a colony level developmental process whereby all the zooids in a single reiterated sequence arise from a single bud, is a synapomorphy of the Codonophora. The feeding zooids and reproductive elements of the examined Cystonectae arise from independent buds, as in other Hydrozoans. We hypothesize that the origin of pro-bud subdivision established a new organizational framework that allowed for the diversification of colony form and extreme division of labor in the Codonophora.

S8-2.3

DURICA, D.S., KUPFER, D., NAJAR, F., SO, S., TANG, Y., GRIFFIN, K., HOPKINS, P.M., ROE, B.; ddurica@ou.edu. University of Oklahoma
LIMB REGENERATION AND EXPRESSED SEQUENCE TAG SEQUENCING IN FIDDLER CRAB

We have constructed several directional and randomly-primed cDNA libraries from mRNAs isolated during progressive stages of fiddler crab (*Uca pugilator*) limb regeneration. Data from these libraries is being assembled into an on-line database (<http://www.genome.ou.edu/crab>) that is both BLAST and keyword searchable; the data set will also be available through GenBank. The first characterized library was made from mRNA isolated four days post-autotomy, when the first sign of morphological differentiation, cuticle secretion, is observed. Analysis of approximately 1500 cDNA clones led to assignment of 485 contigs and 429 singletons, for a total of 914 sequences. Of these, approximately 63% showed no homology on database searching. Analysis of these unclassified sequences relative to sequencing with 5 or 3 specific primers showed approximately equal numbers in each category, suggesting that the no hit clones may contain a large number of new genes. Biological assignments for the approximately 37% of ESTs based on KEGG (Kyoto Encyclopedia of Genes and Genomes) are broken down into metabolism or regulatory categories, and a detailed list of assignments based on the NCBI COG (Clusters of Orthologous Groups) outline format is available. These ESTs include several genes that may be potentially ecdysteroid-responsive, such as homologs to chaperone proteins and cuticle protein genes. Homologs to arthropod proteins involved in retinoid/terpenoid metabolism have also been identified. To investigate potential ecdysteroid-responsive candidate genes, hormone induction experiments are currently in progress, using primer sets designed from database sequence information and quantitative real-time PCR.

AMS

ECKELBARGER, K.; University of Maine

THE DAWN OF INVERTEBRATE ZOOLOGY IN AMERICA: A TRIBUTE TO THE PIONEERS

In the early 19th century, America had virtually no invertebrate zoologists as we know them today, but there were men and women studying invertebrates who described themselves as “naturalists” or “natural philosophers”. Interest in invertebrates was overshadowed by greater attention toward botany, geology, and paleontology, although entomology and conchology were also popular. This presentation will trace the rapid rise of the broader field of invertebrate zoology: from the policies of Thomas Jefferson, who encouraged exploration and discovery; through the great upsurge of activity stimulated by Harvard’s Louis Agassiz in mid-century; to the eventual proliferation of journals, textbooks, museums, marine labs, university departments, and professional societies that focused on invertebrate biology during the late 19th and early 20th centuries. The field-based teaching of philosophy of Louis Agassiz and other invertebrate pioneers (“Study Nature, not books”) is still alive today in many American universities, although increasing specialization has left few invertebrate zoologists who resemble the naturalists of the 19th century. Many of our predecessors spent considerable time collecting and studying living animals in the field and were equally skilled in vertebrate and invertebrate biology (including insects), as well as in botany, geology, and paleontology. As we enter a new century, reflecting on our past may give us the perspective to evaluate progress in our field and to set a vibrant future course.

65.2

EDWARDS, T.M., MOORE, B.C., GUILLETTE, L.J.; tedwards@zoo.ufl.edu. Environmental Health Sciences, University of Florida

METAMORPHIC SEX CHANGE: EVOLUTIONARY INSIGHT FOR ENDOCRINE DISRUPTION STUDIES

Metamorphosis is marked by developmental bipotentiality. Classical metamorphosis allows an individual to express more than one phenotype in its lifetime, without a change in genotype. Consider *Lythrypnus dalli*, the bluebanded goby. Under permissive social conditions, this tiny, protogynous fish undergoes rapid and complete sex change. Females become males in an impressive display of adult sexual bipotentiality. In this example, sex change is easily argued to be a form of metamorphosis, defined as a developmental transition marked by anatomical and physiological remodeling. Theoretically, metamorphosis provides a dramatic model of how environment profoundly affects phenotype through changes in gene regulation. In the field of endocrine disruption, numerous studies describe the masculinization of females or the feminization of males by environmental contaminants. These changes are not metamorphic in the classical sense. However, our understanding of their underlying mechanisms is informed by our appreciation for the role of gene regulation in metamorphic sex change. In humans, for example, during the first six weeks of development, the reproductive system is anatomically indistinguishable between males and females. The cells, tissues, and primordial organs needed for either sex are present in both sexes. Therefore, despite the apparently decisive nature of genetically determined sex, there remain the vestiges of developmental sexual plasticity that result from a shared ontogeny between the sexes. We suggest that it is this shared ontogeny that makes abnormal masculinization or feminization possible.

32.1

ELF, P.K., ROBERT, K., THOMPSON, M., FIVIZZANI, A.; pelf@umn.edu. University of Minnesota Crookston, University of Sydney, University of North Dakota

TEMPERATURE-DEPENDENT SEX DETERMINATION IN A VIVIPAROUS LIZARD: WHAT ROLE DO HORMONES PLAY?

The Australian skink, *Eulamprus tympanum*, is a viviparous reptile that exhibits temperature-dependent sex determination (TSD). In this system the pregnant female actively thermoregulates to select the sex of her offspring. The pattern displayed is female-male, with exclusively males produced at 32°C, approximately 75% males at 30°C, and 55% males at 25°C. Sex steroid hormones in the yolks of reptile eggs have been implicated in the process of sex determination in some TSD species, but little is known about the involvement of sex steroids in *E. tympanum*. In preliminary studies we found that circulating maternal plasma hormones appeared to be more sensitive to temperature than those in the yolk, and in fact male circulating plasma hormones demonstrated a similar phenomenon. To further investigate these findings three experiments were designed to determine the dynamics of the hormonal environment of developing embryos and temperature effects on plasma hormones. In the first experiment yolk and plasma samples were collected from pregnant skink females maintained at the predominantly male (30°C) and female (20°C) producing temperatures and these were assayed for androstenedione, DHT, corticosterone, estradiol and testosterone. In the second experiment, male skinks were incubated at either the male or female producing temperature for a week then half from each group were switched to the alternate temperature and plasma was sampled from all animals and hormones measured at 24 and 48 hours after the switch. In the third experiment pregnant females incubated at the male producing temperature were treated with estradiol during the thermosensitive period to accomplish sex reversal of the embryos. Here we present outcomes of these experiments.

14.1

ELZEY, S.P.; selzey@cisunix.unh.edu. University of New Hampshire
SEXUAL DENTAL DIMORPHISM IN FOUR SPECIES OF SKATES FROM THE WESTERN GULF OF MAINE

Tooth morphology of four species of skate found in the Western Gulf of Maine was examined. These species were the little skate (*Leuconaja erinacea*), the winter skate (*L. ocellata*), the smooth skate (*Malacoraja senta*), and the thorny skate (*Amblyraja radiata*). Differences in cusp length and angle were found between adult male and adult female skates as well as differences between juvenile and adult male skates. Adult males possess longer sharper teeth that protrude more prominently into the mouth than the females or the juveniles. Although this trend is seen in all four species it is more pronounced in the two smaller species, the little skate and the smooth skate. The tooth morphology change at the size of maturity in the males suggests that the teeth play a roll in the reproduction of the skate, most likely due to the need for the male to hold on to the female during mating. Bite scars were seen on female skates, which corroborates this theory. The results of an ongoing study examining hormone effect on tooth morphology and skin thickness in the little skate will also be discussed.

S4.8

EMLET, R.B.; remlet@darkwing.uoregon.edu. University of Oregon, OIMB

FUNCTIONAL AND ECOLOGICAL LIMITS ON SIZE AT METAMORPHOSIS OF MARINE INVERTEBRATES

Just as egg size can influence many aspects of the larval stage, size and condition at metamorphosis have consequences for juvenile growth and survival. Here I examine several factors that may set the lower and upper limits to size at metamorphosis. Invertebrate larvae feed and swim with cilia or muscle and are small (\leq mms). There is often a habitat transition that accompanies the transformation from larva to juvenile, and newly metamorphosed juveniles will grow larger (mms to cms) with relatively little change in form. Juveniles can be no smaller than what is required for survival in this new habitat. Lower limits to juvenile size may be set by requirements of sufficient energy reserves, requirements for juvenile feeding, growth, movement, and by competition. Upper limits to juvenile size may be set by larval form, mechanisms of larval swimming and feeding, and specific gravity of the competent larva including juvenile components. Because larger larvae and juveniles may be more easily seen, visual predation may also limit size at metamorphosis. I will present data from echinoderms and other phyla to explore patterns in size at metamorphosis in light of larval form and swimming mechanisms and juvenile feeding, attachment and movement.

2.5

ENGESZER, R.E., ALBERICI DA BARBIANO, L., RYAN, M.J., PARICHY, D.M.; rayeng@mail.utexas.edu. University of Washington, University of Texas at Austin

AN ANALYSIS OF SHOALING PREFERENCE IN THE ZEBRAFISH, *DANIO RERIO*

How social aggregations arise and persist is central to our understanding of evolution, ecology, behavior and psychology. When social groups arise within a species, evolutionary divergence and speciation can result. To understand this diversifying role of social behavior, we must examine the internal and external influences that lead to nonrandom assortment of phenotypes. Many fishes form aggregations called shoals that reduce predation risk while enhancing foraging and reproductive success. Thus, shoaling is adaptive, and signals that maintain shoals are likely to evolve under selection. Given the diversity of pigment patterns among *Danio* fishes, visual signals might be especially important in mediating social behaviors in the group. Our understanding of pigment pattern development in the zebrafish *D. rerio* allows integrative analyses of how molecular variation leads to morphological variation among individuals and how morphological variation influences social interactions. Previous work elucidated the role of early environment in determining social preference in the zebrafish. Here, we examine the time during which shoaling behavior and preferences arise. Furthermore, we assess the salient elements of the visual signal for shoaling, using multiple pigment pattern mutants and closely related species. This work provides a foundation for examining the proximate mechanisms involved in shoaling, and more generally, the genetic and environmental factors contributing to social behaviors in this biomedically important model organism.

S7-2.7

EREZYILMAZ, D.F., RIDDIFORD, L.M., TRUMAN, J.W.; denizere@u.washington.edu. University of Washington

AN ANCESTRAL ROLE FOR THE METAMORPHOSIS-DETERMINING GENE, *BROAD* IN THE DIRECT-DEVELOPING MILKWEED BUG.

Fossil and phylogenetic evidence show that the metamorphosing insects diverged from direct-developing ancestors about 300 million years ago. To better understand the genetic basis of this divergence, we have focused on the role of the metamorphosis-determining gene, *broad* (*br*). In metamorphosing flies and moths, *br* expression is restricted to pupal development, and its expression at this time is required for production of the pupal stage. Genetic overexpression studies in *Drosophila* show that *br* acts by promoting the expression of pupal-specific genes, while suppressing the expression of larval- and adult-specific genes. We have cloned a homolog of this gene from the direct-developing milkweed bug, *Oncopeltus fasciatus* and have found that unlike its expression in flies and moths, *Ofbr* is expressed at each of the nymphal stages, but is absent at the molt to the adult stage. We used RNAi to test the role of nymphal *Ofbr* expression and found that *Ofbr* knockdown during nymphal development prevents heteromorphosis (the progression in pigment pattern that occurs between nymphal stages). Injected nymphs show normal growth, but simply repeat the pigment pattern at the stage of injection with *Ofbr* dsRNA. In addition, *Ofbr* is required for differential growth, as knockdown of *Ofbr* expression prevents anisometric growth of the wing pads, shifting the growth pattern of these structures into a more isometric mode, like that of the legs and antennae. Our data show that the ancestral role of *br* is to regulate deviations from simple isometric repetition during postembryonic growth. Our data further suggest that the role of *br* in regulating metamorphosis evolved by 1) restricting expression of this gene to one postembryonic instar, and 2) expansion of the number of traits that are regulated by *br*. This work was supported by NSF and NIH grants to JWT and LMR.

51.3

ERWIN, P.M., THACKER, R.W.; erwin@uab.edu. University of Alabama at Birmingham

INCIDENCE AND IMPORTANCE OF PHOTOSYNTHETIC SYMBIONTS IN SHALLOW-WATER SPONGE COMMUNITIES

Symbioses between marine sponges and photosynthetic organisms (e.g. cyanobacteria) have been described from coral reef communities; however, the frequency of these associations and the ecological nature of interactions between hosts and symbionts often remain unresolved. In this study, we determined the number of sponge species harboring photosymbionts and assessed their prevalence in the shallow-water reefs of Bocas del Toro, Panama, by conducting line-intercept transects with measurements of chlorophyll *a* (chl *a*) concentration. Sponges were dominant members of these benthic communities, second in abundance only to stony corals. Twenty-five of the 67 species investigated (37.3%) exhibited high chlorophyll levels (>150 $\mu\text{g/g}$) and accounted for 35.6% of the observed sponge community. Association with photosymbionts is a common strategy among coral reef sponges and may represent an important source of primary productivity in oligotrophic coral reef environments. Additionally, two sponge species known to harbor cyanobacterial symbionts (*Aplysina fulva*, *Xestospongia subtriangularis*) were experimentally shaded to test the effects of reduced light availability on symbiont load and host growth. Six weeks of shading reduced the abundance of symbionts ($>40\%$ reduction in chl *a* for both species). In *A. fulva*, control sponges exhibited over twice the growth of shaded sponges (by volume and mass). In *X. subtriangularis*, no significant difference in growth was observed between control and shaded sponges. These results suggest that the relationship between sponges and their cyanobacterial symbionts varies among host species, with some sponges strongly dependent on symbiont photosynthesis and others unaffected by short-term decreases in symbiont activity.

54.9

ESPINOZA, N.R., CIRILO, S.R., HILL, S., BLOB, R.W.; espinoza@erskine.edu. Erskine College, Due West, Clemson University
LIMB BONE STRAIN IN JUMPING FROGS

A primary requirement of limb bone design is the accommodation of loads experienced during locomotion. Patterns of limb bone loading have generally been viewed as highly conserved throughout tetrapod evolution, but most data have been derived from mammalian and avian species with a restricted range of locomotor styles. Limited data from reptilian lineages (crocodilians, lizards, turtles) have indicated patterns that differ from those of mammals and birds, with reptiles showing lower strain magnitudes but a greater prevalence of torsion. To further examine the diversity and evolution of limb bone loading patterns in tetrapods, and to test how distinctive modes of locomotion affect limb bone loads, we measured *in vivo* strains from multiple locations on the femur of jumping bullfrogs (*Rana catesbeiana*) using surgically implanted rosette and single element gauges. Because the jumps of ranid frogs are an explosive, discontinuous mode of locomotion, we predicted that strain magnitudes in jumping bullfrogs would be higher than those of previously tested reptiles and closer to levels found in mammals and birds. Instead, peak femoral strains in frogs were lower than those of mammals and birds and similar to those of reptiles, including slower moving turtles. Also similar to reptiles, torsional strains were substantial in the frog femur. Several mechanisms might contribute to the moderate strain magnitudes observed in frogs despite their dramatic jumps, including simultaneous activation of extensor muscles on opposite sides of the femur, or increased resistance to deformation through specialization of bone shape or material properties. Moreover, the similarity of loading magnitudes and regimes across amphibian and reptilian taxa suggests that the patterns seen in these lineages might be ancestral features of tetrapod limb bone design.

56.4

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FORELIMB AND CAUDOPELVIC FUNCTION DURING TAKE-OFF IN *RANA PIPPIENS*

The forelimbs of frogs are thought to play balancing or positioning roles during takeoff. However, they may also be important in raising the center of mass (CoM) via forelimb extension prior to takeoff. Conversely, frogs may elevate their CoM solely with their unique caudopelvic (CP) muscles in order to control takeoff angle by: 1) modulating amplitude of the CP muscles; or 2) changing the timing of the motor pattern relative to hindlimb extensors. In order to test these hypotheses we studied *Rana pipiens* (n=15) jumping over short (<20 cm) and long (>45 cm) distances, with an integrated setup consisting of high-speed video (250 fps), EMG, and force plates. Frogs were placed so that they bridged two separate force plates as a way of distinguishing relative contributions of fore and hindlimbs to ground reaction force. In order to examine muscle activity, bipolar electrodes were placed in the following muscles: *m. semimembranosus* (hindlimb extensor); *m. coccygeoiliiacus* (trunk elevator); *m. anconeus* (forelimb extensor); and *m. coracoradialis* (forelimb flexor). Long jumps in *R. pipiens* are characterized by significantly higher mean amplitudes for each of the four muscles examined. However, muscle activation patterns appear to be similar in both types of jumps, with all four muscles being activated simultaneously, suggesting that phase regulation of CP muscles is not the primary mechanism by which frogs control trajectory during normal jumping. In addition, forelimb force records lacked a consistent peak in the vertical direction suggesting that forelimbs do not play a major role in raising the CoM during most jumps.

52.11

EVANS, A.R., WILSON, G.P., JERNVALL, J., FORTELIUS, M.; arevans@fastmail.fm. Institute of Biotechnology, University of Helsinki, Finland, Denver Museum of Natural History
NEW METHODS IN 3D TOOTH SHAPE ANALYSIS: A STUDY OF FORM AND FUNCTION IN MURINE AND SIGMODONTINE RODENTS

The correlation between the dentition and the diet in mammals is a perennial topic of research, due to the importance of the teeth in food processing and their preponderance in the fossil record. However, most often very simple aspects of morphology, such as lengths and widths of teeth or crests, have been used to draw a parallel with ecological and dietary information. The explosion of methods for capturing 3-D surface data on morphology has opened the door to a new range of possibilities in analysis. These are not limited to using two-dimensional representations of teeth and can exploit the full 3-D tooth shape, including true surface areas, volumes and curvatures. In addition, we are now capable of tooth shape analyses that do not require identification of homologous landmarks. Here, we present a new techniques that uses general characteristics of shape to give summary information on aspects that can be related to some functional measures. We demonstrate the application of these techniques in exploring the evolution of dietary groups in two separate radiations of murid rodents, the murines and the sigmodontines. These rodents are very diverse in ecology and diet, ranging from strict herbivores, granivores or faunivores, to having broad diets. Certain general measures of shape, such as complexity (measured as number of distinct faces) and orientation of tooth surfaces, correlate well with diet. The power of these new techniques is displayed in the ability to analyse diverse morphologies in using the same methodologies, not being limited to homological comparisons.

S1.11

FAHEY, J.V., SCHAEFER, T.M., WIRA, C.R.; John.V.Fahey@Dartmouth.edu. Dartmouth Medical School
INNATE AND ADAPTIVE IMMUNITY IN THE HUMAN FEMALE REPRODUCTIVE TRACT: REGULATION BY SEX HORMONES

Understanding the immune system in the human female reproductive tract (FRT) is vital because sexually transmitted infections are a major worldwide health problem. Innate and adaptive immune cells have evolved a variety of mechanisms to protect the host from pathogens, and are also participants in the cyclical reproductive process to prepare for the conceptus. For example, epithelial cells in the upper tract form an uninterrupted physical barrier, secrete natural microbicides into the lumen, produce cytokines and chemokines that attract and activate immune cells, express toll-like receptor molecules that recognize microbial pathogens, and participate in normal physiology of reproduction. The immune system in the FRT is precisely regulated by sex hormones. Estradiol and progesterone influence the number and character of immune cells in the FRT and regulate the ability of immune cells to recognize antigen and control the degree of response. Sex hormones also mediate the cell architecture and cooperation that exists between immune cells. For example, the size of lymphoid aggregates, which consists of a B cell core surrounded by T cells and encapsulated by macrophages, varies during the menstrual cycle. Largest aggregates are found during the secretory phase of the cycle. Among the immune responses regulated by sex hormones in the human FRT are immunoglobulin transport, chemotaxis of immune cells, secretion of microbicides, chemokines and cytokines, proliferation of T cells, and antigen presentation. The overall conclusion from these studies is that the immune system in the FRT has evolved to protect against potential microbial pathogens without compromising fetal survival. Supported by AI 51877, NIH.

25.4

FARLEY, R.D.; roger.farley@ucr.edu. University of California, Riverside
SCORPION RESPIRATORY ORGANOGENESIS: SPIRACLES, SAC-
LIKE INVAGINATIONS AND BOOK LUNG LAMELLAE

Scorpions are thought to be monophyletic, but comparative studies (SEM) show variation in the developmental stage when certain structures appear (heterochrony). Also, transitory structures in embryos of some species may be absent or only slightly expressed in others. Fossils provide evidence of terrestrialization (spiracles, book lung lamellae) in the Devonian/Carboniferous. The initial spiracles in embryos of the basal scorpion families (e.g., Buthidae) lead to sac-like invaginations or slowly developing book lung lamellae. After birth, the first instars continue development on the mother's back until the first molt to independent, foraging nymphs. In embryos of some species (e.g., *Vaejovis spinigerus*, Vaejovidae), spiracle formation is preceded by deep, bilateral lung-like invaginations in the ventral surface of mesosomal segments. In these and other species, small spiracles appear early (before or concurrent with flap-like, primordial sternites) near the ventral, posterior margin of 4 mesosomal segments. Book lung lamellae develop slowly; their formation continues after birth into the first instar and first molt. The spiracles appear to migrate forward as the mesosomal sternites develop. The forward position in nymphs and adults gives space for the elongate poststigmatic muscle. The spiracles can thus be opened as needed, conserving water. This muscle was not seen in the initial marginal spiracles of embryos. In contrast to later molts, the developing book lungs are not shed with the first molt exuvium. The number of lamellae increases in subsequent molts as the juvenile grows. The pace of book lung development may be a factor for reported species differences in mobility and vitality of first instars. They are weak, clinging, still somewhat embryonic in form and non-fluorescent with UV.

34.6

FAULKES, Z.; zfaulkes@utpa.edu. University of Texas, Pan American
DO SHOVEL-NOSED LOBSTERS SHOVEL WITH THEIR NOSES?
Aquatic digging is a poorly understood form of locomotion that typically involves moving through sand. Sand is a granular material with complex physical properties: for example, granular materials can switch between solid-like and liquid-like properties. Because the physics of granular materials are poorly understood, it is difficult to make predictions about aquatic digging from general principles. Descriptions of aquatic digging behaviour, however, might suggest such general principles. Shovel-nosed lobsters (*Ibacus peronii*) live in sandy habitats, and anecdotes suggest that they dig using their "noses" (antennae) as shovels. *Ibacus peronii* in aquaria were videotaped digging into fine sand. Contrary to their suggestive name, shovel-nosed lobsters do not dig with their antennae. Instead, they use the legs to drive the abdomen into sand like a wedge. At the start of a digging sequence, digging behaviour consists of abdominal extension immediately followed by abdominal flexion. As digging continues, the behaviour becomes more complex, consisting of abdominal extension, repositioning the legs during extension, abdominal flexion, and pausing before the next abdominal extension. Digging occasionally ends with tailflips, which cause a small avalanche of sand that often covers the animal. *Ibacus peronii* are slow diggers, often requiring over four minutes to submerge (mean = 276.3 s; n = 9), suggesting that digging by wedging is mechanically inefficient. Although *I. peronii* can dig into a wide range of substrates, animals showed a statistically significant preference for fine sand (~0.3 mm diameter) over shell grit (~5 mm diameter) when presented with a choice between the two ($X^2 = 14.23$, $df = 1$, $p < 0.01$). Animals did not show a statistically significant preference for fine sand or coarse sand (~1 mm diameter) when presented with a choice between them ($X^2 = 1.48$, $df = 1$, $p = 0.22$). Research supported by NSERC (Canada).

66.9

FAUTH, J.E., OLESON, R., KAUP, D.J., MALONE, L.C., CLARKE, T.L.; jfauth@mail.ucf.edu. University of Central Florida
USING CROWD-CONTROL SIMULATIONS TO PREDICT THE
BEHAVIOR OF MOTILE ORGANISMS

Simulation is being used to develop crowd-control models to understand the collective behavior of pedestrians in the street or of people finding their way out of a room or building. The goal is to understand and modify crowd behavior to reduce fatalities during emergencies such as nightclub fires, stadium accidents, and subway or building bombings and other terrorist acts. While crowd-control models are useful for understanding and predicting human behavior, they also can be applied to other motile, multicellular organisms. For example, models can be developed to predict the behavior of animals using ecopassages, the outcome of complex interactions among competing organisms, or the spread of an invasive species. We expanded and generalized the pedestrian motion model by Helbing-Moln'ar-Farkas-Vicsek and used it to investigate a classic biological phenomenon: niche partitioning by salamanders along the streambank-forest floor ecotone. Our model contained four different classes of forces: 1) an action-reaction force between individual salamanders; 2) environmental forces acting on each individual; 3) preferred velocity of movement; and 4) goal forces that reflect movement of individuals toward preferred breeding sites and diurnal refuges. Each of these forces included both physical and social forces, the latter being an action-at-a-distance type force that reflects responses to visual and pheromonal cues. We evaluated model predictions by comparing substrate-choice selection of simulated salamanders with those of real salamanders interacting within experimental mesocosms. Simulations produced realistic salamander behavior, including non-overlapping territories and interspecific niche partitioning.

66.8

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A PRELIMINARY REPORT ON THE IMPORTANCE OF TERMITE
MOUNDS TO THE HERPETOFAUNA OF THE CERRADO OF
CENTRAL BRAZIL

Termite mounds are a distinctive component to the landscape of a variety of habitats worldwide, particularly xeric biomes. The microhabitat provides refuge for smaller wildlife via physical cover and in maintaining more constant internal humidities and temperatures than the surrounding environment. Through faunal rescue projects before and during hydroelectric power plant flooding episodes, we encountered a diversity of herpetofauna within termite mounds of the Serra Da Mesa region, Goiás, Brazil. The surrounding habitat type is known as Cerrado. Our observations led us to ask two questions. First, is there a difference between termite mound herpetofaunal biodiversity before as opposed to during hydroelectric power plant floods? We hypothesized that hydroelectric flooding of the habitat may drive organisms into the mounds for cover and increase their biodiversity during a flooding process. Second, what percentage of the regions herpetofauna normally inhabits termite mounds? We found moderate increases (up to 25%) in herpetofaunal biodiversity and increases in individual numbers during flooding periods. During non-flood periods, we found 23 species of amphibians and 41 species of squamate reptiles in termite mounds (50% and 39% respectively of all species recorded from the region). Our preliminary results suggest that termite mounds are an important resource for significant portions of the herpetofauna of the upper Tocantins River Valley, Goiás, Brazil.

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PRE-EXISTING SENSORY BIAS IN THE POECILIIDAE: ADDITIONAL INSIGHT FROM TWO *XIPHOPHORUS* SPECIES

Previous research has shown that sailfin mollies and guppies prefer red/orange colored objects in a non-mating context. As some guppies also have a mate preference for orange, it has been argued that this preference may have resulted from a sensory bias. That is, these species evolved female preferences for red-orange coloration through selection for other functions (e.g. feeding). Sensory biases may explain the initial evolution of a preference, however the preference could be further modified by natural selection on foraging behavior and/or through sexual selection. Here we further examine the generality of this bias in Poeciliidae, and investigate two species within the genus *Xiphophorus*, *X. cortezi* and *X. variatus*. It should be noted that both of these species have the potential for orange body coloration (i.e. trait). Chromatic preferences for eight differently colored discs were examined by measuring three variables: 1) entries into each color zone 2) duration of zone entries 3) pecks at colored discs. Our results indicate that *X. variatus* and *X. cortezi* do not prefer red and/or orange objects more than objects of other color and lack a specific color preference based upon zone entries and duration of zone entries. These results, in conjunction with previous work, are discussed in a phylogenetic context to address the possible presence of a pre-existing sensory bias within this system.

1.1

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WHEN PREY BECOMES PREDATOR: AN ONTOGENETIC SHIFT IN THE ROLE OF OLFACTION.

During development, sensory systems undergo changes in cell receptor machinery. Such modifications may alter the way an animal perceives its olfactory environment. Here we investigated a cannibalistic interaction between two discrete life history stages of the California newt (*Taricha torosa*). The chemical defense compound tetrodotoxin (TTX), in adult newt skin, is recognized by conspecific larvae as an alarm signal. Yet, alarm behaviors are suppressed when TTX is mixed with odors from alternative adult prey. In laboratory assays, newt larvae were exposed to TTX alone, or in binary mixtures with test compounds isolated from invertebrate prey tissues. Larval escape behavior in response to TTX (0.1 μ M) was significantly reduced when arginine (0.1 to 0.01 μ M) was added. Free-ranging adult newts were exposed to components of prey tissue extracts in the field. Arginine was the most effective feeding attractant, evoking plume-tracking behavior at concentrations as low as 10 nM. A comparable array of arginine analogs and TTX/arginine analog mixtures was tested on adults and larvae, respectively. Adult responses were eliminated by even slight alterations to arginine, such as the addition of a single carbon to the side chain or esterification of the α -carboxyl group. In contrast, larval alarm responses to TTX were inhibited by arginine as well as by analogs maintaining the guanidinium group. Thus, adults were narrowly tuned and larvae broadly tuned to arginine. These combined results show that arginine has opposing effects (inhibitory/stimulatory) on larval/adult newts, and apparently acts on different suites of olfactory receptors in the two life history stages.

15.11

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HOST RANGE EVOLUTION OF THE BACTERIOPHAGE Φ 6: ARE TRADE-OFFS REQUIRED?

Viral adaptation to novel hosts can alter fitness on other hosts, and this change depends on the host-specific effects that mutations exhibit. Here we show that mutants of the RNA bacteriophage Φ 6 that allow growth on the novel host, *Pseudomonas syringae* pv. *glycinea*, are most often costly for growth on the ancestral host, *P. syringae* pv. *phaseolicola*. We isolated a random sample of mutants which allowed growth on the novel host. We measured the fitness effects of these mutations on both the novel host, as well as the ancestral host. The majority of mutations which allow growth on the novel host come with a fitness cost on the ancestral host, although the other mutations allowing growth on the novel host have no inherent cost on the ancestral host. These results suggest that while adaptation to novel host types often has a fitness cost on other host types, such a cost is not a requirement for adaptation to novel host types. These results parallel other studies which have found that adaptation to novel environments often results in fitness losses in other environments.

14.10

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DO TELEOST FISHES WITH DIFFERENT MECHANISMS OF PREMAXILLARY PROTRUSION PRODUCE FUNCTIONALLY SIMILAR BEHAVIORS?

Premaxillary (upper jaw) protrusion in teleost fishes is a key innovation thought to improve prey-capture performance, although the mechanisms underlying this behavior are poorly understood. We examined phylogenetically disparate taxa representing three teleostean jaw protrusion types: *Danio rerio*, an ostariophysan (cypriniform type); *Gambusia affinis*, an atherinomorph (cyprinodontiform type); and *Betta splendens*, a percomorph (acanthopterygian type). The mechanism in *Danio* is independently derived, while the mechanism in *Gambusia* is likely secondarily derived from the acanthopterygian mechanism. Species were imaged capturing prey at 250-500 fps and cephalic movements quantified. *Danio* exhibit the least anterior protrusion of the premaxilla, and only produce half the displacement of other two species. The path of premaxillary protrusion is similar in *Betta* and *Danio*, with the jaw protruding anteriorly and slightly dorsally. In these two species the descending process of the premaxilla swings forward to occlude the sides of the open mouth creating gape profiles approaching 180 degrees. Absolute premaxilla displacement in *Gambusia* is similar to *Betta*, but protrusion occurs in an anterior-ventral direction and the descending process of the premaxilla does not swing anteriorly. We conducted an anatomical survey of taxa closely related to these three species to determine the generality of our findings, and to test the alternate hypothesis that these differences are specializations for feeding on particular prey. Our preliminary analysis suggests that these taxa are good representatives of the three modes of protrusion, irrespective of diet and habitat. Thus, we suggest that the differences among taxa may be functional consequences of differences in the underlying mechanisms of protrusion.

S2-1.6

FETCHO, J.R.; jrf49@cornell.edu. Cornell University
THE COMPARATIVE BIOLOGY OF SPINAL MOTOR NETWORKS IN ZEBRAFISH

After decades of work, the spinal motor networks for swimming and escape in fishes and amphibians are among the best understood motor circuits in vertebrates. These circuits in anamniotes have much in common, but linking their cell types to the circuits in amniotic vertebrates such as birds and mammals has been difficult. Recently a better understanding of the development of spinal cord is allowing us to link cell types broadly among vertebrates and to infer the likely evolutionary changes in networks. The development of spinal interneurons is directed by transcription factors that serve as markers of cell types across species. One good example is the neurons marked by the transcription factor engrailed-1 in different species. The engrailed-1 positive cells in zebrafish are a homogeneous multifunctional population of glycinergic ascending inhibitory interneurons that are rhythmically active during swimming and that play roles in sensory gating, as well as in shaping motor output through monosynaptic inhibitory connections with motoneurons and interneurons. Engrailed neurons in *Xenopus* tadpoles are strikingly similar in structure and function to those zebrafish. In mammals, the engrailed cells are morphologically similar to the zebrafish and *Xenopus* neurons early in life, but later form a functionally more heterogeneous population. Some of the engrailed positive neurons in mammals, such as the long-studied Renshaw cells, play a role that seems to reflect just one of the several roles of individual engrailed cells in zebrafish. The evidence suggests that a primitive multifunctional interneuronal class like that in anamniotes maybe have given rise to several more discrete populations of interneurons in amniotes, each with a more restricted functional role. The unification of cell types across species by transcription factors thus allows simple models such as zebrafish to inform studies of vertebrates more broadly.

26.1

FIELDS, P.A., STROTHERS, C.; peter.fields@fandm.edu. Franklin and Marshall College
MUSCLE-TYPE LACTATE DEHYDROGENASE OF THE GALAPAGOS MARINE IGUANA, *AMBLYRHYNCHUS CRISTATUS*, IS ADAPTED TO HIGH TEMPERATURE.

The Galapagos marine iguana, *Amblyrhynchus cristatus*, is unique among lizards in diving to forage. Air temperatures often exceed 40°C in the Galapagos; however, because of upwelling, sea surface temperatures can fall below 15°C. This temperature variability presents a challenge to the ectothermic *A. cristatus*, because it must be active in both environments. To determine whether this thermal variability has led to biochemical adaptation in *A. cristatus*, we compared kinetics and structure of the glycolytic enzyme muscle-type lactate dehydrogenase (A_4 -LDH) in *A. cristatus* and the congeneric green iguana, *Iguana iguana*. In addition, we examined kinetics and structure of the TCA enzyme citrate synthase (CS) in both species, to determine whether there were differences in temperature adaptation between aerobic and anaerobic pathways. The Michaelis-Menten constant (K_m) for pyruvate of *A. cristatus* A_4 -LDH was lower at every measurement temperature compared to the *I. iguana* ortholog, indicating adaptation to higher temperature in *A. cristatus*. In contrast, there was no difference in Arrhenius activation energy (E_a) between the two orthologs, and the *A. cristatus* A_4 -LDH was less thermally stable than the *I. iguana* enzyme. CS showed no difference in K_m of oxaloacetic acid or E_a between the two species, suggesting this enzyme has not undergone temperature adaptation in *A. cristatus*. An alignment of the 333 a.a. LDH-A monomers reveals four substitutions, of which two are non-conservative; there are two non-conservative substitutions between the 469 a.a. CS orthologs. Our results suggest that selection has favored optimization of anaerobic function to the marine iguanas warm terrestrial habitat, rather than to the cooler temperatures experienced during foraging dives.

38.2

FINKLER, M.S., GILLEM, A.D.; mfinkler@iuk.edu. Indiana University Kokomo
SEX-RELATED DIFFERENCES IN STORED ENERGY RESERVES IN SPRING-BREEDING HYLID FROGS

The energetic cost of reproduction may be considerably higher for females than for males, not only because of a difference in the amount of energy invested in the gametes but from indirect costs associated with maintenance of support tissues, elevated energetic cost of locomotion, etc. Here, we examined how differences in these reproductive costs might impact stored energy reserves (fat and glycogen) in males and females of two species of hylid frog: the spring peeper, *Pseudacris crucifer*, and the western chorus frog, *Pseudacris triseriata*. Although males of both species tend to be slightly smaller than females, their livers were generally larger than were those of females. Moreover, liver mass increased much more with increasing body size in males than in females. Likewise, the liver glycogen contents and carcass non-polar lipid contents were generally higher and increased much more acutely with increasing body size in males than in females. These findings suggest a greater depletion of stored energy reserves in females to fuel a higher pre-courtship energetic cost of reproduction through gamete formation. This in turn may have implications for survivorship during and after the reproductive season.

55.6

FISH, F.E., NUSBAUM, M.K., BENESKI, J.T., KETTEN, D.R., WILLIAMS, T.M.; ffish@wcupa.edu. West Chester University, Woods Hole Oceanographic Institution, University of California, Santa Cruz
DOLPHIN FLUKES AS PASSIVELY SELF-ADJUSTING FLEXIBLE PROPULSORS

The flukes are the main locomotor structure in cetaceans. Effective thrust generation is a function of the fluke kinematics, angle of attack, and fluke shape. We investigated the effect of bending within the caudal region of odontocete cetaceans to determine how changes in angular displacement between caudal vertebrae could effect passive shape change of the flukes. Lateral and posterior views from high-speed video of *Tursiops truncatus* freely swimming and statically pushing against a load cell showed substantial chordwise and spanwise fluke flexibility. Spanwise bending was restricted to the fluke tips. Fluke chord was maximally bent as the fluke changed vertical direction during the oscillatory cycle with a chord reduction of 31.6-35.1%. Internal and external changes of bent flukes were examined with CT scans. Flukes and tailstock were removed from deceased *Delphinus delphis*, *Lagenorhynchus acutus*, *Phocena phocena*, *Peponocephala electra*, and *Tursiops truncatus*, and bent on an adjustable support at 0, 45, and 90°. At 0°, flukes displayed symmetrical cross-sections. Cross-sections of bent flukes (45°, 90°) were asymmetrical and showed a cambered profile. Maximum cambering occurred close to the tailstock and decreased toward the fluke tip. Maximum angular displacement occurred at the ball vertebra, located posterior of the anterior insertion of the flukes on the tailstock. Bending at the ball vertebra passively cambers the flexible flukes. Cambering could increase thrust generation during swimming, particularly during direction reversal in the oscillatory cycle. In addition, bending at the fluke tips would act like winglets to control tip vortices, enhancing thrust production and hydrodynamic efficiency.

S7-2.6

FLATT, T.; Thomas.Flatt@Brown.Edu. Brown University
JUVENILE HORMONE AS AN EFFECTOR OF METAMORPHOSIS AND LIFE HISTORY TRANSITIONS

Hormones, regulatory signaling molecules that coordinate multiple developmental and physiological processes, commonly play central roles in the coordination of life cycles, both among and within species. Life history transitions, for instance from larva to adult or from a non-reproductive to a reproductive state, are typically controlled by hormones, and genetic correlations and trade-offs among life history traits are often hormonally mediated. Some of the best examples for such integratory and modulatory endocrine effects are provided by the lipid-like juvenile hormones (JHs) in insects. JHs are now known to affect a remarkable number of processes and traits, including metamorphosis, behavior, reproduction, morphological polyphenisms, diapause, stress resistance, and aging. In my talk I will review and illustrate the manifold effects of JHs, the probably most versatile animal hormones, with an emphasis on the fruit fly *Drosophila melanogaster*, an organism amenable to both genetics and endocrinology. In particular, I will highlight the role of JH in modulating life history transitions in *Drosophila* and other insects. Evolutionary modifications of JH signaling have played a key role in the evolution of insect metamorphosis and life history. While JHs are most well known for their inhibitory effects on preadult development and metamorphosis, these functions are clearly evolutionarily derived. I will discuss potential ancestral roles of JHs and why JHs might have been co-opted for metamorphic regulation. I will argue that understanding how hormones regulate particular life history transitions such as metamorphosis might help us to understand how hormones regulate life history transitions in general.

20.5

FOLK, D.G., GILCHRIST, G.W.; dgfolk@wm.edu. The College of William and Mary
HEAT-SHOCK RESPONSE AND LOCOMOTORY PERFORMANCE IN *DROSOPHILA* POPULATIONS SELECTED FOR DIVERGENT KNOCKDOWN TEMPERATURES

The thermal environment has a critical influence on the physiological performance of all organisms. To study the impact of temperature change on performance, we have generated replicate lines of *Drosophila melanogaster* that are selected for high or low knockdown temperature (T_{KD}) - that temperature at which flies lose the ability to remain upright or locomote. The up-selected T_{KD} lines (N=4) lose these abilities at $\sim 41^{\circ}\text{C}$, while the down-selected T_{KD} lines (N=4) lose them at $\sim 38^{\circ}\text{C}$. We hypothesize that divergence in the rate of heat shock protein (Hsp) induction and/or the magnitude of the Hsp response at stressful temperatures may mediate the evolved differences in thermotolerance. We present here a temporal profile of induced-Hsp70 expression in the high and low T_{KD} lines following exposure to different periods of heat stress (i.e., 36°C at 10, 20, 30, or 60 minutes). Our data indicate that the high and low T_{KD} lines have evolved divergent patterns of induced-Hsp70 expression in response to a heat pulse. Inducible Hsps, in particular Hsp70, lower synaptic thermosensitivity and protect synaptic function, and presumably locomotory performance, during periods of thermal stress in *Drosophila*. To examine the ability of Hsp70 to protect locomotory performance in our selected populations, we exposed the high and low T_{KD} lines to 36°C for 1 h (followed by 25°C for 1 h) prior to measuring knockdown temperature. We then determined if such a pretreatment, which typically induces Hsp70 expression, allows the flies to remain upright and/or to fly at temperatures significantly higher than their characteristic T_{KDs} .

59.3

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REPRODUCTIVE RESPONSES TO EXPERIMENTALLY REDUCED NEST PREDATION RISK

The reproductive strategy that an individual adopts has long term fitness implications for itself and its offspring. These fitness consequences result in strong selection to express optimal life history and parental care behaviors. Yet, while there is clear variation in reproductive strategies both within and among species, little is known about what environmental factors lead to this variation. For the first time we provide clear experimental evidence that variation in the risk of juvenile mortality across landscapes can induce parents to alter their reproductive strategy. Parents of twelve species of passerine birds exposed to environments with experimentally reduced juvenile predation risk altered their reproductive strategy by increasing their investment in important life history traits such as egg size and clutch mass, as well as altering a suite of parental care behaviors.

54.3

FORD, D.K., HOLLIDAY, C.M.; df362190@ohio.edu. Ohio University, Athens
AN INVESTIGATION INTO THE EFFECTS OF PCB 126 ON BONE DENSITY IN TURTLES

Bone is a metabolically active tissue functioning as a physiological mineral reservoir while also providing support and defense for the organism. However, the physical properties of skeletal tissues may be affected by environmentally available endocrine disrupting compounds (EDCs). PCB 126 is an EDC known to decrease bone density in laboratory rats. Forty-four, 8-month-old, male, *Malaclemys terrapin* (diamondback terrapin) individuals were either treated with PCB 126 or left untreated. Euthanized turtles were screened via X-ray film radiography and image analysis (ImageJ, v1.33) for gross contaminant effects. Based on grayscale pixel values, we observed significant differences in skull, carapacial, and appendicular relative bone density. A subset of heads was subsequently hi-res CT-scanned and voxels were analyzed as a proxy for relative bone density in Amira (v3.0) 3D imaging software. CT data confirmed grayscale density interpretations that PCB-exposed turtles had lower bone density, but these data also revealed density differences among specific head skeletal elements. In addition, general osteological features of the skulls, regardless of treatment, demonstrated that the epipterygoid, prootic, and facial skeleton were markedly denser than the other cranial regions. Ashed heads complemented the image data, showing a significant reduction in head organic content. Overall, turtles exposed to PCB 126 exhibited significantly reduced bone density. Though preliminary, these data suggest researchers should be wary of these emergent ecotoxicological effects because contamination-induced metabolic bone disease could affect interpretation of developmental stages, performance, and overall organismal fitness.

63.5

FRANCIS, A.W.; francis@sigmaxi.org. Villanova University
PHYLOGENY AND FEEDING BIOMECHANICS OF PLEURONECTIFORM FISHES

Mechanical advantage of lower jaw depression and elevation was determined for five families and 10 genera of pleuronectiform fishes. Of the 11 species examined, five were sinistral and six dextral. Mechanical advantage for both lower jaw depression and elevation was lowest for species of Psettodidae and Paralichthyidae. For species of Pleuronectidae, Achiridae, and Cynoglossidae, mechanical advantage of lower jaw depression and elevation was greater. When bilateral measurements of mechanical advantage were compared, opening and closing lever ratios for the ocular side (left in sinistral species and right in dextral species) were always greater than the opposing blind side. Thus, greater speed is generated on the ocular side while greater force is generated on the blind side for all pleuronectiforms examined. The phylogenetic pattern is for basal pleuronectiforms, like Psettodidae and Paralichthyidae, to generate greater force at the tip of the lower jaw by both ocular and blind sides when opening and closing the mandible in pursuit of fish. For more derived pleuronectiforms, like Pleuronectidae, Achiridae and Cynoglossidae, the lower jaw of both ocular and blind sides opens and closes rapidly in pursuit of benthic invertebrates. Thus, there appears to be a shift from basal force generating piscivores to derived velocity generating invertebrate feeders. This trend is also reflected in the degree of asymmetry between ocular and blind side mechanical advantage, with the least asymmetry in more basal pleuronectiforms and greatest in more derived pleuronectiforms.

24.4

FRANZ-ODENDAAL, T.A.; tfranzod@dal.ca. Dalhousie University, Nova Scotia, Canada
GROWTH, DEVELOPMENT, CONSTRAINT AND VARIATION OF THE SKELETAL ELEMENTS WITHIN THE TELEOST EYE

The sclera plays a supportive role in all vertebrate eyes and usually contains two skeletal elements. In bony fish (Teleostei) the scleral cartilage is restricted to an equatorial ring, unlike the situation in tetrapods. Some teleosts (not all) also undergo ossification in the anterior and posterior regions of this ring; these elements are the scleral ossicles. Basal Actinopterygii have a sclerotic ring composed of four elements, not two. A large scale analysis of whole-mount stained bony fish as well as radiographs were examined in order to determine variation and/or constraint of the scleral ossicles and scleral cartilage across living teleost groups, as well as whether there is any correlation between phylogenetic distribution and presence/absence of scleral ossicles. A closer examination of these elements in zebrafish (*Danio rerio*) and the alewife (*Alosa pseudoharengus*) was conducted, which included examination of growth series and histological sections. Results indicate that the shape of the scleral cartilage is uniform across the over 400 species examined. The shape and size of the scleral ossicles are however variable, although their number is highly constrained. Presence/absence of ossicles does not correlate with phylogenetic distribution. Results from the alewife, which has large scleral ossicles compared to zebrafish, show that eye diameter measured against body length shows allometric growth; the scleral ossicles increase in size (length) in proportion to eye growth. Histological analyses revealed some insights into the mode of ossification of the scleral ossicles in teleost eyes.

37.2

FRENCH, S.S., MOORE, M.C.; ssfrench@asu.edu. Arizona State University
IMMUNE AND REPRODUCTIVE SYSTEMS COMPETE FOR RESOURCES IN FEMALE TREE LIZARDS (*UROSAURUS ORNATUS*)

When resources are scarce, organisms are faced with critical challenges trying to optimize competing vital functions. Key among these competing processes are reproduction and immune function. However, few studies have directly demonstrated competition for resources between these two processes. We performed a series of experiments in female tree lizards (*Urosaurus ornatus*), which demonstrated that resource availability drives the trade-off between the reproductive and immune systems. We found that animals on *ad libitum* food were able to sustain both reproduction and immune function whereas animals maintained on a restricted, maintenance diet were not. Specifically, food restricted animals forced to invest in reproduction via FSH injections showed a decreased immune response and food restricted animals forced to mount an immune response showed decreased reproductive investment. These experiments clearly demonstrate resource competition between reproduction and immune function. They further emphasize how resource availability can affect life-history trade-offs.

S3-2.6

FULL, R.J.; rjfull@berkeley.edu. University of California, Berkeley
PRINCIPLES OF NEUROMECHANICS: INTEGRATION OF EXPERIMENTS, MATHEMATICAL AND PHYSICAL MODELS

Locomotion results from high-dimensional, dynamically coupled interactions between an organism and its environment. Fortunately, simple models we call templates can resolve the redundancy of multiple legs, joints and muscles. A template is the simplest dynamical system model that exhibits a targeted behavior. For example, diverse species that differ in leg number and posture run in a stable manner like sagittal- and horizontal-plane spring-mass systems. Templates must be grounded in more detailed models to ask questions about multiple legs, the joint torques that actuate them, the recruitment of muscles that produce those torques and the neural networks that activate the ensemble. We term these more elaborate models anchors. Since mechanisms require controls, anchors incorporate hypotheses concerning the manner in which unnecessary motion or energy from legs, joints and muscles is removed, leaving behind the behavior of the body in the low-degree of freedom template. Guided by direct experiments on many-legged animals, mathematical models and physical models (robots), we postulate a hierarchical family of control loops that necessarily include constraints of the body's mechanics. At the lowest end of this neuromechanical hierarchy, we hypothesize the primacy of mechanical feedback neural clock excited tuned muscles acting through chosen skeletal postures. On top of this physical layer, we hypothesize sensory feedback driven reflexes that increase an animal's stability further and, at the highest level, environmental sensing that operates on a stride-to-stride timescale to direct the animal's body. The challenge of neuromechanical integration demands an interdisciplinary effort to match data systematically across mathematical models, numerical simulations, physical models, as well as biological experiments.

68.8

FULLER, R.; fuller@life.uiuc.edu. University of Illinois
TESTING THE ASSUMPTIONS OF THE SENSORY BIAS MODEL

The sensory bias hypothesis proposes that natural selection on non-mating behaviors (e.g. foraging, anti-predator behavior, etc.) results in correlated responses in female mating preferences due to the fact that the behaviors share a common sensory system. I tested the conditions under which these predictions are upheld using a neural network model. In my simulations, I selected for foraging preferences for red food items (over yellow or blue food items) and examined the effects on female mating preferences for red, yellow or blue males. Small correlated effects occur under some (but not all) conditions. The extent to which such conditions can be expected in nature and the implications for the evolution of mating preferences will be discussed.

68.1

FUXJAGER, M.J., MANGIAMELE, L.A., DAVIDOFF, K.R.B., LOHMANN, K.J.; mattjfe@email.unc.edu. University of North Carolina, Chapel Hill

EFFECTS OF THE MAGNETIC ENVIRONMENT OF SEA TURTLE NESTS ON MAGNETIC ORIENTATION BEHAVIOR IN HATCHLINGS

Magnetic orientation has been documented in numerous animals, yet little is known about the ontogeny of magnetic sensing abilities. We studied whether the magnetic environment in which loggerhead sea turtle (*Caretta caretta*) hatchlings develop affects their subsequent magnetic orientation behavior. Clutches of eggs deposited by nesting females on the beach were permitted to develop in one of two ambient magnetic fields. Half of the clutches were subjected to an altered magnetic field generated by an array of magnets buried around the eggs. The field at different locations within these nests ranged from approximately 1-7 times Earth-strength. The other half of the clutches were treated identically, but surrounded by an array of non-magnetic aluminum bars so that the eggs developed in the natural ambient magnetic field. Hatchling turtles from both groups were subjected to several behavioral assays designed to assess both their orientation behavior and general health. The results indicated that developing in an altered magnetic field affected the way in which hatchlings responded to a regional magnetic field that exists along their migratory route and is normally used as an open-sea navigational marker. However, turtles that developed in the altered field did not differ from controls in other assays of orientation behavior and health unrelated to magnetic field perception. The findings imply that the magnetic environment in which sea turtles develop affects subsequent magnetic orientation behavior and may also affect their ability to exploit the Earth's magnetic field as a navigational marker during their trans-Atlantic migration.

64.3

GALIS, F., VAN DOOREN, T.J.M., METZ, J.A.J., WITKAM, A., WIJNAENDTS, L.C.D.; galis@rulsfb.leidenuniv.nl. Leiden University, The Netherlands, Free University Medical Centre, Amsterdam
THE COORDINATED PATTERNING OF THE EMBRYONIC AXES AND THE CONSERVATION OF THE SEVEN CERVICAL VERTEBRAE

The number of cervical vertebrae is extremely conserved in mammals. Yet, studies on fetal deaths in humans show that new mutants with an effect on this number are common. This indicates that evolutionary conservation is caused by strong stabilizing selection. The cause for the selection appears to be that mutations with an effect on the number of cervical vertebrae almost invariably lead to deleterious pleiotropic effects in other parts of the body. Changes in the number of cervical vertebrae usually involve homeotic shifts of several cervical and thoracic vertebrae. These shifts are due to changes in the early antero-posterior (A-P) patterning of the paraxial mesoderm. Normal metazoan development requires the coordinated patterning of the embryonic axes in all germ layers. Our working hypothesis is that the high interactivity during the early patterning of the axes lies at the core of the conservation of the number of cervical vertebrae. We will discuss to which extent data on human fetuses support our working hypothesis.

67.9

GATESY, J., DEMERE, T., MCGOWEN, M., BERTA, A.; john.gatesy@ucr.edu. University of California, Riverside, San Diego Natural History Museum, San Diego State University
STEPWISE EVOLUTION OF FILTER FEEDING IN BALEEN WHALES

Synthesis of molecular and paleontological data can offer unique insights into the history of complex adaptations. Here, we use a combined phylogenetic analysis of morphological traits and sequence data from the mitochondrial and nuclear genomes to track a major evolutionary transformation in Mysticeti (baleen whales). The origin of baleen and the loss of teeth are correlated with the evolution of obligate filter-feeding in mysticete whales. The transition from tooth-bearing jaws to the edentulous, baleen-lined upper jaws of extant mysticetes, however, was not accomplished in a single evolutionary step. New evidence from the late Oligocene toothed mysticete *Aetiocetus weltoni* documents the presence of palatal nutrient foramina in this archaic taxon; similarly placed palatal foramina house vessels that nourish baleen in extant mysticetes. In the context of our combined phylogenetic analysis, these observations suggest that baleen existed in concert with functional teeth in *Aetiocetus* and likely other basal Mysticeti. To supplement the fossil data, we sequenced three genes critical to the production of dentine/enamel from extant mysticetes and outgroup taxa. *Enamelin* and *ameloblastin*, which are expressed in developing enamel tissue of mammals, have nonsense mutations in several baleen whale lineages and apparently are non-functional. Simultaneous phylogenetic analysis of paleontological and molecular data implies that early toothed mysticetes evolved baleen and that the mineralized adult dentition was subsequently lost over a span of several million years in one clade of Mysticeti, resulting in extant baleen whales which are left with degenerate enamel genes and rudimentary, embryonic tooth buds.

71.3

GAVAND, M., MCCLINTOCK, J.B., AMSLER, C.D., PETERS, R.W.; meghana@uab.edu. University of Alabama at Birmingham
THE USE OF SONICATION AND ADVANCED CHEMICAL OXIDANTS AS MECHANISMS TO ERADICATE MACROINVERTEBRATES IN BALLAST WATER UNDER STATIC AND CONTINUOUS FLOW REGIMES

Ballast water is a major contributor to the introduction of invasive invertebrates. Using an invertebrate model system with three discrete life history phases, cysts, naupliar larvae, and adults of the brine shrimp *Artemia salina* were subjected to single and combined treatments of sonication and advanced chemical oxidants (hydrogen peroxide and ozone) under both static and continuous flow regimes and over different time periods. Combinations of sonication (1.4 kHz) coupled with hydrogen peroxide (100 ppm) and ozone (100 ppm) were synergistic and resulted in mortality levels of 66% (3 min exposure), 100% (2 min exposure) and 100% (3 min exposure) for cysts, larvae and adults, respectively, under both static and continuous flow conditions. Exposure of cysts, larvae and adults to single treatments of sonication or advanced oxidants were less effective and required significantly greater periods of exposure to approach inactivation levels seen in combined treatments. These findings indicate that different life history phases of a macroinvertebrate model organism are inactivated over different time courses but that acoustic cavitation combined with advanced chemical oxidants may be an effective method to eradicate even the most resistant life phases (e.g. cysts) of macroinvertebrates in ballast water. Supported by a grant from the US Fish and Wildlife Service to R. W. Peters, C. D. Amsler, and J. B. McClintock.

35.6

GEE, J.M.; jmg233@cornell.edu. Cornell University
IEG AND BEHAVIORAL RESPONSE TO CONSPECIFIC AND HETEROSPECIFIC CALLS IN HYBRIDIZING AVIAN SPECIES, CALIFORNIA AND GAMBEL'S QUAIL

Divergence in characters that determine choice of mate, such as song, is central to the process of speciation in birds. Prior to complete speciation, preference for song may vary among individuals within a single population. Early experience with song of a particular species may contribute to this variation. This study will determine whether exposure to heterospecific song alters behavioral responsiveness and neuronal activation to heterospecific and conspecific song. In birds that learn their songs (songbirds), exposure to particular song results in both a behavioral preference for that song as well as upregulation of the immediate early gene (IEG), ZENK. In Gambels and California quail, which are non-songbirds with differing calls, hybridization occurs under natural conditions. I reared Gambels quail either with only Gambels quail or with both California and Gambels quail. I scored behavioral preference of Gambels quail that were presented with a choice each of possible pairings of the following acoustic stimuli: Gambels quail calls, California quail calls, or control tones. After rearing treatment and preference testing, I examined ZENK expression in adults that were exposed for 45 minutes to a single acoustic stimulus. Neural regions of interest include the caudal medial nidopallium (NCM), the nucleus preopticus medialis (POM) and the nucleus striae terminalis (BST). The potentially labile nature of song preference permits shifts in song preference to sweep throughout a population, which may lead to rapid evolutionary changes, from hybridization and its consequences, to speciation.

S7-1.4

GEORGIU, C.D.; c.georgiou@upatras.gr. University of Patras
SCLEROTIAL MORPHOGENESIS IN FUNGI IS INDUCED BY OXIDATIVE STRESS

Sclerotium-forming fungi are very important plant pathogens with great biological interest because they can be viewed as models of primitive morphogenesis. They differentiate by asexually producing sclerotia which are usually spherical bodies of aggregated hyphae. In spite of the biological, ecological and agricultural significance of these fungi, the processes involved in their morphogenesis were poorly understood. In 1997, I showed that sclerotium formation in *Sclerotium rolfsii* was accompanied by high levels of lipid peroxidation, a well-established oxidative stress indicator. This finding prompted me to introduce a hypothesis, supporting that sclerotial morphogenesis is induced by oxidative stress. This theory predicts the following: a) Growth factors that eliminate or promote oxidative stress are expected to inhibit or promote sclerotium morphogenesis, respectively. b) Natural or artificial antioxidants and oxidants that eliminate or promote oxidative stress should inhibit or promote sclerotium morphogenesis, respectively. c) High and low oxidative stress growth conditions should increase and decrease the formation of natural antioxidants, respectively. These assumptions have been verified by a series of published data on the effect of certain hydroxyl radical scavengers on sclerotial morphogenesis, on the identification and quantification of certain natural antioxidants (such as vitamin C, beta-carotene) in relation to the fungal undifferentiated and differentiated stages, and on their effect as growth nutrients on sclerotial morphogenesis. Experiments are underway on the role of glutathione, hydrogen peroxide and superoxide radical on sclerotial morphogenesis. The implications of the oxidative stress-induced sclerotial morphogenesis theory may be extended to the use of antioxidants as non-toxic alternatives to classical fungicides.

1.5

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PRE-HATCHING ESCAPE BEHAVIOR IN THE RAINBOW TROUT

Teleost fishes employ diverse developmental strategies that have direct consequences on the ability to perform certain behaviors. *Danio rerio*, zebrafish, have indirect development, where embryos hatch within four days of spawning, and skeletal elements of the cranium and fins are unformed. In contrast, *Oncorhynchus mykiss*, rainbow trout, have intermediate development, where embryos hatch 35 days after spawning, and skeletal elements of the cranium and fins are well formed. After hatching, both species produce an effective escape response that moves the fish's center of mass away from potential predators. Previous research on decapsulated (i.e., the chorion is artificially removed) zebra fish embryos demonstrated that a coordinated escape response behavior appears at approximately the same time as hatching. Given the advanced state of morphological development of the rainbow trout, we predicted that an effective escape response would appear well before hatching in this species. To test this prediction, we decapsulated rainbow trout embryos from as early as five days before hatching and solicited escape responses. Surprisingly, the pattern we observed for rainbow trout was similar to that seen in zebrafish: uncoordinated movements occurred in the days before hatching, and an effective escape response only appeared within the 24 hours before hatching. Thus, the development of this particular behavior is uncoupled from development of the skeletal system. Given the advanced state of development of rainbow trout at hatching, it is likely that the elements of the neural pathway that enable the escape response (e.g., sensory, Mauthner and motor neurons) develop well before hatching. However, this pathway only produces a coordinated and effective escape behavior at hatching, when it is useful to the organism.

67.4

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CONSEQUENCES OF RECENT SECONDARY CONTACT BETWEEN LINEAGES OF *AMEIVA CHRYSOLAEMA* IN THE DOMINICAN REPUBLIC

Historic climate fluctuations have been implicated as playing a significant role in structuring genetic variation within and between species. Repeated expansion and contraction of organismal ranges has caused many instances of secondary contact among divergent population lineages or species. Upon secondary contact these lineages may either maintain their identity due to evolved differences in allopatry or begin to merge and become a single lineage. In this study we use a multilocus approach to examine the consequences of a recent secondary contact between lineages of *Ameiva chrysolaeama*, a large teiid lizard from Hispaniola. In addition, morphological variation is examined across the contact zone to test whether the patterns of variation observed are consistent with a prevailing environmental gradient. By comparing morphological and molecular cline shapes, we examine the relative role of environmental variation in maintaining each cline. These data represent preliminary analyses of a portion of the present author's Ph.D. thesis.

45.4

GIGNAC, P.M., PRIETO-MARQUEZ, A., ERICKSON, G.M., JOSHI, S.H.; pgignac@bio.fsu.edu. Florida State University, Tallahassee

TESTING THE UTILITY OF OSTEOLOGICAL CORRELATES PURPORTED TO REFLECT GENDER IN NON-AVIAN DINOSAURS

Gender in non-avian theropod dinosaurs has been inferred using attributes in the pelvic girdles and tail skeleton that are presumed to be sexually dimorphic. In theory, wider pelvic canals and shorter, more caudally positioned first chevrons in females act to facilitate the passage of eggs through the cloaca. In contrast longer, more cranially positioned first chevrons in males afford ample attachment area for the penile retractor musculature. The American alligator, *Alligator mississippiensis*, has for the most part served as the model taxon for these sexual phenotypes. Nevertheless, little or no quantitative data has been presented showing that these phenotypes truly exist. Here we used wild-caught skeletons of *A. mississippiensis* and the squamate *Iguana iguana* to test whether gender specific morphological differences truly exist in these dinosaurian outgroups. A preliminary sampling of 17 females and 19 males of *A. mississippiensis* and 13 females and 7 males *I. iguana* were examined. Measurements of the pelvic canal area, dorsoventral height and mediolateral width of the pelvic canal, height between the dorsal edge of the ilium and the ventral border of the ischium, and lengths and positions of haemal arches 1 and 2 were made. In addition, a new method of shape analysis (Geodesic Distance Analysis) was used to test for morphological differences in the pelvic canal profile. ANCOVA was used to analyze both the data from measurements and the Geodesic Distance Analysis. No significant correlation between sex and pelvic girdle morphology, chevron length, or position was found. Assertions that the gender of dinosaurs can be assessed based upon osteological differences in the pelvic girdles and caudal axial skeleton were not supported.

5.1

GILL, S.A., ALFSON, E.D., HAU, M.; sagill@Princeton.EDU. Princeton University

THE MYTH OF THE PASSIVE SEX: HORMONAL CONTROL OF FEMALE AGGRESSION IN A YEAR-ROUND TERRITORIAL BIRD

The hormonal control of territorial aggression in female vertebrates is still unclear. We therefore studied buff-breasted wrens (*Thryothorus leucotis*), a resident of the neotropics, in which females aggressively defend the territory year-round. We asked whether (1) females distinguish between the sex of the intruders in their aggressive responses, (2) female aggression differs between pre-breeding and breeding periods, and (3) steroid hormones were correlated in either period with female aggression. We conducted simulated territorial intrusions (STIs) with live female, male or paired decoys combined with playback of song to free-living pairs of wrens in central Panama. Females displayed robust aggressive responses to all stimuli, but responded more intensely to female decoys than either male or paired decoys. Response intensity did not differ between pre-breeding and breeding periods. Following STIs, most females had detectable plasma concentrations of testosterone (T), 5 α dihydrotestosterone (DHT), and dehydroepiandrosterone (DHEA), whereas estradiol was undetectable in most females. T concentrations following female STIs were elevated in females tested during the pre-breeding season relative to when they were caring for young and relative to control females. T and DHT concentrations were correlated, but neither DHT nor P varied predictably between seasons or stimuli. DHEA was present in the highest concentration of any steroid hormone, and may be an important precursor of sex steroids for regulation of year-round territoriality in females. Our results suggest that both T and DHEA may play a role in facilitating aggression in female buff-breasted wrens.

S6-1.1

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EVOLUTION AND FUNCTION IN SEROTONERGIC SYSTEMS

Serotonin was first identified as a neurotransmitter in clams, and then mammalian brain. The history of its evolution as an intercellular messenger and CNS neurotransmitter is only recently begun to be appreciated through comparative studies of vertebrates and invertebrates. Lophotrochozoans (snails and leeches), insects and decapod crustaceans have been intensively studied for the past five decades as accessible model systems for studying neural bases of behavior. A natural fallout has been the accumulation of a broad base of knowledge of the chemistry and functions of serotonin in neural networks. Parallels and contrasts can be drawn for the anatomy and neuropharmacology of serotonin in the protostome invertebrates and mammals that suggest considerable serotonergic function has been conserved, despite marked divergence in anatomy and behavior. Integrative, comparative studies of the neurotransmitter can yield insight for how its contemporary roles in behavior and development arose.

13.10

GILLIS, G.B.; ggillis@mtholyoke.edu. Mount Holyoke College
STRAIN AND ACTIVATION IN THE THIGH MUSCLES OF GUINEA PIGS DURING LEVEL, INCLINE AND DECLINE LOCOMOTION

There is a well-documented relationship between body size and limb posture in mammalian quadrupeds. Larger animals adopt a more upright limb configuration during locomotion whereas smaller animals limbs are held in more flexed positions. It is unclear whether these differences in limb posture impact the strain regimes of the underlying muscles. To address this issue, the actions of homologous muscles in animals of different size must be compared. In this study, sonomicrometry, electromyography and high-speed video are used to characterize the patterns of length change and muscle activity in two muscles of the guinea pig hindlimb: the vastus lateralis, a knee extensor, and the anterior biceps femoris, a hip extensor. These data can be compared to data from the same muscles in other mammalian species to determine if a pattern between size and muscle function emerges. In the guinea pig, both the biceps and vastus are activated near the start of stance in each stride and activity extends through 70-80% of stance in both muscles. EMG intensity increases with locomotor speed, and at a given speed, is highest on an incline and lowest on a decline. Strain in the biceps consists mainly of shortening during stance (14-17% of rest length) as the hip joint extends. The vastus undergoes a stretch-shorten cycle during stance as the knee flexes then extends. The amount of stretching and shortening are nearly equivalent (6-10% of rest length). When compared to other taxa, guinea pig EMG patterns are comparable for both muscles, as are strain regimes in the biceps. However, vastus strain patterns appear to differ among animals of different size, with smaller animals (e.g., rats and guinea pigs) exhibiting as much or more stretching than subsequent shortening during stance and larger animals (e.g., goats, dogs and horses) more shortening than initial stretching.

BA.

Gillooly, J.; University of Florida
THE GEORGE A. BARTHOLOMEW AWARD LECTURE: LINKING BIOLOGICAL CURRENCIES IN ECOLOGY AND EVOLUTION

Metabolic rate sets the rates of resource uptake from the environment, and resource allocation to survival, growth, and reproduction. It provides a basis for using first principles of physics, chemistry, and biology to link the biology of individual organisms to the ecology and evolution of populations, communities, and ecosystems. Here I present a model for how metabolic rate varies with body size and temperature. This model can be extended to predict other ecological and evolutionary rate processes at higher levels of organization, including rates of population growth, food web dynamics, and rates of nutrient cycling in ecosystems. I will give two examples by showing how this model can predict rates of molecular evolution, as well as the storage and flux of phosphorus in organisms. I will conclude by speculating how metabolic theory can provide other insights into the structure and function of ecological communities.

32.3

GILMAN, C., WOLF, B.; cgilman@unm.edu. University of New Mexico
LIZARDS, EGGS, AND ULTRASOUND: TESTING THE EFFICACY OF QUANTIFYING REPRODUCTIVE EFFORT IN SQUAMATE REPTILES USING PORTABLE ULTRASONOGRAPHY

Most studies of reproductive effort in lizards have required that individuals be sacrificed to obtain population level data on life history traits such as clutch and egg size. While this approach provides insight into population level life history traits it precludes a critical examination of individual performance over both intra-annual and inter-annual time scales. These insights are crucial for broader knowledge of how individuals allocate resources to reproduction over varying lifetimes in the face of environmental variation. In this study we validated the use of a laptop sized portable ultrasound system as a nondestructive means of quantifying reproductive investment in five species of lizards with a range of body sizes, forms, and life histories. We present data from 46 gravid females in sizes and forms ranging from *Uta stansburiana* to *Crotaphytus collaris* and *Phrynosoma cornutum*. Lizards were scanned live while mechanically restrained, and egg number and dimensions were measured and recorded using virtual calipers. Observations were then validated by sacrifice and dissection. We found that for most species ultrasound scans produced egg counts that deviated from the true counts by 0.19 ± 1.12 SD for clutch sizes of 2 to 9 (mean 4 ± 1.34 SD) and 2.50 ± 6.77 SD for clutch sizes of 18 to 41 (mean 26 ± 9.15 SD). Egg measurements using the virtual calipers produced clutch volume measurements that deviated from the true measurements by 0.24 ± 0.99 SD cm^3 over clutch volumes ranging from 0.07 to 10.76 SD cm^3 (mean 2.24 ± 2.632 SD cm^3), and 2.03 ± 6.28 SD cm^3 over clutch volumes ranging from 0.58 to 20.26 SD cm^3 (mean 10.85 ± 8.35 SD cm^3). This study shows that ultrasonography in the field is a viable nondestructive method for quantifying reproductive effort in lizards.

S4.6

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FUNCTIONAL LINKS AMONG LIFE PHASES AND THE CONSEQUENCES FOR INDIVIDUAL PERFORMANCE IN DECAPOD CRUSTACEANS

I review the effects of past environmental conditions on traits and performance in decapod crustaceans. I consider two critical points of the life cycle: the hatching of larvae and the metamorphosis to the juvenile phase. Biomass at hatching, larval developmental rates, and tolerance to food limitation are positively correlated with egg biomass. In estuarine crabs, larval performance may result from the combined effects of osmotic conditions on the allocation of reserves per egg, the loss of biomass during embryogenesis, and the acclimation state of individuals. The ability to acclimate varies intraspecifically, among broods from different estuaries. Effects of larval environment on performance of juveniles may occur as the consequence of responses to parental habitat cues or variable larval development. Lack of parental cues leads to a delay in the metamorphosis, to reduced size and biomass. Variability in larval development, i.e. the existence of alternative developmental pathways with varying number of stages, produces a complex effect. Longer pathways are followed more frequently if larvae hatch with low biomass or if they experience food or osmotic stress. Larvae following a long pathway may metamorphose later but with an increased size and biomass, and a high tolerance of food limitation. Field-oriented approaches to evaluate the effects of past environmental conditions on present performance are, in decapod crustaceans, indeed a great challenge due to the mobility of most of the life stages. Ongoing research in this topic evaluates the natural patterns of variability in quality of settling larvae, and the consequences for juvenile survival and growth.

64.4

GIRIBET, G., EDGEcombe, G.D., KRISTENSEN, R.M., MARTINDALE, M.Q., SEAVER, E.C., SORENSEN, M.V., ROUSE, G.W., WHEELER, W.C.; ggiribet@oeb.harvard.edu. Museum of Comparative Zoology, Harvard University, The Australian Museum, Zoological Museum, University of Copenhagen, Kewalo Marine Laboratory, University of Hawaii, University of Copenhagen, South Australian Museum, American Museum of Natural History
ASSEMBLING THE PROTOSTOME TREE OF LIFE

Protostomes comprise more than 95% of extant animal diversity. Here we will present our NSF ATOL research grant to integrate and disseminate the broadest possible collection of information on selected representatives of all protostome phyla to address questions of their origin and evolution over more than 540 million years. To do this, we sampled multiple evolutionary lineages of extant taxa from each protostome phylum and relevant extinct Cambrian, Ordovician, and Silurian fauna. From these taxonomic samples, we have extracted broad-based genomic information derived from PCR, rt-PCR and EST techniques, and integrate these sequence data with new ultrastructural, fine anatomical, and developmental data using gene expression approaches as well as cell-lineage studies and 4D-microscopy. Such a large and diverse data set (ca. 250 taxa, 20 Kb per specimen, ca. 500 morphological characters and complex developmental variants) will require novel and intensive databasing tools (for reliable storage and retrieval of information) and computational approaches. Extensive fieldwork is being conducted to collect high quality fresh material suitable for developmental, ultrastructural, and molecular analysis. This multidisciplinary approach to the problem of protostome evolution should yield a result of high stability and utility for a range of studies on the evolution of animals; such as origins of mesoderm and body cavities, nervous system, spiral cleavage and potential correlates between the evolution of specific loci and general organismic patterns.

29.6

GOBUSH, K.S., WASSER, S.K.; gobush@u.washington.edu. University of Washington, Seattle
PATTERNS OF GENETIC RELATEDNESS IN A POACHED POPULATION OF AFRICAN ELEPHANTS *LOXODONTA AFRICANA*

Widespread poaching in the 1980s potentially altered the demographic structure of matrilineal African elephant groups (*Loxodonta africana*) in many populations by decreasing the number of old, adult female kin (Barnes and Kapela, 1991, Poole, 1989). Using non-invasive genetic and observational techniques, we examined the patterns of genetic relatedness and group cohesiveness among adult female elephants in a heavily poached population to detect the demographic signature of such a disturbance. We observed intra-group cohesiveness and inter-group associations and collected dung samples from over 85 elephant family groups over a 25-month period in Mikumi National Park, Tanzania. Fecal microsatellite DNA analysis was used to determine degree of relatedness among adult females within groups and between groups. Cohesiveness and relatedness within groups differed greatly. Some groups maintained a consistent membership of only close relatives, while others consisted of only non-relatives. Some groups also displayed a more fluid composition, with adult females changing adult female partners frequently. These findings differ from what has been described about African elephant social structure by other researchers focused on more protected populations, and may have implications for adult female reproductive output, stress physiology and competitive behavior. We will also discuss these topics, which we are additionally investigating.

51.5

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MODULAR GROWTH OF A GORGONIAN CORAL GENERATES PREDICTABLE PATTERNS OF COLONY AND POPULATION GROWTH

The modular construction of colonial organisms can generate complex growth patterns that incorporate both growth and partial mortality. While that patterning can confound simple descriptions of growth it is not a necessary outcome of modularity. In some cases, modularity can generate predictable patterns of colony growth that are amenable to modeling approaches more commonly used in unitary organisms. Colonies of the Caribbean gorgonian *Pseudopterogorgia elisabethae* from a 20 m deep population in the Bahamas exhibit such characteristics. Mass was highly predictable from colony height, following a power function with an exponent of 2.1 ($r^2 = 0.94$). Height and mass were also closely related to age, determined both on the basis of counts of annual growth rings and extrapolations of colony growth rates from other Bahamian populations. Based on those data and observations of spawning, colonies reach sexual maturity at 5-7 y and can live to 35-38 y. As growth declines with increasing size/age maximum colony biomass accumulation occurs at 15-18 y (41-43 cm height). Size/age distributions were used to estimate survivorship which when applied to a von Bertalanffy population model suggest a maximum yield at 10-12 y (31-32cm). *P. elisabethae* is harvested in the Bahamas by cropping colonies. Although not a model of the cropping process, the data suggest that allowing colonies to grow to more than 30 cm can maximize yields.

11.6

GOLDMAN, D.I., CHEN, T.C., FULL, R.J.; digoldma@berkeley.edu. University of California, Berkeley
A TEMPLATE FOR RAPID VERTICAL CLIMBING

Inverted pendulum and spring-mass templates exist for walking and running, respectively, but no such low parameter, general model exists for rapid vertical climbing. Surprisingly, rapid vertical climbing of cockroaches reveal similar dynamics to geckos, despite differences in leg number, morphology and attachment mechanism. During a stride each animal's center of mass (COM) cyclically accelerates up the wall at a frequency equal to its stepping frequency, while undergoing cyclical lateral accelerations at one-half this frequency. Animals produce these dynamics by generating similar single leg forces. Legs generate forces to pull the animal up the wall with no deceleration as they pull laterally toward the midline. Cockroaches generate the common COM dynamics using an alternating tripod gait. During a step the lateral force developed by the middle leg on one side of the body exceeds the sum of the lateral forces of the front and hind legs on the opposite side of the body. The COM accelerates toward the side of the middle leg stance. Geckos ascend using a trotting gait. During a step the hind leg lateral force exceeds that of the contralateral fore-leg and the COM of the animal accelerates toward the side of hind-leg stance. We model the common COM dynamics as a two degree of freedom system with a rigid mass that cyclically attaches to the wall by a spring in series with an actuator oriented at an angle β relative to the body axis. At the beginning of a step, the actuator is maximally displaced while the spring is at rest length. As the actuator decreases length, the spring extends and accelerates the body vertically as well as laterally. This sequence repeats on the contralateral side of the body. We hypothesize that the climbing template allows animals to attain rapid vertical climbing with simple control strategies.

S9-1.1

GOLDSTEIN, J.L., HEPPELL, S., BRAULT, S., LUTCAVAGE, M.E.; jennifer.goldstein@comcast.net. University of Massachusetts Boston, Oregon State University, University of New Hampshire
REPRODUCTIVE STATUS AND BODY CONDITION OF ATLANTIC BLUEFIN TUNA IN THE GULF OF MAINE, 2000-02: CONSERVATION IMPLICATIONS

The Gulf of Maine (GOM) is an important seasonal foraging habitat for Atlantic bluefin tuna (ABT). Current management models assume that the western stock of ABT travel to the GOM annually after spawning in the Gulf of Mexico in late spring, yet recent findings from pop-up and archival tag programs suggest a more complex scenario, including trans-Atlantic migrations, multi-month residency in the central north Atlantic, and years in which some tagged animals do not return to the western Atlantic at all. In light of these new findings, we examined the reproductive status and body condition of ABT in order to define the energetic status bracketing their migration patterns outside the GOM. Data from this study may help to determine if habitat protection is needed in areas other than traditional spawning and feeding grounds. During the fishing seasons of 2000-2002, 257 ABT ranging in size from 185-291cm and weights of 75-134kg were sampled as part of an ongoing study of foraging energetics. Histological analysis identified six distinct reproductive stages for each sex. With a few exceptions, females fell into two stages: stage 1, indicating immaturity or a resting stage, and stage 6, indicating recent spawning activity. Males were found in all stages of development. Approximately 30% of female ABT landed in June and July showed signs of recent maturity, possibly indicating an alternative spawning location. A multivariate analysis will be performed to define the relationship between reproductive status and body condition, as measured by a body condition index, and adipose fat reserves.

42.5

GOYMANN, W., MUCK, C., SCHWABL, I.; goymann@orn.mpg.de. Max Planck Institute for Ornithology
BLOCKING ANDROGEN AND ESTROGEN ACTION DOES NOT AFFECT TERRITORIAL BEHAVIOUR OF SEX-ROLE REVERSED FEMALE BLACK COUCALS *CENTROPUS GRILLII*

In male birds, territorial behavior and song during the breeding season is commonly modulated by androgens. In classically polyandrous bird species, the sex roles are reversed, i.e. females aggressively defend territories or partners and vocalize, whereas males provide all parental care. Are androgens involved in the regulation of territorial and singing behavior in these females as well? The classically polyandrous bird species that have been investigated so far do not show a reversal in sex steroid levels. However, androgens may act at low concentrations if the sensitivity of the target tissues in the brain of females is increased. To test this, we implanted free-ranging female black coucals, a classically polyandrous bird, with an androgen receptor blocker and an aromatase inhibitor to prevent androgen action through the androgen receptor and conversion to estrogens. We investigated territorial and vocalization behavior of experimental and control implanted females. Experimental and control birds did not differ in territorial aggression (latency to respond, vocalization rate, closest approach) towards a simulated territorial intrusion with a stuffed dummy and playback of black coucal territorial vocalizations. Also territory size and passive vocalization rate during a three week period after implantation did not differ between experimental and control birds. It seems as if androgen action via the androgen and estrogen receptors is not involved in the immediate control of territorial behavior in female black coucals. However, we cannot exclude non-genomic action of androgens that are not mediated via the intracellular receptors. Also, androgens may be only required for the activation of these behaviors at the beginning of the breeding season.

68.6

GRACE, M.S., VANDYKE, J.U.; mgrace@fit.edu. Florida Institute of Technology
INFRARED IMAGING IN PIT VIPERS: COMPLEX BEHAVIOR FROM A THERMAL CONTRAST DETECTOR

Crotaline snakes (pit vipers) form images of their environments based upon input from either the eyes or infrared (IR)-imaging pit organs alone, or from the two systems together. We hypothesize that the IR imaging system, like the visual system, is fundamentally a contrast detector, operating on the basis of differential emission of IR energy from thermally distinct objects in the environment. To test this hypothesis, we investigated how thermal contrast influences IR imaging and response behavior in the copperhead (*Agkistrodon contortrix*). Temporarily-blinded copperheads were presented with targets creating positive, negative, or zero thermal contrast differentials with respect to controlled background temperature. Behavioral responses (tongue flicks, head turns and strikes) to positive and negative thermal differentials were greater than responses to zero differentials, and snakes preferentially targeted warm aspects of thermal differentials (behaviors were expressed in phase with motion of warm targets against a cool background, but in exact antiphase with motion of cool targets against a warm background). Snakes often exhibited defensive behavior such as rapid tail vibration in response to positive and negative differentials, and sometimes struck at moving targets. Strikes were always directed at the warm aspect of thermal differentials (strikes never occurred in zero contrast situations). These results show that thermal contrast is the basis of IR imaging in pit vipers, and suggest that IR-imaging snakes may be hard-wired to respond preferentially to warm objects. In addition, this is the first direct experimental evidence that pit vipers utilize the IR system for defensive behavior. Moreover, these results demonstrate that fundamental properties of IR imaging and vision are similar.

1.2

GRANT, J.B.; jbgrant@nrel.colostate.edu. Colorado State University
ONTOGENY OF DEFENSIVE BEHAVIOR AND ADAPTIVE COLORATION IN LARVAE OF THE PANIC MOTH, *SAUCROBOTYS FUTILALIS*

Many lepidopteran species have radically different coloration in early and late larval instars. This ontogenetic variation in morphology is most likely due to temporal changes in the costs and benefits associated with foraging and defensive behaviors. Larvae of the panic moth, *Saucrobotys futilalis*, lack cuticle pigment during most of the first three instars, which causes them to appear the same green as their host plant. The cuticle begins to produce pigmentation in the third instar and in the last two instars is an aposematic orange with black spots. Although all instars are gregarious, early larvae behave much differently than mature larvae. Cryptically-colored early larvae are patch-restricted foragers, wriggle when attacked, do not defensively regurgitate, and are extremely vulnerable to predator attack. Mature larvae employ a nomadic foraging strategy, which results in a more exposed lifestyle and concomitant enhancements in defensive strategy. This ontogenetic switch in foraging strategy corresponds with the use of regurgitation and immobility as defensive responses. I show that 1) larval color changes predictably with instar; 2) larval defensive behaviors change with instar; and 3) the intertwining of behavior and morphology are important in the development of aposematic coloration in this species. My results demonstrate the importance of detailed natural history studies in elucidating the underpinnings of certain behavioral phenomena.

2.1

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Arizona State University
FORAGING EFFORT AND METABOLISM IN EUROPEAN AND AFRICAN HONEY BEES

African honey bees (*Apis mellifera scutellata*) are one of the most successful invasive species known, for they have spread from Southern Brazil throughout the Americas in less than 50 years. During their spread they have out-competed, hybridized with, and eventually replaced existing European honey bee populations (mainly *Apis mellifera mellifera*). The success of the African honey bee is largely due to faster colony growth, and this growth is dependent upon obtaining more resources, in particular pollen. Little is known about how African honey bees achieve a higher rate of pollen collection, but one proposed mechanism is that African honey bees collect more pollen by greater individual foraging effort. A line of evidence that suggests this is that African honey bees have repeatedly been found to have higher mass-specific metabolic rates. Assuming equal efficiency, that higher metabolic rate will translate into increased power output which we should see in various aspects of foraging effort. This study determined whether co-fostered African and European honey bees differed in several aspects of foraging effort including: number of trips per hour, trip length, load size, and percentage of pollen foragers. To characterize the relationship between metabolism and foraging effort, we also looked for correlations between these aspects of foraging effort and metabolism. Our data show that even though African foragers had higher mass-specific metabolic rates, they did not show increased foraging effort in the majority of variables measured. Additionally, no strong correlation existed between metabolism and aspects of foraging effort. These data show that African bees are using a mechanism other than increased foraging effort to collect more pollen, and cast doubt on the validity of our assumption of equal efficiency. Supported by NSF IBN 093410 to JHE, JFH, & GJH.

37.7

GRINDSTAFF, J.L., SMITH, H.G.; Jennifer.Grindstaff@zoekol.lu.se.
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INTESTINAL PARASITISM DURING DEVELOPMENT AFFECTS MORPHOLOGY AND ORNAMENTATION OF RING-NECKED PHEASANTS

Although it is generally assumed that effects of the developmental environment are transient and have little impact on adult phenotype, a growing number of studies have found persistent effects of developmental stress on adult morphology and physiology. Several studies have found long-term effects of early nutritional conditions on morphology, secondary sexual characters, and physiology. However, it is likely that other sources of developmental stress may also have long-term effects on offspring phenotype. In particular, exposure to parasites and other pathogens during early ontogeny may have profound effects on adult morphology. Ring-necked pheasants (*Phasianus colchicus*) naturally suffer from high levels of intestinal parasitism (in our population over 90% of birds have at least one worm). These intestinal parasites include the nematodes *Heterakis gallinarum*, *Syngamus trachea*, and capillary worms (*Capillaria* spp.). To assess the effects of parasitism during development on adult morphology and ornamentation, we reduced intestinal parasite levels in one-half of naturally infected pheasant chicks using the anthelmintic drug fenbendazole. Pheasants experimentally cleared of intestinal parasites exhibited significantly faster tarsus growth and body mass gain. These effects were particularly pronounced in males. Furthermore, growth of the tarsal spur, a secondary sexual ornament of male pheasants, was also significantly enhanced by the removal of intestinal parasites. As the pheasants mature, we also expect to find effects of the removal of parasites during development on wattle coloration and final body size. Developmental stress induced by intestinal parasitism may have long-term effects on pheasant morphology and ornamentation, thereby maintaining ornamentation as an honest signal of an individual's developmental history and possibly genetically based parasite resistance.

7.1

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MARINE TELEOST OSMOREGULATION INVOLVES HIGHLY ACIDIC AND HYPEROSMOTIC FLUID ABSORPTION BY THE INTESTINE

In marine teleost fish, continuous diffusive water loss is compensated by seawater ingestion. Imbibed seawater is desalinated by the esophagus resulting in roughly iso-osmotic intestinal fluids allowing for water absorption across the intestinal epithelium. In addition to apical $\text{Na}^+:\text{K}^+:2\text{Cl}^-$ co-transport (NKCC), apical anion exchange (AE) contributes by as much as 70 % to Cl^- uptake and thereby water absorption. In the gulf toadfish, *Opsanus beta*, hydration of endogenous epithelial CO_2 provides most of the HCO_3^- for exchange with Cl^- across the apical membrane. The H^+ resulting from the CO_2 hydration reaction is excreted across the basolateral membrane via Na^+/H^+ exchange (NHE) which rely on the Na^+ gradient established by the lateral Na^+/K^+ ATPase (NKA). The high intestinal HCO_3^- secretion rates ($0.3\text{-}0.4 \mu\text{mol cm}^2/\text{h}$) resulting from AE suggest high metabolic rate of the intestinal epithelium which is consistent with high levels of NKA and a high density of mitochondria. Both secondary active HCO_3^- secretion and Cl^- uptake via AE as well as Na^+ and Cl^- absorption via NKCC is ultimately fueled by the activity of NKA. The metabolic waste product, CO_2 , arising in part from the oxidative phosphorylation required to sustain NKA activity is used (after being hydrated) as a counter ion for Cl^- uptake via AE resulting in highly energy efficient Cl^- absorption. Furthermore, the exchange of cellular CO_2 , which is osmotically benign, for Cl^- uptake provides an osmotic driving force for water absorption. The basolateral H^+ extrusion results in a highly acidic absorbate with a calculated osmotic pressure of 500-600 mOsm. (Supported by NSF IAB 0416440).

S8-2.1

GROSS, P.S.; grossp@musc.edu. Medical University of South Carolina, Charleston
FUNCTIONAL GENOMICS APPROACHES TO UNDERSTANDING STRESS RESPONSES AND DISEASE IN SHRIMP

Pathogens in the marine environment have caused catastrophic losses to shrimp aquaculture. The manner in which marine crustaceans respond to pathogens is complex and largely unknown. In addition, the role of anthropogenic and natural factors in the etiology of shrimp disease and their effects on immunity is, at best, poorly understood. This is particularly true in the case of antiviral immunity for which there is virtually nothing known about host resistance. We have taken a functional genomics approach to gain an understanding of the underlying genetics of disease response and immunity in crustaceans, using the Pacific white shrimp, *Litopenaeus vannamei* and White Spot Syndrome Virus (WSSV) as models. The Pacific white shrimp is a commonly aquacultured species in many parts of the world and WSSV has had a devastating effect on farms growing the Pacific white shrimp. The strategy employed relies on the discovery of novel genes with putative roles in immune response using of ESTs derived from standard and redundancy depleted cDNA libraries and to a lesser extent enriched disease-responsive libraries generated by suppression subtractive hybridization (SSH). In addition, these cDNA clones are being used to generate microarrays to examine disease response in detail. We hypothesize that infection triggers changes in gene expression that are at least partially reflective of an immune response. By characterizing these disease-responsive genes, we aim to gain an understanding about the kinds of pathways involved in the invertebrate antiviral defense.

61.1

GROSS, J.B., HANKEN, J.; jgross@fas.harvard.edu. Museum of Comparative Zoology, Harvard University
EMBRYONIC ORIGIN OF ADULT CRANIAL CARTILAGES IN *XENOPUS*: A VIEW FROM THE CREST.

Characterizing the embryonic origin of the adult skull in frogs has long been problematic. This is due largely to the technical difficulty of following embryonic cells through and beyond metamorphosis. The origin of cranial cartilages is of particular interest since many structures are lost, remodeled or form initially as the tadpole metamorphoses to an adult. We traced long-term contributions of cranial neural crest to the adult skull in *Xenopus laevis* using a technique of chimeric grafting of transgenically labeled neural crest. The mandibular stream gives rise to first arch structures in the tadpole (e.g., Meckels and palatoquadrate cartilages). Similarly, these structures retain their cellular origins from the mandibular stream in the adult. Cells from the hyoid stream had an unexpected distribution in several adult cartilages, particularly in the nasal region, e.g., alary cartilages and nasal septum. Some portions of the nasal region, however demonstrated a mixed origin, receiving cells from both mandibular and hyoid streams. Interestingly, the branchial stream contributes minimally to cartilage in the post-metamorphic skull. The pattern of derivation in *Xenopus* differs markedly from those reported for other vertebrate models (chicken and mouse) suggesting the contribution of neural crest to adult cranial cartilages is more labile than previously revealed. The pattern in *Xenopus* may be a consequence of the evolution of metamorphosis in anurans having significantly altered the spatial distribution of these embryonic cells between early juvenile stages and adulthood. Supported by NSF EF-0334846 (AmphibiaTree) and the Milton Fund (Harvard University).

39.6

GUADAGNOLI, J.A., TOBITA, K., REIBER, C.L.; jguadagnoli@touro.edu. Touro University, Nevada, Henderson, University of Pittsburgh, University of Nevada, Las Vegas
ASSESSING CHANGES IN THE PRESSURE-AREA RELATIONSHIP IN THE OPEN CIRCULATORY SYSTEM OF A DECAPOD CRUSTACEAN, *PALAEEMONETES PUGIO* IN RESPONSE TO HYPOXIA.

Cardiovascular changes during hypoxic exposure have been studied extensively in both vertebrate and invertebrate systems. Pressure-volume loops have been used extensively in vertebrate systems to study the cardiac contraction cycle and ventricular function, however this tool has not previously been used to assess ventricular function in the open circulatory system of invertebrates. Invertebrate systems are often regarded as less efficient than closed circulatory systems yet there are remarkable similarities in the pressure wave-forms of the open system of decapod crustaceans to pressure wave forms of animals with a closed system. Given these similarities and the ability of animals to alter cardiac function in response to hypoxia, we used the pressure-area (P-A) relationship as a measure of changing ventricular function in grass shrimp exposed to hypoxia. Grass shrimp were exposed to normoxia (150Torr) and hypoxia (50 and 15Torr) while simultaneously measuring intra-ventricular pressure and ventricular area (via digital imaging). A computer program synchronized the pressure-area signals to generate P-A loops. The P-A relationship of the single ventricle of this open circulatory system possesses many features similar to the P-A relationship of the mammalian ventricle. The area encompassed by the P-A loop provides an estimate of stroke work, which fell during hypoxic exposure. There was a significant drop in peak pressure and an increase in minimal pressure that resulted in an overall fall in pressure during hypoxic exposure. Cardiac output was maintained at 50Torr but fell significantly at 15Torr. These alterations in cardiac parameters contributed to alterations in the P-A relationship and overall cardiac work.

34.7

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RADIOLARIAN DIVERSITY AND MORPHOLOGY: STRUCTURAL ADAPTATIONS TO THE DEEP SEA

Radiolarians are marine protists that form intricate siliceous “skeletons”. Although these forms have drawn attention since the 19th century, currently radiolarians are most familiar to paleontologists and marine geologists who study their sedimented remains. The natural history of living species, especially of those living in the deep sea, is only poorly known. I will present results from submersible collections of intact radiolarians living between 200 and 3000 meters. These observations give new insight into their natural history, diversity, bioluminescence, coloniality, and their complex structural adaptations.

29.4

HAGERTY, B.E., TRACY, C.R.; bh@biodiversity.unr.edu. University of Nevada, Reno
IDENTIFICATION OF POPULATION STRUCTURE FOR A RARE AND CRYPTIC SPECIES: IMPLICATIONS FOR CONSERVATION

The underlying spatial structure of populations within a species provides perspective for conservation planning. Direct methods are often used to estimate movements of individuals among populations and other ecological processes. However, direct methods typically involve widespread radio-tracking, which can be expensive and labor-intensive at the least, and perhaps infeasible to obtain adequate statistical power to discern general population phenomena in wide ranging species. Often, indirect methods, using genetic markers, can be used to estimate movement of individuals among places, and to infer ecological and evolutionary processes. These methods can be particularly useful with rare and/or cryptic species. The desert tortoise (*Gopherus agassizii*) is both a rare and cryptic species inhabiting the Mojave Desert of the southwestern United States. Adequate direct measurements are difficult because the species ecological properties. Desert tortoise is long-lived, spends a majority of its time below ground in burrows, is cryptically colored, inhabits an extensive range, and is classified as threatened due to declining population numbers. We have genotyped individuals across the range of the Mojave desert tortoise using highly variable microsatellite markers to identify the underlying spatial structure of the Mojave populations. We find that there are genetically distinct clusters of the desert tortoise, and that these clusters reflect natural barriers to movements of individuals within the species range. The results of our study have important implications for the conservation this rare and cryptic species.

25.6

HAHN, D.A.; dahahn@ufl.edu. University of Florida
CHARACTERIZATION OF HEXAMERIC STORAGE PROTEINS DURING DEVELOPMENT AND REPRODUCTION IN THE FLESH FLY, *SARCOPHAGA CRASSIPALPIS*

Unlike vertebrates, insects are capable of accumulating substantial amino acid reserves and do so primarily in the form of hexameric storage proteins. Documenting the allocation of amino acids to current utilization versus storage for later use is fundamental to understanding the regulation of nitrogen metabolism in insects. I have identified the major storage proteins in the flesh fly, *Sarcophaga crassipalpis*, and described their phenology during immature and reproductive development. *S. crassipalpis* contained two storage proteins, one homologous to the Larval Serum Protein-1 (scLSP-1) and one homologous to LSP-2 (scLSP-2) characterized in other flies. scLSP-1 was present in the hemolymph throughout the feeding phase of the third instar, after which it was taken up into the fat body upon wandering. Larvaly-derived LSP-1 stores were primarily depleted during the larval-pupal transition and during pharate adult development, and were not detectable in adults. scLSP-2 was present in the hemolymph early during the third instar feeding stage but was taken up by the fat body prior to the onset of wandering and utilized during pupation and pharate adult development. scLSP-2 was also present in substantial amounts in the blood of adult females. While detectable in adult males, levels of scLSP-2 were significantly lower than in females. This suggests that scLSP-1 provides amino acid stores to support the significant tissue remodeling and growth that occurs during metamorphosis and pharate adult development. In contrast, the developmental profile and adult sex differences in scLSP-2 suggests roles in both development and reproduction. Future investigations will focus on understanding the role of these proteins in direct development, seasonal developmental arrest, and reproduction.

S3-1.4

HALE, M.E.; mhale@uchicago.edu. University of Chicago
CELLS, CIRCUITS AND SWIMMING: EXAMINING THE NEUROMUSCULAR CONTROL OF LOCOMOTION WITH THE ZEBRAFISH (*DANIO RERIO*)

Understanding the organization and function of neural circuits in the brain and spinal cord has been a major goal of neuroscientists. The high complexity and inaccessibility of the central nervous system has made such work challenging. One of the most productive areas for neural circuit investigation is the locomotor system, which has been studied in a wide range of vertebrates and invertebrates. Recently, the zebrafish has emerged as a valuable model for such work. The transparency of the zebrafish larva makes it possible to visualize, record from, or disrupt neurons and muscle cells in the live animal. Behavior can be correlated with cell activity or circuit perturbation to test hypotheses of function. Genetic techniques provide valuable tools for manipulating morphology and function. I will present our work that focuses on examining the functions of hindbrain and spinal cord cell populations. By imaging activity in groups of hindbrain neurons while recording movement patterns we have been able to examine subtle aspects of neuromuscular control of movement. By ablating neuron populations and assessing the effects on behavior, we have been able to determine roles of specific neuron cell types in locomotion. Supported by NIH NS043977 and NSF IBN0238464.

S2-1.5

HALPERN, M.E., KUAN, Y.S., SANTHAKUMAR, K., GAMSE, J.T.; halpern@ciwemb.edu. Carnegie Institution, Vanderbilt University
LEFT-RIGHT ASYMMETRY IN THE ZEBRAFISH BRAIN

In the human cortex, the left hemisphere functions differently from the right. How this specialization arises and the corresponding anatomical substrates are poorly understood. The zebrafish epithalamus is a valuable model for exploring how L-R differences form in a vertebrate brain. We have characterized genes expressed asymmetrically in this region of the developing brain and examined regulation of such L-R differences. A homologue of nodal, which encodes a TGF-beta signal that mediates asymmetric development of the heart and visceral organs, is expressed in the left side of the pineal organ. There it sets the directionality of asymmetry, generating L-R bias at the individual and populational level. To the left of the pineal lies the parapineal, where it influences the adjacent brain nucleus, the left habenula, to develop differently from the right habenula. Loss of nodal causes LR randomization in parapineal position and habenular laterality. Ablation of the parapineal blocks laterality and both habenulae develop similarly. Asymmetry of the habenulae extends to their efferent projections and innervation of the midbrain target, the interpeduncular nucleus/ Left habenular neurons project along the entire dorsoventral extent of the target, while right habenular neurons project only ventrally. The stereotypic projection pattern is disrupted by parapineal loss. We identified mutations that affect habenular development specifically, left-right differences, or differentiation of habenular cholinergic neurons. Our results reveal a hierarchy of genetic and cellular interactions underlying L-R specification of the dorsal diencephalon and formation of neuronal midbrain connections.

67.3

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A PRELIMINARY MOLECULAR ANALYSIS OF THE THERAPHOSID GENUS *APHONOPELMA* AND ITS IMPLICATIONS ON THE PRESENT MORPHOLOGICAL TAXONOMY

The Theraphosid genus *Aphonopelma* belongs to the infraorder Mygalomorphae, a group thought to be relatively primitive and highly conserved morphologically. The genus ranges throughout the southern third of the United States from the Californian coast east to the Mississippi River with 50 recognized species in the US. The taxonomy of *Aphonopelma* has to date been completely reliant on morphological data and several species of *Aphonopelma* in North America have been described on the basis of a single individual collected. In this work, we tested the validity of the geographical boundaries of *Aphonopelma hentzi* using the molecular characters of 16S and CO1. By sampling two populations of *A. hentzi*, one from the northern end of its range in central Missouri and the other population in the southern portions of its range in north-central Texas and comparing the molecular diversity found within the species with that found in a population of a geographically adjacent *A. hollyi* sampled in the panhandle of Texas. Additionally, the diversity within colonial aggregations was assessed using the mitochondrial markers as well as microsatellite markers to determine whether in fact these aggregations were matriarchal in nature.

16.1

HANDRIGAN, G.R., HAAS, A., WASSERSUG, R.J.*; tadpole@dal.ca. Dalhousie University, Halifax, Canada, University of Hamburg, Germany
BONY-TAILED TADPOLES: THE FORM, FUNCTION, AND FATE OF SUPERNUMERARY CAUDAL VERTEBRAE IN ANURANS

The anuran axial skeleton consists of no more than 9 presacral vertebrae, a single sacral vertebra, and a coccyx fused with the urostyle. The coccyx is formed from 2-4 neural arch pairs, whereas the urostyle arises from the hypochord, an endoderm-derived tissue. Tadpoles from one anuran family, the Megophryidae, deviate from this archetype in bearing supernumerary vertebrae in their tails. At least 4 of 11 genera from this Asian family share the character: *Leptobranchella* (>25 caudals), *Leptolalax* (2-3), *Megophrys* (12-14), and *Ophryophryne* (12-14). Tadpoles from each genus are typically found in streams, where their additional vertebrae may facilitate escape from strong currents by burrowing into the stream bed. The caudal vertebrae of megophryids are rudimentary they have centra without neural arches and ossify differently in each genus. In *Leptobranchella*, for instance, the centra are initially cartilaginous; however, in *Megophrys*, each centra develops from dorsal and ventral pairs of ossified anlage with no apparent cartilaginous precursors. At metamorphosis, the most proximal caudal vertebrae are incorporated into the coccyx. The remaining vertebrae, however, are resorbed along with other tail structures, a process assisted by multinucleate, osteoclast-like cells. The presence of caudal vertebrae, a plesiomorphic trait, in megophryids confirms that the underlying machinery for caudal vertebral development has been retained in some modern anurans, and suggests that the anuran Bauplan, tightly conserved in most families, can still change in response to extreme environments. It remains to be seen which genes involved in axial skeletal development (e.g., *Pax1*, *Pax9*, *Uncx-4.1*) have been suppressed in non-megophryid anurans.

61.2

HANKEN, J., GROSS, J.B.; hanken@oeb.harvard.edu. Harvard University
FATE MAPS EVOLVE, TOO: NEURAL CREST DERIVATION OF THE BONY SKULL IN FROGS, REVEALED BY TRANSGENIC LABELING

We utilize a novel transgenic labeling system to assess the contribution of cranial neural crest to the bony adult skull in the clawed frog, *Xenopus laevis*. This system is suitable for long-term labeling of embryonic cells and for tracing their contribution to adult-specific structures, including those that in metamorphosing amphibians form after a prolonged larval period. Results constitute the first direct evidence of neural crest derivation of most cranial bones in amphibians and represent only the second comprehensive fate map for the vertebrate osteocranium. Neural crest derivation of the bony skull in anurans is more extensive than that reported for any other vertebrate. Crest-derived territory extends caudally to include the entire length of the frontoparietal bone in the skull roof (cranial vault) and the rostral portion of the paired exoccipital bones, which enclose the foramen magnum at the rear of the skull. Additional features that differ from those seen in other vertebrates include a significant contribution from the hyoid crest migratory stream to rostral bones, which generally are regarded as derived from the mandibular crest stream. Apparent variation among species in the embryonic derivation of the bony skull may mean that the neural crest-mesoderm boundary has shifted within the skull during vertebrate evolution, and that a given bone in one species may form from a different precursor cell population than the homologous bone in another species. This would offer an example of evolutionary lability of neural crest biology, which in most other respects is highly conserved among species. Alternatively, these data may indicate errors in the traditional assessment of specific cranial bone homologies among vertebrate classes. Supported by NSF EF-0334846 (Amphibia Tree).

13.8

HANNA, J.B., GRIFFIN, T.M.; jbh6@duke.edu. Duke University
CLIMBING ENERGETICS IN PRIMATES: EFFECTS OF BODY SIZE

Non-human primates move in a three-dimensional environment, but little is known about the physiological demands of climbing. In this study, we examined the metabolic power of climbing in non-human primates spanning more than an 8-fold range in mass. We also examined the vertical climbing efficiency in non-human primates because one can readily and unambiguously measure the minimum rate of performing work against gravity. The rate of oxygen consumption (VO_2) was measured at rest and during climbing in 5 species of primates ranging in body mass from 0.160-1.35kg: *Loris tardigradus* (LT), *Cheirogaleus medius*, *Nycticebus pygmaeus*, *Saimiri boliviensis*, and *Eulemur mongoz* (EM). Animals were trained to climb a vertical rope treadmill at their maximum sustainable speed while enclosed in a Plexiglas chamber. VO_2 was measured during 10-20 minutes of steady-state climbing. We calculated the cost of transport (COT) and compared this to the predicted value for level locomotion by primates using the regression equation from Taylor et al. (1982). Results show that: 1) gross COT decreased with body size, although not significantly ($p = 0.15$; range=133-109 J kg⁻¹ m⁻¹ for the smallest (LT, 0.160kg) and largest (EM, 1.35kg) animals, respectively), 2) gross climbing COT was similar to that predicted on the level for small primates (<0.5kg) and nearly double that predicted for the two large animals, and 3) net climbing efficiency did not vary significantly with size ($p = 0.53$; mean net efficiency = 13.8%). These data indicate that the mass-specific COT for climbing does not decrease with body size as much as predicted for level locomotion. The similar net climbing efficiencies across size suggest that mechanical power output to lift the body against gravity is the primary determinant of the metabolic power required for climbing. Support from a NSF GRF, NSF DIG (BCS-04-52631), SEB traveling fellowship, and NIH grants P40-RR001254 & AR051672.

37.4

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SEASONAL, SEX-, AND AGE-RELATED VARIATION IN SERUM IMMUNOGLOBULIN LEVELS IN THE RED-EARED SLIDER TURTLE

The immune system of ectothermic vertebrates fluctuates seasonally, being sensitive to both environmental and hormonal cues. Low immunocompetence often occurs during the winter and the mating season, when energy and resources are directed away from the immune system towards self-maintenance and reproduction, respectively. Additionally, variation in male and female reproductive biology, as well as ontogenetic changes in resource allocation may lead to variation in immune function. We examined seasonal, sex-, and age-related variation in serum immunoglobulin (Ig) levels in the red-eared slider turtle (*Trachemys scripta elegans*). Serum samples were obtained monthly from March to September from both sexually immature and mature males and females trapped from a natural population. Using protein gel electrophoresis, we separated the five main classes of serum proteins (albumin, alpha-1, alpha-2, beta, and gamma) based on their electrical charge and size. Because Igs are present mostly in the gamma class (and are referred to as gamma globulins), we were able to determine changes in the relative proportions of Ig in serum by examining changes in the gamma globulins. In general, across both sexes, levels of circulating gamma globulins increase seasonally, and sexually mature individuals have higher levels than immature individuals. We also detected sex-specific variation in the levels of gamma globulins across the sampling period. These patterns suggest that ontogeny and reproductive cycles do influence at least some components of immune function in turtles.

S9-1.3

HARRISON, J.F., FEWELL, J.H., GRAYSON, D.L., HUNT, G.J., BARND, B.D.; j.harrison@asu.edu. Arizona State University, Purdue University

AN ENVIRONMENTAL PHYSIOLOGIST PERSPECTIVE ON THE INVASION OF THE AMERICAS BY AFRICANIZED HONEY BEES

Africanized honey bees are a classic invasion species: introduced by man, spreading rapidly, and out-reproducing native species including the conspecific European honey bee. This invasion has had major human health and economic effects, some of which may further increase. Physiological and ecological approaches were used to successfully predict the distribution limits of Africanized bees. Behavioral differences (honey storage) rather than thermal tolerances or heat production appear to explain range differences between bee races. Multiple traits appear to account for the success of Africanized vs. European honey bees, including: 1) faster colony growth rate, 2) reproduction at smaller colony size, and 3) greater dispersal tendency and ability. Several studies suggest that faster colony growth rates relate to a greater tendency to forage for pollen vs. nectar, which allows a higher intake of protein for brood production. Africanized worker honey bees have greater mass-specific flight metabolic rates but do not appear to use these capacities to bring in more resources. However, the higher flight metabolic capacities of reproductives may facilitate the greater dispersal capacities of Africanized swarms and possible reproductive advantages of Africanized males. Quantitative trait loci mapping has identified specific loci correlated with both behavioral and physiological trait differences between Africanized and European bees, and provides beginning steps toward determination of the specific genes responsible for the invasive success of these bees. Supported by NSF IBN 093410 to JHF, JFH and GJH.

17.1

HART, M.W., SUNDAY, J., KEEVER, C.C.; mike_hart@sfu.ca. Simon Fraser University

DISPERSAL AND CLIMATE HISTORY IN SEA STAR POPULATION GENETIC STRUCTURE

The NE Pacific bat star *Patiria miniata* is widespread and abundant in southern and central California, the outer coasts of British Columbia, and southeast Alaska, but is rare or absent north of Cape Mendocino (CA) to Cape Flattery (WA). This range disjunction includes the maximum southern extent of the last Pleistocene glaciers (LGM). One plausible explanation for this present-day distribution is post-Pleistocene expansion (via planktotrophic larval dispersal) from southern and northern glacial refuges without gene flow between their descendants. An alternative explanation is northern extirpation followed by post-Pleistocene range expansion from California northward, plus some ecological process that excludes this species from shallow marine habitats of Oregon and Washington. Our recent genetic studies appear to refute both of these simple explanations. For example, mtDNA measures of population differentiation between Bodega Bay, CA (south of the LGM) and Tofino, BC (on Vancouver Island, well north of the LGM) are very small ($\Phi_{ST} = -0.007$, $P = 0.52$). In contrast, differentiation between BC populations on Haida Gwaii (Queen Charlotte Islands) and Vancouver Island (<500 km apart) is very large ($\Phi_{ST} = 0.226$, $P < 0.01$). The former pattern is probably due to post-Pleistocene gene flow from south to north that re-established some northern populations extirpated by ice. The latter pattern is probably due to lengthy isolation of some populations in northern ice-free refuges. The absence of more recent gene flow on this smaller scale might be due to divergence of the (northward) Alaska and (southward) California current systems offshore of Queen Charlotte Sound. Notably, the south-to-north gene flow that connects California and Vancouver Island populations is in the direction opposite to the California current that appears to isolate northern populations from each other.

76.4

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EVOLUTION OF THE MATERIAL PROPERTIES OF SPIDER DRAGLINE SILK

The evolution of biological materials is poorly understood, but is critical for understanding biodiversity. For example, the performance, and hence evolution of spiders is dependent on the silks they spin throughout their lives. The material properties of these fibers, such as the strength, toughness, extensibility, and stiffness, affect a myriad of ecologically important functions. Here, we examine the evolution of dragline silk material properties across a phylogenetically diverse sample of 21 species of spiders. Material properties such as strength and toughness can vary by more than four-fold across species. Further, the associations between different properties are complex with some traits evolving independently of one another (e.g. strength and extensibility) and others demonstrating correlated evolution (e.g. extensibility and toughness). Material properties also have different degrees of phylogenetic signal, with similarities between closely related species in stiffness and strength, but very little similarity in extensibility and toughness. The overall picture that emerges is complex, with a mosaic pattern of trait evolution that produces a diverse set of materials across spider species.

3.3

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OUT IN THE COLD: PHYSIOLOGICAL PERFORMANCE AFFECTS BEHAVIOR OF DEER MICE

Physiological performance (e.g., summit metabolism (VO_2max) or basal metabolic rate (BMR) is often thought to be ecologically significant. If VO_2max (which describes the upper limit to heat production) and BMR (which describes the lower limit to heat production for a normoothermic endotherm) are ecologically significant, they may act by influencing behavior, particularly in the cold. We conducted a laboratory study to test whether BMR or VO_2max was correlated with behavior of 48 deer mice exposed to a series of cold temperatures. Each mouse had a warm nest box connected via a tube to an environmental chamber that contained food, ice chips, and a running wheel. Behavior was monitored while temperature in the environmental chamber was -5, -10, or -15 C for two days each. BMR was measured before and VO_2max was measured before and after cold exposure. We used a linear mixed-model with repeated measures to analyze the data. Total time active in the cold was negatively correlated with temperature. Bout length (when mice were out of the nest box) decreased at colder temperatures, but number of bouts did not. Bout length increased with change in VO_2max (post VO_2max - pre VO_2max). Food consumption decreased at colder temperatures resulting in loss of body mass. Mice with greater increases in VO_2max ate more and lost less mass. Even though BMR is only part of the overall demand for energy, mice with higher BMR lost mass more rapidly under cold stress than mice with lower BMR. Our study suggests that mice with low BMR and larger capacity to increase VO_2max may be best able to tolerate cold environments. In summary, physiological performance can affect behavior in response to environmental conditions. Supported by NSF IBN 9410693.

S7-1.3

HE, Y., TANG, R., HAO, Y., STEVENS, R.D., PEI, Z.-M.*; zpei@duke.edu. Duke University, Duke Medical Center
NITRIC OXIDE REPRESSES ARABIDOPSIS FLOWERING

Nitric oxide (NO) plays an important role in many physiological processes in animals, such as smooth muscle relaxation, neurotransmission, and immune stimulation. It has also been implicated that NO also regulates multiple physiological and developmental processes in plants, including etiolation, seed germination, leaf expansion, senescence, stomatal closure, and responses to abiotic and biotic signals. In plants, the formation of NO can be attributed to NO synthase (NOS) and nitrate reductase, as well as non-enzymatic sources. Nevertheless, the molecular mechanisms by which NO acts remain largely unknown in plants. We found that NO represses the floral transition in *Arabidopsis thaliana*. Plants treated with NO, as well as a mutant overproducing NO (*nox1*), flowered late, whereas a mutant producing less NO (*nos1*) flowered early. NO suppressed *CONSTANS* and *GIGANTEA* gene expression and enhanced *FLOWERING LOCUS C* expression, which indicates that NO regulates the photoperiod and autonomous floral pathways. Because NO is induced by environmental stimuli and constitutively produced, it may integrate both external and internal cues into the floral decision.

31.1

HEAD, J.M., TERWILLIGER, N.B.; jhead1@uoregon.edu. University of Oregon, OIMB
CRUSTACEAN RESPONSES TO HYPOXIA: THE ROLE OF HIF-1 α .

The habitats of aquatic crustaceans are highly variable with respect to conditions such as temperature, salinity, and oxygen tension. We are investigating the possible role of the hypoxia-dependent transcription factor, Hypoxia Inducible Factor-1 (HIF-1), in the response of crustaceans to hypoxia. In other organisms, the α subunit of HIF-1 dimerizes with the β subunit under hypoxic conditions and translocates to the nucleus to regulate genes involved in abrogating the negative effects of hypoxia; including genes involved in oxygen transport. We had previously discovered a HIF-1 α homologue in the brachyuran crustacean *Cancer magister*. Southern blots and northern blots have been performed to further characterize *hif-1 α* in *C. magister*. We have demonstrated *hif-1 α* expression in normoxic crab anterior gill, hepatopancreas, heart, VTG, and hypodermis via PCR. We have also identified a *hif-1 α* homologue in another brachyuran crab, *Callinectes sapidus*, which is 93% similar to the *C. magister* amino acid sequence. In addition, several consensus HIF-1 α binding sites have been identified in the promoter regions of several hemocyanin subunits of *C. magister*, indicating that HIF-1 α may play a role in its regulation in hypoxic conditions. In comparisons with the recently published *hif-1 α* homologues in *Palaemonetes pugio* and *Apis mellifera*, as well with vertebrate species *Xenopus laevis* and *Oncorhynchus mykiss*, suggest that the gene is highly conserved. We hypothesize that, in crustaceans, the HIF-1 system plays a significant part in regulating gene expression in an oxygen-dependent manner. Supported by NSF IGERT(JH), Evonuk Fellowship(JH), Sigma Xi(JH), and NSF 9984202(NBT).

S5-2.6

HEASMAN, J., TAO, Q., YOKOTA, C., KOFRON, M., LIN, X.; heabq9@chmcc.org. Cincinnati Childrens Research Foundation
THE CANONICAL WNT PATHWAY AND AXIS FORMATION IN *XENOPUS LAEVIS*

The establishment of the dorso-ventral and anterior posterior axes in *Xenopus* embryos has long been known to depend on a canonical Wnt signaling pathway, since beta catenin-depleted embryos lack axes. However the mechanism of activation of the pathway is controversial, and has generally been considered to occur intracellularly. We have shown recently that the canonical pathway is dependent on maternally localized Wnt11, and has all the characteristics of a regular, ligand-activated canonical Wnt pathway. Further confirmation of this will be presented, specifically that the pathway also depends on the Wnt co-receptor LRP6. The potential conservation of this patterning mechanism among other vertebrate groups will be discussed.

10.2

HEIDINGER, B.J., NISBET, I.C.T., KETTERSON, E.D.; bheidinger@indiana.edu. Indiana University
ATTENUATION OF THE STRESS RESPONSE MAY MEDIATE AN INCREASE IN REPRODUCTIVE PERFORMANCE WITH AGE IN THE COMMON TERN *STERNA HIRUNDO*

In many organisms, reproductive performance increases with age. However, we currently have little information about the physiological mechanisms underlying this commonly observed pattern. One physiological mechanism that may be important in mediating age-related differences in reproductive performance is the stress response. In response to stressors, vertebrates release glucocorticoids (CORT) which stimulate a physiological cascade that enhances survival, but concurrently inhibits reproduction and parental care behaviors. If modifications of the stress response underlie age-related changes in reproductive performance, the stress response should be attenuated with age. We tested this prediction in a free-living population of common terns *Sterna hirundo* using a standardized handling stress protocol. In addition, we investigated the effects of exogenously elevated CORT levels on parental behavior. We found that while baseline CORT levels did not vary with age, the magnitude and amount of CORT released throughout the stress response declined significantly with age. In addition, we found that adults that received CORT injections spent significantly less time incubating than adults given control oil injections. Taken together, these results suggest that an attenuation of the stress response may mediate an increase in reproductive performance with age.

S2-2.4

HERNANDEZ, L.P.; phernand@gwu.edu. George Washington University
ZEBRAFISH: A MODEL SYSTEM FOR INVESTIGATING THE
GENERATION OF NOVEL FEEDING MECHANISMS

Most research using zebrafish exploits the enormous conservation seen within vertebrate embryogenesis and early larval development. Such conserved processes allow easy extrapolation regarding biomedical implications. Yet in ignoring what makes zebrafish different, we are overlooking the utility of the zebrafish as a model organism for investigating the origin of morphological novelty. While comparative anatomists often ignore this unassuming fish, it possesses a number of interesting and poorly investigated feeding adaptations, including both a unique means of premaxillary protrusion as well as a unique pharyngeal jaw mechanism. Thus, such novelties exist not only in the morphological features used to procure prey, but also in those structures used in processing prey. Functional morphologists have long examined the functional significance of premaxillary protrusion, yet their work has focused largely on the mechanics of feeding in adult perciforms. The highly speciose Cypriniformes possess a novel median bony element, the kinethmoid, which allows for a different mechanism of premaxillary protrusion. We have examined the development and function of this important feeding innovation. Interestingly, even in closely related species there exists functionally relevant variation in kinethmoid structure. Moreover, while pharyngeal jaw development has been described within the Cichlidae, little work exists examining the development of the novel pharyngeal jaw structure within the Cyprinidae. Given that the Cyprinidae lack oral jaw teeth, there must exist significant selection for efficient pharyngeal jaw processing in these species. Understanding the function and development of these two feeding adaptations may add considerably to our knowledge of the development and evolution of morphological innovations.

50.3

HERNANDEZ, R.A., SECOR, S.M., ESPINOZA, R.E.; raymond.a.hernandez@socal.rr.com. California State University, Northridge, University of Alabama, Tuscaloosa

IS A DIETARY JACK OF ALL TRADES A MASTER OF NONE?
ADAPTABILITY OF GUT FORM AND FUNCTION IN AN
OMNIVOROUS LIZARD

Omnivory can be viewed as a jack-of-all-trades dietary strategy that allows some animals to exploit a variety of food items. However, the extent to which omnivores can adaptively regulate gut form and function in response to different diets has not been widely investigated. When reared on specialist diets, do the digestive systems of omnivores respond like specialists, or are they constrained by the jack-of-all trades/master-of-none paradigm? We raised 56 wk old (22 g) omnivorous bearded dragons (*Pogona vitticeps*) for 20 wk on either a diet of ground alfalfa (herbivore), crickets (carnivore), or a 50/50 mix of both (omnivore). We compared aspects of gut form (histology, mass, surface area) and function (apparent digestive efficiency, rates of nutrient transport) and used rates of growth as a measure of whole-animal digestive performance. Herbivores had relatively smaller stomachs and large intestines than carnivores, but not omnivores, and herbivores had smaller small intestines than both carnivores and omnivores. Lizards raised on the herbivore diet exhibited higher rates of both nutrient transport and capacity for proline and glucose than carnivores, but similar rates as omnivores. Herbivores grew slower than omnivores, but had similar growth rates as carnivores. These results indicate that the digestive system of *P. vitticeps* exhibits considerable plasticity in gut function, which, at a proximate level, may be advantageous to this ontogenetic diet-shifting (carnivory to omnivory) lizard. However, the apparent lack of plasticity in gross gut morphology may be indicative of an evolutionary hurdle constraining this omnivore from specializing further on plants, and may provide insight into why herbivory is so rare in reptiles generally.

23.3

HERREL, A., JAMES, R.S., VAN DAMME, R.; anthony.herrel@ua.ac.be. University of Antwerp, Belgium, Coventry University, UK
MUSCLE PHYSIOLOGY CONSTRAINS BEHAVIOUR IN
LIZARDS: PHYSIOLOGICAL BASIS FOR THE FIGHT VS. FLIGHT
PARADIGM

Previous workers have noted that some agamid lizards show a temperature dependent behavioural shift where a flight response is used at high temperatures. In contrast, at low temperatures, lizards turn towards their aggressor and try to bite (Hertz *et al.*, 1982). Here we examine the physiological basis for this behavioural shift in the lizard *Trapelus pallidus*. Behavioural experiments confirmed previous observations and indicated that lizards turned around to bite more at lower temperatures. *In vivo* performance data show that the thermal dependence of bite force is much smaller than that of sprint speed. *In vitro* physiological data for the m. caudofemoralis (the major hindlimb retractor) and the m. adductor mandibulae externus (the largest jaw closer muscle) show that the effect of temperature on contraction speed (eg. twitch time to peak tension, half relaxation time) was much greater than that of temperature on force generation (eg. peak twitch and tetanic force). However, whereas the effect of temperature on force production was most pronounced for the limb muscle, the effect of temperature on contraction speed was greatest for the jaw muscle. Our data suggest that the observed behavioural shift is driven by the direct effect of temperature on muscle contractile performance, which in turn affects whole organism performance traits. Moreover, our data show local physiological adaptation in the jaw and limb muscles to their primary function (force vs. speed). Hertz, P.E., R.B. Huey and E. Nevo (1982) Fight versus flight: body temperature influences defensive responses of lizards. *Anim. Behav.* 30: 676-679.

15.5

HEULIN, B., STEWART, J.R., SURGET-GROBA, Y., BELLAUD, P., JOUAN, F., LANCIEN, G., DEUNFE, J.; stewarjr@etsu.edu. Station Biologique de Paimpont, France, East Tennessee State University, Johnson City, University Rennes, France

HISTOLOGY AND HISTOCHEMISTRY OF THE UTERINE
GLANDS AND EGG SHELL OF THE REPRODUCTIVELY
BIMODAL LIZARD, *LACERTA VIVIPARA*

Thinning of the eggshell is a major innovation in the evolution of viviparity in squamate reptiles. The eggshell typically consists of several layers of organic fibers overlain by calcium carbonate. We studied oviparous and viviparous females during vitellogenesis and early gestation in a reproductively bimodal lizard to test the hypothesis that reduction in eggshell thickness is correlated with reduction in preovulatory recrudescence of the uterine glands. The eggshell of both reproductive modes consists of an inner boundary layer that stains positively for acidic mucosubstances and a thicker fibrous layer that stains for disulfide and sulfhydryl rich protein. The fibrous layer is 10 times thicker in oviparous females. During late vitellogenesis the glands of oviparous females are 60% larger than those of viviparous females. Because uterine glands of both reproductive modes stain positively for disulfide and sulfhydryl groups and the uterine epithelium is positive for acidic mucosubstances, we conclude that the uterine glands are the likely source of the fibrous proteinaceous layer and the uterine epithelium secretes the inner boundary layer. Our methods did not include study of the source of calcium carbonate which is present in oviparous but not viviparous eggshells. Our intraspecific comparison supports the hypothesis that thinning of the eggshell is coincident with the evolution of viviparity and is regulated by reduction in uterine glands.

S7-2.1

HEYLAND, A., MOROZ, L.L.; aheyland@ufl.edu. The Whitney Laboratory for Marine Bioscience, Saint Augustine, University of Florida
SEARCH FOR NEURONAL TRANSCRIPTS INVOLVED IN THE METAMORPHIC TRANSITION OF THE SEA HARE *APLYSIA CALIFORNICA*

Metamorphosis among many marine invertebrate species involves a radical transition from a larval to a juvenile/adult body plan that can occur in a remarkably short period of time. Metamorphic competence directly precedes this radical change in morphology and can best be described as the developmental potential of a larva to undergo the radical transition in response to environmental signals. Such signals (i.e. settlement cues, substrate architecture, temperature, food etc.) are modulated via neuronal gene networks. A metamorphic pattern with competence and a fast radical transformation evolved many times independently in animals and we hypothesize that similar signaling modules have been co-opted for the regulation of a) the development to competence and b) the interpretation and modulation of environmental signals. However the actual signaling architecture underlying these processes is largely unknown for the majority of marine invertebrate species. We used representative oligo-arrays constructed from transcripts obtained from the *Aplysia californica* (sea hare, Mollusca) central nervous system to explore the following two questions: 1) What neuron specific genes are expressed during development to metamorphic competence? 2) What neuron specific genes are expressed immediately after settlement, i.e. upon exposure to specific environmental signals. We validated our expression analysis of specific neuropeptides, nuclear hormone receptors and chemoreceptor molecules using *in situ* hybridizations. Support Contributed By: NIH, NSF, & McKnight BR Foundation.

45.5

HIERONYMUS, T.L., WITMER, L.M.; th108702@ohiou.edu. Ohio University, Athens
FROM ARMOR TO ANCHOR: CHARACTER EVOLUTION OF THE SKIN AND HORNS OF RHINOS

Previous reconstructions of extinct rhinocerotid taxa have invoked three separate patterns of nasal horns, but without specifying an explicit and mechanistic relationship between unpreserved soft tissues and available osteological correlates. New data on the anatomy and histology of rhinoceros horn attachment allows a reevaluation of previous reconstructions and an assessment of character evolution in the dermis and epidermis that make up these unique horns. Numerous osteological specimens of extant rhinoceros and taxa with similar dermal histology were examined to test a mechanistic hypothesis of osteological correlate formation in relation to an epidermal horn. Sixteen extinct rhinocerotoid taxa were then examined for osteological correlates indicative of derived dermal architecture and keratinous horns. The resulting character scores were optimized onto a composite phylogeny of Rhinocerotidae. Based on the co-occurrence of these osteological correlates with other morphological features commonly associated with agonistic behaviors, a phylogenetically independent pairwise comparison was conducted to determine the extent of character correlation among a diverse array of extant mammalian taxa. This study found a consistent osteological correlate of horn attachment related to mechanical epigenetic control of bone growth. This correlate is separate from the correlate of derived dermal architecture that occurs elsewhere on the skull. The latter first appears at the base of Rhinocerotidae in the Middle Eocene, while true horns do not appear until the Late Oligocene Early Miocene, and only within the crown group Rhinocerotini. Character correlations between the relevant soft tissues and other features in many extant mammalian taxa provide a basis for reconstructions of behavior and ecology in extinct rhinocerotids.

44.6

HIGHAM, T.E., DAY, S.W., WAINWRIGHT, P.C.; tehigham@ucdavis.edu. University of California, Davis, Rochester Institute of Technology
CAN PEAK BUCCAL CAVITY PRESSURE BE USED TO PREDICT PEAK FLUID SPEED DURING SUCTION FEEDING IN FISHES?

Suction-feeding fish capture prey by rapidly expanding their buccal cavity, which generates a flow of water directed towards their mouth. A sub-ambient pressure inside the buccal cavity is associated with this expansion, and the magnitude of this pressure differs considerably among species of fish and within an individual. Although peak sub-ambient pressure is thought to be proportional to fluid speed squared by Bernoulli's principle, no study has measured both pressure and fluid speed simultaneously. Thus, we quantified buccal pressure and fluid speed simultaneously during feeding in four individuals of largemouth bass, *Micropterus salmoides*. We measured pressure by inserting a transducer through the skull of the fish so that the tip of the transducer was flush with the dorsal surface of the buccal cavity. We measured fluid speed using digital particle image velocimetry (*DPIV*). A laser sheet was positioned on the mid-sagittal plane of the fish so that the fluid speed could be measured along a transect extending from the center of the fish's mouth. We found that peak pressure was significantly correlated with the peak fluid speed ($r^2=0.61$; $P<0.01$) of the same feeding. However, the magnitudes of the pressures were much greater (up to 5 times) than those estimated from the measured fluid speeds. We found that peak pressure preceded peak gape and peak fluid speed by an average of 14 ms and 18 ms, respectively. Thus, although correlated, pressure is sub-maximal at the time of peak fluid speed. In conclusion, a substantial amount of variation in peak fluid speed cannot be explained by peak pressure, suggesting that a mechanism other than pressure is being modulated by the fish in order to alter fluid speed. Supported by NSF IOB-0444554.

52.1

HILL, R.I.; rihill@berkeley.edu. University of California, Berkeley
MORPHOLOGY AND LOCOMOTOR MIMICRY IN ITHOMIINE BUTTERFLIES (NYMPHALIDAE)

Neotropical ithomiine butterflies (Nymphalidae) exhibit rampant convergent evolution of color patterns. It is not uncommon in lowland rainforest to find up to nine color patterns at a site, with several species from 2-5 genera exhibiting each pattern. This color pattern convergence is an excellent example of Müllerian mimicry involving mutually distasteful species. Unpalatable butterflies in general have associated kinematic and morphological traits such as slow flight, low wing beat frequency and rearward displaced center of body mass. Mimicry among unpalatable butterflies is known to extend to flight morphology and kinematics in *Heliconius* butterflies, but the generality of this locomotor mimicry has not been tested. Morphological measurements of 38 species of ithomiine butterflies from an assemblage in eastern Ecuador containing eight mimetic color patterns, or mimicry rings, are used to examine whether locomotor mimicry exists in the ithomiines. Do species that share color pattern also share flight morphology? Principal components and discriminant function analyses are used to assess which morphological traits best discriminate among mimicry rings. Comparative analyses using a molecular phylogeny are also used to examine scaling relationships and morphological trait evolution.

57.6

HILLENIUS, W.J., MADERSON, P.F.*; paulmader@verizon.net. Coll. of Charleston, Brooklyn College of CUNY
DOES PITH STRETCH A FEATHER?

The proverbial lightness of feathers, usually attributed to an aerodynamic role, results from delicate pulp caps within the tubular calamus and spongy pith within spathe components. In both rachis and barbs, the medullary pith, enclosed by denser cortical epithelia, certainly provides a strong, yet flexible and light, beam structure. However, we propose an additional, developmental role for the pith tissues. Immature keratinocytes initially appear as a sheet of tightly packed, polygonal cells situated between the epithelial sheath and the turgid dermal core. Within this sheet patterned β -keratinogenic rachideal and barb ridges then appear. At first rectangular, these ridges gradually transform into the approximately rounded rachis and flattened, branched barbs. On their own, the mechanical environments provided by sheath and core tissues neither hinder nor help the elongation and flattening of cortical epithelial cells or barbule elongation. We propose that the unique swelling of differentiating pith cells, analogous to expanding foam insulation, provides a critical mechanical force permitting epithelialization of cortical tissues. By the time the sheath splits and dermal regression occurs, breakdown of intercellular contact between adjacent barbs and barbules, followed by terminal dehydration of the constituent cells, allows spathe deployment. This explanation of pith development in modern feathers supports an evolutionary model of feather origins via patterned splitting of a keratinized extension of an ancestral scale. It implies that pith, originally serving to facilitate splitting, was an excessive construction (*sensu* Gans, Evolution 1979) whose strength and lightness were later selected for in the context of flight.

S5-2.2

HINMAN, V.F., DAVIDSON, E.H.; vhinman@caltech.edu. Caltech
EVOLUTION OF MESODERM SPECIFICATION IN ECHINODERMS: GENE REGULATORY NETWORK ARCHITECTURAL REORGANIZATION ACROSS IMMENSE PERIODS OF EVOLUTIONARY TIME

This presentation will focus on the gene regulatory network (GRN) evolution of endomesodermal specification among echinoderms. GRNs detail the regulatory interconnections that prescribe developmental fate. Currently, there exists an extensive GRN that describes the specification of endoderm and mesoderm in echinoid echinoderms (sea urchins). This GRN serves as an excellent platform for evolutionary comparisons of GRNs in other taxa. Such comparisons will reveal the architectural reorganization of GRNs that must underlie evolutionary change in morphological features. We have previously shown that the early GRN that specifies the very beginnings of endomesodermal specification in sea urchins is highly conserved in the starfish *Asterina miniata*, although these two classes of echinoderms last shared a common ancestor around 500MYA. In later development, in both taxa, the endomesoderm is further specified as endoderm or mesoderm. In sea urchins, the mesoderm is specified by a Delta signal from a cell lineage (the micromeres) that is completely absent in starfish, and in fact in all other classes of echinoderms. This method of mesoderm specification must therefore be a derived feature of sea urchins. Embryological and phylogenetic evidence meanwhile suggests that starfish mesoderm specification is more likely pleiomorphic. A comparison of GRNs involved in specification of the mesoderm in starfish and sea urchin will be presented.

60.1

HOCHBERG, R.; hochberg_rick@yahoo.com. University of Massachusetts, Lowell
IMMUNOHISTOCHEMISTRY AND 3-D CEREBRAL ARCHITECTURE IN SPECIES OF *ASPLANCHNA* (ROTIFERA)

The structure of the rotifer nervous system has been historically depicted as a simple network of neurons that innervate equally simplistic sensory and motor organ systems. Until recently, very little was known about the nature of these connections or the neurotransmitters involved, especially within the cerebral ganglion. Species of *Asplanchna* are especially amenable to neurobiological investigation because of their large size and ease of culture. They also display a simple behavioral repertoire that can be manipulated by pharmacology and mechanical stimulation, allowing for the identification of neurons that elicit specific responses. The purpose of the current investigation was to map out the structure of the cerebral ganglion in two closely related species of *Asplanchna*, thereby providing a foundation for future studies that wish to investigate the physiology of rotifer nervous systems. Comparisons were made between saccate female forms of *Asplanchna brightwelli* and *A. priodonta*, two polymorphic freshwater species, using antibodies to three neurotransmitters: Serotonin, FMRFamide, and SCPb. Confocal microscopy and computer modeling permitted unprecedented views of the three-dimensional structure of each rotifer's brain, revealing differences in the number of immunoreactive perikarya and their connections. Anti-serotonin staining provided the best insight into brain architecture, revealing 20 bilateral pairs of 5HT perikarya in *A. brightwelli* compared to only 3 bilateral pairs in *A. priodonta*. Moreover, cerebral decussations were only present in the former species, though their pathways were not easily traced. Additional differences were also present. Details of the rotifer nervous system are discussed in reference to future research on cyclomorphosis, polymorphic induction, and phylogeny.

S7-1.6

HODIN, J.; hodin@u.washington.edu. Hopkins Marine Station
EXPANDING NETWORKS: A HYPOTHESIS FOR THE EVOLUTION OF METAMORPHOSIS

Metamorphosis is a more or less radical morphological transition between two multicellular phases in an organism's life cycle, often marking the passage from a pre-reproductive to a reproductive life stage. It generally involves major physiological changes and a shift in habitat, feeding mode, etc., and can be subdivided into a long-term phase that involves substantial morphological remodeling, and a shorter-term phase (settlement in marine invertebrates, "adult eclosion" in insects, fruiting body emergence in mushrooms) where the actual shift in habitat occurs. In most echinoderms (sea urchins, sea stars, sea cucumbers and their kin), these two phases are fairly distinct: at the end of larval development, an essentially fully-formed juvenile is present within the larval body. At settlement, this juvenile rapidly emerges. I will present data from several echinoderms outlining a core regulatory network: thyroid hormones regulate the morphogenetic transition from bilateral larva to pentamerous juvenile (longer-term phase); thyroid hormones interact antagonistically with the NO repressive network regulating settlement (the shorter-term phase); and the transmission of environmental settlement cues to induce a physiological response involves multixenobiotic efflux transport activity. I will explore how this core regulatory network can be acted on by natural selection to suit the diverse ecological needs of disparate echinoderm larvae, and speculate on the ways that exposure to xenobiotic pollutants and other compounds might influence successful settlement of juveniles in the wild.

52.9

HOFFMAN, E.A., GOODISMAN, M.A.D.; eahoffma@mail.ucf.edu. University of Central Florida, Georgia Institute of Technology
GENOMIC ANALYSIS OF CASTE DIFFERENTIATION IN YELLOWJACKET WASPS

Highly eusocial insects exhibit one of the most remarkable examples of polyphenism, the occurrence of discrete alternative phenotypes produced from a single genotype. Individuals belong to distinct castes (e.g. queens or workers) that exhibit strikingly different morphology and behavior. In this study we used yellowjacket wasps (*Vespula squamosa*) to address two questions concerning the molecular underpinnings of caste evolution. First, we sought to determine whether molecular differences increase between castes as development proceeds and morphology and behavior become more divergent. Second, we sought to determine whether the patterns of expression in *Vespula squamosa* are similar to those of the honey bee (*Apis mellifera*). To investigate these questions we compared expression patterns derived from 11 cDNA libraries constructed from different development stages of *Vespula squamosa*. We found that expression differences did indeed increase with developmental stage. Moreover, developmental stage was more influential than caste on determining patterns of gene expression. Finally, these patterns were different than patterns of gene expression previously identified in the honey bee. This is likely due to the independent evolution of caste in these two taxa.

40.6

HOLLIDAY, C.M., WITMER, L.M.; ch338800@ohiou.edu. Ohio Univ
EVOLUTIONARY MORPHOLOGY OF THE ORBITOTEMPORAL REGION IN ARCHOSAURIA

The orbitotemporal region is a structurally complex, functionally important, and phylogenetically informative cephalic space built by elements of the palate and braincase which includes trigeminal nerves, adductor muscles, and other topologically conservative structures. However, little is known about the regions evolution in Archosauria, obscuring knowledge of regional patterns among amniotes. Tests of similarity and congruence among soft and bony adductor chamber contents were conducted in a large survey of extant and fossil archosaur taxa revealing a mosaic of structural patterns associated with the braincase and palate. Iterative losses of the epipterygoid within seemingly disparate adaptive contexts occurred along the lines to Crocodylia and Neornithes, as well as within at least three terminal non-avian dinosaur clades (e.g., Ornithopoda, Ceratopsidae, and Sauropodomorpha). Complementing these changes, neomorphic bony walls of the laterosphenoid developed, altering the topology of the trigeminal nerves, cavum epiptericum, and temporal fossa, as well as impacting the functional properties of the palatocranial junction. Associated modifications in muscular structures include the loss of m. levator pterygoideus through Tetanurae, an enlarged m. protractor pterygoideus in Tyrannosauridae, and the development of a complex, multidirectional suite of protractor muscles in Ornithopoda. These functional characteristics suggest adaptations for maintaining intracranial rigidity via a passive, soft-tissue, stay system, which is interpreted to be a plesiomorphic feature that birds exapted for powered cranial kinesis.

12.4

HORISAWA, S., DUDLEY, R.; sagiri@socrates.berkeley.edu. University of California, Berkeley
THREE-DIMENSIONAL WING KINEMATICS OF ERRATIC FLIGHT IN FREE-FLYING BUTTERFLIES

Many insects can fly erratically. In particular, it is well known that butterflies exhibit erratic, irregular, and unpredictable flight paths which might help in evading attack from aerial predators. Palatability of butterflies is correlated with diverse morphological features, flight speeds, and flight trajectories: palatable butterflies tend to fly erratically and rapidly, whereas unpalatable butterflies tend to fly regularly and slowly. We focus on the erratic flight in palatable butterflies and already determined three-dimensional body kinematics to characterize irregular flight paths. In this presentation, we determined three-dimensional wing kinematics of erratic flight in free-flying palatable butterflies, Morpho butterflies (*Morpho amathonte*) by filming 164 sequences with three fixed high-speed video cameras at 125 frames/s in a big insectary on Barro Colorado Island in the Republic of Panama.

20.2

HORTON, B.M., LONG, J.A., HOLBERTON, R.L.; brent.horton@umit.maine.edu. University of Maine, Orono
A POSSIBLE ROLE OF CORTICOSTERONE IN MEDIATING TRANSITIONS FROM MIGRATION TO BREEDING IN MALE WHITE-THROATED SPARROWS (*ZONOTRICHIA ALBICOLLIS*).

Corticosterone plays an important role in both migratory preparation and refueling during stopover. Little is known, however, about how birds balance the competing energetic demands of recovering from migration and initiating breeding once they reach the breeding grounds. Here, we investigate how adjustments in baseline corticosterone may affect physiology and behavior during the transition from migration to breeding. Males were captured upon arrival on breeding territories, brought into captivity, and implanted with intra-peritoneal Alzet osmotic pumps filled with either a moderate dose of corticosterone (MD), a low dose of corticosterone (LD), RU-486 (RU), or vehicle only (VO). Plasma corticosterone, body mass, and furcular fat score were measured at 1, 4, and 7 days following implantation, while locomotor activity and food intake were measured daily. Testes and pectoral muscles were harvested on the 7th day. MD and LD males showed significant increases in food intake and furcular fat deposition, but had reduced pectoral muscle mass compared to RU and VO males. MD males, despite having higher food intake than LD males, also had significantly greater muscle loss. Changes in total body mass, in conjunction with muscle and fat data, indicate that muscle loss occurs rapidly in MD males and is compensated only by increased fat deposition. There was no effect of treatments on locomotor activity or testis size. These data suggest that increased baseline corticosterone may facilitate an increase in food intake to replenish fat stores used during migration, but at the expense of skeletal muscle. Testis size was not affected, however, suggesting that moderate increases in corticosterone may not compromise breeding readiness.

54.4

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THE MORPHOLOGY, MECHANICAL PROPERTIES, AND COMPOSITION OF THE ACELLULAR RIBS IN A TELEOST FISH *MYOXOCEPHALUS POLYACANTHOCEPHALUS*

The material properties of cellular bone have been studied extensively, however, little is known about either the cellular or acellular bone of fishes. Teleost fish, many of which have skeletons comprised entirely of acellular bone, represent over half of extant vertebrates, 95% of all fishes, and are a model system to investigate the material properties of these two types of bone. We studied the great sculpin *Myoxocephalus polyacanthocephalus* (n=9), a sit-and-wait benthic predator that inhabits the temperate waters of the Pacific Northwest and has an acellular bony skeleton. We used a three-point-bending technique and custom MatLab script to assess stiffness and cross-sectional area along each rib and the rib series. The composition of ribs was also quantified. The ribs of the great sculpin are hollow cylinders of acellular bone. Stiffness (E) decreased distally along the rib but varied across the rib series. First and second moment of area decreased distally along the rib and along the rib series. The average rib is comprised of approximately 65% inorganic material.

67.1

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THE EFFECTIVE POPULATION SIZE OF A COLONY OF COLLARED LIZARDS: ANOTHER LOOK AFTER THREE GENERATIONS

Previous investigation, using demographic and temporal (genetic) methods, indicate a small effective population size (N_e) and low dispersal rates for a colony of collared lizards (*Crotaphytus collaris*) in central Oklahoma. Because these results are based on one generation of data, the N_e estimates may be an overestimate of the actual N_e . We re-examined the N_e estimates using allele frequency changes (allozymes) over three generations in a temporal estimate of N_e . We observed a loss of rare alleles in the samples and a decline in single-locus heterozygosity between the first and third generations sampled. In the first-generation sample, all loci were in Hardy-Weinberg Equilibrium (HWE). By the third-generation sample, two loci showed significant deviation from HWE. The temporal N_e estimate based on these allele frequencies was substantially lower than those previously calculated for both the temporal and demographic methods. This suggests that our previous N_e estimates using a shorter generation time may have overestimated the N_e of this colony of lizards.

29.10

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ASSESSMENT OF BRAZILIAN FREE-TAILED BAT (*TADARIDA BRASILIENSIS*) POPULATIONS USING ADVANCED INFRARED THERMAL IMAGING

The Brazilian free-tailed bat (*Tadarida brasiliensis*) is widespread in the southwestern United States between March and October, where it typically roosts in caves, buildings and bridges, forming some of the largest aggregations of mammals known to mankind. Each night these bats emerge from their roosts to feed on enormous quantities of insects, providing one of the most impressive examples of a large scale insect control service to both natural and agroecosystems. Yet, despite their estimated impact on insect populations, the exact role of this species is poorly understood by the scientific community. The goal of our project is to develop and apply new empirical and analytical methods for the accurate and reliable census of large numbers of bats using advanced infrared thermal imaging. Bat emergences were monitored at 6 major colonies in Texas and New Mexico using high-performance infrared thermal cameras. Seasonal trends were followed monthly at 3 of these sites. Recordings of the nightly emergences were analyzed using adaptive visual recognition algorithms that automatically identify and track individual bats. We present the first accurate and reliable estimates of the number of Brazilian free-tailed bats at 6 locations in Texas and New Mexico. Our data indicate large fluctuations in the size of the colonies on a seasonal as well as daily basis. Some of these fluctuations reflect the migratory habits of these bats, but others may be linked to large-scale weather patterns and related insect availability. These results will be discussed in the context of multi-scale ecological and economic modeling as well as in developing plans for the protection of these bats as an important national resource.

21.4

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FEEDING RATES OF COMMON ANTARCTIC GAMMARID AMPHIPODS ON ECOLOGICALLY IMPORTANT SYMPATRIC MACROALGAE

Single species feeding trials employing both fresh algal tissues and alginate food pellets containing dried finely ground algal tissues were conducted to examine the relative palatability of sympatric Antarctic macroalgae (three brown and five red macroalgal species) to three common herbivorous gammarid amphipods (*Proteoblingia gracilis* Chevreux, *Gondogeneia antarctica* (Chevreux) Thurston, and *Metaleptamphopus pectinatus* Chevreux). In fresh algal tissue bioassays, both the amphipods *P. gracilis* and *G. antarctica* consumed significantly greater amounts of the red alga *Palmaria decipiens* over all other seven species of macroalgae. The amphipod *M. pectinatus* failed to consume measurable quantities of fresh thalli of any macroalgae and therefore is likely to feed on other resources. In food pellet bioassays, the consumption rates of amphipods fed eight different species of macroalgae were compared with consumption rates on a highly palatable control green alga. Alginate pellets containing finely ground tissues of *P. decipiens* were consistently the most palatable of any of the macroalgae to *P. gracilis* and *G. antarctica*, while pellets containing the brown algae *Desmarestia menziesii*, *D. anceps* and the red alga *Plocamium cartilagineum* were not consumed by any of the three amphipod species. Regression analysis indicated that feeding rates of the amphipods *P. gracilis* and *G. antarctica* on alginate food pellets were not significantly correlated with known species-specific parameters of macroalgal nutritional quality (%N, %C, C:N ratio, soluble protein, soluble carbohydrate, and lipid). Therefore, differences in amphipod macroalgal palatability are most likely related to other factors including physical and/or chemical deterrents.

33.4

HUGGINS, K.A., NAVARA, K.J., HILL, G.E., MENDONCA, M.T.; huggika@auburn.edu. Auburn University
LONG TERM PERFORMANCE DETRIMENT IN SONGBIRDS WITH EXTENSIVE CAROTENOID-BASED PLUMAGE COLORATION: ARE CAROTENOIDS TOXIC?

Although there is extensive literature addressing the beneficial effects of carotenoids as antioxidants and immune enhancers, there are also studies that indicate that high doses of carotenoids may actually have a toxic effect. Songbirds with extensive, carotenoid-based plumage tend to maintain high levels of circulating carotenoids in plasma, which could represent a potential tradeoff between maintaining brightness at the expense of carotenoid-related toxicities. To test this hypothesis, we maintained American goldfinch males on either a high (n=40) or a low (n=40) dose of lutein/zeaxanthin treatment for 60 days during the time of molt. We took blood samples from animals before, during, and after supplementation, and analyzed the samples for baseline corticosterone as a measure of physiological stress, glutathione as a measure of oxidative stress, and creatine kinase as a measure of muscle degradation. Additionally, we tested muscle function in a subset of the population using a vertical jump test, a novel technique that tests the performance capability of the pectoral muscles in birds. We found that creatine kinase levels were significantly higher in animals receiving a high dose of dietary carotenoids, indicating the presence of muscular degradation in these birds. The birds supplemented with the high dose of carotenoids also significantly reached lower elevation in the jump trials (p=0.0009) indicating that there was a direct effect between increased carotenoid intake, increased creatine kinase levels and outward physical ability. Further results will be discussed.

76.11

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EXPERIMENTAL EVOLUTIONARY ADAPTATION TO ENVIRONMENTAL PH IN THE BACTERIUM

Abstract The evolutionary responses of organisms to changes in abiotic environmental factors such as temperature and pH have been of longstanding interest, because they are naturally variable and can sometimes reach stressful or even lethal levels. We discuss our current research using the bacterium *Escherichia coli* to study evolutionary responses over 2000 generations across an environmental acidic-alkaline pH range. Populations of *E. coli* (in six-fold replication) were exposed to one of four different constant conditions: benign ancestral pH of 7.2, stressful novel acidic pH of 5.4, stressful novel alkaline pH of 8.0, and benign novel pH of 6.4. All four groups showed improved relative fitness in their own specialized pH environment (direct fitness response). One might expect that a fitness gain in a specialized environment would result in a fitness loss in other environments as a cost of specialization, or tradeoff. Our results seem to provide support for tradeoffs when examined at a large group level. However, closer investigation of the individual 8.0 pH lines revealed that although some exhibited tradeoffs, other lines demonstrated no tradeoffs and actually increased relative fitness in all tested pH environments. Supported by NSF Grant IBN9905980 and NASA Grant 632731

52.5

HULSEY, C.D., STREELMAN, J.T.; dh251@mail.gatech.edu. Georgia Tech
CICHLID PHARYNGEAL JAW FUSION: IS SUTURING THE KEY TO UNPARALLELED TROPHIC DIVERGENCE?

The pharyngeal jaw of cichlids and other labroid fishes may represent a key innovation that facilitated their unparalleled trophic divergence. However, the cichlid pharyngeal jaw exhibits a transitional phenotype between the condition found in most bony fish and the morphology in other Labroidei. In cichlids, fusion of the lower pharyngeal jaw (LPJ) results from a suture between the two lower ceratobranchials that form a single fused bone in most Labroidei. To examine what novel abilities a fused pharyngeal jaw may confer and also what may have originally favored greater fusion of the labroid jaw, LPJ suturing was examined in Heroine cichlids. Among and within cichlid species, the presence of an external LPJ suture and feeding specialization on mollusks was evolutionarily quite variable, but greater suturing was highly correlated with molluskivory. Both pharyngeal jaw splitting under compression and the forces used to crush mollusks in the wild suggested greater LPJ suturing in the trophically polymorphic *Herichthys minckleyi* functionally strengthens the pharyngeal jaw. Using 3D computed microtomography (micro-CT), we show that external suturing is a good indicator of the extent the LPJ is sutured internally. During labroid diversification, pharyngeal jaw fusion likely helped to reinforce the LPJ during pharyngeal processing thereby increasing the ability of cichlids to exploit durable prey.

46.3

HURLEY, I.A., SCEMAMA, J.L., PRINCE, V.E.; ihurley@uchicago.edu. Organismal Biology & Anatomy, The University of Chicago, The University of Chicago
THE MECHANISM AND CONSEQUENCES OF DUPLICATE GENE PRESERVATION A COMPARISON OF *HOXB1* DUPLICATES ACROSS TELEOST FISH

Vertebrate evolution is characterized by gene/genome duplication events, and there is strong evidence that a whole genome duplication occurred in the lineage leading to the teleost fishes. We have focused on the teleost *hoxb1* duplicate genes as a paradigm to investigate the mechanism and consequences of duplicate gene preservation. Previous analysis of the zebrafish *hoxb1* genes found good evidence that the duplicates were preserved via subfunctionalization (McClintock et al., 2002). The combined expression patterns of the two zebrafish *hoxb1* genes together resemble the expression pattern of the single *HoxB1* gene of tetrapods, possibly due to degenerative changes in complementary cis-regulatory elements of the duplicates. We have tested the hypothesis that preservation of *hoxb1* duplicates via subfunctionalization is a synapomorphy of the teleost fishes. Consistent with this theory, analysis of *hoxb1* genes from divergent teleosts shows that upstream *hoxb1a* cis-regulatory elements are highly conserved, whereas equivalent *hoxb1b* elements show significant variation. We have compared *hoxb1* expression patterns in zebrafish, medaka and striped bass, and used transient transgenic analysis to test directly whether degenerative changes in cis-regulatory elements underlie subfunctionalization in these species. It has also been demonstrated that zebrafish *hoxb1* duplicates have evolved different functional capacities (McClintock et al. 2001). We have used a gain-of-function approach to compare the functions of *hoxb1* duplicates from zebrafish, medaka and striped bass in order to uncover the consequences of duplicate gene preservation across the teleost group.

HUSAK, J.F., LOVERN, M.B.; jerry.husak@gmail.com. Virginia Tech, Oklahoma State University

SEXUAL SELECTION ON WHOLE-ANIMAL PERFORMANCE: LIZARD LOCOMOTION AND MATING SUCCESS

Studies of sexual selection have focused mainly on morphological and behavioral traits, whereas studies of the evolution of physiological and morphological traits have focused on selection acting on whole-animal performance. Most of these studies of performance evolution have focused on the role of natural selection via differential survival, but the general approach of examining whole-animal performance as the trait directly under selection (instead of morphological traits) may be applied to studies of sexual selection. We investigated the potential for sexual selection on sprint speed performance in collared lizards (*Crotaphytus collaris*), considering the influence of circulating hormone levels as possible alternative targets of sexual selection. Among territorial, adult male collared lizards, only sprint speed significantly predicted territory area and number of offspring sired as determined by genetic paternity analysis, whereas body size, head size, and hindlimb size did not. Neither testosterone nor corticosterone levels correlated with sprint speed, territory area, or number of offspring sired. Thus, our results provide a direct link between whole-animal performance and mating success, suggesting that intra-sexual selection acts directly on sprint speed performance and drives the evolution of underlying morphological traits. Behavioral traits contributing to mating success likely interact with, or are constrained by, whole-animal performance, leading to variation in mating success within a population.

21.3

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DIETARY TOXIN SEQUESTRATION IN TWO POPULATIONS OF A TOAD-EATING SNAKE, *RHABDOPHIS TIGRINUS*

Rhabdophis tigrinus (Colubridae: Natricinae) is a bufophagous (toad-eating) snake from Asia that possesses unusual defensive glands under the skin on the dorsal surface of the neck. These nuchal glands have been reported to contain bufadienolide steroids similar to those that toads produce from cholesterol precursors. However, morphological and behavioral evidence has suggested that *Rhabdophis* does not synthesize defensive bufadienolides but rather sequesters them from ingested toads. In support of this hypothesis, we recently demonstrated that *Rhabdophis* must be born to a chemically-defended dam or consume a diet of toads in order to express bufadienolides in the nuchal glands. In this study we compared the composition of nuchal gland fluid in animals from toad-rich and toad-free islands. Nuchal gland fluid was collected from hatchlings from these two localities after they had been fed diets either containing or lacking toads. These samples plus extracts of the bufonid prey were analyzed with ¹H-NMR and HPLC. *Rhabdophis* from the toad-free island lacked bufadienolides in their nuchal glands and accumulated the toxins only when fed toads. In contrast, all hatchlings from the toad-rich island contained bufadienolides in their nuchal glands regardless of diet. These data provide further evidence of dietary toxin sequestration and maternal provisioning of bufadienolides by *Rhabdophis*.

22.4

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ECOLOGICAL AND BEHAVIOURAL CORRELATES OF COLOUR POLYMORPHISM IN A LACERTID LIZARD, *PODARCIS MELISELLENIS*

The co-existence of different colour morphs within a single population occurs in many animal and plant species. Several adaptive hypotheses have been put forward to explain this phenomenon (e.g. negative frequency-dependent selection, niche variation, non-random mate choice), but often it remains unclear how different selective forces create a balance that allows a permanent polymorphism. Most of the explanations predict that the colour morphs will differ in aspects of their life history and behaviour. For instance, male colour may be related with a specific reproductive strategy, territorial behaviour, and dominance. In turn, the diversity in life history and behaviour should be reflected in differences in animal design and performance. In a population of the Croatian wall lizard *Podarcis melisellenis* we found a striking polymorphism in abdomen and throat coloration: animals are white, yellow or orange. Testing hypotheses about the evolution of colour polymorphism requires an integrative approach. Here, we present data on various life history aspects of *Podarcis melisellenis*. We quantified the frequency of the different morphs along a transect on the island of Lastovo, Adriatic Sea, Croatia. The three colours exist in males and females, but in different proportions. In males, yellow individuals are the least common morph; in females, orange is the rarest colour. For a limited set of individuals we quantified morphological, performance and habitat characteristics. Orange males are clearly bigger than white or yellow, resulting in a different performance capacity. Also, behavioural observations were made in the field for several individuals of every morph. Colour morphs seem to differ in some aspects of their behaviour and microhabitat use.

11.2

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THEORETICAL ASPECTS OF BIPEDAL LOCOMOTION IN KANGAROO RATS: COMPARISON OF FIELD AND LABORATORY LOCOMOTION WITH RESPECT TO NEURAL CONTROL MECHANISMS

Infrared films (taken with a PC164C-EX Infrared camera and CML4IR Intelligent IR Lens, Supercircuits, <http://www.supercircuits.com/>) of bipedal locomotion in kangaroo rats, *Dipodomys ordii* were used to obtain normal feeding locomotor behaviors of kangaroo rats in the field (Alibates Quarry, Texas). The filming arena included a 100 cm x 50 cm x 50 cm wooden frame with bicycle reflectors at 10 cm intervals on each of the three axes, placed on open areas of a dirt road, near vegetation. Locomotor parameters measured included: stride length, jump height, stride time, angle of projection, and velocities, and accelerations of individual joints (toe, ankle, knee). We treated the kangaroo rat as a simple projectile and modeled the motion using initial parameters of the measured angles of projection, initial body velocity, and an average body mass of 49.6 g (taken from museum specimens of these species). Most movements of the kangaroo rat were significantly different from the predicted values, suggesting that motivational differences may alter many components of limb and body movements. Since some predicted values varied significantly from measured values, we hypothesized that characteristics of the soil may affect locomotion. Traction on fine sand may strongly affect parameters such as stride length and jump height, thus leading the animal to greatly alter its angle of projection in order to achieve the speeds, stride lengths and jump heights desirable for eluding predators or achieving an energetically efficient method of feeding. The study was partially funded by West Texas A&M University and the Ronald E. McNair post-baccalaureate achievement program.

35.1

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CRYPTIC PLUMAGE DIMORPHISM IN *APHELOCOMA* SCRUB-JAYS: ASSESSING VISIBLE AND ULTRAVIOLET REFLECTANCE ACROSS SPECIES AND SUBSPECIES

Recent studies of avian vision and plumage coloration have revealed a surprising degree of cryptic sexual dimorphism, with many examples of sex-based differences in UV reflectance that are invisible to humans. We examined the potential for cryptic plumage signaling in the genus *Aphelocoma*. This group of five scrub-jay species ranges across southern and central North America and includes cooperatively breeding species, (*A. coerulescens* and *A. unicolor*), island populations (*A. insularis*), tropical species (*A. unicolor*), and widespread species with considerable intraspecific variation in life history and appearance (*A. ultramarina* and *A. californica*). We assessed the visible and UV reflectance properties of *Aphelocoma* plumages using a fiber optic spectrometer to perform a series of reflectance measurements on hundreds of museum specimens representing all species within 10 subspecies groups. We then calculated quantum photon catches based on a corvid visual system to interpret the reflectance data in the context of what the birds perceive. We found subtle but potentially important differences in reflectance both between adult males and adult females and between first basic (subadult) and definitive basic (adult) plumages of some groups. Although we lack data for some subspecies groups, we have found it somewhat common for female adults to have distinctly brighter blue feathers. This characteristic appears to be most pronounced and consistent throughout the plumage in the cooperatively-breeding Florida Scrub-Jay (*A. coerulescens*), which implies a relationship between sexual dichromatism and complex breeding systems.

53.8

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ENDOTHELIN RECEPTORS IN THE KILLIFISH, *FUNDULUS HETEROCLITUS*, GILL

The endothelin (ET) signaling cascade is traditionally viewed as three paracrines, ET-1, ET-2 and ET-3 that bind to two membrane bound receptors, ETA and ETB. Generally, when ETs bind to receptors on vascular smooth muscle (VSM) cells constriction is observed; however if ET binds to endothelial ETB receptors, nitric oxide (NO) and prostaglandins (PGs) are produced leading to subsequent relaxation of the underlying VSM. ET stimulation of NO and PGs can also result in inhibition of ion transport in the mammalian kidney and recently this cascade was hypothesized to inhibit ion transport in the opercular epithelial lining from the fish *Fundulus heteroclitus* (killifish), which is a model for the seawater teleost gill. Previous physiological experiments suggest that ET receptors (ETRs) are present in the fish gill. The gill is a multifunctional organ that receives 100% of cardiac output, which is channeled through a complex network of vessels and sinuses. We hypothesize that the ET signaling cascade may be involved in regulation of local blood pressure and flow through the gill and/or regulation of gill function. To further characterize the gill ET signaling axis, we have sequenced the mRNA of the ETRs from the killifish gill, and found three ETR transcripts from separate genes, ETA, ETB1, and ETB2. Tissue distribution and effects of environmental salinity on the killifish ETR mRNA expression were determined. Also, the cells in the gill that express ETR mRNA and proteins were localized with in situ hybridization and immunohistochemistry. Future experiments to sequence and characterize the ET genes are in progress and are needed to better understand the ET signaling cascade and its potential regulation of blood flow and gill function in fishes.

16.3

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DEIODINASES AND THE CONTROL OF METAMORPHOSIS IN THE CARNIVOROUS LARVAE OF THE ANURAN *LEPIDOBATRACHUS LAEVIS*

Anuran metamorphosis is one of the most extreme processes in vertebrate development. Typically it transforms a microphagous, herbivorous, aquatic larva into a macrophagous, terrestrial adult. This process is dependent on thyroid hormone (TH), which initiates - via nuclear receptors - a cascade of gene expression in responding tissues. It has been hypothesized that changes in the thyroid hormone-regulated metamorphic program mediate the evolutionary diversification of larval and adult morphology. This could be accomplished via temporal changes in tissue sensitivity and responsiveness to thyroid hormone on a tissue or organ-specific level. Recent studies point to the type II and type III deiodinase enzymes as potential players in the tissue-specific control of the metamorphic response. To investigate the role of these enzymes in the evolution of larval morphology, I focus on the extreme jaw morphology exhibited by the megalophagous carnivorous larvae of the South American frog *Lepidobatrachus laevis*. These tadpoles possess massive jaws and an enlarged head that allow them to consume prey, including other tadpoles, whole. These features, as well as a functional stomach and adult-like gut, mean the larvae of *L. laevis* attain adult characteristics while still in the larval state. At metamorphosis these structures are less extensively remodeling relative to the typical anuran tadpole. Of interest is the role of the local manipulation of active TH by the deiodinases on the metamorphic response in these adult tissues. To address this question I use an analysis of gene expression and enzyme activity during metamorphosis in whole tadpoles as well as on jaws grown in tissue culture.

29.1

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ELUSIVE SPECIES: A NOVEL APPROACH TO MEASURING ACTIVITY AND SAMPLING AVAILABILITY

Many species present difficulties for studying behavior and/or abundance due to their elusiveness. Desert tortoises (*Gopherus agassizii*) are elusive because they remain underground in burrows for approximately 90% of the time where they can be hidden from sight. We introduce the concept of the elusiveness filter as a heuristic to illustrate how this cryptic behavior can obscure, and sometimes bias, studies and surveys. For example, methods for monitoring status and trends of desert tortoise populations have resulted in contentious debates about the efficacy of different methods. It appears that all methods are highly variable in the precision and accuracy of density estimates they can produce. Distance Sampling (and alternative approaches to calculate density) requires precise estimates of the availability of tortoises to be sampled (G_0). G_0 is currently estimated from samples of tortoises (focal animals), which are located periodically with telemetry throughout the sampling season. For the purpose of estimating population density, the entire sampling season is assumed to have a constant value of G_0 , and as this is certainly not correct, this assumption introduces additional imprecision. Here, we describe a method for correcting for this elusiveness filter when estimating densities of desert tortoises by using time-specific estimates of G_0 . Our method involves estimating tortoise availability (and activity) from models built from environmental data (relative humidity, temperature and light intensity) collected by small data loggers affixed to focal animals. Additionally, we show how tortoise availability (and activity) can be modeled as a function of a suite of climatic variables using artificial neural networks and other multivariate clustering algorithms.

48.3

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GENOMIC REGULATION OF THE *DLL-A/B* GENE CLUSTER IN
CIONA INTESTINALIS.

The ascidian *Ciona intestinalis* has a compact genome, including an apparent homolog of the *Dlx* clusters in vertebrates. The *Dll-A/B* cluster in *C. intestinalis* is much smaller than its vertebrate counterparts, and in combination with the ability in ascidians to introduce transgenes by electroporation, forms a good model system for the study of the common genomic motif of clustered developmental genes. We have made a 20 kilobase construct with a reporter gene inserted in an exon of *Dll-B*, which includes the entire gene cluster along with upstream regions. This transgene faithfully reproduces much of the endogenous spatial and temporal pattern of expression for *Dll-B*. Comparison with reporter constructs which include less flanking DNA, and/or a reporter gene inserted in *Dll-A*, suggest that interactions between *cis*-regulatory elements and both of the cluster's promoters are in part responsible for the specificity of the endogenous expression pattern.

54.11

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KEEPING AN OPEN MIND: INVESTIGATING POACHER SKELETAL MORPHOLOGY

Poachers (Agonidae) are an obscure family of fish nested within the sculpins. They are benthic fish typically found in the sub-arctic waters of the Northern Pacific. Poachers are an intriguing family in that they possess a wide range of body forms (44 species in 22 genus) characterized by bony dermal plates that cover their bodies. Some members possess well-defined post-cranial pits that are developed to varying degrees. Agonids make several low-pitched humming sounds, but the method of sound production has not been determined. Our project focuses on the unusual anatomy of the post-cranial pit and its possible applications, specifically in bioacoustics. A high-resolution CT scan of *Bothragonus swani* (Rockhead Poacher) was used for anatomical study. Using a 3-D imaging program we observed the depth and diameter of the cranial cavity and the distinct skeletal morphology of the anterior half of *B. swani*. The anterior-most ribs have been modified to closely follow the contours of the calcified pit and may be the source of the humming sounds via stridulation. Bones in very close proximity to the calcified pit are also present and appear to be closely associated with a series of skull bones that lead to projections that cradle the animal's ear bones, the otoliths, potentially serving as a specialization for hearing. We also identified and described several different sound types from *Agonopsis vulsa* (Northern Spearnose Poacher). Recordings were taken at different times of the day and in different situations (single fish and grouped with others). Perhaps the most interesting sounds recorded were those below the threshold of human hearing (sub 20Hz) called infrasound.

46.2

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TRANSGENIC ANALYSIS OF THE MECHANISM OF CYPRINIFORM ORAL TOOTH LOSS

We are interested in the developmental genetic mechanisms responsible for evolutionary change in fish dentition, and are specifically investigating the mechanism of oral tooth loss in cypriniform fishes. In a survey of genes with known tooth expression in mammals, we found that *Dlx2* ortholog expression is missing from the oral epithelium of the cypriniform zebrafish. Such expression is present in fish species retaining oral teeth, however, such as the relatively closely-related characiform *Astyanax mexicanus*, as well as the more distantly related Japanese medaka. To test whether a *cis*-regulatory mutation rendered cypriniform *Dlx2* orthologs incapable of oral expression, we created a reporter transgenic containing 4 kb of zebrafish genomic sequence 5' of the *dlx2b* transcription start attached to GFP. We found in both transient injections of this construct and a stable transgenic line, that GFP is expressed in zebrafish pharyngeal tooth epithelium but not in the oral region. Injection of the same construct into *A. mexicanus* drives reporter expression in the epithelium of both pharyngeal and oral teeth. This indicates that evolution of *dlx2b* expression is the result of changes in *trans*-acting factors, rather than of changes to the gene itself. We have previously reported that Fibroblast growth factor (Fgf) signaling is required for *Dlx2* ortholog expression in zebrafish pharyngeal teeth. Application of an Fgf pathway inhibitor to the *dlx2b*:GFP zebrafish transgenic line similarly eliminates GFP expression in pharyngeal teeth, indicating that this element requires Fgf signaling for its dental expression. We are currently investigating the Fgf pathway as a candidate *trans*-acting factor responsible for loss of oral *Dlx2* ortholog expression in cypriniforms and perhaps loss of oral teeth as well.

56.5

JACKSON, B.E., DIAL, K.P.; brandon.jackson@mso.umt.edu. University of Montana, Missoula
ALLOMETRY OF AVIAN FLIGHT PERFORMANCE: CONTRIBUTION OF LEGS AND WINGS DURING MAXIMAL BURST TAKE-OFF AND VERTICAL FLIGHT

Previous work on bird takeoff and vertical flight has been relatively limited either by the selection of the performance variables or by the phylogenetic scope of the study. In an effort to comprehensively measure the allometry of flight performance, we are quantifying the burst vertical, burst horizontal, and high-speed angular accelerations for a range of species and body masses. Here we present our progress to date on whole-body performance, detailed 3D wingbeat kinematics, and hindlimb power production during maximal burst takeoff and vertical flight. We used a force plate and four synchronized high-speed video cameras to quantify the relative contributions of both legs and wings during lift-off, as well as the 3-D kinematics and dynamic morphology of birds flying vertically (2.5 m). Among species of columbids (N=4; mass range 40g - 480g), wing span, wingbeat frequency, and mass specific whole-body take off power scale as predicted by isometry and the frequency-dependent power hypothesis: proportional to $M^{1/3}$. However, in the current sample of passerine species (N=8; 9g - 78g) wing span scales in proportion to $M^{0.20}$, frequency as $M^{-0.19}$, and take off power is independent of body mass. Both peak ground reaction force (mean 5.0 X body weight) and mass-specific hindlimb jump power (mean 49 W/kg^{-1}) are independent of body mass in both the columbids and passerines, with no significant differences between clades. While flight performance in galliforms (N=4 species from Tobalske and Dial 2000) and the columbids scales predictably from the frequency-dependent power hypothesis, the pattern in passerines is less clear and will require an evaluation over the full range of body sizes and ecologies within this highly speciose clade. (Supported by NSF)

S7-2.3

JACOBS, M.W., DEGNAN, B.M.; mwjacobs@u.washington.edu. University of Washington, University of Queensland
DELAY OF METAMORPHOSIS IN SOLITARY ASCIDIANS: GENETICS, MORPHOLOGY, AND ECOLOGY

Metamorphosis is both an ecological and a developmental genetic transition that an organism undergoes as a normal part of ontogeny. Many organisms have the ability to delay metamorphosis when conditions are unsuitable. This strategy carries obvious benefits, but may also result in severe consequences for larvae that run low on time and energy. Some solitary ascidians exhibit extensive precocious differentiation of juvenile structures when the tadpole larval phase of the life cycle is prolonged. We used microarrays to investigate the genetic consequences of delay of metamorphosis in larvae of *Herdmania curvata*, a solitary ascidian, which displays a conservative amount of precocious morphological differentiation. We did not detect any significant genetic change between competent and aged larvae, although there was a trend for expression levels of many genes, such as lectins, which are normally up-regulated during metamorphosis, to drop over prolonged larval life. We could not find any significant differences in gene expression levels between juveniles from delayed tadpoles and juveniles from tadpoles which metamorphosed as soon as they were competent, suggesting any changes in RNA levels that occur during an extended planktonic period are compensated for during early metamorphosis. These data suggest that (i) despite some morphological change over extended larval life, *Herdmania* are essentially in genetic stasis as larvae, and (ii) molecular mechanisms exist during early metamorphosis to ensure that postlarvae derived from different aged larvae are morphogenetically equal. We will discuss our results in the context of developmental patterns in other ascidians (both solitary and colonial), microarray studies of metamorphosis in other invertebrates, and ecological consequences of delay of metamorphosis.

5.2

JAWOR, J., RICHARDSON, J., KETTERSON, E.; jjawor@indiana.edu. Indiana University, Bloomington
DO HORMONES OTHER THAN TESTOSTERONE INFLUENCE INTRASEXUAL AGGRESSION IN FEMALE DARK-EYED JUNCOS (*JUNCO HYEMALIS*)?

Hormones and aggressive behavior have been widely studied in male birds, but not as widely in females. In some species, female aggression has been linked to increases in testosterone (T), while in others no relationship has been found. Previous research with female dark-eyed juncos (*Junco hyemalis*) found that experimentally increased T led to increased aggression, but endogenous T did not co-vary with aggression or dominance. Here we investigated whether steroid hormones other than T, estradiol (E2), progesterone (P), or DHEA, increased in females after interacting with a same-sex, conspecific intruder. Thirty females were allowed to establish residence in breeding aviaries and bond with a male. After 48hrs, they were presented with either a female conspecific, or a control heterospecific intruder. Each female was her own control, and the order of presentation of hetero- or conspecific intruders was randomized and occurred one week apart. To compare pre- and post-challenge hormone levels we collected plasma samples prior to and 30min after introductions. Rates of aggression by the resident female were also recorded. Resident female juncos were almost always aggressive towards the conspecific, and were never aggressive to the heterospecific intruder. Hormone assays are currently underway. Hormone levels pre- and post-intrusion will be compared to each other and to rates of aggression. Findings from this research will further our understanding of the hormones influencing female aggression, particularly during the breeding season when selection may have favored a trade-off between hormonally mediated maternal effects and hormones that mediate female aggression.

37.8

JIANG, Q., GOETZ, F.W., PHILLIPS, R., PLACE, A.R.; jiangq@umbi.umd.edu. Center of Marine Biotechnology, Baltimore, Marine Biological Laboratory, Woods Hole, Washington State University, Vancouver
CHITINASE- A NEW MEMBER IN THE FISH INNATE IMMUNITY REPERTOIRES

Chitin is an unbranched homopolymer of β -(1, 4) linked N-acetyl glucosamine (NAG) residues and is the second most abundant carbon polymer, after cellulose, on earth. Chitin and its deacetylated derivative, chitosan, have been shown to possess immunostimulating properties in plants, mammals, and fish. Specifically, chitin and chitosan enhance T-cell functionality, natural killer (NK) cell activity, and interferon (IFN) production from activated NK cells. In addition, they induce macrophages to produce interleukins (IL-1 β , IL-12 and IL-18), tumor necrosis factor (TNF- α), macrophage stimulating factor (MAF) and colony-stimulating factor (CSF). Vertebrates possess an enzyme in gastric tissue that specifically recognizes and hydrolyses chitin-releasing dimers from the nonreducing end of the polymer. We have purified and cloned the gastric chitinase (Onmy-CHIT.01) from rainbow trout (*Onchorhynchus mykiss*) and found a second form locating in myeloid cells of rainbow trout. The second form, Onmy-CHIT.02, displays 58% identity with the gastric ortholog and possesses all the characteristic protein motifs found in the 18 glycosyl hydrolyase family (E.C 3.2.1.14), which is secreted upon stimulation. The tissue distribution of the two transcripts as assessed by quantitative real-time PCR, showed that the gastric chitinase was expressed exclusively in the stomach while the myeloid cell chitinase was found predominantly in the head kidney, kidney and spleen. We also screened a rainbow trout BAC library and found both genes located on chromosome 17 of the rainbow trout. The gene regulatory mechanisms are currently under investigation.

46.6

JIMENEZ, L.; jimenez2@adelphi.edu. Adelphi University
PRELIMINARY PHYLOGENY OF THE TILEFISHES BASED UPON THEIR CYTOCHROME B AND 16S GENE SEQUENCES

Tilefishes are found worldwide. Tilefishes are presently thought by some to be monophyletic (i.e. belong to one family, Branchiostegidae, comprised of two subfamilies, Malacanthinae and Branchiosteginae). Another alternative theory is that the tilefishes consist of two separate phyletic lines, Branchiostegidae and Malacanthidae, each warranting family distinction. There are a total of forty-two nominal species of tilefishes. The analysis of two mitochondrial genes, cytochrome b (cyto. b) and 16S, from representative species of each genus, *Branchiostegus*, *Caulolatilus*, *Lopholatilus*, *Hoplolatilus*, and *Malacanthus*, has been performed. As the group has not been examined molecularly, custom primers were used for the cyto. b gene amplification. The 16S gene has been isolated and sequenced each of the representative species of tilefishes and outgroups examined. The cyto. b gene has been isolated and sequenced in a number of the tilefishes and outgroups. A preliminary phylogenetic tree has been constructed utilizing PAUP.

57.7

JOHNSEN, S., KELBER, A., WARRANT, E.J., SWEENEY, A.M., WIDDER, E.A., LEE, R.L., HERNANDEZ-ANDRES, J.; sjohnsen@duke.edu. Duke University, Lund University, Harbor Branch Oceanographic Institution, US Naval Academy, University of Granada
THE COLOR OF NIGHT: TWILIGHT AND NOCTURNAL ILLUMINATION AND ITS EFFECTS ON COLOR PERCEPTION

Recent studies have shown that some nocturnal insect and vertebrate species have true color vision, even under starlight. Given this, their vision would be affected by changes in the spectral quality of twilight and nocturnal illumination, due to the presence or absence of the moon, artificial light pollution and other factors. We investigated this in the following manner. First we measured the spectral irradiance (from 300 to 700 nm) during the day, sunset, twilight, full moon, new moon, and in the presence of high levels of light pollution caused by high pressure sodium lamps. The spectra were then converted to both human-based chromaticities and to relative quantum catches for the nocturnal hawkmoth *Deilephlia elpenor*, which has color vision. The reflectance spectra of various flowers and leaves and the red hindwings of *D. elpenor* were also converted to chromaticities and relative quantum catches. Finally, the achromatic and chromatic contrasts (with and without von Kries color constancy) of the flowers and hindwings against the leaves were determined under the various lighting environments. The twilight and nocturnal illuminants were substantially different from each other, resulting in significantly different contrasts. The addition of von Kries color constancy significantly reduced the effect of changing illuminants on chromatic contrast, suggesting that, even in this light-limited environment, the ability of color vision to provide reliable signals under changing illuminants may offset the concurrent 3-fold decrease in sensitivity. Given this, color vision may be more common in crepuscular and nocturnal species than previously considered.

59.2

JOHNSON, M.A.; mjohnson@biology2.wustl.edu. Washington University, St. Louis
DOES WHERE AN ANIMAL LIVES DETERMINE ITS BEHAVIOR? THE ROLE OF MICROHABITAT IN LIZARD TERRITORIALITY

Many animals defend territories to monopolize resources. Despite much work on interspecific variation in territoriality, little is known about the role of habitat in this behavior. Specifically, species that occur in different habitats may experience dissimilar selective pressures, resulting in different territorial behaviors. To determine the effects of habitat structure on territoriality, I quantified aggressive display behaviors and territory overlap for six territorial species of Caribbean *Anolis* lizards occurring in a range of microhabitats. I also measured the microhabitats occupied by each species. Results from this work indicate that species occurring in more open microhabitats perform more territorial behaviors than those in more cluttered microhabitats, but that species in open microhabitats have a higher degree of territory overlap within sexes. Because male territoriality in *Anolis* is presumably primarily a means to increase mating opportunities, I am also conducting molecular paternity analyses of hatchlings from the populations studied in the field to determine if the different territorial strategies result in different spatial patterns of paternity among species.

42.2

JOHNSTON, G.I.H., MOORE, M.C.; gjohnston@asu.edu. Arizona State University
TRANSFER OF MATERNAL CORTICOSTERONE TO YOLK IN PREOVULATORY AND POSTOVULATORY TREE LIZARD (*UROSAURUS ORNATUS*) EGGS

Eggs of many vertebrates contain yolk steroids of maternal origin, which can profoundly influence offspring development, growth, and behavior. How and when steroids get into the yolk is still not clear. Are they intentionally deposited or just incidentally taken up? We are particularly interested in the effects that maternal stress hormones, such as corticosterone, can have on offspring. In this study we examined when the eggs are susceptible to elevated maternal corticosterone levels. We implanted both vitellogenic (preovulatory) and gravid (postovulatory) tree lizards (*Urosaurus ornatus*) with corticosterone. It is usually assumed that maternal steroids are deposited into yolk during egg formation, so we predicted that implanting the mother during vitellogenesis would elevate yolk hormone levels. However, since there is no longer a large blood supply to the shelling eggs in the oviduct, we predicted that high maternal corticosterone levels during gravidity would have little effect on yolk corticosterone levels. Surprisingly, yolk corticosterone was elevated in eggs from females implanted both while vitellogenic and while gravid. We believe this is the first evidence that maternal steroids can be deposited into oviductal eggs. This finding greatly increases the time window during egg production when eggs are susceptible to influence by maternal steroids, especially in species like tree lizards in which the eggs can remain in the oviduct for 10-30 days and perhaps longer.

14.9

JORDAN, L.K.; ljordan@ucla.edu. University of California, Los Angeles
ECOMORPHOLOGY OF STINGRAY MECHANOSENSORY AND ELECTROSENSORY SYSTEMS (ELASMOBRANCHII: BATOIDEA)

Elasmobranch fishes (sharks, skates, and rays) demonstrate remarkable sensory capabilities which are used for a variety of purposes including locating and capturing prey. This study relates the feeding ecology of stingray species representing the benthic, benthopelagic, and pelagic habitats to the anatomy of their mechanosensory and electrosensory systems. These systems allow elasmobranchs to locate prey by detecting water movements and electric fields respectively. Elasmobranchs are widely considered opportunistic generalist feeders, though some species exhibit dietary specialization. Existing literature on the stomach contents of three species, *Urolophus halleri*, *Myliobatis californica*, *Dasyatis (Pteroplatytrygon) violacea*, is compared to species abundance data from the same locations to identify selective feeding on certain prey. Morphometric measurements and detailed maps of sensory anatomy were constructed and analyzed for each species. *U. halleri* is a benthic ray feeding primarily on small epifaunal benthic invertebrate prey. The lateral line of this species shows a high proportion of non-pored ventral canals while the electrosensory pores are concentrated ventrally around the mouth. *M. californica* is a benthopelagic ray, capable of utilizing both benthic and pelagic environments, which feeds primarily on deeply buried infaunal benthic invertebrates. The lateral line system is highly branched with a large number of pores per branch which may help it locate water jets from the siphons of buried prey. *D. violacea* is a pelagic ray typically caught in the upper 100m in coastal waters. *D. violacea* feeds on highly mobile fishes and invertebrates, primarily squid. The lateral line branching and ratio of pored to non-pored canals is intermediate in this species. Relationships between the ecology of these three species, including their habitat and prey, and sensory morphology are explored.

23.2

JOST, J.A., HELMUTH, B.S.T.; jostj@biol.sc.edu. University of South Carolina

THERMAL TOLERANCE OF *GEUKENSIA DEMISSA*: THE EFFECT OF DAILY MAXIMUM TEMPERATURES ON GROWTH AND MORTALITY

Predicting alterations in communities due to climate change requires elucidation of both the physiological limits and the exposure ranges of organisms in the field. The Atlantic ribbed mussel, *Geukensia demissa*, is a dominant component of salt marsh ecosystems from the Gulf of St. Lawrence to Northeast Florida, an exposure gradient that would be expected to encompass temperatures from -20°C to above 50°C. Published laboratory studies indicate a tolerance range of 22°C to 40°C. However, since body temperature patterns in the field are not known, resolution of the discrepancy between expected field temperatures and published physiological limits is not currently possible. I have documented spatial and temporal patterns in the body temperature of the mussel *Geukensia demissa* by examining the effects of microhabitat, body size, and body position within the sediment in a South Carolina estuary for a period of two years. These data suggest that the upper lethal limit for this species is much higher than 40°C, and model body temperatures up to 51.5°C have been recorded. Using these field data, I developed a laboratory experiment to determine the effects of temperature on mortality and growth rate. Mussels were exposed to the same daily maximum temperature (ranging from 30-55°C) for a period of three months. Data suggest that 100% mortality occurs at 55°C, 75% mortality at 50°C, and <5% mortality at 30, 35, 40, and 45°C. Growth rate data suggests that mussel growth decreases with increasing maximum temperature. These data suggest that *Geukensia demissa* is living close to its thermal limits in Southern salt marshes. Therefore, there is a potential for mussel mortality with global climate change, leading to changes in salt marsh community structure.

33.2

JOYNER-MATOS, J., CHAPMAN, L.J., JULIAN, D.; jjoyner@zoo.ufl.edu. University of Florida, Gainesville, McGill University, Montreal

ELEVATED DISSOLVED OXYGEN LEVEL INFLUENCES FINGER-NAIL CLAM (*SPHAERIUM* SP.) STRESS PROTEIN EXPRESSION AND POPULATION DISTRIBUTION IN A UGANDAN PAPYRUS SWAMP

Abiotic factors can affect species distribution by stressing organisms to their physiological limits. In a population distributed along an abiotic gradient, organisms on the distribution edge may be more stressed than those in the center, where conditions may be benign. We tested this hypothesis using cellular-level biomarkers. The freshwater clam *Sphaerium* sp. inhabits papyrus (*Cyperus papyrus*) swamp/river systems in Uganda. In this system, ecotonal gradients from normoxia to hypoxia occur along streams feeding into the swamps. Across one such gradient, DO levels were lowest in the swamp (mean DO = 0.82 ± 0.18 mg/L), 3.05 ± 0.07 mg/L in the ecotone, and 5.46 ± 0.24 mg/L in the stream. Average clam density was high but patchy in the swamp (mean 74.9 ± 15.4 clams/0.5m², range 8-246 clams/0.5m²). Clam densities decreased along the ecotone, and clams were absent in stream sites. Across the gradient, clam abundance was negatively related to DO ($r = -0.629$, $p < 0.0001$). The internally-brooding clams likely spend their entire life cycle in extreme hypoxia. Elevated DO may influence their distribution since hyperoxia increases endogenous free radical production, causing oxidative damage. To test whether edge clams were stressed, we analyzed expression levels of 10 stress proteins (CuZnSOD, MnSOD, GPx, HO-1, ubiquitin, Hsp60, Hsp70, Grp75, sHSP, and OGG1-m) in clams from four sites. Seven of the proteins (but not GPx, Grp75, or HO-1) had the following pattern: clams from the dense interior of the swamp, ~200 m from stream input, had low expression levels, whereas clams at swamp sites 90m and 30m from the distribution edge had increased expression, and clams at the distribution edge had significantly decreased protein expression ($p < 0.021$). While this pattern could indicate that edge clams were not stressed, an alternative interpretation is that edge clams were stressed beyond a critical level at which elevated stress protein expression could not be maintained.

38.1

KAHN, P.F., MENDONCA, M.T.; kahnpu@auburn.edu. Auburn University

SEASONAL CHANGES IN SEX STEROIDS OF THE GOPHER TORTOISE (*GOPHERUS POLYPHEMUS*) AND THEIR RELATIONSHIP TO UPPER RESPIRATORY TRACT DISEASE

Anthropogenic factors have contributed substantially to the decline in threatened gopher tortoise populations. However, disease may also be a considerable threat to the survival of this species. Gopher tortoises are susceptible to Upper Respiratory Tract Disease (URTD), a bacterial infection caused by *Mycoplasma agassizii*. It is well established that the endocrine and immune systems are highly integrated in vertebrates; hence, physiological responses to disease can affect the production and release of sex steroids. Therefore, while low recruitment rates in gopher tortoises are primarily the result of nest and hatchling predation, it is important to monitor sex steroids in these animals to determine if URTD has deleterious effects on reproductive function. In this study, blood samples were taken from gopher tortoises at Fort Benning, Georgia, during spring and summer sampling periods. The blood samples were analyzed for the presence of antibodies to *M. agassizii* using an ELISA. In addition, we conducted radioimmunoassays to measure circulating plasma levels of testosterone (T) in males and 17β-estradiol (E) in females. We hypothesize that symptomatic tortoises with low antibody titers will exhibit seasonally uncharacteristic sex steroid levels.

34.8

KAISER, A., KLOK, C.J., SOCHA, J., LEE, W.K., FEZZAA, K., QUINLAN, M.C., HARRISON, J.F.; akaise@midwestern.edu. Midwestern University, Glendale, Arizona State University, Tempe, Argonne National Laboratory@title:Structure, function, and allometry of the tracheal system of Darkling Beetles (Tenebrionidae)

The air-filled tracheal system of insects utilizes the advantages of the high solubility of oxygen in air and the low energetic costs of gaseous transport to support very high rates of oxygen uptake. However, does use of this system limit insect size? In this study we compare tracheal structure and function of four species of adult Darkling Beetles (Tenebrionidae) over a range of body mass from 1.6 mg (*Tribolium castaneum*) to 1700 mg (*Eleodes obscura*). We analysed tracheal structures and dimensions using phase-contrast x-ray synchrotron imaging at Argonne National Laboratory. The general layout of the tracheal system was very similar in all four species. All but the prothoracic pair of spiracles open into the subelytral cavity. Structure and function of spiracular valves are similar in all species. The tracheal manifolds are connected by tracheal trunks. Air sacks are absent. Swaying of the tracheal system, caused by abdominal movements, and tracheal compressions were observed in all species, but occurred more frequently in larger beetles. Both mechanisms are likely to induce convective gas transport. The tracheal system takes up a bigger proportional area in larger beetles, thus exhibiting a greater investment in respiratory structures. Mass-specific metabolic rates decrease with size, so tracheal investment relative to mass-specific oxygen demand increases dramatically. Hyperdevelopment of the tracheal system in larger insects may allow compensation for distance effects on diffusion, but may eventually result in limitation on insect size. NSF 0419704 (J.F.H), NSF IBN0344963 (M.C.Q.)

53.10

KAJIMURA, S., AIDA, K., DUAN, C.; cduan@umich.edu. University of Michigan, Ann Arbor, University of Tokyo, Japan
UNDERSTANDING HYPOXIA-INDUCED GENE EXPRESSION IN EARLY DEVELOPMENT: IN VITRO AND IN VIVO ANALYSIS OF HIF-1-REGULATED ZEBRAFISH IGFBP-1 GENE EXPRESSION

Insulin-like growth factor binding protein-1 (IGFBP-1) is a hypoxia-inducible gene. Previous studies have shown that the induction of IGFBP-1 expression by hypoxia is a conserved physiological mechanism acting to restrict IGF-stimulated growth and developmental process under hypoxic stress (Kajimura et al., PNAS, 2005). The molecular mechanisms underlying hypoxia-induced IGFBP-1 gene expression in the embryonic tissues, however, are not well understood. Here we show that the hypoxia-inducible factor (HIF)-1 pathway is established in early embryogenesis and mediates hypoxia-induced IGFBP-1 expression in zebrafish embryos. Hypoxia exposure or HIF-1 α overexpression significantly increased the zebrafish IGFBP-1 gene transcription in cultured cells in vitro and in developing embryos in vivo. Although the zebrafish IGFBP-1 promoter contains 13 consensus hypoxia response elements (HREs), deletion and point mutation analysis revealed that only the HRE positioned at -1090/-1086 is required during hypoxia and HIF-1-induced IGFBP-1 expression in vitro and in vivo. Further experiments revealed the presence of a putative HRE ancillary sequence (HAS) adjacent to the -1090/-1086 HRE but not the other HREs. Mutation of the HAS greatly reduced the responsiveness of the IGFBP-1 promoter to hypoxia and to HIF-1. These results suggest that HIF-1 mediates hypoxia-induced IGFBP-1 gene expression in early development by selectively interacting with the -1090/-1086 HRE in a context/location-dependent manner.

14.2

KAJIURA, S.M., FORNI, J.B., SUMMERS, A.P., TYMINSKI, J.P., WILLIAMS, A.T.; kajjiura@fau.edu. Florida Atlantic University, University of California, Irvine, Mote Marine Laboratory
SEXUAL DIMORPHISM IN ELASMOBRANCH FISHES

Sexually dimorphic head shape is well documented in vertebrates from teleosts to mammals. However, only a single example of sexually dimorphic head shape is documented in the more basal chondrichthyan fishes. At sexual maturity, the rostral cartilages of male bonnethead sharks, *Sphyrna tiburo*, elongate concomitantly with the rod-like cartilages of the male intromittent organs (claspers) to create a distinct bulge along the anterior margin of the cephalofoil. We propose that the rostral cartilage elongation is a byproduct of endocrinological changes at the onset of sexual maturity that stimulate growth of the clasper cartilages. To determine if this phenomenon is unique to *S. tiburo* or widespread among the elasmobranchs, we examined rostral cartilage length and head shape among five coastal skate species (Rajidae) from the Atlantic basin. Twelve homologous landmarks on the head were digitized and a Procrustes analysis, thin plate spline, and principal components analysis were used to visualize and test for differences between the sexes. For all species, juveniles failed to demonstrate a sexual dimorphism in head shape whereas adults differed significantly. However, unlike *S. tiburo*, head shape differences among the skates were attributed to a suite of skeletal changes and not exclusively to an elongation of the rostral cartilages. Thus, sexually dimorphic head shape may be widespread among adults within the class Chondrichthyes and close examination of the rostral cartilages of other elasmobranch species may reveal previously overlooked differences. The basal location of the chondrichthyan fishes within the vertebrate clade extends the earliest appearance of cephalic sexual dimorphism among the vertebrates.

40.5

KAMMERER, C.F.; cfkammer@uchicago.edu. University of Chicago
TEMPORAL PATTERNS IN NON-MAMMALIAN SYNAPSID MORPHOSPACE

Non-mammalian synapsids (commonly called mammal-like reptiles) were the dominant group of terrestrial vertebrates during the Permian and much of the Triassic Period (~280-200 million years ago). Although patterns of taxonomic distribution are well studied in the group, comparatively little attention has been given to quantifying changes in morphological disparity during their history. I undertook a geometric morphometric analysis of non-mammalian synapsids using 16 cranial landmarks. Digitized images of synapsid skulls were analyzed using Procrustes methods in the TPS suite of programs, with relative warps analysis used to determine the major components of shape-based variance in the data. The majority of variance was related to facial elongation and relative size of the sensory capsules. Synapsid evolution in the Permo-Triassic is characterized by three major pulses of morphospace exploration: the initial radiation of the pelycosaurs (non-therapsid synapsids), the radiation of the therapsids in the late Permian, and the radiation of two therapsid subgroups, the cynodonts and kannemeyeriiform dicynodonts, following the Permo-Triassic extinction. The Permian pulses follow a boom and bust pattern in which the maximal area of occupied morphospace is achieved very early in clade history, followed by extinction-mediated contraction, and subsequent reexploration of the initial morphospace by a survivor taxon. The Triassic radiation breaks from this in that major areas of morphospace lost in the Permo-Triassic extinction are never reexplored by the survivor taxa. Furthermore, the cynodonts gradually increase in cranial disparity throughout their history, rather than establishing an early range of morphotypes that is subsequently filled in by increases in taxonomic diversity.

19.6

KEEVER, C.C., HART, M.W.; ckeever@sfu.ca. Simon Fraser University
EVOLUTION OF REPRODUCTIVE MODE IN ASTERINID SEA STARS

Asterinid sea stars have evolved diverse modes of reproduction and larval development that include planktonic larval dispersal with suspension feeding (or planktotrophy, the ancestral state for the Asterozoa), brief larval dispersal with non-feeding morphology (lecithotrophy), non-dispersing larval development in benthic egg masses, and internal brooding with live birth of juveniles. All three derived modes of reproduction appear to have evolved in parallel several times. Reconstruction of ancestral modes of development at internal nodes in an asterinid molecular phylogeny could be used to infer the order and timing of changes in mode of development. Unfortunately, prior independent attempts by Mike Hart and Cliff Cunningham to do so using 20th century parsimony and likelihood methods produced equivocal results and suggested that this particular problem may be inherently difficult. We have recently attempted to improve upon these results through expanded taxonomic sampling of mtDNA sequences (our own and those of Jon Waters and colleagues) and reproductive characters (especially by Maria Byrne), application of Bayesian methods of phylogenetic inference, and the use of new analytical methods of ancestral character state inference. Bayesian methods gave a well-supported tree topology with some high posterior probability estimates for ancestral states of some life history characters. The results appear to provide a more robust basis for inferring patterns of character change and for exploring correlations between modes of reproduction and genetic, ecological, or historical factors that are causes or consequences of this extensive life history variation. We use the phylogeny as the basis for analyzing correlations between mode of reproduction and population genetic structure.

6.1

KELLY, D.A.; diane@zygotegames.com. Zygotegames LLC
USING GAMES TO REINFORCE FACTS AND CONCEPTS IN
THE BIOLOGICAL SCIENCES

Ironically, although biology is filled with competitive events, educational biology games often reward the mastery of names and facts without addressing their underlying organizational framework. Zygotegames LLC is trying to move beyond this trivia game model for games based on the biological sciences. We use a strategy game model that reduces the amount of luck required to win the game, rewarding instead skill and mastery of the games conceptual framework. For example, in *Bone Wars: The Game of Ruthless Paleontology*, players build dinosaur skeletons with incomplete fossil material and revise them as better material appears. Although players refer to anatomical descriptions of dinosaur fossils during play, the iterative process that drives the game is a rough model of hypothesis testing. In *Biota*, players build ecosystems using the underlying concepts of a food web, succession, and environmental disturbances. In both games, players are exposed to a great deal of factual information, but the games are driven by understanding how to use the information in a larger conceptual framework rather than by simple recall.

13.4

KENNEDY, N.K., FARTASH, A., VAN VALKENBURGH, B.; nwideman@ucla.edu. University of California, Los Angeles
ADAPTATIONS OF THE CERVICAL SPINE TO PREY CAPTURE
IN CANINES

Modern canines practice two different kinds of prey capture: pounce/pursuit and pursuit predation. Typically, smaller canines use the pounce/pursuit method and hunt prey their size or smaller, while larger canines use the pursuit method and often kill prey much larger than themselves. Killing relatively large prey solely with the jaws should place substantial loads on cervical vertebrae. Although previous research has documented craniodental adaptations for predation in canids, little quantitative work has been done on the neck. This study explores the relationship between the osteology of the cervical spine and prey capture by comparing three extant canines with a spectrum of diets from least carnivorous to hypercarnivorous. The cervical vertebrae of foxes, coyotes and wolves were measured and digital images were evaluated for additional measurements. After adjusting for size, the data were compared to each other using multivariate statistics to reveal significant differences in the structure of the cervical spine. Preliminary results indicate that there are significant differences in some cervical measurements, indicating that vertebral morphology can be used to infer aspects of hunting behavior in extinct canids.

6.2

KENNEDY, N.K., WORDEN, K.J., RUSSELL, A.A., FREKING, F.F.; nwideman@ucla.edu. University of California, Los Angeles
THE GK-12 PROGRAM AT THE UNIVERSITY OF CALIFORNIA,
LOS ANGELES: MAKING SCIENCE EXCITING FOR STUDENTS
IN URBAN SCHOOLS

In the UCLA GK-12 program (funded by the National Science Foundation), the Divisions of Physical and Life Sciences come together with the School of Education to address the issues of mathematics and science instruction in the lowest performing local schools. In this three year program, graduate students in the Physical and Life Sciences, known as GK-12 Fellows, are paired with first year secondary science and mathematics teachers in urban middle and high schools. The challenges of classroom management in urban schools, the time required to prepare new daily lesson plans, and the limited resources and facilities available in urban schools prevent new teachers from developing and conducting inquiry-based activities. Our program addresses this void. The GK-12 Fellows work side-by-side with the teachers and assist them in designing and implementing inquiry-based lessons that meet the needs of all students—especially low income, racially, culturally, and linguistically diverse learners. In addition to describing the program, two Fellows will share their personal experiences in the GK-12 program.

16.2

KERNEY, R.; kerney@fas.harvard.edu. Harvard University
AN UNEXPECTED ROLE FOR THE SKELETAL REGULATOR
RUNX2 IN ANURAN DEVELOPMENT

The runt related transcription factor *Runx2* has profound effects on differentiation of the vertebrate skeleton. In zebrafish, chicken, and mouse its mRNA is expressed in early skeletal condensations, and its active protein is critical for the formation of mineralized bone and maturation of cartilage. We have investigated the expression pattern of this gene in two frog species: the metamorphosing *Xenopus laevis* and direct-developing *Eleutherodactylus coqui* using both RT-PCR and *in situ* hybridizations. While skeletal specific mRNA expression patterns are conserved, an additional region of mRNA expression is present in the developing central nervous system of both frog species. Morpholino based gene knock-down experiments reveal an important role for *Runx2* in both early neurogenesis and the establishment of the tadpole specific chondrocranium. These novel roles for this transcription factor depart from earlier investigations in other model organisms. Additionally, the timing and distribution of *Runx2* mRNA expression differs between *E. coqui* and *X. laevis*, in accordance with several developmental differences between these two species with varied developmental modes.

27.4

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PATTERNS OF ECOLOGICAL DIVERSIFICATION WITHIN *PSEUDOTROPHEUS TROPHEOPS*, A SUBGENUS OF ROCK DWELLING CICHLID FROM LAKE MALAWI

The haplochromine cichlids of Africa's Great Lakes have become a celebrated example of adaptive radiation. Unfortunately, phylogenetic analysis of the Lake Malawi species flock has been confounded by the lack of appropriate morphological characters and an exceptional rate of speciation, which has allowed ancestral molecular polymorphisms to persist within species. To overcome this problem we used Amplified Fragment Length Polymorphism (AFLP) to score more than 7,000 restriction fragment polymorphisms in order to reconstruct the evolutionary relationships among 20 species of the ubiquitous rock dwelling subgenus *Pseudotropheus tropheops*. Our results suggest that this lineage forms a monophyletic clade that should be elevated to genus status. This clade has diversified and spread throughout the southeast arm of Lake Malawi without differentiation of either oral or pharyngeal jaw dentition, but has coincided with repeated modification of the oral jaw architecture in order to recapitulate biter and sucker trophic morphs.

35.5

KIM, T.W., KIM, T.G., CHOE, J.C.; ocean74@snu.ac.kr. Seoul National University

THE EVOLUTION OF COURTSHIP STRUCTURE BUILDING IN FIDDLER CRABS: HAS IT EVOLVED FOR PREDATION AVOIDANCE IN BOTH SEXES?

In some species of fiddler crabs, pair formation is composed of male claw waving, female attraction to semidome-like structures (e.g. hoods, semidomes, pillars), and underground mating. The sensory trap hypothesis, corroborated by arena experiments, suggests that the structures are used for searching females to avoid predators. In *Uca lactea*, such orientations by females to semidomes in the non-courtship context occur only in mating periods. During non-mating periods when males did not court females, females had no orientation bias between holes with and without semidomes. In the courtship context, females preferred males courting with semidomes. Thus our findings suggest that courtship structures in *U. lactea* might have evolved by female choice based on aesthetic preference. Our experiments also showed that males used the courtship structures as a landmark for homing while courting females. Furthermore, males with semidomes courted more freely than ones without semidomes by increasing the deviation between direction to the burrows and the lateral axis of the body. Therefore, the courtship structures might have originally evolved through pressures from predator avoidance in males.

S1.7

KIM, C.H.; carolkim@maine.edu. University of Maine

THE ROLE OF ARSENIC IN MODULATING INNATE IMMUNITY IN THE ZEBRAFISH

The innate immune response constitutes the first line of defense against invading pathogens and can be perturbed by environmental toxicants such as arsenic. Arsenic is a metalloid toxicant that is present in many toxic waste sites and can accumulate in groundwater and well water. Exposures to such non-toxic levels of arsenic have been associated with various human diseases including skin and internal cancers, diabetes mellitus, and atherosclerotic diseases. In addition, arsenic compounds have also been shown to modulate the innate immune response by altering phagocytic activity, inhibiting clearance of bacteria from the infected host, and perturbing cytokine regulation. This study reports the effects of the environmental toxicant, arsenic, on the innate immunity of the zebrafish, *Danio rerio*. The small size and short generation time of the zebrafish, combined with the sequenced genome and the knowledge of developmental processes, have made the zebrafish an ideal model to study the effects of environmental toxicants such as arsenic. We have found that respiratory burst activity and TNF- α expression are decreased by arsenic exposure, and that arsenic reduces Mx expression, but enhances type I interferon (IFN) expression over time. Arsenic also decreases induction and alters the kinetics of IFN and Mx expression in virus-infected zebrafish. We have extended these studies by examining perturbations in other innate immune factors, including respiratory burst activity, mRNA expression of components of the Toll Signal Transduction pathway, cytokines, inflammatory factors, and resistance to pathogen challenge in arsenic-exposed zebrafish larvae.

S2-2.5

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DORSOVENTRAL PATTERNING OF FACIAL BONE MORPHOLOGY

Evolution within the Endothelin1 (Edn1) regulatory pathway might underlie key features of craniofacial evolution. Bone morphology within the opercle-branchiostegal ray series of the hyoid arch varies marvelously in different actinopterygians, and zebrafish *edn1*-pathway mutants mimic the macroevolutionary changes. Edn1 plays a central role in dorsoventral (DV) facial patterning; expressed ventrally in the embryonic pharyngeal arches it determines how many skeletal elements will develop, their DV positions, sizes, and shapes. Since identifying genes responsible for vertebrate macroevolution currently is impossible, we have examined microevolution of opercular morphology in threespine sticklebacks, where direct genetic studies are straightforward. Evolution from Alaska marine to lake forms is accompanied by correlated size reduction and DV shortening of the opercle, underlain by a major-effect QTL on LG19. The zebrafish studies suggest that both changes can come about simultaneously by up-regulation of Edn1, which motivates the hypothesis that in sticklebacks developmental bias is influencing morphological evolution of the operculum. Current work examines this proposal. (Supported by the NIH and NSF).

57.8

KINANE, S., THOMAS, F.I.M.; skinane@mail.usf.edu. University of South Florida

BLEACHING IN THE CORAL *PORITES DIVARICATA*: EFFECTS OF TEMPERATURE, LIGHT, AND WATER MOTION

Coral bleaching, the loss of endosymbiotic dinoflagellates (zooxanthellae) or their photosynthetic pigments, is affecting coral reefs throughout the world. High water temperature and strong solar irradiance contribute to coral bleaching and there is evidence that water motion may lessen these effects. We examined the effects of temperature, light, and water motion on coral bleaching in the shallow-water coral *Porites divaricata*. A fully-factorial randomized block design was used to test the effects of two levels of each of these three variables on bleaching. Bleaching was measured as a change in zooxanthellae density and chlorophyll *a* concentration over the course of each four-day experiment. Stress on zooxanthellae Photosystem II was monitored using a pulse-amplitude modulated (PAM) fluorometer. We measured minimum dark-acclimated fluorescence (F_o), maximum dark-acclimated fluorescence (F_m), and variable fluorescence ($F_v = F_m - F_o$). Decline in the ratio F_v/F_m during the course of each experiment was used to quantify photoinhibition and bleaching stress. High temperature and high light caused a reduction in zooxanthellae density, chlorophyll *a* concentration, and F_v/F_m . Temperature- and light-induced bleaching was reduced in high-velocity water flow ($15\text{--}20\text{ cm s}^{-1}$) compared with low velocity flow ($2\text{--}3\text{ cm s}^{-1}$).

15.7

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PHYSICAL AND ECOLOGICAL CORRELATES OF LONGEVITY IN PACIFIC ROCKFISHES (*SEBASTES*)

We examined correlations in ecological and physical habitat traits of members of the genus *Sebastes*, a diverse group of fishes in the family Scorpaenidae that inhabit the North Pacific. Members of this genus exhibit a range of life history traits, the most striking of which is the extraordinary longevity of some species (>150 years). Life-history theory provides the expectation that ecological traits such as asymptotic body size, age at maturity and size at maturity, and community size are positively correlated with lifespan. Alternatively, physical traits of habitat such as depth (pressure), temperature, and oxygen metabolism may underlie physiological mechanisms explaining lifespan. We used raw species comparisons as well as phylogenetically independent contrasts in order to control for the possibility that the correlation in traits was due to evolutionary history. The phylogenetic analysis was conducted with the most recent phylogeny available for the group and with estimates of ecological traits (maximum size, age at maturity and size at maturity) and physical habitat traits (depth, temperature, and dissolved oxygen concentration) compiled from the literature. We used multiple regression of the explanatory variables against longevity for both the raw species comparisons and the independent contrast analysis. We found that after correcting for phylogenetic correlation, age and size at maturity were significant predictors of longevity. This approach allows us to evaluate the correlates of longevity and consider several alternative hypotheses for longevity (rate of living, low extrinsic mortality, phylogenetic inertia). Our examination of this group allows us to make a unique contribution to our understanding of *Sebastes* species life history and the mechanisms underlying evolution of longevity.

S5-1.3

KINGSLEY, E.P., RABINOWITZ, J., LAMBERT, J.D.*; dlamber2@mail.rochester.edu. University of Rochester

A NANOS ORTHOLOG IS REQUIRED FOR ENDOMESODERM SPECIFICATION IN THE SNAIL *ILYANASSA*

In the several animal phyla with spiralian development, most of the mesodermal structures are thought to derive from one particular cell, the 4d micromere. This cell is a prominent example of mesendoderm in animal development, and one of the most conserved aspects of spiralian development. The MAPK pathway is required for the differentiation of 4d derivatives in molluscs, and available evidence suggests that it plays the same role in annelids. We have now implicated another developmental regulatory molecule in 4d development: the nanos protein. Nanos is a conserved RNA-binding protein that has roles in germ cell specification and embryonic patterning. In a screen for localized mRNAs in the embryo of the mollusc *Ilyanassa obsoleta*, we found that a nanos orthologs (IoNanos) was highly enriched in the 3D macromere cell, then restricted to one of its daughter cells, the 4d cell. We have generated loss-of-function phenotypes for IoNanos with morpholino oligonucleotides, and also performed the first comprehensive analysis of the effects of 4d deletion. The IoNanos loss-of-function phenotypes are lacking the same set of 4d derived-structures as 4d deletion larvae, indicating that IoNanos is required for specification of the 4d cell lineage. We discuss the role of Nanos in embryonic patterning and mesendoderm specification.

15.2

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BREAKING THE TEMPERATURE-SIZE RULE: RAPID POPULATION DIVERGENCE IN THERMAL REACTION NORMS

The temperature-size rule is a common pattern of phenotypic plasticity in which higher temperature during development results in a smaller adult body size (i.e., a thermal reaction norm with negative slope). We examine genetic and parental contributions to population differentiation in thermal reaction norms for size, development time and survival in the Cabbage White Butterfly *Pieris rapae*, for two geographic populations (Seattle WA and Chapel Hill NC) that have diverged within the past 100-150 years. We used split-sibship experiments with two temperature treatments (warm and cool) for *P. rapae* for each population. Mean adult mass was significantly greater in NC than in WA populations for both temperature treatments; mean size decreased with temperature (the temperature-size rule) for the WA population, but size increased with temperature for the NC population. There were significant parental contributions to thermal reaction norms for survival, resulting in decreased mean survival for the WA population in warm conditions. Our study shows that the temperature-size rule and related thermal reaction norms can evolve rapidly within species in natural field conditions. Rapid evolutionary divergence argues against the existence of a simple, general mechanistic constraint as the underlying cause of the temperature-size rule.

26.2

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DIFFUSION LIMITATION OF AEROBIC METABOLISM IN MUSCLE FIBERS

The net rate of metabolic processes in cells depends on the competition between the catalytic capacity of the system and the diffusive flow of substrates to the reaction center. While the diffusion component is typically ignored, it exerts greater control over metabolic flux as either rates of ATP turnover or intracellular diffusion distances increase. ATP turnover rates during steady-state metabolic work may differ by many fold among muscle fibers of different organisms. In addition, muscle fibers in different animal groups can range in size from a few microns to >5mm in diameter, and the intracellular diffusion distances between mitochondria can vary in a similar fashion. In the present study, we used a reaction-diffusion model to examine the interaction between diffusion distance, ATP supply and ATP demand in muscle fibers of different organisms in an effort to determine whether aerobic capacities are likely to be limited by intracellular metabolite diffusion. Our results indicate that metabolite diffusion probably exerts significant control over metabolism in some types of muscles, but many muscle types are not close to being limited by intracellular diffusion. In these latter cases, the maximal rate of sarcolemmal oxygen flux may be a more important determinant of fiber metabolic design.

14.4

KLEY, N.J.; nathan.kley@stonybrook.edu. Stony Brook University
FORM AND FUNCTION OF THE HYOLINGUAL APPARATUS IN BLINDSNAKES (SERPENTES: SCOLECOPHIDIA)

Tongue flicking is a chemosensory behavior known to occur widely among squamate reptiles (lizards and snakes). In general, tongue flicking is thought to be most highly developed in advanced snakes (Colubroidea), which exhibit rapid, multiple oscillation flicks. In contrast, most lizards perform slower, single oscillation flicks. However, the tongue flicking behavior of blindsnakes (Scolerophidia), which are phylogenetically intermediate between lizards and advanced snakes, has remained unknown. I used high-speed videomicroscopy to study tongue flicking in representatives of the three families of blindsnakes (Anomalopidae, Leptotyphlopidae and Typhlopidae). All species studied were found to exhibit rapid, multiple oscillation flicks. However, tongue flicking in the anomalopid *Liotyphlops* was found to be unusual in two respects. First, the tongue is not protruded progressively further with each oscillation, as it is in leptotyphlopids, typhlopids, and other snakes. Rather, it is partially retracted between oscillations. Second, relative protrusion distances in *Liotyphlops* are much lower than those observed in leptotyphlopids and typhlopids. Studies of serial histological sections and whole-mount immunohistochemically stained specimens suggest that high-magnitude tongue protrusion in Leptotyphlopidae and Typhlopidae is facilitated by the morphology of the *Mm. hyoglossi*, which are extremely long due to the posterior position of the hyoid in these clades. The peculiar posterior placement of the hyoid in Leptotyphlopidae and Typhlopidae may have evolved to maintain the volume of the *Mm. hyoglossi* necessary for effective hydrostatic elongation of the tongue, as selective pressures acted to reduce the cross-sectional area of the head (and thus the tongue) during the early evolution of these highly miniaturized snakes.

76.10

KLOK, C.J., KAISER, A., MCKINLEY, B., RASCON, B., HENRY, J., LEE, W.K., SOCHA, J., HARRISON, J.F.; cjklok@asu.edu. Arizona State University, Midwestern University, Argonne National Laboratory
PLASTIC AND EVOLUTIONARY RESPONSES OF BODY SIZE AND TRACHEAL DIMENSIONS TO ATMOSPHERIC OXYGEN CONCENTRATION IN FRUITFLIES

We measured the effect of rearing oxygen levels for single generations (10, 21, 40, 60% oxygen) or up to ten generations (10, 21, 40% O₂) on body size and tracheal dimensions of *Drosophila melanogaster*. These varying atmospheric oxygen concentrations produced consistent positive relationships between adult body size (live mass) and oxygen concentration. This occurred in both small and larger founding populations (5 or 30 founding females per replicate). In addition, we tested whether the sensitivity to oxygen levels occurred primarily at larval or pupal stages by rearing flies under varied oxygen conditions within one stage (larval vs. pupal) only. These experiments indicated that growth rates during both larval and pupal stages are oxygen-sensitive. A possible explanation for this positive relationship between size (mass) and atmospheric oxygen is that more energy and material reserves are directed toward optimizing the tracheal system at lower oxygen levels, thereby reducing growth of other tissues. To date, there have been no studies of the effect of rearing oxygen levels on the tracheal system of adult *D. melanogaster*. Images of flies meso- and metathoracic leg tracheae were captured using x-ray synchrotron imaging at the Advanced Photon Source, Argonne National Laboratories. Dry mass, femur lengths and tracheal dimension measures were taken to investigate allometric relationships related to oxygen selection. Supported by NSF 0419704

S2-1.4

KOCHER, T.D.; tdk@cisunix.unh.edu. University of New Hampshire
FROM NATURAL SYSTEMS TO LABORATORY MODELS: COMPARATIVE GENOMICS OF TELEOST FISHES

The thousands of species of cichlid fishes in the lakes of East Africa are not only an evolutionary wonder, but also a natural mutant screen for phenotypes ranging from morphology to behavior. To facilitate genetic analysis of these natural mutants, we have developed a suite of genomic resources for African cichlids, including extensive genetic maps of microsatellite markers, and a physical map based on fingerprints of 35,000 BAC clones. We have also developed a variety of bioinformatics tools to relate these maps to the more completely sequenced genomes of pufferfish, medaka and zebrafish. Gene order is highly conserved among these fishes at scales of several megabases, which is facilitating the comparative positional cloning of genes for natural mutant phenotypes. Our studies have provided insights into how the developmental system is genetically modified to produce different trophic morphologies. Current work is aimed at identifying the genes underlying the rapid diversification of color patterns and sex-determining systems among these species. A similar comparative genomic approach would allow other fish species with interesting biology to be developed into practical laboratory models.

67.8

KOEPFLI, K.-P., GOMPPER, M.E., EIZIRIK, E., HO, C.-C., LINDEN, L., MALDONADO, J.E., WAYNE, R.K.; klausk@lifesci.ucla.edu. University of California, Los Angeles, University of Missouri, Columbia, Faculdade de Biociencias, PUCRS, Smithsonian Institution, National Museum of Natural History
MOLECULAR PHYLOGENY REVEALS EXTENSIVE MORPHOLOGICAL PARALLELISM IN THE PROCYONIDAE (MAMMALIA: CARNIVORA)

The Procyonidae have played a central role in resolving the controversial systematics of the giant and lesser pandas, but the phylogenetic relationships of species within the family itself have received much less attention. Cladistic analyses of morphological characters conducted during the last two decades have resulted in topologies that group ecologically and morphologically similar taxa together. We examined procyonid phylogenetics based on the combined data from nine nuclear and two mitochondrial gene segments totaling 6,534 bp. We were able to fully resolve the relationships within the family with strongly supported, congruent results from four methods of phylogeny reconstruction. We identified three distinct lineages within the family: a (*Nasua*, *Bassaricyon*) clade, a (*Bassariscus*, *Procyon*) clade, and a *Potos* lineage, which was basal to the other two clades. These findings, which are in strong disagreement with prior fossil and morphological-based assessments of procyonid relationships, reemphasize the morphological and ecological flexibility of these taxa. In particular, the morphological similarities between kinkajous and olingos reflect the independent acquisition of traits via parallel evolution associated with an arboreal lifestyle rather than ancestry. The strong discordance between the molecular and morphological estimates of procyonid phylogeny mirror similar findings for certain groups of primates, including hominoids, and other groups of carnivorans. In support of these other studies, our results suggest that, in certain cases, cranio-dental evidence may not be a reliable indicator of phylogenetic affinity.

55.5

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NOVEL PECTORAL FIN KINEMATICS DURING STEADY SWIMMING IN A BENTHIC FISH, THE LONGHORN SCULPIN, *MYOXOCEPHALUS OCTODECIMSPINOSUS*

Myoxocephalus octodecimspinosus (Cottidae: Scorpaeniformes) is a benthic fish that lacks a swim bladder and is negatively buoyant. This species uses large, fan-shaped pectoral fins in a previously undescribed swimming behavior. We filmed four individuals using two synchronous high-speed, high-resolution cameras, one in lateral and one in dorsal orientation. These views were calibrated to produce a 3-D view of the pectoral fins during swimming. We were then able to digitize and examine the 3-D position of individual fin rays at different stages of the behavior. When the fish is at rest on the substrate, the fin is adducted against the body. The 10 most dorsal rays are long, and are oriented in the cranial-caudal direction. The much shorter ventral rays are oriented in the dorsal-ventral direction and are usually in contact with the substrate when the fish is at rest. At the initiation of slow swimming, the most dorsal fin ray acts as the leading edge when the fin is drawn cranial, parallel to the flow. The fin rays are feathered, with the medial face of the fin oriented dorsally and the lateral face of the fin oriented ventrally. The fin is then held still as the caudal fin provides the propulsive force during swimming. The swimming bout ends when the fins are adducted and the fish returns to rest. The short ventral rays likely play a role when the fish transitions from swimming to resting on the substrate. This wing-like conformation of the fin without oscillation is a novel use of the pectoral fins in fishes. We hypothesize that the pectoral fins are used as aerofoils to generate lift during caudal fin-propelled swimming thereby counteracting the weight of the fish in water.

2.3

KROCHMAL, A.R.; krochmala@uhd.edu. University of Houston, Downtown
THERES NO SUCH THING AS A FREE LUNCH: ON THE ADAPTIVE VALUE OF SCAVENGING IN SNAKES

Snakes are generally considered consummate predators, and therefore, scavenging by snakes has traditionally been discounted or ignored. However, recent reviews, combined with the ubiquitous observation that captive snakes regularly feed on carrion, indicate that snakes have a high propensity for scavenging. Documented episodes of scavenging by snakes have been touted as opportunistic events, but empirical investigations have shown that some species prefer carrion over live prey and that certain snake species consume either primarily or exclusively carrion. It therefore holds that there may be advantages to exploiting carrion as a food source which extend beyond energetic considerations. For example, snakes feeding on carrion might exhibit higher digestive rates and / or digestive efficiencies than do snakes consuming fresh prey items. Similarly, scavenging snakes might have a reduced basking time relative to snakes feeding on live prey items, and thus a reduced risk of predation. Finally, feeding on carrion might reduce the specific dynamic action of a snake, the spike in metabolic rate which follows feeding. To document and quantify the adaptive value of scavenging in snakes, I measured the digestive rate, digestive efficiency, basking time, and specific dynamic action of snakes relative to prey type (carrion vs. live prey). Findings will be discussed in light of the current utility of scavenging and will shed light on the initial adaptive force which drove the evolution of carrion feeding in snakes.

25.2

KURATANI, S., NAGASHIMA, H., KURAKU, S., USUDA, R.; saizo@cdb.riken.jp. CDB RIKEN, Kobe, Japan
NATURE AND FUNCTION OF THE CARAPACIAL RIDGE IN THE TURTLE EMBRYO

The turtle carapace is an evolutionary novelty acquired through the modification of rib patterning. In the turtle embryo, the lateral margin of carapacial anlage is seen as the carapacial ridge (CR), which has been thought to play an essential role in the patterning of rib growth. To reveal the developmental origin and function of CR, we picked up the Chinese soft-shelled turtle, *Pelodiscus sinensis*, and performed cell labeling, and surgical experiments on the CR precursor. We found that the CR mesenchyme is derived from the lateralmost part of the dermomyotome, and the CR arises as the lateralmost axial structure just medial to the Wolffian ridge. Thus the CR does not belong to the lateral body wall. Removal of CR did not alter the rib growth, only inhibiting the turtle-specific fan-shaped pattern of the ribs. To identify the molecular mechanisms to differentiate CR, we performed a comprehensive screening of genes expressed specifically in the CR, using microbead-based differential cDNA analysis and real-time RT-PCR. We identified the turtle orthologues of *Sp5*, *CRABP-I*, *APCDD1* and *LEF-1* to be expressed in the CR with high intensity. Although these genes have been maintained in genomes throughout the major vertebrate lineages, they appeared to have acquired novel expressions in the CR in the turtle lineage. In relation to the CR-specific expression of *LEF-1*, we detected the nuclear localization of beta-catenin protein in the CR epidermis, suggesting that the canonical Wnt signalling is involved in carapace evolution. Overexpression of dominant-negative form of LEF-1 protein in the CR resulted in the local inhibition of CR. We conclude that the acquisition of the shell did not necessarily involve the creation of novel genes, but may have been based on the co-option of a pre-existing developmental module.

14.6

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VENOUS DRAINAGE IN SHORT- AND LONG-FACED MAMMALS

In mammals, the venous drainage of the head proceeds through two major channels. The veins of the rostrum unite to form the facial vein, which picking up the linguo-facial and the superficial temporal vein, becomes the external jugular vein. (Humans are an exception.). The venous drainage of the brain case, proceeds from the uniting of the various veins of the brain (especially the superior and inferior sagittal sinuses) to form the transverse sinus at the occipital end of the brain case. This sinus, runs laterally and exits the cranial cavity as the internal jugular vein, after picking up the superior petrosal sinus, which runs backward along the lateral wall of the brain case. Between the two drainage systems is the ophthalmic plexus which can drain blood in either direction. In mammals with large rostra, the greater drainage volume should be via the external jugular, and the jugular foramen should be relatively small, while in short faced forms the greater volume should be via the internal jugular, and the foramen relatively larger. Comparison of series of Dog and Cat skulls shows this supposition to be correct. The length of the foramen/width of skull divided by the rostral length/total length of skull gives a double proportion that is significantly larger in cats. Non parametric statistics must be used for the comparison.

5.3

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DEHYDROEPIANDROSTERONE (DHEA) AND TERRITORIAL AGGRESSION IN THE EUROPEAN NUTHATCH

During breeding, territorial aggression in male birds is closely linked to secretion of gonadal testosterone (T). However, hormonal regulation of territoriality outside of the context of reproduction, when T circulates at basal levels, is not as clear. Recent studies propose that the steroid dehydroepiandrosterone (DHEA) may support territoriality during non-breeding. DHEA can be synthesized by the adrenals and converted to androgens and estrogens in the avian brain. We examined the role of DHEA in the regulation of non-breeding aggression in the European nuthatch (*Sitta europaea*). This species defends food caches throughout the year and shows aggressive responses to conspecifics during both the breeding and non-breeding periods. Because female nuthatches are as aggressive as males, this species serves as an excellent model to also investigate the hormonal correlates of female aggression. Our field studies demonstrate that plasma DHEA is detectable during breeding and non-breeding in both sexes, while plasma T is detectable only in breeding males. We also experimentally treated free-living male birds with DHEA during autumn and examined aggressive responses to simulated territorial intrusion. DHEA-treated birds showed increased aggression in comparison to controls. Our results support previous findings and suggest that plasma DHEA may serve as an important alternative to T in the regulation of territorial behavior, especially because circulating T also stimulates costly physiological and morphological changes. Minimizing costs associated with territoriality may be especially important in the examined population of nuthatches given the harsh winter conditions in Oslo, Norway (avg. temp. of -4° C, snow cover ≈ 88.5 ; 20 days/month).

51.6

LAPID, E., CHADWICK, N.E.*; chadwick@auburn.edu. Bar Ilan University, Auburn University

CORAL SWEEPER TENTACLES AS PROBES TO REMOTELY DETECT COMPETITORS

Inducible elongated tentacles in sea anemones (catch tentacles, fighting tentacles) and corals (sweeper tentacles) have been proposed to function in prey capture, sexual reproduction, and damage to competitors. We add here a possible function as probes for the remote detection of advancing competitors. Nocturnal field surveys on the Red Sea brain coral *Platygyra daedalea* showed that most colonies directed sweeper tentacles toward nearby corals (< 5cm distant) and appeared to inflict unilateral tissue damage, but that some extended sweepers in random directions (21% of N=100 colonies). Laboratory experiments revealed that feeding tentacles transformed into extremely elongated sweeper tentacles at about 30 days following contact with coral competitors. Throughout the study year, brain corals also spontaneously developed sweepers on areas not facing competitors and eventually transformed them back into short feeding tentacles at a rate of 15 ± 7 (mean \pm STD) tentacles colony⁻¹ year⁻¹. This rate appears sufficient to remotely detect most slow-growing coral neighbors and for maintenance of a wide coral-free zone around brain corals in the field. This behavior also may prevent faster-growing acroporid table corals from overtopping brain corals at some distance above the colony. Random morphogenesis of sweeper tentacles as pre-emptive probes to detect and damage advancing competitors may contribute to the persistence of some massive corals on Indo-Pacific coral reefs. Random development of elongated probe-like tentacles also may serve a similar function in other sessile cnidarians.

56.1

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NEUROMECHANICAL EVENTS THAT TRIGGER BALLISTIC PREY CAPTURE IN TOADS.

Ballistic tongue projection in toads is an extremely rapid movement that depends upon the storage and recovery of elastic strain energy. Elastic energy is stored in the depressor mandibulae muscles and in-series connective tissues during 50-250 ms of depressor mandibulae activity that precedes mouth opening. Stored energy, recovered during mouth opening, is used to power tongue projection. Elastic energy storage requires a mechanism that resists mouth opening prior to movement. Recovery of stored energy requires a mechanical trigger to reduce the resistance so that the mouth can open. Toads possess well-developed maxillary grooves that lock the mandible in place, via wet adhesion, when the mouth is closed. Our results indicate that this locking mechanism resists mouth opening with a force that is at least 2.5 times the maximum isometric force of the depressor mandibulae muscles. Obstruction of the locking mechanism in freely-behaving toads reduced the duration of depressor mandibulae activity prior to mouth opening by >50% and reduced mouth-opening velocity by >70%. We hypothesize that the submentalis muscle functions as the active trigger. This muscle is ideally positioned to deform the mandible at the mentomeckalian joint and break the wet adhesion. The submentalis exhibits a burst of activity 25 ms prior to mouth opening. Premature stimulation of the submentalis muscle (25 ms after the onset of depressor mandibulae activity) resulted in a 25% decrease in mouth-opening velocity, presumably because early activation reduced the time available for energy storage by the depressor mandibulae muscles. A simple algorithm that controls depressor mandibulae force and the timing of submentalis activation is sufficient, in principle, to control ballistic prey capture in toads.

75.2

LAUDER, G.V., MADDEN, P., MITTAL, R., DONG, H., BOZKURTAS, M., DAVIDSON, N., TANGORRA, J., HUNTER, I.; glauder@oeb.harvard.edu. Harvard University, George Washington University, Massachusetts Institute of Technology
PECTORAL FIN FUNCTION IN SUNFISH: EXPERIMENTAL HYDRODYNAMICS, COMPUTATIONAL FLUID DYNAMICS, AND CONSTRUCTION OF A ROBOTIC MODEL

Fishes are noted for their ability to maneuver and position themselves accurately even in turbulent flows. This ability is the result of the coordinated movement of fins which form flexible control surfaces that allow thrust vectoring. We have embarked on a research program designed to understand the dynamics of pectoral fin function in sunfish (*Lepomis macrochirus*) and to construct a robotic pectoral fin thruster. We used digital particle image velocimetry (DPIV) on the fins of freely swimming fishes and computational fluid dynamics (CFD) to calculate flows based on measured 3D kinematic data. DPIV experiments used a stereo configuration, transverse plane orientation, and high sample rate (500 fps) to capture streamwise vorticity and to reconstruct time-dependent fluid momentum changes in three dimensions. Both DPIV and CFD data demonstrate that the fin can generate thrust throughout the fin beat. Two simultaneous attached leading edge vortices are present as the fin cups laterally during abduction. A proper orthogonal decomposition (POD) of fin kinematics allowed identification of three primary modes of fin motion which were used individually and in combination to calculate fin flows and study the relationship between kinematic and hydrodynamic performance. Thrust is generated by a combination of an accelerating spanwise wave, cupping of the fin surface during abduction, and area increase during fin retraction. A first generation robotic model of the bluegill sunfish pectoral fin has been developed that can reproduce the complex pectoral fin motion.

71.2

LAUFER, H., DEMIR, N., PAN, X., STUART, J., KOEHN, U.; laufer@uconn.edu. University of Connecticut, Storrs
SHELL DISEASE IN THE LOBSTER MAY BE RELATED TO ALKYLPHENOLS

Shell disease (SD) is a disfiguring, bacterial infection of the carapace of as many as 70% of lobsters in eastern Long Island Sound. SD depreciates the animals economic value, and may result in death. We found alkylphenols, which are endocrine disruptors, in the hemolymph of lobsters. These are long-lived anthropogenic pollutants resulting from plastics manufacture and degradation, from lubricants, detergents, among others. We have analyzed 134 inshore lobsters for alkylphenols by GC/MS with a detection limit of 0.3 ng/ml and have found them in 37 animals. Statistical analysis was done by Mann-Whitney Test. SD lobsters contain alkylphenols with greater frequency (42%, N=13 of 31) compared to unaffected lobsters (23%, N= 24 of 103). Four alkylphenols were found, #1: 2-t-butyl-4-(dimethylbenzyl)phenol; #2: 2,6-bis-(t-butyl)-4-(dimethylbenzyl)phenol; #3: 2,4-bis-(dimethylbenzyl)phenol; and #4: 2,4-bis-(dimethylbenzyl)-6-t-butylphenol. Compound 1 occurred in 29% (N=9 of 31) of SD, and at a concentration 8 times higher than in 9% of unaffected lobsters (N=7 of 103), (P**=.001). Compound 2 occurred in 13% (N=4 of 31) of SD lobsters at a concentration 945 times higher than in 9% of unaffected lobsters (N=7 of 103) (P=.127). Compound 3 occurred in 35% (N=11 of 31) SD lobsters at a concentration 4 times higher than in unaffected lobsters with 20% (N= 21 of 103) (P*=.047). Compound 4 was present in 35% of SD lobsters (N=11 of 31) with a concentration 20 times higher than in unaffected lobsters, which have this compound in 18% of the lobsters (N=19 of 103) (P*=.024). Thus, alkylphenols are found in greater frequency and in higher amounts in SD animals than in unaffected animals. We conclude that alkylphenols may play an important role in the production of shell disease in lobsters. (Supported by Sea Grant College Program and CT DEP)

49.1

LAVIN, S.R., MCWHORTER, T.J., KARASOV, W.H.; srlavin@wisc.edu. University of Wisconsin
DIFFERENCES IN PARACELLULAR ABSORPTION: A FUNCTION OF SOLVENT DRAG OR PORE SIZE?

Increasing evidence indicates that birds have more extensive intestinal non-mediated, paracellular absorption of hydrosoluble compounds than do mammals. The mechanism(s) underlying this difference has not been studied. More paracellular absorption may be due to increased water and dissolved solute flux across the tight junction between intestinal enterocytes (solvent drag) and/or a larger tight junction effective pore size. Using a recirculating duodenal perfusion technique and a range of perfusate osmolalities in pigeons and Sprague-Dawley rats, we measured the absorption of fluid and D-glucose, as well as a series of carbohydrate probes not known to be transported by mediated pathways and ranging in molecular weight. We chose these species because in our experiments on intact animals, pigeons had almost twice the absorption of smaller probes than rats. We hypothesized that if increased paracellular absorption is due to increased solvent drag, then pigeons would have greater water absorption concurrent with paracellular probe absorption than rats. We also hypothesized that a larger effective pore size in pigeons would lead to greater passage of larger molecules. We found that rats and pigeons absorb D-glucose at a comparable rate. Pigeons had greater absorption of inert carbohydrate probes, yet fluid absorption was not more extensive than rats, and pigeons absorbed carbohydrate probes when net water absorption was nil. These data are inconsistent with the notion that pigeons have greater solvent drag than rats. We also found an inverse relationship between probe molecular weight and probe absorption in both species. Our results suggest that greater paracellular nutrient absorption in pigeons is not due to increased solvent drag but instead may be a function of the tight junction effective pore size between intestinal enterocytes. Supported by IBN-0216709 to W.H.K.

32.6

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PREDICTING LOGGERHEAD SEX RATIOS: CONFOUNDING EFFECTS OF TEMPERATURE VARIATION AND THERMOSENSITIVE PERIOD

Temperature-dependent sex determination was studied in loggerhead sea turtles (*Caretta caretta*) nesting on Wassaw (2000-2004) and Blackbeard Island (2001-2004) NWRs in Georgia. Sex ratios were estimated for 18 nests using histological analysis of gonadal tissue from 10 hatchlings per nest. Each nest contained a temperature data logger. The temperature and sex ratio data were used to estimate a "natural" pivotal temperature and transitional range of temperatures (TRT). For these natural nests which did not experience rain events during the thermosensitive period, the natural pivotal temperature was estimated to be 29.3°C and the TRT was estimated to be 28.7-30.1°C. These estimates were similar to previously published pivotal temperature for Atlantic loggerheads based on constant incubation temperatures. Sex ratios varied widely in nests experiencing temperatures near the pivotal. This may be due to factors such as variation in pivotal temperature between clutches and fluctuation in daily temperature (especially from rain events). The temperature and sex ratio data were also used to evaluate the thermosensitive period by altering its predicted length and timing in order to determine a best-fit model for predicting sex ratios. The sex ratio data from the 18 nests indicate that both male and female hatchlings were produced with a yearly range of 60-85% female. However, this female bias is significantly less than those reported for nesting beaches in Florida. Therefore, Georgia beaches may be of conservational significance due to the increased production of males.

51.2

LEE, K.A., WIKELSKI, M., KLASING, K.C.; kellylee@princeton.edu. Princeton University, University of California, Davis
INDICES OF HUMORAL AND INNATE IMMUNITY IN TROPICAL BIRDS ACCORDING TO DIET AND HABITAT TYPE

Immune defense strategies are intricately linked to the ecology, physiology, life history and evolutionary history of the host. We measured several indices of standing immune defenses, including natural antibodies and complement activity, in more than sixty tropical bird species from forest interior and edge habitats. We will present broad-scale comparative analyses exploring the major ecological and phylogenetic correlates of variation in these immune defense measures, and suggest ways these data can be used to inform conservation decisions.

17.3

LEE, T., Ó FOIGHIL, D.; taehwanl@umich.edu. University of Michigan
PLACING THE FLORIDIAN MARINE GENETIC DISJUNCTION INTO A REGIONAL EVOLUTIONARY CONTEXT USING THE SCORCHED MUSSEL, *BRACHIDONTES EXUSTUS*, SPECIES COMPLEX

The well-documented Floridian Gulf/Atlantic genetic disjunction provides an influential example of presumed vicariant cladogenesis along a continental coastline for major elements of a diverse nearshore fauna. However, it is unclear if it represents a local anomaly for regionally distributed morphospecies, or if it is merely one of many such cryptic phylogenetic splits. We aimed to place the scorched mussel Gulf/Atlantic genetic disjunction into a regional phylogenetic perspective by incorporating genotypes of nominal conspecifics sampled throughout the Caribbean Basin as well as those of eastern Pacific potential geminate species. Our results show it to be one of multiple latent regional genetic disjunctions, involving five cryptic Caribbean species. Disjunctions involving three stem lineages pre-date formation of the Isthmus of Panama, although four of the five cryptic species have within-Basin sister relationships. Surprisingly, the Atlantic clade was also found to be widespread in the southern Caribbean, and a northward range extension after the last glacial maximum was suggested for Atlantic coast-specific genotypes. Our new data seriously undermine the hypothesis of a Floridian vicariant genesis and imply that the scorched mussel Gulf/Atlantic disjunction represents a case of geographic and temporal pseudocongruence. All five Caribbean Basin cryptic species exhibited an intriguing pattern of predominantly allopatric distribution. A number of lines of indirect evidence favor the hypothesis that this pattern of distribution is maintained primarily by post-recruitment ecological filters rather than by oceanographic barriers to larval-mediated gene flow.

59.4

LEE, D.N., TANG-MARTINEZ, Z.; dnl62e@umsl.edu. University of Missouri - St. Louis
OF EARLY SOCIAL ENVIRONMENT ON THE PHYSICAL DEVELOPMENT OF PRAIRIE VOLES

In general, the size at birth, size at weaning, and growth rate of rodents vary with differences in the early environment a neonate experiences (Mendl 1988). This study examines the impact of sire and siblings on the physical development of prairie voles, *Microtus ochrogaster*. Two questions are examined. 1) How does a male parent affect the physical development of its offspring? 2) How does the presence of siblings affect the physical development of pups? Previous studies have demonstrated that there is an inverse relationship between litter size and mean pup weight at birth. Particularly, individual prairie vole pups born to larger litters tend to have lower individual weights (Solomon 1994). However, preliminary analysis of our data reveals that the presence or absence of the father affects weight at weaning, and that pups raised with siblings are lighter at weaning. Other measurements of physical development, like the age in days at which eyes open or the age at which independent movement occurs may be different for pups raised in different early social environments. Measures of physical development may have fitness consequences like the likelihood of survival.

13.6

LEE, D.V.; dvlee@fas.harvard.edu. Harvard University
ELASTICITY IN THE JOINTS AND WHOLE LEGS OF GOATS VS. DOGS: TRADING ECONOMY FOR PRECISION?

While dogs (*Canis lupus familiaris*) are excellent long-distance runners and terrain generalists, goats (*Capra hircus*) are specialists on rough, mountainous terrain. The disparate mechanical requirements of these two niches suggest that associated structural and functional differences may be apparent in the limbs. Here the joint and whole leg mechanics of goats and dogs of similar size were examined during running and a serial actuator-spring model was applied to determine spring characteristics. Two force platforms were used to measure ground reaction forces and centers of pressure of individual footfalls while a motion capture system recorded joint and foot marker positions. Joint moments and angles as well as leg force and length were computed from these data. The total positive and negative work done by actuators was expressed as a fraction of total positive and negative joint (or leg) work. This was termed actuation ratio and yielded values between zero (pure spring-like behavior) and one (pure actuation). The spring constant determined by the model was that which minimized the actuation ratio. The principal joint spring of the goat forelimb was the metacarpo-phalangeal. In contrast, the principal joint spring of the dog forelimb was the wrist. The principal hindlimb joint spring was the ankle in both goats and dogs. Considering the leg force and linear deflection of the leg from shoulder (or hip) to foot revealed similar actuation ratios in goats and dogs but substantially different spring constants. Forelegs and hindlegs of goats were found to be nearly twice as stiff as those of dogs. This substantial difference may reflect the competing requirements of stiffness for precision foot placement in rough terrain and compliance for greater elastic energy storage and enhanced economy.

21.1

LEHMAN, E.M.; ellehman@indiana.edu. Indiana University, Bloomington

TETRODOTOXIN AS A MATERNALLY-ENDOWED DEFENSE AGAINST EGG PREDATION IN THE ROUGH-SKINNED NEWT, *TARICHA GRANULOSA*

Antipredator defenses include behaviors to evade capture, physical structures to deter predation, and noxious or toxic chemicals aimed at predators. While adults are often well protected, early life history stages (e.g., eggs) often are more vulnerable. In these cases, parents may provide defenses either through their behavior or through chemicals provided to the embryo. Nest defense behaviors have been well studied, but relatively little is known about chemical defenses in eggs. Studying the defenses of early life history stages is particularly interesting because of the influence early survivorship can have on population growth rates. Rough-skinned newts, *Taricha granulosa*, possess tetrodotoxin (TTX), a neurotoxin that inhibits the propagation of nerve signals, leading to paralysis and potentially death in most organisms that ingest it. TTX acts as a chemical defense against predatory garter snakes in adults, and is also present in newt eggs. Field work has shown that caddisfly larvae prey upon newt eggs, despite the presence of TTX. Because adults do not defend eggs, TTX may be eggs only defense against predation. It was previously unknown to what degree caddisfly larvae consume eggs of varying toxicity and how TTX affects them. Here we report the results of several studies, including field and laboratory studies of predation as a function of egg toxicity, and the influence of predator cues on developing newt embryos. The relationship between newt eggs and their caddisfly predators, the effect of TTX on this relationship, and the potential for co-evolutionary interactions in this system will be discussed.

51.7

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WHAT LIES BENEATH THE SURFACE: QUANTIFYING COMPLEX THERMAL ENVIRONMENTS ON CORALS REEFS

Understanding patterns of water temperature on coral reefs has become of prime importance in forecasting patterns of physiological stress due to changing environmental conditions. However, these patterns are often based on daily measurements of sea surface temperature, which by necessity neglect higher frequency temporal fluctuations in water temperature. A growing body of evidence suggests that corals are physiologically sensitive to rapid temperature changes on time scales of minutes to hours. We collected high frequency temperature data on six coral reefs in the Caribbean, Bahamas, and Florida Keys. Data were collected at 10–16 min intervals across depths from 10–36 m between 1997 and 2004, and analyzed along with concomitant records of sea surface temperature. Variability associated with high frequency internal waves and semi-diurnal (M2) internal tidal forcing was persistent at 5 out of the 6 sites and increased with increasing depth. Diurnal variability associated with daily heating and cooling of the water column was significant at all sites with greatest magnitude at shallowest depths. The maximum within-day temperature ranges of 2–8 °C were of equal magnitude to the seasonal range of daily mean temperatures at all sites. The amplitude of the seasonal variability showed a direct relationship with latitude among sites. By contrast, the variability at daily and faster frequencies showed a more complex relationship to site latitude and was greatest at the highest and lowest latitudes. Interactions of depth, site, and season across the study region are associated with distinct signals of thermal variability that may have significant implications for the physiology and ecology of corals and other reef organisms.

24.6

LIAO, J.C., FETCHO, J.R.; jl10@cornell.edu. Cornell University
IDENTIFICATION OF SENSORY SPINAL INTERNEURONS BY USING OPTICAL, GENETIC, AND ELECTROPHYSIOLOGICAL TECHNIQUES IN LARVAL ZEBRAFISH

Sensory feedback is critical to move successfully in complex environments, yet little is known about the pattern of cellular activity in response to sensory inputs to the spinal cord. Here we use optical, genetic, and electrophysiological techniques to understand how sensory inputs shape different locomotory behaviors in larval zebrafish. An initial step in this process is to identify which neurons are active in response to stimuli. To this end we adopt two complementary techniques. First, we injected a green fluorescent calcium sensor into the cord to visualize cellular activity across several body segments in response to electrical skin stimuli. Experiments were performed on larvae (3–5 dpf) raised from embryos that were injected with DNA containing a general neuronal promoter linked to a red fluorescent protein (DS-red). DS-red clearly reveals soma and axon morphology and thus facilitates subsequent identification of active cells. Second, we recorded ventral root motor activity while simultaneously patch clamping individual neurons. Our data indicate that localized skin stimuli elicit action potentials in glutamatergic Rohon Beard cells and commissural primary ascending interneurons (CoPAs). In contrast, commissural secondary ascending interneurons (CoSAs), which have hindbrain contacts like CoPAs but have smaller somata, only display sub-threshold post-synaptic potentials. GABAergic dorsal ipsilateral interneurons (DoLAs) also fire action potentials in response to skin stimuli, perhaps to modulate sensory activity. The post-synaptic targets of these cells, along with their patterns of recruitment, may determine how different motor behaviors are initiated and modulated by sensory inputs.

39.1

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WHAT THE *ELEODES* GOING ON: CYCLIC GAS EXCHANGE IN THE XERIC BEETLE, *ELEODES ARMATA*

In insects, the discontinuous gas exchange cycle or DGC is now fairly well understood, though its selective correlates and evolutionary genesis remain elusive. Less well described and far less appreciated (in the sense of understood), cyclic gas exchange is a portmanteau term for patterns of gas exchange that involve a degree of active spiracular control, but do not allow for interpretation in terms of the triphasic DGC. CGE is not uncommon in insects and some studies suggest it may be the rule rather than the exception. Puzzlingly, although CGE should theoretically impose a respiratory water loss penalty, it is quite common among xeric insects. Here we describe the occurrence, nature and kinetics of the CGE in a common xeric arthropod, the darkling circus beetle *Eleodes armata*, a prominent inhabitant of deserts in the southwestern USA. We demonstrate that steady-state CGE regulates a constant endotracheal pO₂, and does so in the face of challenges in the form of changes in ambient pO₂. Moreover, CGE in *Eleodes* is also characterized by intermittent and cyclic episodes of excess CO₂ emission, and the interaction between these events, the extent of hypoxic or hyperoxic challenge, and the role of the subelytral chamber, comprises an important part of this talk.

32.5

LIGON, D.B., LOVERN, M.B.; day.ligon@Okstate.edu. Oklahoma State University

MATERNAL, SEX AND INCUBATION TEMPERATURE EFFECTS ON AN ENDANGERED TORTOISE, *GEOCHELONE SULCATA*

Embryonic and neonatal phenotypes are affected by a number of factors such as genotype, maternal investment and environmental conditions during development. Because of its role in determining sex in many turtle species, effects of incubation temperature (T_{inc}) on hatchling turtles have received a great deal of attention from evolutionary ecologists. Additionally, population declines experienced by many turtle species around the world have resulted in several conservation programs aimed at producing turtles in captivity for subsequent release. Thus, our goals for this study were two-fold: (1) to investigate ways in which effects of T_{inc} might be evolutionarily adaptive; and (2) to determine whether T_{inc} could be manipulated in captivity to maximize hatchling quality. To this end, we investigated the effects of T_{inc} on a wide variety of traits in an endangered tortoise, *Geochelone sulcata*. Eggs were collected from six nests produced in captivity and incubated at five constant temperatures spaced at 1° C intervals (range = 28.5°-32.5° C). Our results indicate that, independent of sex, T_{inc} affected hatchling size and body condition, both of which are predicted to affect hatchling quality. Additionally, males had higher levels of circulating testosterone than females, and females exhibited a higher incidence of scute abnormalities than males. There was no indication of metabolic compensation to T_{inc} . After statistically correcting for differences in egg mass, clutch differences were observed in hatchling size, body condition, and testosterone. Our results remain inconclusive regarding the adaptiveness of TSD, but suggest that, in addition to sex, T_{inc} effects on hatchling quality should be considered in conservation-oriented propagation programs.

3.5

LIKNES, E.T., GUGLIELMO, C.G., SWANSON, D.L.*; eric.liknes@augie.edu. Augustana College, University of Western Ontario, University of South Dakota

FUEL STORAGE AND MOBILIZATION STRATEGIES ASSOCIATED WITH SEASONAL ACCLIMATIZATION OF RESIDENT PASSERINES

Seasonal acclimatization in small birds wintering in cold climates generally results in the upregulation of metabolism in winter to meet enhanced thermoregulatory demands. We measured lipid and glycogen stores, muscle fatty acid binding protein (H-FABP) levels, and circulating levels of triglycerides, free-fatty acids, glucose, and uric acid to determine whether, as part of the process of seasonal acclimatization, black-capped chickadees (*Poecile atricapillus*), house sparrows (*Passer domesticus*), and white-breasted nuthatches (*Sitta carolinensis*) modulate attributes of fuel storage, mobilization and/or transport to meet enhanced winter thermoregulatory demands. Carcass lipid mass varied little seasonally in chickadees, but was greater winter than in summer for sparrows (38%) and nuthatches (43%), however this variation was not significant. Pectoralis intramuscular lipid was from 22-56% greater in winter birds, but this difference was not significant. In most cases, muscle glycogen levels did not vary significantly between seasons or treatments. Pectoralis H-FABP was significantly elevated in winter in chickadees and nearly significantly in nuthatches. Seasonal patterns of plasma metabolite response to different temperature exposures showed little seasonal variation. Thus, fuel storage and mobilization do not appear to be major targets of adjustment associated with seasonal acclimatization in these species, but modulation of intracellular lipid transport may be an important component of seasonal acclimatization.

39.5

LILLYWHITE, H., SAWYER, W.G., HEATWOLE, H.; hbl@zoo.ufl.edu. University of Florida, Gainesville, North Carolina State University, Raleigh
A FUNCTIONAL INTERPRETATION OF PULMONARY STRUCTURE IN MARINE SNAKES

Snakes exhibit exceptional variation in pulmonary structure, related in part to demands of the gravitational environment. Terrestrial and especially arboreal species have short vascular segments, which may extend <10% of body length to minimize gravitational intravascular pressures when the animal is upright. The remainder of the lung is a simple, elongate, saccular structure that does not function directly in gas exchange. In contrast, the vascularized parenchyma of aquatic species constitutes a much larger proportion of the total lung structure, with saccular terminations either absent or restricted to a relatively short posterior segment. The gravitational pressure problem is eliminated in water because the hydrostatic pressure gradient of the medium approximately equals that in the pulmonary vascular system (which may also collapse for some length due to external pressures if a snake is at depth). Empirical data and mathematical model demonstrate a hypothesized advantage of the elongated vascular parenchyma in the aquatic species: it maximizes the air volume that can be stored in the lung and remain in contact with exchange surfaces without becoming positively buoyant. In deeper diving species, the posterior saccular lung is thick, muscular and mucogenic. Moreover, in the vascular lung, gas exchange surfaces are well developed in peripheral radial compartments but not in the central lung lumen. We hypothesize that collapse of more peripheral gas exchange units and storage of lung gas in the saccular segment both act to minimize nitrogen uptake at depth. Thus, oxygen uptake from the lung might be intermittent and dependent on active muscular control to move gas from the saccular segment or lumen to peripheral exchange surfaces.

40.2

LIOW, L.H.; lhliow@midway.uchicago.edu. University of Chicago
LINEAGE LONGEVITY: LUCK AND A LITTLE FLEXIBILITY GO A LONG WAY

Some lineages are more persistent through geologic time than their relatives, so much so they are sometimes called living fossils and conjure up images of freaks of nature. Are persistent taxa really distinct ecologically or morphologically from their less persistent relatives? Using a database of well-fossilized and well-documented microfossils, the trachyleberidid ostracodes, I ask if longer-ranging genera and species are distinct in their morphology from shorter-ranging ones. I also ask if longer-ranging species and genera are ecologically more versatile, as measured here by depth distribution, than shorter-ranging ones. I show that longer-ranging genera cannot be distinguished from shorter-ranging genera with respect to their morphological distance from the mean of the family. However, there is evidence that species that are morphologically more variable at the population level tend to persist for longer intervals in the fossil record. The number of depth zones that a species occupies is positively correlated with its longevity, but not significantly so. The duration distribution of genera that are both shallowly and deeply distributed is significantly different from those that are bathymetrically more restricted. However, the mean number of depth zones occupied by the species constituting a genus, shows no relationship to its longevity. I conclude that persistent trachyleberidid taxa are in general not much different from their relatives in terms of morphological distance from the family mean or ecological versatility, as measured by the number of depth zones they occupy. However, some ecological flexibility and morphological variability, combined with what can be termed luck, could contribute to prolonged persistence through time.

64.1

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DEVELOPMENT OF THE SKELETOGENIC MESODERM IN THE OPHIUROID *OPHIOCOMA WENDTII*

Both sea urchin and brittle star species give rise to embryos and larvae with well developed skeletal spicules, while sea cucumber and sea star embryos have reduced or absent larval skeletons. The uncertain phylogenetic position of brittle stars in relation to the other echinoderm classes makes it unclear whether the similar skeleton in urchins and brittle stars is a shared ancestral trait, or due to convergent evolution. Here we examine the development of the mesoderm in a brittle star, *Ophiocoma wendtii*, and describe the isolation and characterization of a cDNA encoding a fragment of Alx1 from this species. This gene is involved in the gene regulatory network leading to skeleton formation in sea urchins, and is also expressed in the skeletogenic mesoderm in brittle star embryos. The time course of expression of the Alx1 gene in brittle stars is similar to that of sea urchins, although there are differences in the spatial expression pattern that reflect the differences in mesoderm development in brittle stars.

S6-2.2

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NEURAL CONTROL OF BODY PATTERNING IN THE EUROPEAN CUTTLEFISH *SEPIA OFFICINALIS*

Unshelled cephalopods exhibit a wide range of body patterns used for camouflage, inter- and intra-species communication. Body patterns in cephalopods are highly plastic; they are generated in less than a second and can be held for a fraction of a second or for hours. These body patterns are formed by a unique chromatophore system under direct neuromuscular control. The goal of our lab is to fully elucidate the mechanisms underlying body patterning behavior in cephalopods, with a primary emphasis on the European cuttlefish *Sepia officinalis*. Our studies on chromatophore activity show that several neurotransmitters control chromatophore expansion. Glutamate mediates rapid chromatophore expansion where as FMRFamide-related peptides (FaRPs) are responsible for a much slower rate of chromatophore expansion. Immunocytochemical studies confirm the presence of both types of transmitters in the neurons in the anterior (ACL) and posterior chromatophore lobes (PCL) and also in the peripheral terminals of chromatophore motoneurons. Some of these neurons were immunopositive for both glutamate and FaRPs. Molecular studies in the cuttlefish revealed 2 FaRPs encoding genes in *Sepia*. *In situ* experiments showed that one of the FaRPs encoding gene is expressed in the ACL and PCL. Reconstruction studies using nerve backfilling and electrical stimulation suggest the possibility of a topographic mapping within the PCL of the chromatophore motoneurons. Experiments with other cephalopods reveal that the glutamate/ FaRPs regulation of chromatophore activity is widespread among the cephalopods. Although all species appear to have the glutamate system, a functional FaRP control system is limited to cuttlefish and octopi

37.1

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PROTEOMIC ANALYSES REVEAL THAT COMPONENTS OF THE CYTOSKELETAL NETWORK ARE UP-REGULATED BEFORE HIBERNATION IN FENCE LIZARDS

We are undertaking long-term studies aimed at understanding the mechanistic basis of differences in life-history strategies among populations of the fence lizard *Sceloporus undulatus*. One aspect of these studies employs proteomics. Because the liver is metabolically central, we examined differences in the liver proteome from seasonally acclimatized lizards (Nebraska population, collected 7/04 & 9/04). Proteins were extracted from whole livers of individual animals (n=6 for 7/04 and 5 for 9/04) and separated by 2-dimensional gel electrophoresis. Homologous bands were compared across gels and seasons to assess relative differences in protein expression. Bands of interest were excised and submitted to mass spectrometry analyses for identification (trypsin digestion, ESI-LC-MS/MS(FTD), CID, MALDI-TOF). To date, >50 proteins have been analyzed. Among these are 6 bands up-regulated -2-14 fold in the fall; all of these bands (except one that remains unidentified) are components of the cytoskeletal network (tropomyosins, cytoke- ratin, actin). We hypothesize that the cytoskeletal network becomes more active in the fall when metabolic fuel is moved through the cell for storage (e.g. in fat bodies). In the spring, components of intermediary metabolism (cytochrome C oxidase, short-chain dehydrogenase) are up-regulated. We hypothesize that these changes support high activity and growth in the spring. In addition, overall diversity of protein expressed is different between seasons, with a mean of 591 bands resolved in the fall, and 800 in the Spring (p<0.01). We contend that liver cells may reduce protein diversity during sub-acute stress (hibernation), and we have seen similar responses in other organisms (fish) with other stressors (parasitism and high-calorie diet).

45.1

LONGRICH, N.R.; longrich@ucalgary.ca. University of Calgary
AQUATIC MARSUPIALS FROM THE LATE CRETACEOUS OF NORTH AMERICA

Following the end of the Cretaceous, a wide range of mammals became adapted to life in water, but no strong evidence is available for aquatic mammals during the Mesozoic. Recently, a series of unusual, large (1.4-2.6 cm) mammalian caudal vertebrae were identified from the Campanian Judith River group of Alberta. These vertebrae are flat, broad and bear large transverse processes. Their resemblance to the vertebrae of the platypus (*Ornithorhynchus*) and beaver (*Castor*) suggests an oarlike tail used for steering underwater. The vertebrae do not seem to pertain to multituberculates; of the remaining mammals in the fauna, only the stagodont marsupials *Eodelphis browni* and *E. cutleri* are large enough to account for them. As in river otters (*Lutra canadensis*) and mink (*Mustela vison*), *Eodelphis* exhibits unusually heavy tooth wear, perhaps indicating a diet of fish and shellfish. The Maastrichtian *Didelphodon* (including *D. vorax*, *D. padanicus*, and *D. coyii*) is a larger, more specialized stagodont, and possesses robust mandibles and bulbous premolars resembling those of the sea otter *Enhydra*. The teeth possess large, planar wear facets and are sometimes worn down to the roots, providing evidence of resistant prey items. It may have preyed on the diverse gastropods and bivalves of the Hell Creek and Lance formations. A semiaquatic lifestyle also predicts heavy bones to decrease buoyancy. As predicted, the jaws of stagodonts have greatly thickened cortices. The large size of stagodonts and their occurrence alongside a diverse freshwater biota are also consistent with semiaquatic habits. Stagodonts therefore represent the earliest known aquatic mammals. The largest mammals in Late Cretaceous North America were aquatic, underscoring the extent to which dinosaurs constrained mammalian diversification, yet stagodonts also hint at an underappreciated ecological diversity among Mesozoic mammals.

8.5

LÓPEZ-DUARTE, P.C., TANKERSLEY, R.A.; plopez@fit.edu. Florida Institute of Technology
ENDOGENOUS SWIMMING RHYTHMS OF FIDDLER CRAB ZOEAE FROM DIFFERENT TIDAL REGIMES

Larvae of the fiddler crab *Uca pugilator* are released near the time of high tide and are exported to shelf waters to undergo development. Previous studies indicate that newly hatched zoeae use selective tidal-stream transport (STST) to migrate from estuaries to coastal areas. In areas with semi-diurnal tides, the STST behavior of larvae is mediated by a circatidal activity rhythm that is characterized by upward vertical migration into the water column during ebb tide followed by a descent toward the bottom during flood tide. We tested the hypothesis that *U. pugilator* zoeae from different tidal regimes possess endogenous activity rhythms that match local tidal patterns. Ovigerous crabs with late-stage embryos were collected from locations lacking tides (microtidal) and from areas with diurnal and mixed tides. Following hatching, larvae were placed in constant conditions and swimming activity was monitored continuously for 96 h. Zoeae from the diurnal regime exhibited a rhythm with a periodicity of ~24.2 h, consistent with the tides at the collection site. Crabs from areas with mixed tides displayed activity rhythms with two dominant periodicities at 12.6 h and 23.5 h, reflecting the main semi-diurnal and diurnal components of this tidal pattern. At both locations, peaks in larval activity occurred during the time of expected ebb currents, which is consistent with STST behavior favoring seaward transport (i.e., ebb-tide transport). Finally, zoeae from microtidal areas exhibited circatidal rhythms similar to those observed in crabs from areas with semi-diurnal tides. Differences in the activity patterns of zoeae from the three tidal regimes suggest that STST behaviors are controlled by multiple endogenous clocks or multiple couplers linked to a single clock.

32.2

LOURDAIS, O., DENARDO, D.F*, HOFFMAN, T.C.M.; denardo@asu.edu. Arizona State University
MATERNAL BROODING IN THE CHILDREN'S PYTHON (*ANTARESIA CHILDRENI*) PROMOTES EGG WATER BALANCE

Pythonine snakes show extended care of their clutches with maternal egg brooding. While brooding may provide the eggs thermal advantages via insulation and, in some species, shivering thermogenesis, it is also possible that it promotes water conservation in the clutch. In this study we experimentally tested the functional significance of maternal brooding relative to water balance in the Childrens python, *Antaresia childreni*, a small species that does not shiver during incubation. First, we found that eggs were very sensitive to dehydration when exposed to sub-saturated air. Consistently we found that evaporative water loss (EWL) from the clutch was high. Clutch EWL was positively influenced by clutch mass, reflecting the independent influences of litter size and egg mass on water loss. Mean egg EWL was inversely related to litter size, suggesting the conglomerated clutch behaves as a single unit with a decreasing surface to volume ratio with increasing clutch size. Maternal brooding had a dramatic impact, reducing and possibly eliminating clutch EWL. Indeed, EWL values of brooding females were lower than EWL of females alone. Overall, these results demonstrate that brooding behavior can be an extremely efficient posture, promoting egg water balance in pythons. Interestingly, a preliminary inter-specific comparison suggested that Childrens python eggs are more sensitive to water loss than are the eggs of colubrid snakes.

S6-1.2

LOVELL, P.J., KOHN, A.B., MOROZ, L.L.; plovell@whitney.ufl.edu. University of Florida, St. Augustine and Gainesville
MOLLUSCAN NEURITES GROW INTO THE GENOMIC ERA: INSIGHTS FROM *APLYSIA* TRANSCRIPTOME

In developing nervous systems, neurons are faced with the daunting task of finding appropriate synaptic targets located far from their own cell bodies. To accomplish this, neurons extend long neurites tipped with active growth cones to physically traverse the distance and respond to guidance molecules along the way. This neurite outgrowth can be modeled in cell culture where molluscan neurons regenerate robustly under controlled conditions. Specifically, we employed several classes of identified *Aplysia* neurons to model both induced neurite outgrowth and regeneration of isolated neurites following damage. We took advantage of the fact that neurite outgrowth of molluscan neurons can be easily induced or restricted simply by changing properties of the cell culture media. Specifically, neurons cultured in media supplemented with fresh haemolymph grow extensively while the same type of neurons do not grow in media supplemented with boiled haemolymph. Neurite outgrowth has been shown to be dependent on both transcription and translation of new proteins and a variety of distinct mRNA transcripts are known to be located extrasomatically, however, lack of broad scale molecular profiling tools have limited studies to individual transcripts of interest. In the current study, we have used broad scale EST collections from both whole neurons and isolated neurites as well as microarray analysis to investigate the genomic basis of neurite outgrowth from cultured identified *Aplysia* neurons at the transcriptome level.

S6-2.3B

LOWE, C.J., ARONOWICZ, J., TERASAKI, M., KIRSCHNER, M., GERHART, J.; clowe@uchicago.edu. University of Chicago, University of Connecticut, Harvard Medical School, University of California Berkeley
HEMICHORDATE DEVELOPMENT AND THE EVOLUTION OF CHORDATE NERVOUS SYSTEM

How the chordate central nervous system evolved from their invertebrate ancestors has a long history in evolutionary biology, yet it remains one of the greatest puzzles in zoology. Hemichordates are one of the most promising groups for addressing this issue due to their potential morphological affinities to the chordates that originally led Bateson to classify them as chordates. The dorsal and ventral nerve cords have both been proposed to be the homolog of the chordate dorsal nerve cord at various times by a range of investigators. However, more recently, earlier classical descriptions have been largely over-looked, yet show clearly that the nervous system is entirely decentralized, and the two cords are best described at axonal tracks rather than true cords. We have been characterizing the development of a direct-developing enteropneust species of hemichordate, *Saccoglossus kowalevskii*. This work has compared the expression in *S. kowalevskii* of conserved regulatory genes involved in the specification and patterning of the chordate central nervous system in both the anteroposterior and dorsoventral dimensions. The surprising initial results from this work has shown a remarkable conservation of the relative expression of genes involved in the antero/posterior patterning of the entire neuraxis of the chordates during the development of *S. kowalevskii* despite a fundamental difference in neural organization. A more complex story emerges when comparing the genes involved in dorsoventral patterning, but *bmp* clearly has a fundamental role in dorso/ventral patterning in hemichordates as shown by functional experiments. I will discuss the evolutionary implications of these data to both the evolution of chordates and the evolution of neuroanatomy.

S1.9

LUTTON, B.V., CALLARD, I.P.; bram@bu.edu. Boston University
ENDOCRINE-IMMUNE INTERACTIONS AND REPRODUCTION IN ELASMOBRANCHS: INVESTIGATIONS OF THE LITTLE SKATE, *LEUCORAJA ERINACEA*

Bi-directional interactions between gonadal hormones and the cells and factors of the immune system are critical for reproduction and immune function. The elasmobranchs (sharks, skates, and stingrays) offer a unique approach to the study of such physiological interactions. These are the only species in which the gonads are directly associated with an autonomous immune tissue, the epigonal organ, and they are the first taxon in which all the components of the adaptive immune system are present. In this study we have begun to characterize the relationship between the epigonal organ and the ovaries of the little skate, *Leuconaja erinacea*. Timed arterial perfusions demonstrated a vascular pathway from the epigonal organ to the ovarian follicles, and corrosion casting further supported the direct vascular connection between the two tissues. Whole ovary sections were stained with hematoxylin and eosin, and microscopic analysis illustrated direct cellular contact between leukocytes of the epigonal organ and follicle wall cells of the ovary. Immunohistochemistry and *in vitro* experiments demonstrated that the hypothalamic-pituitary-gonadal axis appears to play a direct role in immune regulation via modulation of leukocyte turnover (proliferation and apoptosis), while the leukocytes and/or secreted factor(s) of the epigonal organ seem to regulate, at least in part, steroidogenesis from follicle wall cells. Interactions between sex hormones and the immune system have been implicated in autoimmune diseases and ovarian cancer, yet current studies continue to search for the mechanisms of action. The sharks, skates and stingrays serve as excellent models because they offer novel perspectives with regard to the evolution of physiological mechanisms.

S2-2.1

MABEE, P.M.; pmabee@usd.edu. University of South Dakota, Vermillion
INTEGRATING CTOL-RELATED STUDIES WITH AVAILABLE PHENOTYPE AND GENOMICS DATABASES FOR THE ZEBRAFISH

The developing phenotype figures prominently in the work of developmental biology, and connecting gene expression and function to phenotypic effects are major emphases in studies of zebrafish and other model organisms. Approaches toward making this connection include gene misexpression and the isolation of single gene mutants that have discrete effects on body pattern, followed by examination of the effects on the resultant phenotype. The data resulting from these approaches is voluminous, and discovering the complex gene networks that connect sequence to phenotype will require increased bioinformatics efforts and new tools. We are taking an ontology approach to connect the evolutionary anatomy and image database that we are developing in our Cypriniformes Tree of Life (CToL) group to existing zebrafish genomic databases. Ontologies are controlled vocabularies that formally represent hierarchical relationships between defined biological concepts. They turn the free text descriptors of anatomical characters into computable data that can be explored and mined. Practically, in order for the growing databases in each area to connect in a way that evolutionary questions can be addressed, a shared ontology for homologous modules of the phenotype must be referenced. We expect the cross talk between our (CToL) group and the ZFIN (Zebrafish Information Network) group to result in the connection of our systematic characters to corresponding genomic data. I will present two use cases to demonstrate the broad utility of this approach.

20.1

MACDOUGALL-SHACKLETON, S.A., MACDONALD, I.F., KEMPTER, B., ZANETTE, L.; smacdou2@uwo.ca. University of Western Ontario
NUTRITIONAL STRESS, BRAIN DEVELOPMENT AND SONG REPERTOIRES IN SONG SPARROWS

The developmental stress hypothesis posits a mechanism by which birdsong can be maintained as an indicator of male quality. HVC, a brain region critical for learning and production of birdsong, rapidly develops at a time of nutritional stress during the nestling and fledgling stages. Birds best able to withstand this stress should learn to produce the best songs. We tested this hypothesis in song sparrows, *Melospiza melodia*, a species in which females prefer large song repertoires. Hand reared birds were food restricted or fed ad lib. At 3 weeks of age, food restricted males and females both had reduced size of HVC compared to birds fed ad lib. There was also a large sex difference in HVC size. Food stressed birds also had a smaller telencephalon, but the reduction in HVC size remained significant when the effects of overall reduction in brain size were controlled. Thus, nutritional stress specifically impairs HVC development in both sexes. We also examined the size of HVC in breeding adult males and found it was positively correlated to song repertoire size. Combined, these data support the developmental stress hypothesis as a mechanism by which song repertoires can be an indicator signal in song sparrows.

52.10

MAHLER, L., KEARNEY, M.; lmahler@biology2.wustl.edu. Washington University, St. Louis, Field Museum of Natural History
THE PALATAL DENTITION IN SQUAMATE REPTILES: MORPHOLOGY, DEVELOPMENT, ATTACHMENT, AND REPLACEMENT

The palatal dentition in squamate reptiles is poorly known compared to the marginal dentition. We surveyed species of all squamate families for the presence of palatal teeth. For those exhibiting palatal teeth, we investigated palatal tooth morphology, arrangement, development, attachment, and replacement patterns. We found substantial variability at familial, generic, and specific levels among non-ophidian lizards for the presence of palatal teeth, and for the arrangement and number of palatal tooth rows. However, snakes are much more uniform in both respects.

Palatal teeth are morphologically similar to the marginal teeth or, in some cases, relatively simpler. In squamates with palatal teeth arranged in single rows, new teeth develop in the dental lamina along the labial edge of the tooth row. In others, various modifications of the dental lamina accommodate tooth replacement across multiple tooth rows or fields. Ankylosis of palatal teeth occurs either within a shallow resorbed cavity or on a raised ridge on the surface of the element. Tooth replacement patterns on the palate generally mirror those on the dentigerous marginal elements.

Patterns of variability found in this study imply tradeoffs between phylogenetic, functional, and developmental constraints. The strong correspondence in morphology and replacement patterns between marginal and palatal dentitions supports the hypothesis of developmental homology between them. In addition, there is some evidence for modularity of palatal tooth expression, and for phylogenetic non-independence of palatal teeth occurring on different palatal bones.

8.6

MAHON, B.C., NEIGEL, J.E.; bcmahon@louisiana.edu. University of Louisiana at Lafayette

A REAL-TIME PCR ASSAY FOR DETECTION AND QUANTIFICATION OF CRUSTACEAN LARVAE IN PLANKTON SAMPLES

The study of larval dispersal at sea has historically been a labor intensive process involving long and tedious hours of sorting and attempts at identification of larvae based on morphological characters. Recent research however has shown the feasibility of detection and quantification of even single larvae of crustaceans or fish from plankton samples with molecular techniques. Our study utilizes species-specific dual labeled oligonucleotide probes in a real-time PCR assay for detection and quantification of multiple crustacean species from plankton samples collected in coastal areas of central California. Results of these tests are compared to actual larval counts from replicate splits from the same plankton tows to test for: 1) species-specificity; 2) sensitivity limits; and 3) quantitative accuracy. Results of these tests will be presented along with potential applications.

30.5

MANOR, R., WEIL, S., OREN, S., AFLALO, E.D., VENTURA, T., LAPIDOT, M., CHALIFA-CASPI, V., SAGI, A.; mnor@bgu.ac.il. Ben-Gurion University of the Negev, Israel

FISHING OUT UNIQUELY EXPRESSED GENES OF THE ANDROGENIC GLAND IN THE AUSTRALIAN CRAYFISH *CHERAX QUADRICARINATUS*

The Australian crayfish *Cherax quadricarinatus* is a gonochoristic decapod species in which the androgenic gland (AG), an organ unique to male crustaceans, regulates sex differentiation, sexual secondary characteristics, and behavior. It is thought that the AG exerts its effects through androgenic gland hormone(s), not yet identified in decapods, whose synthesis and secretion are mediated by AG uniquely expressed genes. In order to identify such genes, a subtractive cDNA library of *C. quadricarinatus* AGs was constructed using cDNA from AGs as the "tester" and cDNA from other peripheral glands as the subtractive reference. cDNA products of the subtractive library were cloned, sequenced and an automated BLAST-X search suggested similarity to other known proteins in different organisms. So far, 200 sequences were analyzed and assembled into 49 putative genes, part of them could be assigned to metabolic pathways and a few were putatively identified as structural proteins. The majority of the putative genes showed no significant similarity to any known proteins in the Swiss-Prot database. Twenty of the above transcripts were tested by RT-PCR and two confirmed to be uniquely expressed in the AG. Northern blot analysis of these two genes revealed transcripts of 1000 and 2000 bp. Seeking full sequence of these uniquely expressed genes will help in identification of their functions.

58.3

MARIONI, N.K., TRACY, C.R., ZIMMERMAN, L.C.; NatalieM@bio-diversity.unr.edu. University of Nevada, Reno

EFFECTS OF DECLINING LAKE LEVELS ON FISH POPULATIONS: LAHONTAN CUTTHROAT TROUT AND TUI CHUB IN WALKER LAKE, NV

Prior to the 1960s, Walker Lake, NV was inhabited by five fish species. Extensive water consumption for agriculture, which has reduced water inflow from the Walker River, and high rates of evaporative water loss have contributed to declining lake levels for decades. Consequently, the concentration of dissolved solids in the lake has been increasing. This change in water chemistry has caused the extirpation of three species of fish, and today, only Lahontan cutthroat trout *Oncorhynchus clarki benshawi* and tui chub *Gila bicolor* remain in the lake. Lahontan cutthroat trout (LCT) apparently persist because individuals have a notable ability to survive in water high in salinity (Sigler et al. 1983, Beutel and Horne 1997) Here, we address the question of the distribution and abundance of fish (LCT and tui chub) as a function of the lake characteristics. Water was characterized in terms of depth, temperature, dissolved oxygen, conductivity, and total dissolved solids (TDS) measured bi-weekly between May 2003 and April 2005. Fish were enumerated with respect to depth using a Bottomline Tournament Master 5300 fish finder along 63, one kilometer transects. Water data were collected at each fish survey location. The average depth of the lake has declined by approximately 0.5 meters per year in 2004 and 2005, and water conductivity has increased steadily as a result. Distribution and abundance of fish varied seasonally, and it appears that fish are occasionally forced into areas outside of their optimal thermal and aerobic range. Preservation of Walker Lake warrants continued research to investigate approaches to maintaining and increasing the number available fish refuges.

63.3

MARKEY, M.J., MAIN, R.P., MARSHALL, C.R.; markey@fas.harvard.edu. Harvard University

IN VIVO CRANIAL SUTURE FUNCTION AND SUTURE MORPHOLOGY IN THE EXTANT FISH *POLYPTERUS*

This study describes the mechanical role cranial sutures play in fish during feeding, and presents a quantification of fish suture morphology using microCT scanning. To measure suture deformation during feeding, strain gauges were surgically implanted across selected sutures in the skull roof of 4 individuals of *Polypterus endlicheri*. After surgery, sutural strains were measured during feeding along with high-speed videos of the feeding events. In each trial, suction feeding versus biting on prey was established, and head lifting, hyoid position, and gape were quantified. Suction feeding shows more stereotyped strain patterns than biting in *Polypterus*, and peak strains during suction exceed biting strains. In both feeding types the interfrontal suture (IF) is generally loaded in tension, the interparietal (IP) suture is loaded in compression, while the frontoparietal (FP) suture experiences compression or tension depending on feeding mode. MicroCT scans of the experimental animals indicate that the IP suture is interdigitated in cross section, while the IF suture is more flat-edged. These observations are consistent with published correlations of suture form and function (i.e., interdigitation indicates compression). In contrast, the highly overlapping FP suture may represent a compromise between varying tensile and compressive loads. Several metrics, some new to this study, were used to quantify suture shape in the CT scans, and test the hypothesis that shape variation within a suture is greater than variation among individuals. Further, we reject the hypothesis that the ectocranial trace of a suture predicts its 3D shape. These metrics and correlations between suture morphology and function may be used to help make inferences about feeding mode in living and extinct taxa.

41.6

MARSHALL, C.D., DEHNHARDT, G.; marshalc@tamug.edu. Texas A&M University at Galveston, Ruhr-Universität Bochum
SUCTION CAPABILITY AND PERFORMANCE IN FEEDING HARBOR SEALS (*PHOCA VITULINA*)

Measures of suction generation capability in harbor seals were collected as part of a comparative study on the feeding performance of pinnipeds. Although suction is thought to be an important component of the feeding repertoire in harbor seals there are no data to support or refute this premise. Three harbor seals were presented pieces of fish in an experimental apparatus that forced seals to choose between ingesting fish by biting or suction. A Millar MPC 350 pressure transducer and portable electrophysiological recording system was used to collect pressure forces during feeding. Feeding behavior was videotaped and synchronized with physiological data using a pair of flashing LED lights that generated a corresponding square wave pattern. Harbor seals used suction, biting, and some hydraulic jetting when feeding from the apparatus. The mean suction force recorded was 11.3 kPa (S.D. +/- 7.59). The maximum suction pressure measured over 352 feeding events was -46.3 kPa. The mean duration of suction events were 0.6 s (S.D. +/- 0.36) and ranged from 0.1 s to 2.06 s. A positive pressure preparatory phase often preceded the main suction event. In some instances a small post-suction event positive in pressure was observed. These supplemental phases presumably served to remove excess water from the mouth either just before or just after a suction event. Suction capability of harbor seal in this study were considerably smaller in magnitude compared to suction specialists such as bearded seals and walruses, but were strong enough to be an important component of the feeding repertoire.

S4.10

MARSHALL, D.J.; d.marshall@unsw.edu.au. University of Queensland
TRANSGENERATIONAL OFFSPRING SIZE EFFECTS IN MARINE INVERTEBRATES

In marine invertebrates, the larval and adult stages of many species are often ecologically distinct and as consequence these stages have been traditionally been viewed as physiologically separate. More recently, we have begun to recognize that metamorphosis does not represent a new beginning and events during the larval stage can influence adult performance. I will discuss recent work that suggests that the links between life-history stages are even more pervasive than we currently appreciate. For several species of marine invertebrate, I have found that events during one generation can strongly affect performance in the subsequent generation and events during the haploid phase can affect performance in the diploid phase. All of these links are mediated by changes in offspring size or offspring quality. I will discuss the implication of these strong links for the way we view the ecology of marine invertebrates and the evolution of offspring size in this group.

S1.4

MARTIN, L.B., WEIL, Z.M., NELSON, R.J.; lmartin@mail.psy.ohio-state.edu. The Ohio State University
THE IMMUNE DEFENSES OF RODENTS: MODEL SYSTEMS FOR BRIDGING CONSERVATION, MEDICINE, AND ECOPHYSIOLOGY.

The control of disease in humans and other species has been improved greatly through study of the molecular and cellular processes underlying immune responses. Recent ecological approaches to studying the vertebrate immune system have provided insight, however, into why immune defenses often vary among and within species. Here, we discuss the results of two eco-immunological studies on rodents from our lab. In the first study, we investigated the effects of trenbolone, a growth promoter of cattle, on wound healing, antibody production to a novel antigen, and *ex vivo* bacterial killing in house mice. Because trenbolone has androgenic properties, we expected it would suppress components of immune activity like endogenous androgens sometimes do. In our study, trenbolone retarded wound healing in mice to a similar degree as exogenous testosterone; bacterial killing and antibody production assays are in progress. In the second study, we asked whether the different paces of reproductive life of six species of *Peromyscus* mice influence the architecture of their immune systems. We expected that species that reproduce prolifically would invest in cheaper immune defenses than more reproductively conservative species, leading their immune systems to be biased to developmentally cheaper, non-specific defenses overall. This hypothesis was generally supported: in smaller, reproductively prolific species, bacterial killing capacity was stronger, but primary and secondary antibody responses to a novel antigen were weaker and rates of wound healing were slower relative to larger, less prolific species. Altogether, these studies indicate that adaptationist approaches to understanding the vertebrate immune system may improve human health and conservation efforts.

29.7

MARTIN, K.L., JOHNSON, P.B., MORAVEK, C., ASHLEY, R., MATSUMOTO, J.; kmartin@pepperdine.edu. Pepperdine University
CITIZEN SCIENTISTS ASSESS POPULATIONS OF AN ELUSIVE, CHARISMATIC FISH

For the past four years, California citizens have volunteered to monitor the spawning runs of the grunion in an effort to understand more about the species and the strength of its populations along the coast. The grunion, a small silver marine fish that spawns by moonlight on sandy beaches, eludes capture by standard fisheries methods. Prior to this study, the most recent range-wide assessment had been done in 1947. This fish supports a recreational fishery, and grunion runs are part of the culture and lore of southern California beaches. Starting in San Diego in 2002, our citizen science effort has now expanded statewide with more than 400 trained volunteers observing from over 50 beaches in 2005. From San Diego to the San Francisco area, volunteer Grunion Greeters report their data via a web questionnaire so that it is instantaneously available. Results are provided to beach workers and policy makers for use in management decision. This year Grunion Greeters identified previously unknown locations for grunion spawning runs, including a new northward range extension and a resident population in San Francisco Bay. They provided consistent, reliable observations on heavily used urban beaches across southern California for 10 nights during the peak of the spawning season, enumerating the number and density of grunion, the time of the run, any predators or human anglers, and weather features. Contributions from trained non-scientists have increased our understanding of the way that grunion use sandy beaches and have helped to mitigate human impacts on their critical spawning habitat. In addition, these observations have greatly enhanced our scientific understanding of the biology of this unique, elusive, charismatic fish. Funded by NOAA, Calif. Sea Grant College, and NFWF.

22.6

MARTIN III, A.L., MOORE, P.A.; artmart@bgnet.bgsu.edu. Bowling Green State University
THE EFFECTS OF SHELTER OCCUPATION ON CRAYFISH AGONISTIC INTERACTIONS

Dominance provides access to resources such as mates, food, shelter, and other objects promoting survivorship and fitness (Wilson 1975). Shelters serve as a good source of protection from predators and conspecifics. The possession of a shelter by a crayfish increases its probability of winning an agonistic encounter. Therefore, the variability of shelter qualities in an environment should influence an individual's shelter choice. Little is known about crayfish shelter choice and the variability of quality between various shapes and sizes of shelters. The amount of light or darkness within a shelter may be an indication of shelter choice. This may be related to the number of openings on a shelter that allow light to enter. Thigmotactic stimuli may also influence shelter choice indicating tight fit shelters relative to body size are higher quality shelters. Some work has shown that darker shelters may have more influence on indicating a shelter preference in crayfish than do thigmotactic shelters (Steele et. al. 1997). Our study quantifies crayfish social interactions and shelter choice in the presence of conspecifics. Size matched crayfish bouts were analyzed to quantify social dominance hierarchies. Dominant individuals acquire higher quality resources providing an insight to resource shelter quality. The shelters used in this experiment are half-pipe PVC that consists of a variable number of openings and radii. Dominant individuals acquire higher quality resources than subordinate animals, but little evidence supports crayfish social structures and their influence on resource acquisition. Shelter preference and the social dynamics established when competing for such resources is an important study designed to develop an understanding for these interactions in the field.

27.2

MASSEY, S.E., CURTIS, N.E., PIERCE, S.K.; pierce@cas.usf.edu. University of South Florida, Tampa
IDENTIFICATION OF A RETROVIRUS THAT MAY HAVE A ROLE IN THE LIFE CYCLE AND CHLOROPLAST SYMBIOSIS OF KLEPTOPLASTIC SEA SLUGS.

The annual life cycle of the kleptoplastic sea slug, *Elysia chlorotica*, ends in synchronous mortality during the early summer in salt marshes along the New England coast. Coincident with the deaths, we have discovered the expression of a novel, endogenous virus in every slug. The virus contains RNA, has the fine structural morphology of a retrovirus, sediments at a buoyant density characteristic of retroviruses and displays reverse transcriptase (RT) activity. We have cloned viral sequences from RNA obtained from purified virus, some of which match the sequence of the retroviral *pol* gene. These characteristics all confirm that the virus is a novel marine retrovirus. We are examining further the molecular aspects of the retrovirus in order to investigate its impact on the endosymbiotic lifestyle of the host sea slug. Supported by NSF IBN 0314227.

S1.1

MATSON, K.D., KLASING, K.C., SCHEUERLEIN, A., RICKLEFS, R.E.; kdm50c@umsl.edu. University of Missouri-St. Louis, University of California-Davis
IMMUNE FUNCTION DIFFERENCES BETWEEN CONTINENTAL AND ISLAND FORMS: A SYMPTOM OF AN ISLAND SYNDROME?

Assuming immune defenses are costly, birds with an evolutionary history on relatively disease-free, oceanic islands should exhibit reduced immune function as part of a general island syndrome of reduced interspecific (in this case, parasite-host) interactions. In fact, some endemic birds of Hawaii have experienced population declines because of their failure to resist infection by introduced pathogens. We measured several components of the immune system in birds from continents and oceanic islands to investigate the evolutionary lability of immune function. Comparisons were made between 15 phylogenetically matched pairs of species/populations in North America and on the islands of Hawaii, Bermuda and the Galapagos. The island populations included endemics, natives, and recent introductions. We employed three protocols to measure eight variables: hemolysis, hemagglutination, haptoglobin concentration, and enumeration of five leukocyte types. All assays were based on a single blood sample subdivided into cellular (blood smear) and plasma (frozen until analysis) components. Implications of this study for conservation of island species, and more generally for evolutionary and physiological ecology, will be discussed.

48.2

MATUS, D.Q., PANG, K., THOMSEN, G.H., MARTINDALE, M.Q.; matus@hawaii.edu. University of Hawaii, Kewalo Marine Laboratory, Stony Brook University
SIGNALING PATHWAY COMPLEXITY IN THE DEVELOPMENT OF AN ANTHOZOAN CNIDARIAN

Cnidarians (corals, sea anemones, and jelly fish) occupy an important phylogenetic position within the Metazoa, as a potential sister group to the Bilateria. As a group, textbooks have long characterized cnidarians as diploblastic and radially symmetrical around their longitudinal axis (the oral-aboral axis). *Nematostella vectensis*, the starlet sea anemone, a member of the Anthozoa, is currently being developed as a model cnidarian in which to investigate the origins of the mesodermal germ layer and bilaterality, synapomorphies of the Bilateria. Recent work suggests that *N. vectensis* possesses the molecular framework of anterior-posterior and dorso-ventral axial patterning, belying the sea anemones simple morphological appearance. The *N. vectensis* genome has recently been sequenced, and has provided a useful tool for isolating and characterizing both the complement and deployment of many bilaterian patterning genes and signal transduction pathway members. We report a surprisingly rich complement of key metazoan signal transduction pathway family members and their antagonists, including *hedgehog*, *TGF- β* , *Wnt*, and *FGF* families, many of which are absent from the derived ecdysozoan model organisms, *Drosophila melanogaster* and *Caenorhabditis elegans*. We also show the deployment of members of these signal transduction pathways via *in situ* hybridization during embryogenesis in *N. vectensis* that suggest a startling potential role of many of these pathways in both the origins of an endomesodermal germ layer and bilateral symmetry.

S2-1.1

MAYDEN, R.L., CONWAY, K., CHAMBERLAIN, S., HASKINS, M., SCHNEIDER, L., SUDKAMP, M., TANG, K., WOOD, R.M.; maydenr@slu.edu. Saint Louis University, St. Louis

PHYLOGENETIC RELATIONSHIPS OF *DANIO* WITHIN THE ORDER CYPRINIFORMES: A FRAMEWORK FOR COMPARATIVE AND EVOLUTIONARY STUDIES OF A MODEL SPECIES

The evolutionary relationships of species of *Danio* and the monophyly and phylogenetic placement of the genus within the Family Cyprinidae and Subfamily Rasborinae forms fundamentally important phyloinformatics for necessary for direct evaluations of an array of pertinent questions in modern comparative biology. While the genus is not one of the most diverse within the family, historical decisions have made this group and *Danio rerio* as one of the most important biological models in some areas of biology. Many investigations across the breadth of biological sciences have used this species or presumed close relatives to address specific questions that can have lasting impact on the hypothesis and theory development in vertebrates. Largely lacking from this picture has been a holistic picture of the exact phylogenetic or evolutionary relationships of this species, the genus, and presumed close relatives. If there is one thing that the previous century did learn in comparative biology it was that many organismal attributes, pathways, ecologies, behaviors, speciation, etc. of species are historically constrained and their origins and functions are best explained via a historical or phylogenetic context. Herein, we provide a comprehensive evaluation of the phylogenetic placement of the model species *Danio rerio* within *Danio* and many of the hypothesized closely related species and genera. Our analysis is derived from two nuclear genes (Rag 1, S7) and three mitochondrial genes (ND4-5, CO1, Cyt b) evaluated using maximum parsimony and Bayesian analyses. This effort is part of a much larger targeted Cypriniformes Tree of Life Initiative (www.cypriniformes.org).

8.9

MCALISTER, J.S.; jmca@unc.edu. University of North Carolina, Chapel Hill

ENVIRONMENTAL HETEROGENEITY AND THE EVOLUTION OF PLASTICITY IN PANAMANIAN ECHINOID LARVAE

Theoretical models predict that phenotypic plasticity should evolve in response to changes in environmental heterogeneity. To test the hypothesis that historical changes in heterogeneous food resources are associated with the evolution of plasticity, I studied the expression of morphological plasticity of food collection structures in larvae of echinoid Echinoderm geminate species pairs found off the coasts of Panama. Closely related species of sea urchins in the genera *Diadema*, *Echinometra*, and *Eucidaris* formed when the Panamanian Isthmus raised 2.8-3.1 million years ago and created two different food level environments: variably high food levels due to strong, seasonal nutrient upwelling in the eastern Pacific versus constant low food levels due to little nutrient upwelling in the western Caribbean. In response to food limitation, larvae of several other echinoid species elongate a food collecting ciliated band by lengthening larval arms during early larval development. For this study, larvae from multiple full-sib pairings of each species were reared in one of two different replicated food environments (1 and 5 algal cells/microliter) for 10 days post fertilization. 3-D morphological measurements of individual arm and body lengths were made for over 3600 larvae. My prediction was that Pacific species larvae would express greater arm and ciliated band length plasticity than Caribbean species larvae, in response to heterogeneous environments, as found in the eastern Pacific. This study will contribute to our understanding of the effects of food level heterogeneity on the evolution of phenotypic plasticity and the degree to which plasticity varies among related taxa.

41.2

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FUNCTIONAL BASIS FOR INTERSEXUAL DIFFERENCES IN BITE FORCE IN THE LIZARD *ANOLIS CAROLINENSIS*

In many species of lizards, males attain greater body size and have larger heads than females of the same size. Often this dimorphism in head size is paralleled by a dimorphism in bite force. However, the underlying functional basis for the dimorphism in bite force remains unclear. Here, we test whether males are larger and have larger heads and bite forces than females for a given body size in a large sample of green anoles (*Anolis carolinensis*). Next, we test if overall head shape differs between the sexes of *A. carolinensis*, or if instead, specific aspects of skull shape can explain differences in bite force and jaw adductor muscle mass. Our results show that *A. carolinensis* is indeed dimorphic in body and head size and that males bite harder than females. Geometric morphometric analyses show distinct differences in skull shape between males and females, principally reflecting an enlargement of the jaw adductor muscle chamber in males. Jaw adductor muscle mass data confirm this result and show that males have larger jaw adductors (but not jaw openers) for a given body and head size. Thus, the observed dimorphism in bite force in *A. carolinensis* is not merely the result of an increase in head size, but involves distinct morphological changes in skull structure and the associated jaw adductor musculature.

23.4

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FORAGING AND WATER REQUIREMENT IN TERRESTRIAL COTTONMOUTH SNAKES

Cottonmouth snakes (*Agkistrodon piscivorus conanti*) inhabiting the Cedar Keys of Florida are terrestrial and dependent on condensation or rainfall for drinking water. Field studies indicate that snakes lose body water between rainfall events and are active at deficits up to 12 % of body mass. These snakes feed on marine fish that are dropped or regurgitated by nesting sea birds, which compounds the osmotic problem related to dehydration. During a prolonged drought when snakes were inactive, we found individuals in holes beneath ground with body water deficits averaging 16% of hydrated body mass. In the laboratory, we determined the critical water deficit at which snakes exhibited sluggish movement and flaccid skin on the posterior body, nearing death if the dehydration had continued. The mean critical deficit measured in 9 snakes was 33.8 ± 2.4 % of initially hydrated body mass. Snakes refused to eat fish at a mean water deficit of 22.9 ± 4 % of initial mass, but did so following drinking and recovery of water balance. Measurements of oxygen consumption suggest there is no significant depression of standard rates of metabolism during dehydration to critical water deficit. We conclude that during drought conditions both energy and water are conserved primarily by inactivity and seclusion below ground. However, inactivity separates snakes from food resources (fish carrion) that are ephemeral in these insular habitats. In the wild, snakes drink water from several sources including pools or wet surfaces on leaves, water from rainfall that collects on the head while it is held upright, and body surfaces that collect rainwater when a snake is coiled. Condensation appears to provide an additional sporadic source of fresh water.

58-2.2

MCCCLINTOCK, T.S., DERBY, C.D., ACHE, B.W.; mcclint@uky.edu. University of Kentucky, Georgia State University, University of Florida
PHYSIOLOGICAL GENOMICS OF LOBSTER OLFACTION

Several fundamental observations about olfaction were made first using lobsters, largely due to advantages that stem from their anatomy and a wealth of background knowledge. Investigating the molecular basis for the function of the lobster organ has also proved fruitful. Reasoning that gene products specific to, or enriched in, the olfactory organ will help identify its unique properties, we have used expression profiling strategies such as differential amplification by PCR to identify molecular markers of the olfactory sensory neurons, their auxiliary cells, secretory cells of the associated aesthetasc tegumental glands, and reactive epithelial cells critical for the remarkable ability of the organ to regenerate itself. More importantly, the identity of these markers make predictions about novel physiological processes such as glutamatergic input to the olfactory sensory neurons and the production of neuroactive biogenic amine hormones by the auxiliary cells that surround the inner dendrites of the olfactory sensory neurons. More recently, bioinformatics of ESTs from more than 5,500 cDNAs confirms the preponderance of neurons in the mature zone of the olfactory organ. To allow testing of hypotheses about which mRNAs are most closely associated with the olfactory organ and its functions, we generated a cDNA microarray. As a first test of the array, we compared olfactory organ with dactyl, a taste organ, and identified 115 gene products that discriminate between these two chemosensory tissues. We are now in position to use mRNA abundance to investigate the olfactory organ as a molecular system by observing the responses of thousands of mRNAs to experimental manipulation.

53.1

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ARE WE MISSING A MINERALOCORTICOID IN FISH? EFFECT OF CORTICOIDS AND RECEPTOR INHIBITORS ON SALINITY TOLERANCE OF ATLANTIC SALMON

It has long been held that cortisol, acting through a single receptor, carries out both glucocorticoid and mineralocorticoid actions in teleost fish. The recent finding that fish possess a gene with high sequence similarity to the mammalian mineralocorticoid receptor, and has similar binding characteristics in the expressed protein, suggests the possibility that a hormone other than cortisol carries out some mineralocorticoid functions in fish. To test for this possibility, we examined the ability of cortisol, 11-deoxycorticosterone (DOC) and aldosterone to increase salinity tolerance in Atlantic salmon. In vivo cortisol treatment for 6 to 12 days that resulted in increased physiological levels of cortisol also resulted in increased gill Na,K-ATPase (NKA) activity and improved salinity tolerance (lower plasma chloride after a 24 h seawater challenge). Administration of DOC and aldosterone did not increase either NKA activity or salinity tolerance. RU486 effectively blocked the ability of cortisol to increase NKA activity and salinity tolerance, but spironolactone was only partially effective. Neither RU486 or spironolactone blocked changes in gill NKA activity or plasma chloride 6 days after transfer of fish from fresh water to seawater or from seawater to fresh water. The results provide support that cortisol, and not DOC or aldosterone, regulates salinity tolerance in salmonids, but do not rule out a role for DOC or aldosterone in other osmoregulatory or physiological actions.

65.4

MCCOY, K.A., AMICK, A.M.; kristam@zoo.ufl.edu. University of Florida
METAMORPHOSIS AND REPRODUCTIVE GROWTH AND DEVELOPMENT

Plasticity in size at and time to metamorphosis in amphibians is well documented. For example, tadpoles developing in temporary ponds will quickly metamorphose in response to decreasing water levels resulting in small size at metamorphosis. Thus, strong tradeoffs exist between development and growth when environmental conditions are poor. Amphibians that metamorphose at larger sizes survive better and reproduce at younger ages than animals that metamorphose at smaller sizes. One possible reason for this relationship is that small metamorphs may not be in adequate condition to reproduce in their first year. We hypothesize that individuals in less hospitable environments may also allocate more energy to development of structures necessary for metamorphosis than toward growth or development of gonads (because they are not immediately required). Few, if any, studies have explicitly tested whether the growth or developmental rates of amphibian gonads can vary, or whether reproductive structures exhibit tradeoffs in growth and development similar to those commonly found in the soma during metamorphosis. We test the hypotheses that 1) animals fed a restricted diet would have less developed or smaller gonads at metamorphosis than those fed large quantities (exhibit plasticity), and 2) in food restricted environments tradeoffs exist where gonad development is maximized while gonad growth is sacrificed. These types of tradeoffs could occur when reproductive organs exhibit plasticity in their growth and development. The ability to differentially allocate energy between somatic and reproductive growth and development could be an important mechanism used to maximize the development of structures required for metamorphosis (i.e. limbs, or carnivore gut) when environmental conditions are unfavorable. Furthermore, tradeoffs within the gonad during development could influence fecundity and life time fitness.

66.10

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PREDATOR INDUCED PHENOTYPIC PLASTICITY: INFLUENCE OF PREY SIZE, DENSITY, AND EXPERIENCE

Adaptive phenotypic plasticity in response to predators has been documented for many organisms. However, most studies have only examined the phenotypic responses of organisms of a single size class and density in the presence of a particular (usually large) predator. Few studies examine predator induced phenotypic changes and their effects on predator-prey interactions for prey and predators of different sizes or at different densities. For example, prey may exhibit different phenotypic responses to a gape limited predator than to a non-gape limited predator. In this study, we determined how induced defenses, prey density, prey size and predator size interact to affect prey survival. Specifically we exposed treefrog (*Hyla squirrella*) tadpoles to small gape limited (*Pachydiplax longipennis*) and large non-gape limited (*Tramea carolina*) invertebrate predators to examine how the functional responses of these predators change with prey size and the preys prior experience with each predator. We found that both size and prior predator experience affect tadpole survival. Tadpoles survived better when exposed to a familiar predator than when introduced to a novel predator. We also report on a suite of predator specific phenotypic responses including a variety of behavioral metrics, growth rates, developmental rates, and morphology. In addition, we report on among individual variation in phenotypic responses. Integrating multiple phenotypic responses (both among individuals and populations) and assays of performance (i.e. survival) in the presence of different predators is critical for understanding how phenotypic plasticity influences the outcome of species interactions.

S2-2.2

MCCUNE, A.R.; arm2@cornell.edu. Cornell University
INSIGHTS FROM NATURAL VARIATION IN DANIO RERIO

Most genetic screens of zebrafish have relied on artificial mutagenesis to generate genetic mutants. However, by inbreeding individuals from wild populations of zebrafish, many natural mutations can be recovered. Study of such natural mutants can be just as informative about genetic and developmental mechanisms as study of artificially generated mutants, but, in addition, study of natural mutants will characterize the actual variation available to the evolutionary process in nature. Study of genetic and phenotypic variation and the mechanistic relations between them is at least as important to understanding the evolutionary process as is the study of natural selection. Comparative (interspecific) study of phenotypes and genotypes reveals evolutionary change that has already occurred; intraspecific study of variation informs us about evolutionary potentials. To the extent that intraspecific variation in living populations parallels interspecific variation, study of intraspecific variation can also suggest genetic/developmental mechanisms that have produced evolutionary change. In a screen of natural mutants in wild-caught zebrafish, we discovered that the phenotype of most recessive lethals exposed by inbreeding included loss or non-inflation of the gas bladder. While this trait has been little studied and the individuals lacking gas bladders have been discarded in other screens, loss of the gas bladder is fascinating from an evolutionary perspective. Among teleosts, the dominant group of living fishes, loss of the gas bladder has occurred many times independently. For the widely convergent loss of gas bladders seen among teleost fishes, both adaptive evolution and developmental bias are implicated. It remains an evolutionary developmental mystery why the loss of the gas bladder can occur so easily and in so many genetically different ways.

52.2

MCELROY, E.J., REILLY, S.M.; em386403@ohiou.edu. Ohio University
THE EVOLUTIONARY RELATIONSHIP BETWEEN FORAGING MODE AND LOCOMOTOR FUNCTIONAL MORPHOLOGY IN LIZARDS

Foraging mode has impacted many aspects of lizard biology. Locomotion is centrally important to foraging and therefore the morphology and function of the locomotor system should be a strong correlate of foraging mode phenotype. Here we present an initial assessment of the evolutionary patterns between foraging mode and locomotor functional morphology among lizards. We collected whole-body mechanics, simple kinematics, and limb-segmental morphology data on 14 species spanning a phylogenetically diverse 10 families. A racetrack with incorporated force plate was synchronized with high-speed video to quantify whole-body mechanics and simple kinematics. We used multivariate and phylogenetic analyses to understand the relationships between morphology, function, and the evolution of foraging behavior. Sit-and-wait foragers appear to have locomotor functions that facilitate fast locomotion (i.e. trotting gait, running mechanics, low percent recovery). Wider foragers appear to retain the same locomotor functions at fast velocities. However, the evolution of wider foraging strategies is characterized by a reduction in moving velocity to facilitate prey recognition and capture. At slower velocities, wider foragers add a new suite of locomotor functions (i.e. lateral sequence diagonal couplets gait, walking mechanics, and substantial energy recover). These novel locomotor functions are thought to facilitate sustained slow velocity locomotion via improved energy economy and stabilization. Phylogenetically sit-and-wait foraging is hypothesized to be the ancestral phenotype with wider foraging behaviors evolving multiple independent times. Our data support this idea: each time wider foraging evolves, the locomotor system evolves in a unique and independent way.

19.5

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MOLECULAR EVIDENCE FOR HYBRIDIZATION BETWEEN TWO ALCYONIID SOFT CORAL SPECIES WITH CONTRASTING LIFE HISTORIES

Numerous studies have now documented both the potential for and past occurrence of interspecific hybridization events in scleractinian corals and other anthozoan cnidarians. The evolutionary importance of hybridization in these groups is still widely debated, however, with views ranging from hybrids as evolutionary dead-ends (immortal mules) to the idea that coral populations represent syngameons within which species boundaries are fluid over space and time. We report evidence for a probable case of hybridization between two soft coral species giving rise to a hybrid lineage that reproduces predominantly by asexual propagation. *Alcyonium digitatum* is a gonochoric, broadcast spawning soft coral that is common throughout the NE Atlantic. In the Irish Sea it is sympatric with an undescribed sibling species, *A. sp. A*, that is hermaphroditic and broods its larvae. In two mixed-species populations we have found numerous individuals that resemble *A. sp. A* morphologically but are white, a color typically found only in *A. digitatum*. Data from allozymes, RAPD fingerprints and rDNA ITS polymorphisms support the hypothesis that these white individuals are F1 hybrids between *A. digitatum* and *A. sp. A*. Moreover, all white individuals shared the same multi-locus genotype, suggesting that the hybrid genotype is being maintained in the population by asexual reproduction. To our knowledge, this is the first report of hybridization between species with such different modes of reproduction.

19.4

MCGOVERN, T.M.; tmcgovern@disl.org. Dauphin Island Sea Labs
SELF-FERTILIZATION IN THE BROODING SEA ANEMONE
AULACTINIA INCUBANS

Despite the potentially negative consequences (inbreeding depression) associated with inbreeding, self-fertilization in simultaneous hermaphrodites offers various genetic and ecological advantages. Several conditions, including mating between relatives in kin-structured groups, may serve to reduce inbreeding depression and lead to a greater tolerance of self-fertilization. Selfing is therefore predicted to be more common in groups with limited dispersal including brooding marine invertebrates. In this study, I use patterns of Amplified Fragment Length Polymorphism (AFLPs) to examine in situ selfing rates in the brooding anemone *Aulactinia incubans* collected from 5 populations in the San Juan Islands of Washington state. Results demonstrate that selfing is highly variable between families, even within a population. Population averages suggest that selfing may be more common in some populations than others, though differences are not significant. Selfing rates are correlated (though not significantly) with a crude metric of kin structure, but more work is needed to determine if local selfing rates reflect variability in kin structure (and possibly tolerance for selfing) on a microgeographic scale or whether variability in selfing results from other factors such as differences in the availability of self and/or outcross sperm.

14.8

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THE MECHANICAL DESIGN OF THE SUPERFICIAL NEURO-MAST IN ZEBRAFISH

The superficial neuromast (SN) is a microscopic structure within the lateral line system of fish that is used to detect water flow. The morphology and material properties of these delicate structures are not well understood and it is consequently unclear how they filter mechanical information. Therefore, the present study examined the shape and stiffness of SNs in larval zebrafish (*Danio rerio*). SNs are composed of a transparent gelatinous matrix that is anchored to the body by 4 to 16 hair cells. Using a novel visualization technique, we found that the cupula maintains a tapered cylindrical shape along its height and that this tapering increases above the tips of the kinocilia of the hair cells. This finger-shaped structure has a diameter of approximately 10 μm at its base, extends about 40 μm from the surface of the body. We calculated the flexural stiffness of SNs from measurements of its deflection when pushed (1 to 100 pN) with a carbon fiber. We found the Young's modulus to range between 1 and 100 Pa, which is a range comparable to that of mucus. The elongated geometry and flexible material of the SN suggest that the SN bends when exposed to the hydrodynamic loads typical of swimming fish. Therefore, the beam dynamics of the SN play an important role in the detection of hydrodynamic signals by the lateral line system.

S9-2.2

MCNAB, B.K.; bkm@zoo.ufl.edu. University Florida, Gainesville
THE ENERGETICS OF REPRODUCTION IN ENDOTHERMS AND ITS IMPLICATIONS FOR THEIR CONSERVATION

The energy expenditure of endotherms, through its impact on rate of reproduction, affects their ability to withstand competition and to tolerate environmental disturbances. For example, the extinction-prone attributes of living terrestrial mammals in China increase with body size and with a decrease in fecundity (Liu and Li 2005). The fecundity of endotherms is influenced both by body size and the level of energy expenditure: small mammals have higher fecundities than larger species and species with low rates of metabolism have lower fecundities than species of the same mass with high rates of metabolism (McNab 1980). Litter size and the rate of post-natal growth increase and gestation period decreases with an increase in basal rate of metabolism. As a consequence, species that are noteworthy for high population fluctuations, such as arvicolid rodents and hares, have high rates of metabolism and reproduction. Furthermore, species with high rates of metabolism appear to out-compete species with low rates when using resources that permit consumers to have high rates of metabolism, which explains why eutherian carnivores out-competed marsupial carnivores, none of which have high basal rates, a replacement that occurred in the Neotropics and Australia (McNab 2005). The dependence of reproduction on basal rate may contribute to our understanding of why there was such a huge die-off of birds endemic to oceanic islands upon the invasion by humans: island endemics appear to be characterized by low rates of metabolism (McNab 2002). The few ungulates that survived from the Pleistocene megafauna in North America have high rates of metabolism, whereas no species with presumptively low rates of metabolism and reproduction, such as ground-sloths and glyptodonts, survived.

49.2

MCWHORTER, T.J., HARTMAN BAKKEN, B., KARASOV, W.H., MARTINEZ DEL RIO, C.; tjmcwhorter@wisc.edu. University of Wisconsin-Madison, University of Wyoming
HUMMINGBIRDS FUEL HIGH METABOLISM WITH BOTH PARACELLULAR AND CARRIER-MEDIATED INTESTINAL GLUCOSE ABSORPTION

Twenty years ago, the highest active glucose transport rate and lowest passive glucose permeability in vertebrates were reported in Rufous and Anna's hummingbirds (*Selasphorus rufus*, *Calypte anna*). These first measurements of intestinal nutrient absorption in nectarivores provided an unprecedented physiological foundation for understanding the foraging ecology of these exceptional creatures. They showed that physiological processes are determinants of feeding behavior. The conclusion that active, mediated transport accounts for essentially all glucose absorption in hummingbirds influenced two decades of subsequent research on the digestive physiology and nutritional ecology of nectarivores. We report new findings demonstrating that the passive permeability of hummingbird intestines to glucose is much higher than previously reported. The fractional absorption of L-glucose (not actively transported in birds) measured using standard pharmacokinetic techniques ($59 \pm 5\%$), an in vivo test of passive permeability, demonstrates that not all sugar uptake is carrier-mediated in hummingbirds. Even while possessing the highest active glucose transport rates measured in vertebrates, hummingbirds must rely partially on passive non-mediated intestinal nutrient absorption to meet their high mass-specific metabolic demands. Supported by NSF grants IBN-0216709 to WHK and IBN-0110416 to CMR.

67.2

MEDEIROS, M.J.; m_j_m@berkeley.edu. University of California, Berkeley
REPEATED EVOLUTION OF FLIGHTLESSNESS IN CAVE-DWELLING MOTHS.

Most insects are capable of sustained flight, but flightlessness has evolved independently several times in insects, especially in females. Certain habitats, such as caves, seem to be correlated with an increased likelihood of evolving flightlessness. However, it is largely unknown whether related lineages that have invaded a habitat associated with flightlessness will repeatedly converge upon a non-flighted state. I investigated the number of times that flightlessness has independently evolved in females of the genus *Schrankia*, a group of Noctuid moths that has invaded caves on the Big Island of Hawaii. Cave-adapted females of this genus are flightless while the males are capable of flight. I collected *Schrankia* moths from a total of five caves on three separate volcanoes and repeatedly dropped individuals in an experimental chamber recording whether they were capable of sustained flight or immediately fell to the bottom of the chamber. I also collected related surface species and sequenced 527bp of the mitochondrial gene COI for a total of 20 species. The results from the drop-test and the COI gene tree showed that this group of moths has invaded caves at least twice and that flightlessness has evolved in each of these cave-dwelling lineages. Based on the age of the caves in which *Schrankia* occur, flightlessness has evolved in as little as 0.1my. These results suggest that at least in some groups, lineages that invade similar habitats may rapidly converge on similar traits.

34.3

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THE SCALING OF CONSTRICTION STRENGTH SNAKES

Constriction was probably one of the key innovations that enabled snakes to subdue relatively large prey animals. It involves a snake placing its body around a prey animal and squeezing, which restrains the prey from escaping and defending itself, and typically kills it quickly. Published observations and experiments on constriction have indicated that it is strong enough to kill prey by suffocation, circulatory arrest, or spinal fracture. However, constriction strength has been measured in very few species of snakes, and thus far only in relatively small individuals. In this study, we derived quantitative predictions about the constriction pressures exerted on prey by snakes of different sizes, and we tested these predictions by measuring constriction pressure in 11 species of snakes. We predicted that constriction pressures range from 38-250 kPa in snakes 1-30 cm in diameter, and we measured pressures of 5-175 kPa in snakes 0.85-12.5 cm in diameter. Constriction pressure varied significantly with snake diameter (in the region that forms the coil) and number of loops in the coil. The measured pressures are high enough to kill many kinds of prey animals by circulatory arrest or spinal fracture, both of which are faster than killing prey by suffocation alone, and therefore are safer for the constrictor. These results help explain how constriction has been a key mechanism in the feeding biology and evolution of snakes.

34.4

MEHTA, R.; rsmeha@ucdavis.edu. University of California, Davis
EVOLUTION OF CONSTRICTION MOTOR PATTERNS IN SNAKES

Behavior results from the integration of morphology, physiology, and biomechanics. Any one of these levels can be examined to gain insight into patterns driving behavioral variation across species. My research takes an integrative approach to test hypotheses concerning the evolution of constriction behavior in snakes. Constriction, a prey immobilization technique, varies among lineages, but detailed kinematics of the constriction posture along with variation in the underlying epaxial muscle activity pattern remains unknown. I studied kinematics and epaxial motor patterns during constriction in a basal snake *Loxocemus bicolor* and two intermediate snakes *Python molurus* and *Boa constrictor* to test whether the variation in constriction kinematics corresponds with underlying epaxial muscle activity patterns. *L. bicolor* used lateral bends to coil around mice. Lateral bending corresponded with unilateral muscle activity patterns. *Python molurus* and *Boa constrictor* used mainly ventral bends to loop around prey. Ventral bending corresponded with bilateral muscle activity. In all three lineages the epaxial muscles fired during coil formation and intermittently during sustained constriction. Viewed in the context of a snake phylogeny these results suggest that the ancestral pattern of constriction involved lateral bending and that pythons and boas use a derived posture. The evolution of different motor patterns may have been driven by prey size.

33.5

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LATITUDINAL VARIATION IN STRESS RESPONSIVENESS IN ANURANS: PRELIMINARY EVIDENCE

Tropical vertebrates generally exhibit a different suite of life history traits from their temperate counterparts. Additionally, there are physiological traits that also exhibit a latitudinal cline. For example, tropical birds and mammals have long been documented as having lower basal metabolic rates than temperate counterparts. Basal testosterone (T) and corticosterone (B) levels have also been shown to be lower in tropical vs. temperate birds. It is hypothesized that, due to the high parasite load in the tropics, tropical species would maintain low levels of hormones that might act in an immunosuppressive manner (e.g. B and T). In a survey of existing metabolic literature on anurans, we found that tropical frogs and toads (38 species, 8 families) also exhibit significantly lower standard metabolic rates than temperate species (47 species, 7 families). To test whether tropical anurans also exhibited low baseline and maximal levels of B, we collected blood immediately upon capture from a variety of species from temperate (US) and tropical (Costa Rica) areas. We then challenged these animals with saline or 100 ng/g BWT of ACTH (adrenocorticotropin hormone), which should stimulate a maximum B response, and collected blood 4 hours after injection. We found that the tropical anurans sampled (n=5 species, 4 families) displayed significantly lower baseline B levels than their temperate counterparts (5 species, 3 families). None of the tropical species sampled exhibited a significant increase in B in response to the ACTH challenge (n=4 species, 3 families), while the same challenge significantly increased B in all the temperate species. Although these data are preliminary, they support the hypothesis that tropical animals would display depressed levels of a potentially immunosuppressive steroid hormone.

9.5

MENZE, M.A., HAND, S.C.; menze@lsu.edu. Louisiana State University
LESSONS IN APOPTOSIS FROM AN INVERTEBRATE EXTREMOPHILE, EMBRYOS OF *ARTEMIA FRANCISCANA*

Embryos of the brine shrimp *A. franciscana* are exceptional in their ability to tolerate anoxia and desiccation at room temperature for years and to maintain viability under conditions that are known in mammalian species to open the mitochondrial permeability transition pore (mPTP), which leads to apoptotic and necrotic cell death. We demonstrated previously that brine shrimp mitochondria lack a calcium-induced permeability transition, cytochrome c (cyt-*c*) is not released via the mPTP, and profound calcium storage capacity likely contributes to the prolonged anoxia tolerance in this species. However, translocation of cyt-*c* by pro-apoptotic Bcl-2 family members such as Bax and Bak remains a possibility, although involvement of cyt-*c* in apoptotic signaling of invertebrates is controversial. Low levels of caspase 9- and caspase 3-like activities can be detected in cell free extracts of *A. franciscana* embryos when measured by cleavage of the fluorogenic substrates Z-DEVD-R110 and Z-LEHD-R110. However, in contrast to our experiments with human hepatoma cells (C3A), adding cyt-*c* to extracts from *A. franciscana* embryos fails to elevate caspase-3 like activity. Furthermore, caspase-9 like activity is highly depressed by KCl. A comparison of kinetic models shows that the best fit is achieved by assuming competitive inhibition between KCl and Z-LEHD-R110. By applying this model, an apparent inhibition constant of about $K_i = 6$ mM is obtained. Thus at a physiological KCl concentration of about 145 mM, a strong inhibition of caspase-9 would occur. Multiple mechanisms are in place that apparently reduce the probability of apoptosis under conditions of energy limitation in this invertebrate. [NIH grant 1-RO1-GM071345-01].

41.3

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THE EFFECT OF FOOD PROPERTIES ON INTRAORAL TRANSPORT KINEMATICS IN LIZARDS

Numerous studies have examined the nature and magnitude of feeding movements during intraoral transport in lizards, but few have quantitatively accounted for the effects of food properties (i.e., mass, hardness, mobility) on the use of the feeding system to process and move prey through the oral cavity. Documenting the kinematic response to altered food properties is important for testing mechanical hypotheses related to feeding, understanding functional or behavioral adaptations for consumption of specific food types, and evaluating the hypothesis that there is a positive relationship between an organism's dietary breadth and modulatory ability during feeding. In this study, intraoral transport kinematics were evaluated in four species of lizards while food properties were strictly controlled. Food mass, hardness, and mobility were independently varied, and the kinematics of the jaws were compared to evaluate the effect of these properties on the use of the feeding system. There was a definite relationship between food properties and the kinematics of the feeding apparatus, although the strength of this relationship varied for different food properties. In general, altering food mass had a more significant effect on intraoral transport kinematics than did changes in food hardness or mobility. For example, increased food mass was associated with changes in kinematics related to both the overall feeding trial and transport stage (e.g., increased trial duration, increased number of gape cycles) as well as with gape cycle kinematics (e.g., increased slow open phase duration). These results indicate that differences in food properties are a major cause of variation in lizard intraoral transport kinematics that should be quantitatively considered in future studies of feeding in lizards.

17.4

MEYER, C.P., KOHN, A.J.; kohn@u.washington.edu. University of Washington, University of Florida
DISPARATE EVOLUTIONARY TRAJECTORIES IN TWO HYPERDIVERSE TROPICAL MARINE GASTROPOD GENERA

In tropical seas, coral reef-associated environments support maximal benthic biodiversity. Hyperdiverse genera (containing 100->500 species) in several animal groups contribute importantly to the high species diversity. We are investigating whether the evolutionary trajectories of modern hyperdiverse taxa share common patterns of radiation in time and space, based on phylogenetic comparisons. We compare and contrast evolutionary diversification patterns in two such genera of prosobranch gastropod molluscs, *Cypraea*, in the Order Neotaenioglossa, and *Conus*, in the Order Neogastropoda. *Conus* is considered to have about twice as many extant species as *Cypraea*, and both genera are presently most diverse in the Indo-West Pacific region, but regional patterns of diversity differ strikingly. Both genera have good fossil records that begin contemporaneously about 55 mybp. However, the *Cypraea* fossil record is preceded by an earlier Mesozoic stem lineage of the Family Cypraeidae, while the ancestor of *Conus* is uncertain but most likely in the family Turridae. Gene sequence data are available for most *Cypraea* species and for about one-third of *Conus* species. They support a prior morphology-based phylogeny of *Cypraea*, while for *Conus* they have generated the first species-level phylogenetic hypothesis. Using data from traditional taxonomic treatments, comparative morphology, paleontology, and molecular genetics, we explore the geography, tempo and mode of their radiations, and whether independent clades attained hyperdiversity by similar evolutionary processes.

35.3

MEYERS, J.J., IRSCHICK, D., VANHOOYDONCK, B.*, HERREL, A.; jjm@dana.ucc.nau.edu. Tulane University, University of Antwerp
DIVERGENT ROLES FOR DIFFERENT COLOR SIGNALS IN A POLYGYNOUS LIZARD: A TEST OF THE REINFORCEMENT AND DUAL-FUNCTION HYPOTHESES

Males of many animal species possess multiple colorful and elaborate sexual signals which are used to signal rival males, females, and potential predators. In this study, we examine the link between multiple sexual signals (throat patch and belly patch) and performance capacity in order to test whether multiple signals reinforce (reinforcement hypothesis) or provide differing (dual function hypothesis) information on male quality. We examined these relationships in the lizard *Urosaurus ornatus*, which exhibits a well-studied set of male morphs that are distinguished by dewlap coloration. Prior studies have shown that aggressive behavior in some morphs (blue dewlapped) make them dominant over other morphs, yet differences in morph performance capacity have not been documented. To examine the relationship between male morphs, sexual signals, and performance we captured 167 male *U. ornatus* at a riparian site in Northern Arizona. We measured external morphology, bite performance, maximum sprint speed and the area of the sexual signals (dewlap and belly patch). We found that the five morphs at our site (yellow-blue, orange-blue, blue, yellow, orange) did not differ in morphology, bite force or maximum sprint speed. Additionally, neither bite force nor maximum sprint speed was correlated with the area of the dewlap. Thus, dewlaps are not indicative of performance capacity but may relay information about behavioral traits such as aggression. In contrast to dewlaps, belly patch size was a significant indicator of increased bite force ability. Our findings support the dual function hypothesis of sexual signals in *U. ornatus*, and reveals that during display behaviors multiple aspects of male performance and/or quality are being communicated.

15.6

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MATERNAL EFFECTS SHIFT THE ALLOMETRY OF A SEXUALLY SELECTED TRAIT IN THE HELICONIA BUG

Sexually selected traits are especially sensitive to environmental conditions. Mothers frequently influence the environment experienced by their offspring, and, thus, play an important role in the expression of sexually selected traits. The neotropical heliconia bug, *Leptoscelis tricolor*, oviposits on several species of heliconia plants. Results suggest that maternal choice of host plant is important for sexually selected trait size in offspring and shifts the scaling relationship of these traits with body size. Such environmentally-induced changes in the relative size of sexually selected traits to body size might be important to our understanding of the use of these traits as indicators of individual quality. Additionally, these results suggest exciting new directions for research on the ecological and evolutionary importance of maternal effects for sexually selected traits.

61.5

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GEOMETRIC MORPHOMETRIC ANALYSIS OF SHELL KINESIS
IN EMYDINE TURTLES

To provide context for an ongoing study of plastron (lower shell) shape variation in the emydine turtle *Emys marmorata*, we examined plastron shape in six other emydine species (*E. blandingii*, *E. orbicularis*, *Clemmys guttata*, *Glyptemys insculpta*, *G. mublenbergii*, *Terrapene ornata*) using geometric morphometrics. We digitized 19 landmarks on photographs of over 1000 specimens, and all landmarks but two were junctions between or extremal points on the sulci separating the plastral scutes. Multivariate regression showed that plastron shape is highly correlated with size in the seven species, although differences exist in how each species shape is affected by size. Pairwise comparisons using MANOVA and canonical variates analyses showed that the seven species have significantly different plastron shapes that can be differentiated with great certainty. Principal components analysis shows that a major component of shape variation among the specimens is related to the presence or absence of a kinetic plastron. *Terrapene ornata* clearly occupies a different region of morphospace than the included taxa with akinetic plastra. However, the kinetic taxa *E. blandingii* and *E. orbicularis* are intermediate in shape between the *T. ornata* specimens and the other taxa. *Emys blandingii* and *E. orbicularis* are more closely related to one of the akinetic taxa (*E. marmorata*) than they are to *T. ornata*, and share the former species semi-aquatic to aquatic lifestyle. Therefore, our results suggest that phylogeny and/or habitat also are important determinants of plastron shape. Additional insight into the relationships between phylogeny, habitat, kinesis, and plastron shape may be gained by the future inclusion of additional *Terrapene* species, which all possess kinetic plastra, but display lifestyles ranging from aquatic to terrestrial.

43.1

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CLAP AND PEEL IN INSECT FLIGHT WITH FLEXIBLE AND
BRISTLED WINGS

In 'typical' insect flight, lift is produced when a leading edge vortex (LEV) is formed and remains attached to the wing and a trailing edge vortex (TEV) is formed and separates from the wing during each stroke. The wings translate along a horizontal plane, and lift forces are produced by this 'vortical asymmetry' (attached LEV and shed TEV). For Reynolds numbers below 40, numerical simulations and physical models have shown that lift is reduced when the TEV is no longer shed from the wing, resulting in vortical 'near-symmetry.' Previous work also suggests that very small insects have developed a trick known as 'clap and fling' to augment lift production. The clap and fling motion introduces vortical asymmetry when the wings fling apart at the beginning of the downstroke. Although the lift enhancing effects of clap and fling increase at lower Reynolds numbers, the drag forces increase considerably, and the ratios of lift to drag forces decrease. Moreover, the relative forces required to clap the wings together and to fling the wings apart grow drastically as the Reynolds number is lowered. A porous media version of the immersed boundary method was used to simulate flexible, bristled wings performing a clap and fling. The results of this study suggest that wing flexibility can lower the drag forces required to fling the wings apart while actually increasing the lift force generated. Augmented lift can be attributed to a flexible peel motion rather than a rigid fling motion. Furthermore, wing ciliation (fringing) might also reduce the drag force required to fling the wings. During fling, the wing surface might act like a permeable 'rake,' but during translation the wing surface might act like a solid plate.

65.3

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INVOLVEMENT OF THE CORTICOTROPIN-RELEASING FACTOR (CRF) TYPE 2 RECEPTOR IN CRF-INDUCED THYROTROPIN RELEASE FROM THE TADPOLE PITUITARY

Corticotropin-releasing factor (CRF) is considered to be the primary hypophysiotropin for corticotropin (ACTH) in vertebrates. In non-mammalian species, CRF induces thyroid-stimulating hormone (TSH) secretion by the anterior pituitary. Recent studies in the chicken (*Gallus gallus*) showed that CRF-induced TSH secretion is mediated by the type 2 CRF receptor (CRF₂). Based on these results we hypothesized that TSH secretion by the tadpole pituitary is mediated by the CRF₂ receptor. Using dispersed bullfrog (*Rana catesbeiana*) anterior pituitary cells in culture we found that CRF, *Xenopus laevis* urocortin 1 (xUCN1), mouse urocortin 2 (mUCN2), *X. laevis* urocortin 3 (xUCN3), and sauvagine (SVG) all markedly enhanced the release of immunoassayable TSH. The CRF-induced TSH release was completely blocked by the general CRF receptor antagonist astressin and by the CRF₂ receptor specific antagonist antisauvagine-30; whereas, the type 1 CRF receptor specific antagonist antalarmin had no effect on TSH release. Injection of CRF, xUCN1, xUCN3 or SVG into Gosner stage 36-37 tadpoles of *Spea hammondi* caused rapid (by 2 hr) and robust increases in plasma thyroxine concentrations. We also found that chronic injection of the CRF₂ specific agonists xUCN3, mUCN2 or mUCN3 accelerated metamorphosis of *Spea hammondi* as measured by hind limb growth and development. Taken together, our data support the hypothesis that TSH release (and therefore tadpole metamorphosis) is mediated by the CRF₂ receptor (supported by NSF grant IBN 0235401 to R.J.D.)

56.3

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RAPID DISCHARGE OF MUSHROOM SPORES

Ballistospore discharge is a feature of 30,000 species of mushrooms, basidiomycete yeasts, and pathogenic rusts and smuts. A few seconds prior to the launch of a ballistospore, a drop of fluid (called Bullers drop) develops at its base. This drop enlarges until it approaches the volume of the spore and then, instantaneously, spore and drop are catapulted into the air. Until recently, the launch process eluded analysis, but spore motion has now been captured using ultra high speed video microscopy. Images obtained at camera speeds of up to 100,000 frames per second demonstrate that spore discharge occurs when the expanding Bullers drop merges with fluid on the spore surface. Although this coalescence may result from the directed collapse of Bullers drop onto the spore, it may also involve the movement of the spore toward the drop. The release of surface tension at coalescence provides the energy and directional momentum to propel the spore and drop into the air. Analyses show that the initial acceleration of the spore exceeds 10,000 g.

47.5

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FROM LARGE TO SMALL TO LARGE: PHYLOGENETIC SYSTEMATICS OF ROTULID SAND DOLLARS AND THEIR TINY RELATIVES

Recent phylogenies of the Clypeasteroidea (sand dollars and allies) recognize 3 clades (Clypeasterina, Laganina, Scutellina). The Laganina contains the strangest of all clypeasteroids. Although many laganine taxa are of medium size (approximately 50 mm test length), the group contains the smallest of all echinoids (less than 10 mm) as well as large forms (more than 90 mm). Phylogenetics indicate that a monophyletic Laganina includes the bizarre rotulids (alien catchers mitts). *Fibulariella*, miniaturized laganines once included in the Fibulariidae, is actually more closely related to rotulids than fibulariids. Previous analyses showed two separate derivations of tiny, almost spherical clypeasteroids lacking internal buttresses: 1) fibulariids, and 2) *Fibulariella*. Our present results undermine this interpretation through cladistic studies of plate architecture and other features of certain key taxa, especially *Fibulariella* and its Eocene relatives in *Thagastea* and *Tarphypygus*. Placement of all these taxa in time and space suggests that there are unexpected changes in diversity and morphology during the evolution of the group. Most significantly, there is a previously unrecognized clade of tiny *Fibulariella*-like laganines in the Eocene neotropics that seems to link the fibulariids with *Fibulariella*. Our phylogeny suggests that *Fibulariella* does not represent a second miniaturization event in the laganines. *Fibulariella* appears to have originated from an ancestor in common with fibulariids. The surprising result is that the rotulids derived their large, flattened sand dollar-like morphology in parallel with true sand dollars. Odd features of rotulids can be traced to a heterochronic bottleneck that occurred when miniaturized ancestors adapted to coasts along west Africa that lacked sand dollars.

53.3

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OVARIAN RESPONSE TO GONADOTROPIN IN ALLIGATOR NEONATES

Ovarian folliculogenesis is a fundamental process of ovarian development modulated by many factors including estrogens, gonadotropins, and transforming growth factor ligands. These molecular mechanisms regulating primordial follicle formation are poorly understood across vertebrates, especially in non-mammalian species. The American alligator first forms follicles during the months following hatching. We have investigated the ovarian endocrine milieu of the neonatal, non-follicular alligator ovary. We have observed that the neonatal, non-follicular ovary responds to exogenous gonadotropin, with significant induction of gene expression for follicle stimulating hormone receptor, estrogen receptors, follistatin, and inhibin/activin subunits. Elevated gene expression occurred concomitantly with an increase in plasma estradiol and inhibin alpha concentrations. We will present further results examining the effects of varying treatment dosages and durations on these molecular and endocrine responses. Additionally, we have investigated differences in these responses between alligators hatched from clutches collected at a highly polluted Florida lake versus those collected at a lake in a relatively uncontaminated wildlife reserve. These results will be presented in light of the ability of early life exposures to detrimentally influence ovarian function and development.

68.3

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DETECTION OF POLARIZED LIGHT BY LOGGERHEAD SEA TURTLES (*CARETTA CARETTA*)

Sea turtles have been hypothesized to use polarized light to find their way during migration and to detect food, but efforts to demonstrate such an ability experimentally have yielded inconclusive results. To investigate possible polarization vision in juvenile loggerhead sea turtles (*Caretta caretta*), we adapted a conditioned choice discrimination method commonly used in animal psychology. The turtles were required to discriminate between two polarized light stimuli, presented side by side in a fully automated experimental arena. The two light stimuli were identical except the plane of polarization was aligned horizontally for one and vertically for the other. The turtles learned to press one of two available paddles depending on whether the stimulus arrangement was horizontal-vertical or vertical-horizontal. Correct choices were rewarded with food and incorrect choices resulted in a time penalty. The turtles clearly discriminated between the two polarized light stimuli. Control experiments, during which the pattern of polarization was disrupted or the plane of polarization was identical for the two stimuli, demonstrated that the polarization patterns, rather than some other element of the stimuli, were the basis for the discrimination. These results provide the first direct evidence that sea turtles can perceive polarized light making loggerhead sea turtles only the second reptile and the first aquatic species to have been shown to do so. This result has important implications for the feeding ecology of sea turtles as perception of polarized light may enable detection of translucent prey. It may also play a role during migration allowing sea turtles to exploit patterns of skylight polarization as an orientation cue.

13.5

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MECHANICS AND KINEMATICS OF 90° TURNS IN GOATS

The ability of animals to maneuver in their environment plays an important role in their survival, especially during predator-prey interactions. For terrestrial animals, vigorous changes of direction, linear accelerations and running turns can be almost daily requirements, but these behaviors have not been thoroughly studied because of their complexity and inherent experimental challenges. Recent work has begun to address turning mechanics in humans, cockroaches and mice. Our goal was to describe the kinematics and mechanics of 90° turns in an upright, cursorial quadruped, the goat, in order to determine how these animals initiate and execute running turns. We hypothesized differential roles for the forelimbs and hindlimbs: goats would initiate turns using their forelimbs to brake, provide lateral impulse and rotate the body axis. The hindlimbs would be used mainly to accelerate the COM linearly in the new heading. We used an infrared motion capture system to record goats running on an indoor track with a 90° turn. Four force plates were placed in the trackway to record GRFs in three dimensions from all four limbs. We calculated linear speed, body orientation relative to approach, shoulder and pelvic girdle orientations, lean angle of the body, parasagittal angle of the limbs, and heading of the COM, and examined these in relation to stance and swing phases. Preliminary analysis shows that goats generate body lean into the turn by repositioning their forelimbs towards the outside of the turn during swing phase, while using both forelimbs and hindlimbs to accelerate the COM in the new heading. Though difficult to study in an experimental setting, non-steady behaviors put a distinct set of demands on the musculoskeletal system, and therefore are important for understanding the relationship between locomotor demands and an animals morphology.

S6-1.2B

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“WHAT IS A NEURON FROM A GENOMIC STANDPOINT?
POLYPHYLETIC ORIGIN AND NATURAL SYSTEM OF NEURONS

I will present and review comparative and novel genomic data related to the diversity of nervous systems and gene expression profiling from various neurons. I will also discuss two evolutionary scenarios of the origin of neuronal organization in evolution: Monophyly vs Polygenesis of neurons. The Polyphyletic Origin (i.e. independent origin of neurons in different lineages) is a more favorable scenario that can explain the enormous diversity of neuronal types and nervous systems across phyla. Emerging data related to the large scale expression profiling at the level of individual identified neurons gene provide unique recourses for novel strategies in NeuroSystematics. Specifically, cladistic and clustering approaches can be employed to construct a natural system of neurons extending classical classification of neuronal subtypes beyond sensory, motor cells and interneurons.

47.3

MOTT, T.; tamimott@berkeley.edu. University of California, Berkeley
MOLECULAR SYSTEMATICS OF BRAZILIAN AMPHISBAENIDS
(REPTILIA, SQUAMATA, AMPHISBAENIDAE)

Amphisbaenians, or worm lizards, are a monophyletic lineage of fossorial squamate reptiles that comprises ca.165 species distributed in Africa and South America primarily. The family Amphisbaenidae includes nearly 90% of all extant amphisbaenians: 17 genera and ca.150 species. Seven of these genera are endemic to South America; six occur in Brazil. The present study reports a comprehensive examination of the relationships of all six Brazilian genera of amphisbaenids using genetic data. In total, 25 species in six genera and four outgroups were sequenced. Nuclear and mitochondrial data were obtained; genes included were RAG-1, C-MOS, BDNF, 16S, and ND2, respectively. Phylogenetic relationships were inferred using Maximum Parsimony and Bayesian analyses. Results suggest that South American amphisbaenids represent a monophyletic lineage. However, within this lineage, *Leposternon* is the only genus recovered as a monophyletic entity using any of the genetic markers; the other genera display either paraphyletic or polyphyletic patterns, suggesting that Brazilian amphisbaenid taxonomy does not reflect phylogeny. I recommend 1) continuing to recognize *Leposternon*, and 2) adopting a metataxon designation for *Amphisbaena**, indicating this status with an asterisk. A better taxonomic accommodation awaits further study.

76.6

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SPHINGOLIPIDS IN THE STRATUM CORNEUM AND THEIR
RELATIONSHIP WITH CUTANEOUS WATER LOSS IN HOUSE
SPARROWS, *PASSER DOMESTICUS*, FROM ARID AND MESIC
ENVIRONMENTS

Lipids in the intercellular spaces in the vertebrate stratum corneum (SC), the outer layer of the epidermis, have been shown to be an important component in the formation and maintenance of the barrier to water vapor diffusion through the skin. Sphingolipids are one of the most important classes of lipids in the SC because they represent almost a half of the amount of the intercellular lipids. Their structural role in the SC is crucial to control of water loss through the skin. Two classes of sphingolipids have been found in the vertebrate SC, ceramides, characterized by a fatty acid bound to a sphingosine base, and cerebrosides, a ceramide with a hexose molecule ester-linked to the sphingosine. We measured cutaneous water loss (CWL) in two groups of House sparrows, *Passer domesticus*, one living in a desert environment, Taif, Saudi Arabia, and another living in a mesic environment, Ohio, USA. We found that CWL was lower in desert individuals. Thereafter, we analyzed the sphingolipids in the SC by reverse phase High Performance Liquid Chromatography (HPLC) and Atmospheric Pressure PhotoSpray™ Ionization (APPI) coupled with Mass Spectrometry (MS), a method that allowed us to identify and quantify each individual sphingolipid molecule in the SC. House sparrow populations showed qualitative and quantitative differences in their sphingolipid molecules. Moreover, desert sparrows had shorter carbon chains in the fatty acids of the sphingolipids, perhaps indicating a lower fluidity of the intercellular lipid structure, and exhibited less variability, both in the number of lipid classes and their quantities, than mesic birds.

S6-2.1

MURRAY, J.A.; james.murray@mac.com. University of Central Arkansas
ADVANCES IN THE NEURAL BASES OF ORIENTATION & NAVIGATION

The ability to locomote in one direction, and the ability to navigate toward a distant goal are related behaviors that are phylogenetically widespread. Orientation includes finding the source of a signal, or movement relative to directional cues. Such abilities may require little more than directionally-selective sensors coupled to turning mechanisms, so this behavior can be implemented by relatively-simple circuits. Navigation involves both the ability to detect direction, as well as a map-sense that provides position. Navigation is less-common and arguably requires greater brain computation than simple orientation, but may be present in arthropods as well as in vertebrates. Great progress has been made in exploring the biophysical and sensory bases for these behaviors, and in recent years the locations and the identity of the cellular transducers of the sensory stimuli (e.g. geomagnetic fields) have been narrowed in some taxa. The sea slug *Tritonia* orients its crawling to chemical, hydrodynamic, and geomagnetic cues. Its brain has ~7,000 relatively-large neurons that facilitate circuit analysis. Recent work has characterized both peripheral and central neural correlates of orientation signals, as well as the control of thrust and turning, and studies of their field behavior have suggested how these disparate orientation systems may be integrated. Direction-selective and position-responsive brain cells have been located in the brains of mammals and birds, and these cells may contribute to a cognitive map that can enable navigation. Navigation strategies inspired from organisms have been implemented in autonomous robots, and programming a strategy into a computer may be analogous to the evolutionary trade-offs between robustly simple neural circuits and more complex neural systems that are more physiologically expensive. The synergy between robotic models and physiology has advanced both fields.

S1.6

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THE DYNAMICS OF IMMUNOCOMPETENCE AND CLIMATE DRIVERS IN CORAL RESPONSE TO DISEASE

Coral reef ecosystems have sustained some of the most damaging effects of climate change. Despite demonstrated impacts and high mortality caused by temperature stress, little information exists on how variations in temperature, UV irradiation and nutrients due to coastal runoff affect the quality of coral immune responses and ability to fight infectious diseases. Using aspergillosis of sea fan corals as a model pathosystem, we are quantifying components of the immune responses of “*Gorgonia ventalina*”. Components of immunity include coral cellular responses such as production of a melanin barrier to isolate the fungus, amoebocyte aggregation, production of oxidative stress proteins and molecules and sclerite purpling and humoral defenses which include the biosynthesis of anti-fungal metabolites. Field sampling and experimental manipulations with the pathogen are the basis for describing coral responses to disease and relationship to environmental drivers. This ecological immunology approach to understanding the dynamics of coral disease and the effects of climate drivers on immune processes is instrumental in developing conservation and management standards for infectious diseases of corals.

12.3

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THE FLEXIBLE HALTERES OF THE CRANEFly *HOLORUSIA RUBIGINOSA*

Animal locomotion requires navigation. As such, animals have evolved a variety of navigational devices, which often take the form of inertial sensors. Because they move in three dimensions, flying insects have greater navigational problems than terrestrial animals. Halteres, shown in past studies of *Calliphora* to be inertial sensors, are an example of an inertial sensor that flying insects have evolved to cope with their navigational problems. Unlike the short, stubby halteres of *Calliphora*, crane flies such as *Holorusia rubiginosa* have elongated halteres with knob-like tips. Does the unique structure and mechanics of crane fly halteres affect the way in which they function? We performed several experiments to determine the function of crane fly halteres. These included ablating the halteres, close-up, high-speed video of a tethered fly's halteres, and finite element modeling. Crane fly halteres are visible with the naked eye; this let us do free-flight experiments in a flight chamber. We tested crane flies with and without halteres, and in some cases reattached the halteres to see if any flight would be regained. The free-flight experiments showed that crane flies can initiate, but not sustain, flight without halteres. Another set of experiments examined tethered crane flies with high-speed videography. We digitized points on each haltere to determine if bending occurred when the halteres reached the top and bottom of each stroke. The experiment showed that a significant amount of bending did occur. We also found that the halteres oscillate independent of the wings. Finite element modeling showed that, by changing the elasticity of the halteres, we could tune them to encode specific forces. Taken together, our results indicate that crane fly halteres may be flexible, tunable gyroscopes.

S8-2.4

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PROTEOMICS AND SIGNAL TRANSDUCTION IN THE CRUSTACEAN MOLTING GLAND

Molting in decapod crustaceans is controlled by the X-organ/sinus gland complex, a neurosecretory center in the eyestalks. The complex secretes a neuropeptide, molt-inhibiting hormone (MIH), that suppresses production of molting hormone (ecdysone), an ecdysteroid secreted by a pair of molting glands (Y-organs or YOs) located in the anterior of the body. Binding of MIH to a YO membrane receptor results in a cyclic nucleotide-dependent inhibition of ecdysteroidogenesis. Eyestalk ablation (ESA) induces a rapid increase of hemolymph ecdysteroid titers. Proteomics has become a powerful tool to identify proteins involved with specific physiological or disease states. We are using expression and cell-map proteomics to determine which proteins are involved in YO signaling, YOs from intact and ES-ablated land crabs (*Gecarcinus lateralis*) were analyzed by 2-D gel electrophoresis and mass spectrometry. ESA causes dramatic changes in the levels of proteins between 12 kDa and 27 kDa. These proteins were selected as putative candidates for molt-regulating factors from both silver and phosphoprotein-stained gels. Nitric oxide synthase (NOS) was identified by immunoblotting and peptide mass fingerprinting (PMF) using MALDI-TOF mass spectrometry as one of the proteins transiently phosphorylated in response to ESA. In addition, MIH interacting proteins were detected using immunoprecipitation with an anti-MIH antibody. These putative MIHBPs (MIH binding proteins) were observed only in intact YO and not in YOs from ES-ablated animals. This suggests that these proteins could be involved in the binding of MIH to its receptor in the YO membrane. We are currently characterizing the MIHBPs by PMF and internal peptide sequencing using ion-trap tandem mass spectrometry. Supported by NSF (IBN-0342982).

73.2

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SUBSTRATE INCREASES SUCTION FEEDING EFFECTIVENESS IN BAMBOO SHARKS

The effectiveness of suction feeding depends on the fluid flow pattern around the mouth and modulation of prey capture. Prior modeling and empirical findings have shown that significant fluid velocities are confined to a region within one mouth width (MW) from the mouth. Therefore the predator must be relatively close to the prey to ensure successful capture using suction. Most of those studies were conducted on bony fishes that feed in the water column. Bamboo sharks, *Chiloscyllium plagiosum*, live in benthic environments and are suction feeding specialists. They typically feed on the substrate, but they occasionally take prey from the water column as well. We predict that, due to conservation of momentum, the velocity field will change shape by decreasing in height and therefore increasing in width and length when feeding on the substrate. This will cause the boundary of the fluid field to lie further away from the mouth, thereby exceeding the theoretical prediction of a maximal one MW distant flow field. To test these predictions, we used high resolution DPIV to analyze the hydrodynamics of feeding from the substrate and water column. A vertical laser sheet was used to illuminate particles and visualize the fluid field. Bamboo sharks were fed squid at various heights from bottom. DPIV analysis showed that the boundary of the flow field can be increased up to 2.5 MW distances due to a passive substrate effect. This indicates that the substrate extends the distance that suction is effective and requires less accuracy than feeding in the water column using the same suction effort. The region of greatest fluid velocity was located slightly anterior to the mouth opening, indicating the presence of a bow wave. Such a wave is the consequence of equilibrium between backwards momentum of water flowing into the mouth and forward movement of the fish itself.

42.6

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YOLK ANDROGENS DIFFER INDEPENDENTLY OF MATERNAL ANDROGENS IN EASTERN BLUEBIRDS: AN EXPERIMENTAL STUDY

Avian females deposit variable amounts of androgen into the yolks of their eggs, a potentially adaptive mechanism for altering offspring quality. It is unclear, however, whether yolk androgen deposition represents a passive reflection of circulating plasma androgens in the female during follicular development or an active shuttling of androgens in response to a social or environmental cue. We stimulated breeding pairs of eastern bluebirds with an intruder presentation during ovarian follicular development. We then compared yolk steroid concentrations in the eggs of stimulated females with yolk steroid concentrations in the eggs of control females. Additionally, we took blood samples from subsets of stimulated and control females and compared hormone profiles of eggs with hormone profiles of female plasma, both independently of and in relation to our experimental design. Regardless of experimental treatment group, patterns of steroid concentrations differed between egg yolks and female plasma. In relation to our experiment, stimulated females deposited significantly more androgens into eggs than control females, suggesting that females increase yolk androgen deposition in response to aggressive encounters. Female plasma androgens, however, were significantly lower in stimulated females than in controls, the complete opposite of concurrently observed yolk patterns. We suggest that eastern bluebirds regulate hormone levels in an adaptive manner in response to environmental change by actively shuttling androgen into eggs. Eggs may act as a sink for the collection of androgens that are produced in response to aggressive encounters. Thus, yolk androgen deposition may be a protective mechanism against androgen-related disruptions of the female reproductive cycle.

60.3

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PATTERNS OF NEURAL EVOLUTION IN NUDIBRANCH MOLLUSCS: FUNCTIONAL DIVERGENCE OF HOMOLOGOUS NEURONS EMBEDDED IN A COMMON NEURAL NETWORK

We are examining the evolution of central pattern generators (CPGs) by comparing the functions of homologues of two identified neurons, Swim Interneuron 1 (Si1) and the Dorsal Swim Interneurons (DSIs), in nudibranch molluscs that exhibit a variety of locomotor behaviors. Si1 is a member of the swim CPG in *Melibe leonina*, which swims by flexing its body from side-to-side (i.e. laterally). Depolarization of Si1 can elicit a swim motor pattern (SMP) in a quiescent preparation. Surprisingly, the homologue of Si1 in another lateral-swimming species, *Dendronotus iris*, was not part of the swim CPG, although it was capable of eliciting an SMP. A similar partial divergence of function was observed with the DSIs and their homologues. The serotonergic DSIs are members of the swim CPG in *Tritonia diomedea*, which swims by alternately flexing its body in the dorsal and ventral directions. Depolarization of a DSI can elicit an SMP and the DSIs also excite crawling neurons. We have identified homologues of the DSIs in 7 species that do not exhibit dorsal-ventral swimming and have named these neurons Cerebral Serotonergic Posterior (CSP) cells. In contrast to the DSIs, which fire rhythmic bursts of action potentials during a *Tritonia* SMP, the CSPs in all 7 species were not rhythmically active. However, CSPs in the lateral-swimming *Melibe* could elicit an SMP and CSPs in two non-swimming species, *Tochuina tetraquetra* and *Triopha catalinae*, excited putative crawling neurons. Thus, homologous identified neurons can diverge significantly in certain functions while retaining other common functions. This suggests that these species share a common neural network that has been reconfigured repeatedly.

S3-2.1

NICHOLS, T.R.; trn@physio.emory.edu. Emory University, Atlanta
DIFFERING ROLES OF LENGTH AND FORCE FEEDBACK IN THE REGULATION OF MOTOR COORDINATION

The study of musculoskeletal biomechanics and muscle physiology is critical to understanding the manner in which neural mechanisms mediate coordinated movement. Substantial progress has been made in elucidating the roles of sensory feedback from muscle spindle receptors and Golgi tendon organs in motor coordination by investigating the interactions of neural and mechanical circuits in the feline motor system. At the level of the spinal cord, excitatory length feedback from the primary endings of muscle spindles is distributed primarily to the muscles containing the receptors and to muscles having synergistic mechanical actions and regulates the mechanical properties of these target muscles. This feedback is distributed to muscles that are undergoing similar mechanical changes to the muscle of origin. Force feedback at the spinal level is subdivided into at least two types. Force feedback can be excitatory, in which case it is distributed primarily autogenically as is the case for length feedback, or inhibitory, in which case it is distributed to muscles that cross different joints and different axes of rotation than the muscle containing the receptors. Excitatory force feedback is also context dependent, appearing during stepping or locomotion but not steady force generation. The response properties of tendon organs and the distribution of force feedback suggest that this feedback adjusts the magnitude of stiffness of the main muscle and of the endpoint of the limb, and also promotes interjoint coordination rather than compensating for nonlinearities in the individual muscles.

58.4

NISHIGUCHI, M.K., JONES, B.W.; nish@nmsu.edu. New Mexico State University
POPULATION DYNAMICS OF SEPIOLID SQUID-*VIBRIO* MUTUALISM FROM THE INDO-WEST PACIFIC

The sepiolid squid-*Vibrio* mutualism is an excellent system for examining mechanisms of cospeciation and host tracking patterns among a wide variety of symbiotic squid species. Currently, we are using genetic diversity and nested clade analyses to examine the variation between three allopatric *Euprymna* squid species: *Euprymna scolopes* (Hawaii), *E. hyllebergi* (Thailand), and *E. tasmanica* (Australia). Using the cytochrome *c* oxidase subunit I locus for host squid species, and the glyceraldehyde phosphate dehydrogenase (*gapA*) locus for *Vibrio* symbionts, we have determined the genetic relatedness of these partners in the Indo-west Pacific as well as the phylogeography and fixation indices between populations of both squids and symbionts. Patterns of host specificity are predominant among symbiont genotypes and their phylogeography, but there is also some evidence of strain variation and secondary colonization, which may preclude that squid populations are not the only driving force for selection of symbiont speciation.

S3-2.5

NISHIKAWA, K.C., LAPPIN, A.K., MONROY, J.A., PILARSKI, J.Q., PIEROTTI, D.J.; Kiisa.Nishikawa@nau.edu. Northern Arizona University
NEUROMECHANICS OF ELASTIC ENERGY STORAGE AND RECOVERY DURING BALLISTIC MOVEMENTS

The goal of our research is to understand the biomechanics and neural control of ballistic movements, using tongue projection in frogs as a model system. Ballistic tongue projection is an extremely rapid, goal-directed movement that requires the coordinated action of numerous muscles. We developed a forward-dynamic, multi-joint model to investigate mechanisms of inter-joint coordination. The model demonstrates that ballistic tongue projection is dynamically stable. Thus, active CNS control is constrained by the mechanics of the feeding apparatus. More than 90% of the force for tongue projection comes from the depressor mandibulae muscles via transfer of momentum from the lower jaw to the tongue. We used in situ force-lever experiments and an elastic recoil model of the depressor mandibulae muscles to investigate the roles of storage and recovery of elastic strain energy in powering ballistic tongue projection. The depressor mandibulae muscles are activated for up to 250 ms prior to movement. The force produced by the depressor mandibulae muscles prior to movement determines not only the displacement of extra-muscular connective tissues and the muscles themselves, but also the total stiffness of the jaw apparatus. In principle, the CNS could control ballistic tongue projection simply by specifying the force in the jaw depressors prior to movement and the timing of rapid unloading. The resulting movement of the lower jaw and tongue is determined by the load-dependent elastic properties of the feeding apparatus. Proprioceptive afferents control the recovery of elastic strain energy by modulating the activity of levator mandibulae muscles prior to mouth opening. Supported by NIH R25-GM56931 and NSF IBN-0240349.

53.2

NORBECK, L., KITTLSON, J., SHERIDAN, M.A.*; mark.sheridan@ndsu.edu. North Dakota State University, Fargo
NUTRITIONAL REGULATION OF THE SOMATOTROPIC AXIS OF RAINBOW TROUT (*ONCORHYNCHUS MYKISS*)

Previously, we isolated and characterized the mRNAs that encode for major elements of the somatotrophic axis of rainbow trout, including two forms of growth hormone receptor (GHR1 and GHR2), insulin-like growth factor-1 (IGF-1), and two forms of insulin-like growth factor-1 receptor (IGFR1A and IGFR1B). In this study, the regulation of the expression these somatotrophic axis components was studied in rainbow trout placed on varying nutritional regimes (fed continuously, fasted continuously, fasted then refed). Fish that fasted for 6 weeks displayed significantly reduced growth compared to their fed counterparts, while refeeding for 2 weeks following 4 weeks of fasting partially restored growth. The expression of hepatic GHR1 (48%), GHR2 (44%), and IGF-1 (85%) mRNAs decreased in fasted fish compared to fed fish. Fasting also reduced the mRNA levels of GHR 1 (47%), GHR2 (67%), IGF-1 (81%), IGFR1A (68%), and IGFR1B (65%) in gill. The expression of IGFR1A (75%) and IGFR1B (110%) increased in cardiac muscle of fasted fish, but levels of these mRNAs were unchanged in white muscle. These results indicate that nutritional state regulates the expression of somatotrophic axis components in a tissue-specific manner. (Support by NSF grant IOB 0444860)

29.2

NUSSEAR, K.E., INMAN, R.D., TRACY, C.R.; knussear@usgs.gov. USGS Western Ecological Research Center, University of Nevada Reno
APPLICATION OF MODELING ACTIVITY AND SAMPLING AVAILABILITY TOWARD IMPROVING MONITORING OF AN ELUSIVE SPECIES

The USFWS is currently assessing the densities of desert tortoise using data from transects and Distance Sampling to calculate population density. This approach requires weighting the data from transects by a measure of the proportion of animals that are unavailable to be sampled due to their unavailability to be sampled because they are sequestered in underground burrows or other underground shelters. Currently, the approach to quantify the proportion of animals available to be sampled is to measure the percent of a small sample of focal animals that are active outside of burrows. The proportion of animals active is typically averaged for the entire season, and also for several geographic regions. This approach to accounting for population-level animal behavior may be misleading for several reasons, including both the statistical and biological consequences of regional and temporal differences in activity patterns, and the statistical effects of the small sample sizes used to estimate activity. The activity of tortoises is generally high during the spring months, and declines steadily as the summer approaches, for example in 2004 there was a significant linear decline in activity from April to late June when transects were conducted. In addition the encounter rate on tortoise surveys declines throughout the season. Our analyses of the effect of time and space variance in availability of tortoises to be sampled, suggests that the accuracy of estimates of tortoise density is currently inadequate and can be improved by integration of more precise models of behavior.

S9-1.2

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LINKING PHYSIOLOGICAL EFFECTS ON ACTIVITY AND RESOURCE USE TO POPULATION LEVEL EFFECTS

Ecological theory has long recognized that population level phenomena like growth, reproduction, mortality, activity and spatial distribution depend on physiological processes. Those processes link the abiotic and resource environments to processes of interest to population, community, and conservation ecologists via the physiome of the organism. Physiological ecology has a long history of examining those linkages, either piecemeal or, when possible, in integrated form. Multiple levels of integration are interposed between the environment, its afforded opportunities for activity and resource acquisition, the physiological constraints on that activity and resource processing, the allocation of resources to life history/demographic processes, and the population level consequences of those processes. Thus, attention is usually focused on situations in which a single physiological process dominates or entirely precludes activity of an animal. We propose that adamantly mechanistic and data based models of individual energy budgets can help bridge multiple levels of integration to link environmental and physiological information to population level processes of interest to conservation biologists. We provide three examples where such models may be useful in terrestrial ectotherms. First, we consider the canyon lizard, *Sceloporus merriami*, and variation in growth rates at different elevations in west Texas. Second, we examine the hydric and thermal constraints on activity and survival of wood frogs, *Rana sylvatica*, in Missouri. Finally, we ask what effects water and temperature might have on desert tortoises, *Gopherus agassizii*, in the Mojave desert. In each case, we argue that models not only suggest constraints on the animals ecology, but also identify variables that need further consideration.

42.4

O'NEAL, D.M., PAVLIS, K., KETTERSON, E.D.; daoneal@indiana.edu. Indiana University, Bloomington, University of Guelph

THE EFFECTS OF EXPERIMENTALLY ELEVATED TESTOSTERONE ON PARENTAL CARE IN FEMALE DARK-EYED JUNCOS

Experimental elevation of plasma testosterone (T) in male dark-eyed juncos (*Junco hyemalis*) has been shown to decrease male parental care, but results in an overall fitness increased due to increased mating success. Potential benefits associated with higher levels of T in males may, however, be offset by deleterious effects in females. In an earlier study we reported that T does not suppress female parental behavior when females are incubating. In this study, we asked whether T interferes with female parental care when females are caring for nestlings. In particular we asked whether T affects nestling feeding or nestling defense. T levels in females were experimentally elevated to their spring maximum using subcutaneous implants. We measured female behavior in the field when young were six days old by videotaping feeding behavior at the nest and by quantifying responses to a mounted predator placed near the nest. T-implanted females showed a significant reduction in the number of nestlings fed per hour and in overall provisioning rate as compared to controls. T-implanted females also exhibited less nest defense than control females, and their nests were more likely to be lost to predators. The reduction in parental behavior due to elevated T indicates that both sexes are sensitive to suppression of parental behavior by T. Our results also suggest that the negative fitness consequences from reduced female parental care may act to constrain the evolution of higher levels of T in male juncos.

44.2

O'REILLY, J.C., INFANTE, C.R., FENOLIO, D.B., DEBAN, S.M.; oreilly@bio.miami.edu. University of Miami, Coral Gables, Harvard University, University of South Florida, Tampa
PREY CAPTURE IN MACROPHAGOUS TADPOLES

Generalized tadpoles (e.g., *Rana*) filter very small food items from the water column or from a suspension generated by scrapping with keratinized jaw sheaths. The upper and lower jaws are protracted simultaneously, and the lower jaw depressors power upper jaw protrusion via a suite of tendons. Regardless of dietary content, food enters the oral cavity in suspension and is filtered at the branchial arches before being swallowed. We examined the prey capture mechanism of larval *Theلودerma*, *Hymenochirus* and *Lepidobatrachus*; three independently evolved macrophagous tadpoles. *Theلودerma*, like generalized tadpoles, possess well-developed keratinized jaw sheaths and protract the upper jaw during mouth opening. They are facultatively macrophagous and readily feed on both mosquito larvae and tubificid worms. *Theلودerma* use both jaw prehension and suction feeding to capture prey items, which they ingest rapidly using hydraulic transport. *Hymenochirus* lacks keratinized mouthparts, is obligatorily macrophagous and only utilizes suction feeding. During prey capture, lower jaw depression powers the extension of its tube-shaped mouth. *Lepidobatrachus* is also obligatorily macrophagous and capable of eating very large prey relative to its own body size. Unlike *Theلودerma* and *Hymenochirus*, *Lepidobatrachus* displays no jaw protraction and prey is generally consumed with a combination of ram and suction feeding. All three species clearly target and attack individual prey items with explosive, episodic feeding behavior in contrast to the rhythmic grazing seen during feeding in most tadpoles.

9.1

OLSON, C.R., VLECK, C.M., VLECK, D.; cro@iastate.edu. Iowa State University, Ames

TEMPERATURE AND METABOLIC RATE: EMBRYONIC BIRDS DEPART FROM AN ARRHENIUS RELATIONSHIP

Temperature has a direct effect on metabolism and growth. This effect is of particular importance to organisms that naturally experience a range of body temperatures induced by environmental or behavioral changes. We report the instantaneous metabolic response of house wren (*Troglodytes aedon*) embryos to episodes of periodic cooling. House wren eggs regularly cool when the incubating adult leaves the nest to forage. Eggs at various stages of development were collected from wren nests and brought to the laboratory. A miniature thermocouple was inserted through the allantoic membrane and placed next to the embryo. Eggs were then cooled and rewarmed over a range of 37.5-15°C while we simultaneously measured instantaneous metabolism and egg temperature. Metabolic rate increased with embryo size and with embryo temperature. Under the Arrhenius model, the natural logarithm of metabolism plotted against the inverse of absolute temperature should yield a linear relationship whose slope is determined, in part, by the underlying physiology and biochemistry of the organism. For house wren embryos, metabolic rates show non-Arrhenius behavior over a biologically relevant range of temperatures. As eggs cool, embryo metabolic rate drops faster than the Arrhenius model predicts. Departure from an Arrhenius relationship across a range of biologically relevant temperatures may occur when different biochemical reaction rates and/or transport functions become uncoordinated. Such metabolic imbalances may account for the observations that wren embryos grow more efficiently at constant temperature than at variable temperatures. A differential growth efficiency should impose selection on incubating adults to maintain incubation temperatures within a narrow range.

36.1

OPHIR, A.G., PHELPS, S.M., WOLFE, J.O.; aophir@ufl.edu. University of Florida, University of Memphis
SELECTION FOR SOCIAL BUT NOT GENETIC MONOGAMY IN THE PRAIRIE VOLE

Perhaps best known for work relating to the study of mechanisms of pair bond formation, the prairie vole (*Microtus ochrogaster*) has emerged as a poster child of monogamous behavior in both popular press and scientific report. The extent to which these mechanisms have been studied, paired with the detailed description of their natural history, positions prairie voles as prime models for investigating how mechanisms underlying monogamous behavior operate under natural conditions. We ran 8 replicates in semi-natural enclosures, using 6 male and 6 female prairie voles per enclosure. We radiotracked subjects to assess association, and assigned paternity to pregnant females using 4 microsatellite loci. We characterized the mating system by comparing in-pair (IPF) and extra-pair (EPF) fertilizations. We found that subjects were neither genetically monogamous nor fully promiscuous ($N_s=27$; both $ps<.05$), and therefore conclude that prairie voles are socially monogamous. We investigated the strength of selection on social and genetic monogamy by comparing the number of offspring produced by paired or single animals and by IPFs or EPFs. Paired males and females had higher fitness than single subjects ($N_{male}=46$, $N_{female}=39$; both $ps<.02$), however subjects that engaged in IPFs or EPFs had comparable fitness success ($N_{male}=24$, $N_{female}=26$; both $ps>.10$). These results support the hypothesis that selection favors social but not genetic monogamy. Because our experimental design focused on fitness effects of fertilization rates, but not parental care or pup defense, we suggest a primary value of pairing emerges from mate-guarding. Prairie voles, which have become a popular species for studies of monogamy and pair bond formation, may serve as a good model for the evolution of mechanisms of love but not fidelity.

50.5

OTT, B.D., SECOR, S.M.; ott009@bama.ua.edu. University of Alabama
POSTPRANDIAL UPREGULATION OF INTESTINAL MORPHOLOGY AND FUNCTION IN *PYTHON*

Infrequently feeding snakes such as boas, pythons, and rattlesnakes have demonstrated that their digestive tract severely downregulates during periods of fasting and rapidly upregulates after the ingestion of a meal. While fasting, small intestinal mass decreases and nutrient transport rates decline as an energy saving mechanism for these snakes. In order to reveal any evolutionary trends associated with these physiological traits in the genus *Python*, we examined postprandial changes in nutrient transport, intestinal mass, and enterocyte size of the blood python (*P. brongersmai*), ball python (*P. regius*), reticulated python (*P. reticulatus*), northern African python (*P. sebae*), and Burmese python fed rat meals equaling 25% of their body mass. In response to the 25% size meal, transport rates of the amino acids L-leucine and L-proline increased on average 1-, 5-, 3-, 5-, and 3-fold for *P. brongersmai*, *P. molurus*, *P. regius*, *P. reticulatus*, and *P. sebae*, respectively. D-Glucose transport rates experienced 27-, 8-, 23-, 14-, and 16-fold increases, respectively. On average, small intestinal mass of all five species increased by 100% above the fasted mass. Nutrient uptake capacity, a product of uptake rate and intestinal mass, increased on average 8-fold for L-leucine, 6-fold for L-proline, and 33-fold for D-glucose for all five species. Enterocyte volume of the small intestine increased with feeding by 30%, 50%, and 50% for *P. molurus*, *P. reticulatus*, and *P. sebae*, respectively, concurrently with a 5-fold increase in microvillus length. With a similar response of the small intestine to fasting and feeding, it appears that these five species utilize the ability to widely regulate intestinal performance to cope with extended periods of fasting.

8.10

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MOLECULAR PHYLOGEOGRAPHY AND REPRODUCTIVION OF THE POECILOGONOUS POLYCHAETES “*BOCCARDIA PROBOSCIDEA*” AND “*B. WELLINGTONENSIS*” (POLYCHAETA: SPIONIDAE): TWO WORMS AND TWO HEMISPHERES

Poecilogony is the ability to alternate between multiple developmental modes. Although rare, poecilognous species are useful models to study reproductive tradeoffs without the complications of historical interspecific differences. The goal of this study was first to construct a molecular phylogeny of several populations of two poecilognous species, “*Boccardia proboscidea*” and “*Boccardia wellingtonensis*”, from the west coast of North and South America respectively, to provide an evolutionary framework in which to examine variation in reproductive traits along latitudinal gradients. Secondly, a comparison of reproductive strategies between these species was made. The phylogenetic analysis based on two genes, 16S and Cyt B, showed that the two species diverged by 6%. Both species have several distinctive haplotypes in their populations, but within each species there was no geographic relation of these differences suggesting that they are due to phenotypic plasticity. The two species produce capsules that contain nurse eggs, and two types of larvae; however, differences were found in capsule dynamics, number of nurse egg, and number and type of embryos produced in the two species which could potentially result in sibling conflict due to cannibalisms and competition for nurse eggs. The role of maternal brooding behavior in these two systems is discussed based on preliminary data. This study constitutes a first step in building an evolutionary framework for comparing (1) intracapsular dynamics and sibling conflict, (2) maternal brooding behavior, and (3) population demographics data, in two sibling poecilognous species in both hemispheres.

73.3

PACE, C.M., GIBB, A.C.; Cinnamon.Pace@nau.edu. Northern Arizona University
FEEDING KINEMATICS OF THE PIKE KILLIFISH, *BELONESOX BELIZANUS*, A PREDOMINANTLY PISCIVOROUS POECILIID

The pike killifish, *Belonesox belizanus*, is the largest member of the Poeciliinae and the only species in this subfamily that is predominantly piscivorous. It shares morphological traits such as an elongate fusiform body, large jaws, and posteriorly placed fins with other piscivorous fishes such as needlefish and barracuda. This represents a deviation from the typical morphology and behavior of the members of the subfamily Poeciliinae, most of which are omnivorous. Therefore, we asked the question does *Belonesox* share key kinematic parameters with its closest relatives or is it functionally similar to other piscivores? We hypothesized that feeding mechanics in *Belonesox* are similar to those seen in other piscivores, but shared ancestry with poeciliids may generate novel aspects of feeding behavior. To test our hypothesis, feeding sequences from juvenile *Belonesox* were captured in lateral and ventral views with digital video at 500 frames/second. X, Y, and Z coordinates were collected from these images using a custom digitizing program. We predicted that *Belonesox* would share functional characteristics with other piscivores such as ram feeding, a large gape and rapid jaw movements. We found that *Belonesox* is a ram feeder, while other poeciliids are suction feeders that prey on invertebrates (i.e., *Gambusia affinis*) or grazers that scrape food from the substrate (e.g., *Poecilia sphenops*). In addition, maximum gape in *Belonesox* is 49% of head length, which is similar to maximum gape in the barracuda (46% of head length). Finally, the feeding behavior of *Belonesox* is much more rapid than that seen in other poeciliids of a similar size. Thus, our preliminary analysis suggests that *Belonesox* feeding behavior is more similar to other piscivores than to other poeciliids.

62.6

PADIAN, K., DIAL, K.P.; kpadian@berkeley.edu. University of California, Berkeley, University of Montana, Missoula
WAS THERE A “FOUR-WINGED” TRANSITIONAL STAGE BETWEEN DINOSAURS AND BIRDS?

The recent discovery of long leg feathers on the first known bird, the Jurassic *Archaeopteryx*, a related small non-avian Cretaceous theropod, *Microraptor*, and a basal Cretaceous enantiornithine bird has fueled speculation that the leg feathers were used in a four-winged gliding stage antecedent to the evolution of powered flight in birds. Proponents argue that the asymmetry of *Microraptor* feathers shows that they were used in flight, and that its claws show that it was arboreal. This scenario has already been adopted uncritically in some quarters, both professional and popular. However, it has not yet been adequately documented or tested. Arboreality is a moot issue because most small tetrapods can climb trees and other heights, and claw geometry alone does not dictate arboreal or cursorial habits. Feather asymmetry or symmetry should be treated with caution when interpreting flying ability. Asymmetrical, curved feathers do not confer flight: they resist torsion and reduce drag; the long leg feathers on raptors are not used to gain lift. Moreover, forelimbs that bear only symmetrical feathers, as in developing ground birds, confer substantial and functional aerodynamic force. Reconstructions of an all-out 4-winged gliding stage appear plausible but require a distension of the hip joint that is difficult to justify anatomically. An assessment of the center and distribution of mass, the configuration and area of the airfoil, and of estimated gliding performance is needed to test claims of gliding ability. On the other hand, a simpler alternative model would allow long leg feathers to help slow the descent of a small animal leaping from a height, whether or not the descent was also slowed by stalling oscillations of the feathered forelimbs. There is as yet no evidence that long leg feathers played any role in the evolution of powered flight.

52.4

PAPASTAMATIOU, Y.P., LOWE, C.G., HOLLAND, K.N.; yannis@hawaii.edu. University of Hawaii at Manoa, California State University Long Beach

VARIATIONS IN THE RESPONSE OF GASTRIC ACID SECRETION DURING PERIODS OF FASTING BETWEEN SHARK SPECIES

Elasmobranchs are the earliest known vertebrates to have developed an acid secreting stomach and also exhibit a variety of foraging modes. Inter-specific differences in the response of acid secretion during periods of fasting are thought to exist amongst elasmobranchs, although the causative factors behind these differences are unknown. We have measured gastric pH continuously, using autonomous pH data-loggers, in free sw!

imming leopard (*Triakis semifasciata*), nurse (*Ginglymostoma cirratum*), and blacktip reef sharks (*Carcharhinus melanopterus*) and found that leopard and blacktip reef sharks continuously secrete gastric acid, while nurse sharks periodically cease acid secretion while fasting. Measurements of acid secretion rates, pepsin levels and a mathematical model of gastric pH changes, suggest that maintaining a continuously acidic stomach may decrease digestion time of a subsequent meal by 5-7 hours in leopard sharks. We hypothesize that frequently feeding shark continuously secrete gastric acid as it provides antiseptic conditions, while reducing digestion time of a subsequent meal. Infrequently feeding sharks periodically shut down acid secretion as an energy conserving mechanisms while fasting.

S2-2.7

PARICHY, D.M.; dparichy@u.washington.edu. University of Washington
EVOLUTIONARY GENETICS OF DANIO PIGMENT PATTERN DEVELOPMENT

The diverse pigment patterns of *Danio* fishes provide an outstanding opportunity to dissect the changes in developmental genetic mechanisms underlying evolutionary transformations of adult form. Whereas zebrafish exhibit horizontal stripes, closely related danios have different numbers of stripes, uniform patterns, vertical bars and other arrangements of neural crest-derived pigment cells. Here, I review recent evidence suggesting key roles for stem cells and cell-cell interactions in producing these various pigment patterns among species.

30.2

PARNES, S., RAVIV, S., ELDOR, R., SINGER, A., KEASAR, C., SAGI, A.; parnes@bgu.ac.il. Ben-Gurion University of the Negev, Israel
THE VITELLOGENIN OF THE PENAEID SHRIMP *LITOPENAEUS VANNAMEI* AND A BIOINFORMATIC ANALYSIS OF DECAPOD VITELLOGENIN DEDUCED AMINO ACID SEQUENCES

Vitellogenin (Vg) is the precursor for egg yolk protein, which stores most of the energy and building blocks for the future embryos in most oviparous organisms. In crustaceans it is synthesized mainly in the hepatopancreas and the ovary and transported to the oocyte through the hemolymph. In addition to *L. vannamei* Vg cDNA that was sequenced in our laboratory, there are now at least eight complete deduced amino acid (aa) sequences of decapod Vg available from the GenBank which are compared in this study. The ORF of decapod Vg is among the largest known (~8 kb), encoding an average of 2576±20 aa which is 4-6 times larger than the average eukaryote protein. The level of aa identities between *L. vannamei* Vg and other decapods is between 40 to nearly 90 %. Theoretical fragmentation of these Vg sequences yielded a long middle segment (approx. 1250 aa) that seems to have an evolution rate which is about 35% faster than its two flanking segments. The first of the latter segments contains a relatively well conserved Lipoprotein N-terminal Domain and an apolipoprotein region. The third segment contains a less conserved von Willebrand factor type D domain that still has to be assigned with a function. There is at least one conserved PC putative cleavage site consensus motif, which was indeed shown to be cleaved in several species. *L. vannamei* and other penaeid shrimps are outstanding in that they lack almost entirely N-linked glycosylation sites while crayfish, crab and caridean prawns have more than 10 such putative sites. An interesting outcome is that decapod Vg phylogenetic trees closely match other morphological and molecular trees, indicating the suitability of this protein for evolutionary studies.

11.1

PARRA, L.G., HYDE, M.L.; lgparra1@go.wtamu.edu. West Texas A&M University, Canyon
CHARACTERIZATION OF BIPEDAL LOCOMOTION WHILE FEEDING IN KANGAROO RATS IN THE NATURAL HABITAT

Kangaroo rats of the species *Dipodomys ordii* were filmed in their natural habitat at Alibates Quarry, Texas using an infrared camera. A 100 cm x 50cm x 50cm frame was built with bicycle reflectors set at 10 cm intervals on the backbone of the frame to allow accurate measurement of distances traveled on the infrared film. The rats were enticed into the frame by placing seeds on either side of the frame. Linear displacement, speeds and accelerations of the toe, ankle, knee, body, and center of gravity were all measured. Angles of projection, jump heights, stride times, and stride lengths were compared to data collected from other studies, which used natural substrates that were made to mimic the caliche substrate in their native habitat. The average velocity of the rats studied in the laboratory was 2.00 m/sec when moving over a bare platform (hard metal surface) and thick foam, 0.022 m/sec on thin foam, and 0.275 m/sec in their natural habitat. The average angle of projection varied from 83- 86° on bear metal and foam substrates in the laboratory. Locomotion on natural substrates filmed in the laboratory had similar measurements to those filmed in their natural habitat (53- 59°, 60°, respectively). Jump height ranged from 1.5- 2.9 cm on natural substrates in the laboratory, 7.8 cm on a bare platform, 8.8 cm on thick foam, 10.5 cm on thin foam, and 2.2 cm in their natural habitat. The difference between the laboratory results and the natural habitat results might be due to motivation. The qualities of the natural habitats may also largely influence locomotor parameters in bipedal kangaroo rats. The study was partially funded by West Texas A&M University and the Ronald E. McNair post-baccalaureate achievement program.

34.9

PATEK, S.N., BAIJO, J., SUMMERS, A.; patek@berkeley.edu. University of California, Berkeley, University of California, Irvine SPRINGS, LINKAGES AND LATCHES: A MECHANICAL MODEL OF THE MANTIS SHRIMPS RAPTORIAL APPENDAGE

Mantis shrimp (Stomatopoda) use a remarkable spring-loaded click mechanism in their raptorial appendages to rapidly capture and process prey. In some mantis shrimp species, the raptorial appendage is specialized for spearing evasive prey, whereas in other species the limb is specialized for smashing hard-shelled prey. Here we propose and test a linkage model that predicts the speed and force outputs within a smasher species, the peacock mantis shrimp *Odontodactylus scyllarus*, based on kinematic and morphometric analyses across multiple individuals. The model focuses on a sliding joint which delivers stored elastic strain energy to the rotation of the striking limb and amplifies the angular rotation of the limb by a factor of two. Using mechanical tests, the elastic energy storage of an exoskeletal saddle-shaped structure in the meral segment was measured. We found that the flexion of this saddle-shaped spring only stores a fraction of the elastic strain energy necessary for the strike, and therefore a second additional region of cuticular elastic energy storage in the meral segment is proposed. Through the use of 3-D CT scans, we dynamically visualized the movable elements and relative mineralization of specific structures. The results of this study provide a model of a mechanically integrated and highly potent prey capture system. With this model, we can begin to examine the morphological variation underlying the fascinating diversity of prey capture strategies across stomatopod species.

S4.2

PEARSON, G.A., SERRAO, E.A.; gpearson@ualg.pt. Universidade do Algarve REVISITING SYNCHRONOUS SPAWNING IN SEaweEDS IS IT JUST ABOUT SEX?

External fertilization is common in the marine environment. However, in the intertidal zone the prevailing hydrodynamic conditions may reduce the effectiveness of external fertilization as a reproductive strategy by dilution of the gametes. Furoid algae overcome this problem by synchronizing gamete release to occur during periods of low water motion. We review our current understanding of the mechanisms controlling gamete release, which include inorganic carbon sensing (water motion proxy), as well as light quality photoreception (a putative depth sensor). The importance of synchronous gamete release in natural populations is predicted to vary with mating system; i.e., highly important for obligate outcrossing species, and less so for self-compatible species. However, long-term data sets for gamete release in natural populations of dioecious and hermaphroditic cogeners (*Fucus vesiculosus* and *F. spiralis*) indicate that patterns of release and levels of synchrony are very similar, independent of mating system (obligate outcrossing and largely selfing, respectively). The occurrence of synchronous gamete release in species with high rates of self-fertilization may indicate that fertilization success is not the only selection pressure operating on the trait. Specifically, synchronous release and fertilization under calm conditions may be equally important in reducing dispersal (and therefore zygote wastage) in intertidal organisms with restricted vertical distributions.

72.5

PEATIE, A.M., CORDER, A.B., FULL, R.J.; apeattie@berkeley.edu. University of California, Berkeley EFFECT OF MORPHOLOGICAL VARIATION ON SINGLE SETA FORCE IN GECKOS

Studies on *Gekko gekko* (the Tokay) have detailed the morphology of their subdigital adhesive hairs or setae as well as their function. The Tokay is fast becoming a model species for setal adhesion. Yet, setal morphology varies greatly across the gekkonids. To test the effect of this variation on adhesion, we measured single-seta force in two species with different setal morphology. *Thecadactylus rapicauda* setae are shorter, wider and have about 3–4 times as many branched tips or spatulae than typical Tokay setae, whereas *Ptyodactylus hasselquistii* setae are longer and have a similar number of spatulae to the Tokay. We measured normal and shear forces at velocities ranging from 0.15–1.5 mm/s using a silicon surface attached to a wire functioning as a cantilever force gauge. A threshold normal preload was required to engage each seta, but increasing preload further did not increase shear force. Velocity did not affect shear force. The average *Thecadactylus* shear force was 2.5 times greater than the Tokay, and 2.2 times greater than *Ptyodactylus*. Detachment angle in *Thecadactylus* averaged 39.9°, *Ptyodactylus* 44.1°, both greater than reported for the Tokay (30.6°). The van der Waals hypothesis of gecko adhesion predicts that an increased number of spatulae should lead to the increased shear force seen in *Thecadactylus*. Further comparative data will be required to determine the effect of setal length and width on shear force. Research groups currently modeling gecko setae mathematically, as well as physically by fabrication, should consider the effect of morphological variation on performance. Future evolutionary analyses will assist in the identification of key functional parameters amongst the diversity of setae in nature.

8.8

PERNET, B.; bpernet@csulb.edu. California State University, Long Beach FEEDING BY LARVAE OF TWO DIFFERENT DEVELOPMENTAL MODES IN THE ANnelID *STREBLOSPIO BENEDICTI*

Females of the spionid polychaete *Streblospio benedicti* produce either small eggs that develop into planktotrophic larvae, or large eggs that reportedly develop into nonfeeding, lecithotrophic larvae. This apparent polymorphism is potentially useful for testing hypotheses on the ecology and evolution of maternal investment and larval development, but critical basic information on the morphology and functional biology of both types of larvae are lacking. Here I report on the nutritional biology of larvae of *S. benedicti*. Immediately after release from the maternal brood pouch, both types of larvae were able to use opposed bands of cilia to capture suspended food particles and transport them to the mouth. This particle capture mechanism has not previously been reported from spionids. In laboratory cultures, both planktotrophic and lecithotrophic larvae regularly ingested captured particles. Laboratory experiments showed that lecithotrophic larvae reared with suspended food grew more rapidly than did sibling larvae reared without food, indicating that these larvae can also digest and assimilate ingested food. Larvae of *S. benedicti* that develop from large eggs are best regarded as facultative planktotrophs rather than obligately nonfeeding lecithotrophs, a result that has important consequences for the interpretation of comparative studies of the ecology and evolution of maternal investment and larval form in *Streblospio*.

21.5

PETERS, K.J., AMSLER, C.D., MCCLINTOCK, J.B., BAKER, B.J.; kpeters@uab.edu. University of Alabama at Birmingham, University of South Florida

PALATABILITY AND CHEMICAL DEFENSES OF ANTARCTIC PENINSULA SPONGES

One of the major benthic taxa in terms of biomass along the western side of the Antarctic Peninsula is Demospongiae. These sponges, which are primarily found at depths greater than 30 meters, are predominantly preyed upon by spongivorous and omnivorous sea stars with the most abundant sea star in our study area being the omnivorous sea star, *Odontaster validus*. In the current study, demosponges were collected from the shallow waters (<40 meters) around Anvers Island, Antarctica. Out of the 51 sponge species collected, 33 (65%) were collected in great enough numbers to have at least three replicates available for live tissue feeding assays. The fresh outer tissue from 24 of the 33 (73%) sponge species was rejected when presented to *O. validus*. There were 22 unpalatable species amenable to separation of inner and outer layers. Using only fresh sponge tissue, 36% of the unpalatable species had the outer layer rejected while the inner layer was not rejected. Crude organic extracts were made of the species that showed any rejection when fed to *O. validus*. The extracts from 13 unpalatable species were used in feeding assays and the lipophilic and/or hydrophilic extract was rejected in all of them. This provides evidence that chemical defenses are an explanation for all of the unpalatability observed in the present study. This research was supported by National Science Foundation awards to CDA and JBM (OPP-0125181) and to BJB (OPP-0125152).

71.5

PETERSON, J.D., ASHE, V.A., MENDONCA, M.T.; peterj1@auburn.edu. Auburn University

SUBLETHAL EFFECTS OF COAL COMBUSTION RESIDUES ON SOUTHERN LEOPARD FROG (*RANA SPHENOCEPHALA*) GROWTH AND CORTICOSTERONE CONTENT THROUGHOUT METAMORPHOSIS

Coal combustion residues (CCR) have become a major global pollutant due to increased usage of energy derived from coal burning power plants. 57 million tons of CCR, containing high concentrations of contaminants, are released into aquatic settling basins each year. Numerous organisms, including anurans, inhabit these basins and wetlands, which puts them in close contact with CCR contaminated substrates. Previous research has shown that CCR pose major threats to wildlife and their natural environments due to the large amounts of trace elements (As, Ba, Cd, Cr, Cu, Fe, Hg, Mn, Pb, Se, Sr, V and Zn) found in water, sediments, and biota from CCR disposal systems. While chronic exposure to CCR is not always lethal, it has been shown to have a detrimental effect on development and morphology in larval anurans. In the current study, Southern Leopard Frog (*Rana sphenoccephala*) tadpoles were exposed to CCR substrates throughout metamorphosis and effects on growth and developmental rate, oral morphology, and corticosterone content were determined. Tadpoles exposed to CCR took significantly more days to complete metamorphosis and hind and forelimb development and weighed significantly less upon completion of metamorphosis when compared to control tadpoles. We also found significantly more oral malformations in tadpoles exposed to CCR. These malformations varied in severity from loss of the most anterior tooth row to loss of all tooth rows and the anterior jaw. Whole body corticosterone content will also be reported. Changes in larval growth, developmental rate, malformations, and corticosterone content may provide insight into the impact these stressors have on key bottleneck events in anuran life history.

33.3

PETES, L.E., WEBB, M.A.H., MENGE, B.A.; petesl@science.oregon-state.edu. Oregon State University, Bozeman Fish Technology Center
DIFFERENTIAL ACCUMULATION OF CAROTENOIDS IN MUSSEL GONADAL TISSUE: A POTENTIAL RESPONSE TO OXIDATIVE STRESS

Field identification of mussel sex based on gonadal pigmentation is a common practice in marine ecology, based on the theory that males have white gonads, whereas females have orange gonads due to carotenoid pigments. However, previous surveys in Oregon revealed that both females and males can exhibit a gradient of gonadal pigmentation from white to orange. To further investigate this phenomenon, monthly field surveys of *Mytilus californianus* pigmentation were conducted from May-September 2004 at four intertidal sites on the Oregon coast. Mussels from the high and low zones were dissected and visually sexed according to reproductive cell shapes at each site. Individuals were also visually classified based on gonad coloration into orange, peach, white, or non-reproductive categories in the field. A subsample of gonadal tissues was processed for histological analyses to confirm sex of mussels and to assess stage of maturity. At all sites and during all months, females from both the high and low zones had orange gonads; however, males in the high zone also had orange gonads, while males in the low zone had white or peach gonads. Orange pigmentation was highest for individuals in June immediately prior to spawning. Spectrophotometric analysis revealed that orange pigmentation was a result of high carotenoid content in gonadal tissue. Since carotenoids are used to protect tissue from oxidative stress, it is possible that mussels in the high zone accumulate carotenoids in order to protect their gametes from oxidative damage. Future investigations will measure the concentration of carotenoids in tissue using HPLC to quantify differences in gonadal pigmentation between the high and low zones.

S4.4

PHILLIPS, N.E., SHIMA, J.S.; nicole.phillips@vuw.ac.nz. Victoria University of Wellington

RECRUITMENT OF MARINE ORGANISMS AROUND WELLINGTON, NEW ZEALAND: A MODEL NATURAL SYSTEM TO EXAMINE CAUSES AND CONSEQUENCES OF VARIABILITY IN LARVAL QUALITY IN MUSSELS AND REEF FISH

Accumulating evidence from laboratory experiments on a range of marine taxa indicates that variation in larval history can influence probability of recruitment success by impinging on the performance of early juveniles. To date much less has been reported on both the causes and consequences of variable larval quality for recruitment of natural populations of marine organisms. In New Zealand, we are using natural environmental variability between adjacent water masses (Wellington Harbour and Cook Strait) to examine these issues in two related studies. In the first, we monitor natural variability in larval size and lipid content for newly settled mussels, and explore relationships between larval quality, larval quantity, and probable recruitment success. We also use CTD data from moorings in Wellington Harbour to determine potential environmental sources of variability in larval quality. In a second study, we examine recruitment of a common reef fish in this region. Using otolith microchemistry to evaluate larval environmental fingerprints, we identify 3 dispersal syndromes (i.e. fish with similar patterns of trace element concentrations across developing larval otoliths), and explore the proportional contributions of these syndromes to discrete recruitment events. Larval quality (total energetic content) covaries spatio-temporally with dispersal syndromes, and experimental translocations of recently settled fish among sites suggest larval quality and site quality interact to determine differential recruitment success among syndromes, and potentially mediate patterns of demographic connectivity among populations.

S7-2.2

PIRES, A.; pires@dickinson.edu. Dickinson College
SIGNALS MEDIATING RAPID LOSS OF CELL ADHESION IN METAMORPHOSIS

Rapid morphological changes that occur during the abrupt metamorphoses of many taxa involve shedding of larval organs and migrations of populations of retained cells. Both processes require rapid modulation of cell adhesion. Veliger larvae of gastropods shed the larval velum during metamorphosis over a period of several hours (*Phestilla sibogae*) or 2–3 minutes (*Crepidula fornicata*). Velar abscission in *C. fornicata* entails sudden loss of adhesion within and among several types of epithelial cells, beginning with detachment of the preoral ciliated cells that line the margin of the velum. The shed cells maintain intracellular esterase activity as revealed by calcein dye and their plasma membranes exclude ethidium homodimer, indicating that they remain intact and metabolically active. Loss of velar cell adhesion can be induced in intact larvae and isolated velar lobes by 10^{-4} M H_2O_2 , or by 10^{-5} M diethyldithiocarbamate, an inhibitor of superoxide dismutase. A burst of oxidative activity has been visualized in detaching preoral ciliated cells during natural metamorphosis of intact larvae, further suggesting a role for endogenous oxidative signaling. Calcium ionophore A23187 (10^{-6} M) also induces loss of velar cell adhesion in intact competent larvae as well as in isolated velar lobes, accompanied by an oxidative burst as in natural metamorphosis. Calcium signaling thus may mediate loss of cell adhesion in the velum. The velum is innervated by neurons that are immunopositive for tyrosine hydroxylase (a catecholamine-synthetic enzyme), 5-hydroxytryptamine, and FMRFamide. Terminals for all of these are concentrated in a marginal zone where the preoral ciliated cells detach at the beginning of velar abscission. Continuing investigations seek to connect efferent neural correlates of metamorphosis to mechanisms for modulation of cell adhesion.

49.4

PODLESK, D.W., MCWILLIAMS, S.R.; podlesak@biology.utah.edu.
University of Utah, University of Rhode Island
BIRDS METABOLICALLY ROUTE EXOGENOUS NUTRIENTS TO REBUILD DIGESTIVE ORGANS AFTER FASTING

Many songbirds catabolize their digestive organs and other proteinaceous tissues while fasting during migration. The gut-limitation hypothesis proposes that after arrival at a stopover site songbirds must rebuild digestive organs prior to replenishing other proteinaceous tissues that were catabolized during flight. Birds may route macronutrients from the diet or from endogenous sources to rebuild the digestive organs. We investigated how macronutrients in diet and the bird were allocated to digestive organs in yellow-rumped warblers, (*Dendroica coronata*), after fasting by comparing tissue mass and carbon and nitrogen isotopic values of multiple proteinaceous tissues from fasted birds and from birds that were fasted and then refed one of two diets with different macronutrients. Birds metabolically routed carbon and nitrogen primarily from the diet to rebuild the digestive organs after fasting, and within 48hrs after the end of the fast, birds were also rebuilding the pectoralis muscle from dietary carbon and nitrogen. Thus, our data support the hypothesis that birds utilize exogenous macronutrients to rebuild the digestive organs after fasting, but our data do not support the prioritized rebuilding of protein stores as proposed by the gut-limitation hypothesis

S4.1

PODOLSKY, R.D., MORAN, A.L.; podolskyr@cofc.edu. College of Charleston, Grice Marine Laboratory, Clemson University
FUNCTIONAL LINKS AND CARRYOVER EFFECTS ACROSS LIFE CYCLES

Life cycles are composed of stages that can vary dramatically in size, form, habitat, and functional attributes. Within-life-cycle functional variation is fundamental to ecological and evolutionary processes because the nature and strength of interactions and selection pressures can change dramatically across stages. Although major life-history transitions like metamorphosis can functionally decouple life cycle stages, recent evidence from the marine literature indicates that experience at one stage can strongly influence performance and the outcome of selection at others. Much of what is known about performance at early stages and functional links among stages comes from studies in the laboratory, in part because early stages of marine organisms are typically small, dispersing, and impractical for in situ tests of performance. As a result, relatively little is understood about performance capacities or selection on functional traits under natural conditions. In this symposium we draw together recent and ongoing work on processes at discrete life-history stages—gametes, embryos, larvae, juveniles, and adults—that emphasizes functional connections among stages. Our goal is to highlight research that has been innovative in (1) surmounting the challenges of translating laboratory measures of performance into a field context, and (2) emphasizing how processes at one life-history stage alter performance and selection at others. We begin by clarifying terms and offering a conceptual framework for understanding under what conditions the consequences of experience at one stage might be expected to carry over to—or be compensated by—experience at subsequent stages.

13.7

PONTZER, H.; pontzer@fas.harvard.edu. Harvard University
LINKING LOCOMOTOR ENERGETICS TO LIMB DESIGN IN TERRESTRIAL ANIMALS

How does limb design, specifically limb length, affect the energy cost of locomotion? Recently, I proposed a new model linking locomotor cost to limb length for terrestrial animals, and tested the model in humans. Here I present a new study applying this LiMb model across species. Subjects from three species—dogs, goats, and humans—performed walking and trotting/running trials on a treadmill while kinematics and oxygen consumption were recorded. The LiMb model was used to predict the cost of locomotion (COL) from limb length and basic kinematics, and model predictions were compared to observed oxygen consumption. The LiMb model outperformed other predictors of COL, including body mass, Froude number, and contact time. Notably, the model predicted COL equally well both within and between different gaits, species, and locomotor anatomies (i.e., bipeds and quadrupeds). To further test the relationship between limb length and COL predicted by the LiMb model, a larger interspecific comparison was performed using measurements of limb length and transport cost taken from the literature. As predicted, limb length explained over 95% of the variation in cost, with no independent effect of body mass. These results suggest muscular force production during locomotion, and therefore locomotor energy cost, is inversely proportional to limb length for terrestrial animals. This relationship between limb length and COL may be useful for comparisons of locomotor performance both in the field and in the laboratory.

S9-2.1

PORTER, W.P., VAKHARIA, N., DUFFY, D.C.; wpporter@wisc.edu. University of Wisconsin, Madison, University of Hawai'i, Honolulu
MODELING THE ENERGETICS AND BEHAVIOR OF THE RARE (EXTINCT?) PO'OULI ON THE LANDSCAPE OF MAUI

Where might we expect to find the rare (extinct?) Po'ouli on the island of Maui? To answer that question we have used state-of-the-art landscape scale microclimate and endotherm models to explore a variety of questions about environmental/physiological/ behavioral constraints on the Poouli. We used Maui's climate data, digital elevation map, slope, aspect, and vegetation cover to reconstruct local microclimates for each month of the year at a pixel resolution of 30 m. We collected data on Poouli properties; mid dorsal and mid ventral feather reflectivities, feather length, and plumage depth and other allometry data and properties of diets of the Poouli from the literature and from Poouli specimens at the American Museum of Natural History in New York. We used this information to compute food and water requirements on a daily basis for the average day for each month of the year. We also computed potential time for activity (foraging time available). We mapped onto the island of Maui locations where food/water requirements were minimized and activity time was maximized to indicate the most likely locations where the birds would function optimally. We also did diet shift scenarios to explore the importance of different diet fractions as they relate to bird function. The landscape scale results of these calculations will be shown.

31.5

POSTEL, U., THOMPSON, F., VINEY, M., BARKER, G., WEBSTER, S., MORRIS, S.*; Steve.Morris@bristol.ac.uk. University of Bristol, UK, University of Wales - UK
RED CRABS ON THE RUN: MOLECULAR BASES OF THE SEASONAL MIGRATION OF *GECARCOIDEA NATALIS*

The terrestrial crab *Gecarcoidea natalis* retains a marine larval stage and on Christmas Island undertakes an annual breeding migration to the coast. The monsoon rainfalls stimulate a near instantaneous switch from hypo- to hyperactivity. How this switch is accomplished and controlled is unknown. We examined changes in gene transcription in the leg muscle. Total RNA of tissue from migrating and non-migrating male *G. natalis* was used to construct two cDNA libraries. First recombinant clones were isolated and insert fragments amplified and sequenced. About 73 % of the ESTs could be assigned to known sequences held in databases using BLAST and contig analysis. Approximately 57 % of the ESTs match proteins related to muscle function. Comparison of sequence frequencies of the libraries revealed differential expression of several genes with the change in physiological states. For example, actin was significantly less transcribed in migrating crabs, which could either indicate a rise in general gene expression during migration and/or might be related to basic changes in the muscle structure. Further indications for migration related structural changes of the muscle tissue are the increase in the transcription of a muscle LIM protein and of a protein with highest similarity to tropomyosin. Ongoing sequencing work is expected to reveal differential expression of genes in addition to those for muscle structural proteins. Specific and key differences between the libraries will now be confirmed by RT-PCR. This non-specific approach to detect physiological differences appears to be an appropriate tool for large scale screening for transcription based changes supporting the physiology of seasonal ecology and behaviour of this crustacean.

S2-1.3

POSTLETHWAIT, J.H., YAN, Y.-L., AMORES, A., CRESKO, B., SINGER, A., RUBIN, D.; jpostle@uoneuro.uoregon.edu. University of Oregon, Eugene, Illinois State University, Normal
CONSEQUENCES OF GENOME DUPLICATION FOR THE EVOLUTION OF DEVELOPMENTAL MECHANISMS IN TELEOST FISH

Genome amplification, probably as a result of genome duplication, occurred prior to two key nodes of chordate evolution: the origin of vertebrates, the most diverse group of chordates, and the radiation of the teleosts, the most species-rich group of vertebrates. After genome duplication, most duplicated genes rapidly revert to single copy, but those retained in duplicate generally come to be expressed in overlapping but distinct patterns in development, a process modeled by subfunction partitioning and the origin of novel functions. How do genetic regulatory networks evolve as duplicated genes change over time? In one hypothesis, a one-to-one relationship of members of the pathway is maintained as subfunctions partition to give two parallel pathways in different subregions of the pre-duplication expression domain. In another hypothesis, pathways evolve as networks with variable and redundant interactions. To approach that question, we are investigating the regulation of duplicated genes in the developmental pathway leading to cartilage and bone and hindbrain patterning in zebrafish and comparing results with the orthologous genes in stickleback and other teleosts. We find that the network model appears to predict better than the parallel model, and that expression patterns of orthologs differ in different teleosts. These evolutionary events after the teleost genome duplication serve as a model for similar evolutionary changes that occurred in the genome amplifications at the base of vertebrate origins.

69.3

PRATT, M.C.; mpratt@bowdoin.edu. Bowdoin College, Brunswick
WILL AN OPPORTUNISTIC INVASIVE BRYOZOAN DISPLACE OR COEXIST WITH OTHER EPIPHYTIC BRYOZOANS IN THE GULF OF MAINE?

The bryozoan *Membranipora membranacea* was introduced into the Gulf of Maine in 1987 and within two years became the dominant epiphyte on kelps. While we know that *Membranipora* can increase the likelihood of breakage of kelps, we know nothing of competitive interactions between *Membranipora* and other epiphytic bryozoans. To determine whether *Membranipora* will outcompete or coexist with other bryozoans, I used field observations and measured feeding, growth, and respiration rates to better understand the life history strategies of *Membranipora* and another epiphytic bryozoan, *Electra pilosa*. *Membranipora* is the dominant epiphyte on kelps from the late summer through the fall, but does not survive the winter well. *Electra* never dominates on kelps, but it survives the winter better than *Membranipora*. *Membranipora* dominates by settling in very high numbers and growing very fast, which allows it to almost completely cover kelp blades. *Membranipora* grows very fast by having a high feeding rate, maintaining a high metabolic rate, and putting the vast majority of its energy into growth. This strategy has a cost, as *Membranipora* does not survive poor conditions as well. While *Membranipora* maintains a high metabolic rate and still puts energy towards growth in low food conditions, *Electra* lowers its metabolic rate and generally puts more energy into maintaining the colony rather than trying to grow further. *Electra* may not be able to compete with *Membranipora* effectively in good conditions, but it may be able to coexist by using spatial and temporal refuges.

S5-1.4

PRICE, A.L., PATEL, N.H.; aprice@salk.edu. The Salk Institute, University of California, Berkeley, Howard Hughes Medical Institute
MESODERM DEVELOPMENT IN ARTHROPODS: A VIEW FROM CRUSTACEANS

The Arthropoda is a highly diverse group of organisms including the Chelicerata, Myriapoda, Crustacea, and Insecta. Studies of comparative development in arthropods can benefit from the vast amount of knowledge garnered from the fruitfly, *Drosophila melanogaster*. But how does mesoderm development of *Drosophila*, an insect, compare with other arthropod groups? We have developed a new arthropod system for studying development: the amphipod crustacean *Parhyale hawaiensis*. Using *Parhyale*, we have explored the cell lineage of mesoderm, molecular aspects of mesoderm patterning, and interactions between ectoderm and mesoderm in the formation of germ band segments. Cell lineage studies in amphipod crustaceans show that three cell lineages from the eight-cell stage contribute to the visceral mesoderm, somatic mesoderm of the head, and teloblast-derived somatic trunk mesoderm. Through ablation studies, we show cell lineages giving rise to the mesoderm have the ability to compensate for one another, suggesting a mesoderm equivalency group is established at the eight-cell stage. The genes *twist*, *snail*, and *mef2* are involved in mesoderm development throughout the Metazoa. We characterized orthologs of these genes from *Parhyale* and find that expression implicates them in patterning, but not specification, of mesoderm. The majority of segmental mesoderm in malacostracan crustaceans is formed via the asymmetric division of eight mesoteloblasts in an anterior to posterior progression. Through ablation experiments, we have investigated the interaction between ectoderm and mesoderm during segmentation. We find that segmentation of the ectoderm is independent of the mesoderm, but segmentation of the mesoderm depends on the ectoderm for organization. These results will be discussed in relation to what is known about mesoderm development from other arthropod groups.

26.3

PRICE, E.R., GUGLIELMO, C.G.; eprice3@uwo.ca. University of Western Ontario
FATTY ACID COMPOSITION OF MUSCLE PHOSPHOLIPIDS IN MIGRATORY SPARROWS

Migratory birds undergo numerous physiological changes in preparation for the high intensity endurance exercise associated with migration. The fatty acid composition of muscle membranes, particularly the n-6/to n-3 ratio of poly-unsaturated fatty acids, has been shown to affect endurance performance in rats and humans. Fatty acid composition is in turn often affected by diet and exercise regime. We tested the hypothesis that photo-manipulated premigratory birds would adaptively modify muscle membrane fatty acids for endurance performance. In addition, we tested the effect of exercise on fatty acid composition of muscles. Captive white-crowned sparrows were split into three groups, 1) short-day (8L:16D) winter birds without exercise, 2) short-day winter birds with exercise, and 3) long-day (16L:8D) premigratory birds. Exercise caused a large and significant decrease in (n-6)/(n-3) ratio of fatty acids in the pectoralis muscle phospholipids. This result may indicate a depletion of n-6 fatty acids as has been suggested from studies of wild migrants. Light cycle had no significant effect on muscle fatty acid composition, suggesting that birds may not prepare for migration by altering muscle phospholipids. This line of research will help us better understand the constraints on high intensity exercise both in migratory birds and in humans.

51.10

QUINN, N.J., KOJIS, B.L.; norman.quinn@uwimona.edu.jm. University of West Indies, Discovery Bay Marine Lab, Jamaica, Division of Fish & Wildlife, St. Thomas
ASSESSING ENHANCEMENT TECHNIQUES TO INCREASE *ACROPORA CERVICORNIS* POPULATIONS AND INCREASE FISH BIODIVERSITY IN JAMAICA

Shallow water *Acropora* species were nearly extirpated on Jamaican reefs in the late 1970s and early 1980s where they remain uncommon today. With the loss of acroporids from hurricanes, disease and the reduction of grazers, macroalgae has proliferated. Restoration of acroporids has been proposed to increase the reef complexity and to assist fishers by increasing fish populations through the improvement of essential reef fish habitat. Comparative fish counts on similar reefs with and without *A. cervicornis* populations demonstrate high fish diversity and abundance on reefs with *A. cervicornis* populations. Reefs with greater *A. cervicornis* biomass have larger edible fish populations. Since June 2004, we have been involved with fishers, hotel operators and environmental groups to increase the biomass of *A. cervicornis* and the complexity of reefs. With protection of these restored reefs we anticipate an increase in fish abundance which should result in greater fish catches for subsistence fishers. However, the potential for *Acropora* spp. to naturally recover should be examined before efforts to restore them are undertaken. Efforts to transplant or restore acroporids are very expensive and unnecessary if they have the natural capacity to recover. We have observed juvenile colony recruitment of *A. palmata* and *prolifera*, but not *A. cervicornis*. While these species appear to be recovering, it appears that the long-term survival of *A. cervicornis* is threatened by lack of successful larval recruitment. This study assessed methods of restoring *A. cervicornis* populations in selected habitats using experimental transplants.

S3-2.7

QUINN, R.D., RITZMANN, R.E., CHIEL, H.J., VAIDYANATHAN, R.; rdq@case.edu. Case Western Reserve University, Naval Postgraduate School
NEUROMECHANICS OF BIROBOTS

Our research has demonstrated the value of focusing on both the biomechanics and neural control of biological organisms as a basis for a new generation of flexible, adaptive robots that can function in unstructured, changing environments. We are developing robots for two distinct purposes. The goal of one line of robots and robotic components is to serve as hardware models to test biological hypotheses. We strive to incorporate as many details of the animals locomotion system as possible in these devices often using new technologies. Our other goal is to abstract the knowledge we have gained about animals and use current technology to develop near-term mission capable robots. These goals are complementary. As we learn more about animal neuromechanics, we can improve our robots capabilities. We have constructed hardware models whose reflexes and biomechanics were based in detail on cockroaches and other insects. We have also constructed patented, mission capable robots (WhegsTM) based on abstracted cockroach locomotion principles, which have their locomotion control mechanisms imbedded in their mechanics (preflexes as suggested by Robert Full of Berkeley). We are implementing insect autonomy mechanisms into the WhegsTM vehicles. Our research also includes developing innovative robots with soft bodies based upon mollusks.

54.7

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MECHANICAL CHARACTERISTICS OF BONE CHANGE LITTLE DURING ANOXIC SUBMERGENCE AT 3 °C IN RED-EARED SLIDER TURTLES, *TRACHEMYS SCRIPTA*

We submerged red-eared slider turtles, *Trachemys scripta*, in nitrogen-equilibrated water at 3°C to investigate mechanical changes that occur in the shell due to acid-base regulation. We analyzed shell samples for hardness and femur samples for hardness, stiffness, peak load, and energy to peak load at 0, 13, 29 and 44 d of submergence. We also measured shell [Ca²⁺], [Mg²⁺], [Na⁺], [K⁺], [CO₂], [inorganic phosphate (P_i)] and [lactate] to correlate changes in shell composition with mechanical changes. Similar to other turtles, red-eared slider turtles had a blood pH=7.09 (control=7.77) after 44d due to a lactacidosis and plasma Ca²⁺ and Mg²⁺ increased significantly. Shell Ca²⁺ remained steady, however shell [CO₂] and [Mg²⁺] decreased over the 44d (from 486 μ ww shell to 369 μ/g ww shell and from 71.0 μ/g ww shell to 53.0 μ/g ww shell, respectively) while shell [lactate] increased (from 0.6 μ/g ww shell to 69 μ/g ww shell). These changes were not accompanied by significant changes to femur stiffness (0d=296.5±33.9 N/mm, 44d=253.1±11.5 N/mm), peak load (0d=204.5±10.4 N, 44d=197.6±7.7 N), energy to peak load (0d=380.9±37.7 Nmm, 44d=334.3±19.5 Nmm), or hardness (0d=35.0±2.6, 44d=32.0±2.3). Shell hardness decreased from 33±2.5 to 28±3.1.

29.9

REICH, K.J., BJORN DAL, K.A., BOL TEN, A.B.; kreich@zoo.ufl.edu. University of Florida

TRACKING ONTOGENETIC SHIFTS IN DIET AND HABITAT OF JUVENILE SEA TURTLES WITH STABLE ISOTOPES

With the exception of loggerheads (*Caretta caretta*), little is known about the habitat use and diet of juvenile sea turtles. Stable ¹³C and ¹⁵N isotope analyses of scutes—the top, keratin layer of a turtle shell—were used to investigate diet and trophic position of North Atlantic juvenile sea turtles (*Chelonia mydas*, *Eretmochelys imbricata*, *Lepidochelys kempii*) prior to their recruitment to neritic waters in Florida and the Bahamas. Scute samples were collected from green turtles (*C. mydas*), hawksbills (*E. imbricata*), and Kemp's ridleys (*L. kempii*) that stranded on Florida beaches and from our study population of green turtles in the Bahamas between 2001 and 2005. We confirmed that scute carries a record of previous diet and habitat use by comparing samples of old and new scute from green turtles that had recently recruited to seagrass meadows in the Bahamas. To establish a baseline isotope signature for sea turtles feeding in the pelagic zone in deep water, oceanic habitat, we analyzed samples from juvenile loggerheads residing in the waters over the mid-Atlantic Ridge for ¹³C and ¹⁵N. Results indicate that, during the first years of life, juvenile loggerheads, green turtles, hawksbills, and Kemp's ridleys all occupy the same type of habitat and feed at a similar trophic level. Our analyses of ¹³C and ¹⁵N signatures of green turtles provide evidence of a shift from a primarily carnivorous diet and pelagic zone, oceanic habitat to an herbivorous diet and neritic habitat. We have established that scute retains a history of stable isotope signatures and that stable isotope analysis is a powerful tool in the ongoing investigation of the ontogenetic shift in diet and habitat of juvenile sea turtles.

72.9

REILLY, S.M., MCELROY, E.J.; reilly@ohiou.edu. Ohio University
TUATARAS AND SALAMANDERS SHOW THAT WALKING AND RUNNING MECHANICS ARE ANCIENT FEATURES OF TETRAPOD LOCOMOTION

The slow lumbering locomotion of tuataras and salamanders represents the original form of quadrupedal locomotion employed by early terrestrial vertebrates. Studies of whole-body mechanics show they use the same walking and running mechanics known in fast moving (cursorial) animals. When walking, these sprawling animals saved energy via pendular mechanics as efficiently as many cursorial animals. However, unlike cursorial animals, tuataras and salamanders do not change gait (they always trot) or mechanics with speed. Thus, walking and running mechanics have been a feature of quadrupedal locomotion since the tetrapods emerged over 400 million years ago, but running was not originally adapted for increasing speed.

65.1

REITZEL, A.M., SULLIVAN, J.C., FINNERTY, J.R.; reitzel@bu.edu. Boston University

METAMORPHOSIS IN THE LIFE HISTORY OF A PARASITIC SEA ANEMONE, *EDWARDSIELLA LINEATA*

Larvae of the sea anemone *Edwardsiella lineata* selectively parasitize the ctenophore *Mnemiopsis leidyi*. Our observations have shown that a parasite excised from the host will differentiate into a larva that can undergo either of two developmental trajectories: re-infect a ctenophore or settle as a benthic juvenile. From a morphological and an ecological perspective of metamorphosis, we suggest that *E. lineata* undergoes two metamorphic events, one from larva to parasite and a second from larva to benthic juvenile. We support these as independent metamorphic processes by 1) differences between the larva (planula) and both parasite and juvenile and 2) morphological and ecological differences in parasite and juvenile stages. The planula is a non-feeding, swimming pelagic stage in the life history and is mostly undifferentiated with at most two mesenteries and an oral-aboral axis. Morphological comparisons of parasites and juveniles showed that juveniles have a typical sea anemone morphology (tentacles, mesenteries with muscles, oral opening with pharynx) while the parasitic stage lacks tentacles, muscles and all or some mesenteries. Feeding mode differs where parasites are suspension feeders on predigested food from the ctenophore and juveniles are tentacular feeders on zooplankton via nematocysts. Metamorphosis from larva to parasite is reversible, a feature uncommon in metamorphic taxa. Since larvae have two trajectories that can be manipulated in the laboratory, *E. lineata* represents an attractive species to study how environmental cues and developmental changes are integrated in metamorphosis. We hypothesize how changes in expression of developmental regulatory genes may underlie the two metamorphic events with comparisons to a closely related anemone, *Nematostella vectensis*.

54.5

RENO, P.L., MCBURNEY, D.L., LOVEJOY, C.O., HORTON, W.E.; preno@kent.edu. Kent State University, NEOUCOM, Rootstown
COMPARATIVE ANALYSIS OF MOUSE METATARSAL OSSIFICATION AND IMPLICATIONS FOR DIFFERENTIAL SKELETAL GROWTH

The diversity of skeletal proportions in mammals is largely achieved by modifying physal growth rate, yet little is known about how growth plate location and growth rate are specified. Like those of most mammals including humans, mouse metatarsals have only a single growth plate. These constitute an excellent model for exploring mechanisms that may underlie growth plate formation and for uncovering potential targets of natural selection for modifying longitudinal growth. Neonatal to 14 day old mice metatarsals were stained with Safranin O or monitored for protein expression via immunohistochemistry. While initially similar, the two ends diverged substantially with respect to the organization and size of their columnar and hypertrophic zones. PCNA expression revealed that a specific proliferation profile is associated with growth plate formation. Surprisingly, the expression of both PTHrP and its receptor are similar in both ends of the metatarsal, suggesting that these play a very general role in regulating endochondral ossification. In contrast, the expression patterns of PTC are distinct, suggesting that Ihh signaling may contribute to the determination of growth plate formation and performance. In addition, these patterns may also underlie the acquisition of novel growth centers in mammals. Comparison of mouse metatarsal ossification patterns to those of alligators revealed that the unidirectional pattern of metapodial growth (i.e., via a single growth plate) is derived in mammals. Comparisons of ossification within different skeletal regions and between divergent vertebrate taxa will therefore be useful in advancing our understanding of the development and evolution of the tetrapod skeleton.

11.4

REVZEN, S., KODITSCHKEK, D.E., FULL, R.J.; shrevz@berkeley.edu. University of California, Berkeley, University of Pennsylvania, Philadelphia
TESTING FEEDFORWARD CONTROL MODELS IN RAPID RUNNING INSECTS USING LARGE PERTURBATIONS

Sensory feedback dominates limb coordination in walking. By contrast, insects are capable of stable running over rough surfaces with no detectable change in motor output to major leg muscles. Passive, dynamic models suggest self-stabilization. A central pattern generator forcing a mass-spring system can model these observations. RHex, a rapid running, bio-inspired hexapedal robot is a physical realization of these models. The robot can self-stabilize over simple terrain when its leg motors are driven with feed-forward clock (CPG-like) signals only. However, RHex requires sensory feedback to its clock to attain comparable speeds over complex terrain. With such feedback, traversal of significant obstacles induces phase shifts in motor timing to coordinate legs. We examined high-speed running in cockroaches to determine whether neural feedback shifts leg phase and/or frequency after encountering an obstacle. Cockroaches were tripped with a hip-high hurdle while running at 25 cm/s on a treadmill. High-speed video tracked the body and distal portion of all six legs versus time. Perturbations struck different legs in different locations, but always caused a significant disruption to the mechanical system for the several strides traversing the obstacle. Cockroaches incurred significant phase and frequency changes. When the pattern of leg motions was extrapolated from before the obstacle to after the obstacle, it failed to match the animals' pattern after recovery in 17 of 22 trials. Results suggest that sensory feedback is likely sent to a CPG-like clock driving leg movements, as required by our physical model. We reject the hypothesis that animals use a feed-forward clock without neural feedback when challenged with large perturbations in rapid running.

8.1

RHYNE, A.L., JOHNSON, K.J., LIN, J.; arhyne@fit.edu. Florida Institute of Technology
ONTOGENETIC SHIFT OF SPECTRAL SENSITIVITY IN THE LARVAL PHOTOTAXIS OF TWO CARIDEAN SHRIMP, *LYSMATA WURDEMANNI* AND *L. BOGGESSI*

We subjected larvae of two species of caridean shrimp (*Lysmata wurdemanni* and *Lysmata boggesi*) to a range of light spectra and intensities to examine their phototactic responses. Larvae were less sensitive to light than some other decapod crustaceans, typically requiring a light intensity of 10^{14} photons $m^{-2} s^{-1}$ to elicit a response. Both species displayed a spectral preference shift from 480 to 520 nm as they progressed from early to late zoeal stages. Spectral preference shifts during ontogeny are previously unknown in crustaceans or, to our knowledge, other taxa. The phototaxis of these larvae is interesting in light of our recent reevaluation the taxonomic status of western Atlantic *Lysmata*. These two species of *Lysmata* are nearly identical to one another morphologically and possess similar larval development; both occur in Florida Bay and on the west coast of Florida. *L. boggesi* has a restricted geographic range (Western Coast of Florida and Florida Bay) and is abundant in shallower water (3-10 meters), while *L. wurdemanni* is widely dispersed in the northwest America but mainly occurs in deeper water in Florida Bay (12-20 meters) and is rare in the seagrass beds on the West Coast of Florida. The unique phototactic responses of these larvae may provide clues as to how maturing larvae prepare for settlement in their respective adult habitats.

75.1

RIBAK, G., WEIHS, D., ARAD, Z.; galr@tx.technion.ac.il. Technion, Haifa, Israel
UNDERWATER MANEUVERABILITY OF CORMORANTS

Great cormorants (*Phalacrocorax carbo sinensis*) forage by swimming underwater in search and pursuit of fish. As buoyant, foot-propelled, submerged swimmers cormorants generate hydrodynamic lift from their body and tail to overcome buoyancy during shallow dives. This implies that the birds must swim above a minimal speed underwater to generate sufficient hydrodynamic forces that will prevent them from surfacing. This minimal swimming speed limitation should affect the ability of the birds to perform sharp turns. We studied the maneuverability of cormorants in pitch, by filming birds performing maneuvers induced by an underwater (1m deep) obstacle course. The difficulty of the maneuver was progressively increased in a series of experiments by reducing the available turning radius inside the obstacle course. The kinematic analysis of the maneuvering birds suggests that minimum turning radius in pitch was 0.54 of the total body length of the birds. In all but the widest turning maneuvers the birds performed powered turns that were comprised of 3 successive paddling cycles per turn. The kinematic analysis suggests that the tail is used as a control surface to generate torque moments that initiate and stops the pitching moments of the body. This mechanism for orientation of the body is supplemented by the hydrodynamic drag from the long cylindrical shaped neck and by variation in the propulsive force of the feet between successive paddling cycles during the turn.

63.6

RICE, A.N.; arice@uchicago.edu. University of Chicago, Field Museum of Natural History

EVOLUTION OF COORDINATION IN FISH FEEDING: THE INTERSECTION OF FUNCTIONAL MORPHOLOGY AND ECOLOGY

Prey capture in fishes is a complex behavioral process. From initial sensory detection of a food item, to the final motor output of jaws and fins, these components have to be coordinated for successful feeding to occur. Despite traditionally being studied separately, recent studies of the interaction of three systems, fins, jaws, and eyes, have revealed components of feeding behavior previously overlooked. Comparing patterns of coordination between different species will elucidate conserved and diversified elements of functional morphological systems in fishes. A detailed molecular phylogeny of wrasses (Teleostei: Labridae) now permits testing of hypotheses of the function and timing of kinetic systems in this diverse group of reef fishes. The present analysis explores the effect of phylogenetic constraint and ecological adaptation in the diversification of coordination patterns during feeding wrasses. To investigate coordination patterns in a phylogenetic context, four species with different feeding ecologies (two piscivores and two molluscivores) from the wrasse tribe Cheilini were studied. To find out how coordination patterns compare with other feeding strategies from across the Labridae, Cheiline coordination patterns were compared with six other wrasses, including two molluscivores, two herbivores, and two planktivores. Patterns of coordination were more similar for fishes of a particular feeding strategy than for a phylogenetic lineage, suggesting that coordination of these systems may represent adaptations to varying ecological selection pressures rather than evolutionary conservation. Diversity in feeding, locomotor, and visual mechanisms seen in wrasses may reflect broader trends in the interaction of feeding and locomotor systems in coral reef fishes as a whole.

8.7

RICE, A., BLUMENSHINE, S., TSUKIMURA, B.; amms21@csufresno.edu. California State University, Fresno

THE INFLUENCE OF ENVIRONMENTAL PARAMETERS ON THE INVASIVE CHINESE MITTEN CRAB, *ERIOCHEIR SINENSIS*, ZOEAE RECRUITMENT DYNAMICS IN SAN FRANCISCO BAY, CA

The Chinese mitten crab, *Eriocheir sinensis* (Crustacea: Decapoda: Grapsoidea), invaded San Francisco Bay, CA, in 1992. The mitten crab has become established in the San Francisco Bay ecosystem following more than a century of global dispersal, including invasive populations in temperate regions of several countries throughout western and central Europe. Mitten crab population dynamics are known to undergo dramatic oscillations, but the factors driving these dynamics are poorly understood. Exploring the link between environmental parameters and how each new cohort contributes to future populations of adult mitten crabs is crucial to understanding what drives the population dynamics of this species. We examined interrelationships of larval recruitment dynamics and environmental factors in the field, such as temperature or outflow. A 7-year data set of mitten crab adult and larval abundance from North San Francisco Bay was analyzed relative to long-term data sets for temperature, salinity, discharge, and abundance of planktivores that existed during the period that the crabs were in the larval stage. Our analysis suggests that temperature, freshwater discharge, and planktivore abundance are three variables that may play important roles in driving the population dynamics of the mitten crab.

72.11

RICHARDS, C.T., BIEWENER, A.A.; richards@fas.harvard.edu. Harvard University

MEASURING MUSCLE POWER *IN VIVO* AND *IN VITRO*: IDENTIFYING MECHANISMS BY WHICH POWER IS MODULATED IN THE *XENOPUS LAEVIS* PLANTARIS MUSCLE DURING SWIMMING

During swimming, *in vivo* power output of the plantaris is obtained by simultaneous recording of muscle activation (by electromyography), length (by sonomicrometry) and force (using a calibrated stain gauge transducer fastened to the plantar tendon). Following *in vivo* measurements, the plantaris is excised from the animal and mounted to a computer-driven lever arm controlling muscle length while measuring force. Patterns of muscle strain and activation timing (previously collected from the intact animal) are imposed to simulate *in vivo* conditions. *In vivo* data shows plantaris power output ranging from 0.19 to 75.92 W/kg, which is correlated with changes in muscle strain rate, peak strain and peak force. Although *in vitro* data is currently too preliminary for conclusive results, we address the question: can *in vivo* muscle power can be predicted from muscle strain and activation data? And we seek to test which parameters (strain magnitude, strain rate and activation timing) most strongly contribute to variation in muscle power both within and beyond the range of muscle function observed *in vivo*.

29.8

RIMKUS, T., GOUVEIA, M., GOMERO, B.; trimkus@marymount.edu. Marymount University

THE EFFECTS OF PASSIVE INTEGRATED TRANSPONDER TAG IMPLANTATION ON THE GROWTH OF HATCHLING PAINTED TURTLES (*CHRYSEMYS PICTA*)

The technology of passive integrated transponder (PIT) tags has allowed the marking of field specimens with certainty of identification after recapture. The effects of PIT tag implantation on growth has been assessed in a few turtle species but only in larger juveniles and adults. These previous studies on the introduction of PIT tags into older turtles report no adverse effect on growth rate. Therefore, hatchling painted turtles (*Chrysemys picta*) were implanted with PIT tags and their growth rates monitored over the course of three months. An additional group of hatchlings were monitored for growth but they did not have PIT tags implanted. The size of the hatchlings made the normal implantation procedure difficult, so a new method of implantation to accommodate for the size of the hatchlings is also discussed and evaluated. After three months of growth there appears to be no significant differences in hatchling mass or carapace length. Therefore, it is proposed that the PIT tags can be used to mark even the smallest of hatchlings in field experiments where individual identity is important in assessing results.

14.5

RIVERA, G.; grivera@clemson.edu. Clemson University, Clemson
MORPHOLOGICAL VARIATION IN A SPECIES OF FRESHWATER TURTLE (*PSEUDEMYD CONCINNA*) INHABITING DIFFERENT FLOW REGIMES

Species with populations that inhabit a wide range of environments frequently display morphological variations that correlate with differences in environmental parameters. Water velocity is a critical feature of aquatic habitats that could impose selection for drag-reducing morphologies. This possibility has been suggested for several species of fishes, in which populations in lotic habitats have more streamlined body shapes than those in lentic habitats. Freshwater turtles provide a novel test of such correlations because they spend a substantial amount of time out of water; thus, selection pressures for hydrodynamic efficiency may be weaker than in fully aquatic fishes. To determine whether this is the case, I assessed intraspecific morphological variation in the river cooter (*Pseudemys concinna*) between two physiographic regions of Alabama, the Piedmont and the Coastal Plain. These regions exhibit dramatically different stream flow velocities that might place different hydrodynamic demands on turtles, with the high-elevation Piedmont characterized by higher flow rates than the flat Coastal Plain. I used geometric morphometrics to analyze three-dimensional landmark data collected from museum specimens. A principal components analysis (PCA) of the landmark data showed separation between the two groups and a Goodalls F-test found significant differences in their overall shape. Upon comparison of the groups, two primary differences emerge: (1) the carapace is flatter in the Piedmont specimens, and (2) the posterior end of the carapace is wider in the Piedmont specimens. These differences would be predicted to enhance swimming performance in faster flowing water, suggesting a correlation between shape and hydrodynamic environment in a semi-aquatic organism.

75.3

RIVERA, A.R., RIVERA, G., BLOB, R.W.; arivera@clemson.edu. Clemson University, SC
AQUATIC TURNING PERFORMANCE OF A RIGID-BODIED VERTEBRATE, THE PAINTED TURTLE (*CHRYSEMYS PICTA*)

The rarity of rigid body designs among aquatic vertebrates suggests that such designs may carry costs that impair functional performance. Although rigid bodies are expected to incur less drag and are more stable during rectilinear locomotion than flexible bodies, previous studies have suggested that aquatic turning performance may be reduced as a trade-off for such stability. In this study, we tested the effect of a rigid design on aquatic turning performance in a species of semi-aquatic turtle, the painted turtle (*Chrysemys picta*). Sixty turns by yearling turtles were recorded in lateral and ventral views using two synchronized high-speed video cameras (150 Hz). For each turn, we measured the limb motions that produced the turn and evaluated two parameters of turning performance, agility (turning rate) and maneuverability (space required to execute a turn). We identified three distinct patterns of limb movements used to execute turns. The most common pattern involved extending the forelimb on the inside of the turn perpendicular to the body, increasing drag and thereby effecting rotation to that side. Two less common patterns of limb movements appear to be differentially employed to balance the speed and/or direction of movement upon entering a turn. Comparisons of turning data from turtles vs. data from flexible-bodied animals support previous findings of reduced turning performance in animals with rigid bodies. However, when compared with rigid-bodied fishes such as boxfish, painted turtles have higher turning rates. Differences in turning performance between turtles and boxfish may be related to differences in the structure of limbs vs. fins that could enhance thrust production in turtles, and differences in body height that might cause greater resistance to rotation in fishes.

50.1

ROARK, A.M., BJORN DAL, K.A.; amroark@ufl.edu. University of Florida
EXPERIMENTALLY IMPOSED PATTERNS OF FOOD AVAILABILITY AND THEIR EFFECTS ON METABOLIC RATE IN INDIAN STICK INSECTS, *CARAUSIUS MOROSUS*

Changes in food availability throughout an animal's lifetime may drastically influence physiology and life history. In this study, we sought to elucidate the effects of different patterns of intake and growth on metabolic rates of Indian stick insects, *Carausius morosus*. *C. morosus* were individually maintained on a diet consisting of leaf discs cut from English ivy, *Hedera helix*. These leaf discs were offered to each insect either ad libitum or in quantities equal to 60% of average ad libitum intake on a mass- and instar-specific basis. Insects were fed according to one of six treatment regimens: continuously ad libitum, continuously restricted, ad libitum until either the beginning of the fifth instar or first oviposition followed by restricted feeding, or restricted until either the beginning of the fifth instar or first oviposition followed by ad libitum feeding. Oxygen consumption rates of these insects were assessed during each of several instars and during adulthood using Scholander respirometers. Insects experiencing different intake patterns exhibited significantly different mass-specific metabolic rates. These results have important implications for life histories in these animals.

4.1

ROBBINS, T.R., WARNER, D.A.; trobbin@mail.usf.edu. University of South Florida, The University of Sydney
FLUCTUATIONS IN THE INCUBATION ENVIRONMENT: DOES THE PATTERN OR MAGNITUDE INFLUENCE EGG SURVIVAL AND HATCHLING PHENOTYPES IN A LIZARD?

Environmental and maternal factors can shape offspring phenotypes in ways that could influence offspring survival and fitness. Most studies that evaluate environmental effects on offspring phenotypic variation use environmental conditions that remain constant throughout the duration of the experiment despite the fact that fluctuations in environmental parameters (i.e., temperature or moisture) occur under natural situations. In a laboratory experiment, we investigated the effects of fluctuating moisture regimes during incubation on eggs and hatchling phenotypes of the fence lizard *Sceloporus undulatus*. Our experimental manipulations allowed us to determine if the pattern and amplitude of biologically meaningful moisture fluctuations influence fitness-related traits of hatchlings. A release-recapture experiment in the field allowed us to explore post-hatching survival under natural conditions. In general, we detected minimal effects of moisture fluctuations during incubation on egg survival, initial hatchling phenotypes, and post-hatching survival. Initial growth rates of hatchlings, however, increased in treatments with fluctuating moisture conditions resulting in larger hatchlings after 4 weeks. These increased initial growth rates likely indicate slower yolk metabolism during embryogenesis in fluctuating treatments. Our results suggest that eggs of *S. undulatus* are extremely efficient at absorbing moisture from the surrounding environment and are resilient to short-term exposure to potentially lethal moisture conditions.

13.11

ROBERTS, T.J., GABALDON, A.M.; Thomas_Roberts@Brown.edu. Brown University, Colorado State, Pueblo
DOES RATE OF FORCE PRODUCTION INCREASE WITH RUNNING SPEED IN INDIVIDUAL MUSCLES?

It has been proposed that increases in metabolic energy cost of running with speed are explained by the higher rates of energy consumption in muscle fibers that produce force more rapidly. This idea is supported by a close correlation between metabolic energy cost and duration of stance force, as measured by the time of foot contact in each step. However, a direct correlation between the intrinsic speed of recruited muscle fibers and time of foot contact has not been demonstrated. We measured force production in the wild turkey lateral gastrocnemius to test for a correlation between foot contact time and rate of force development. Muscle force was measured by strain gages attached to bony tendons. We quantified the rate of force development as the time from start of force to 50% of peak force output ($t_{50\%P}$). *In vitro* experiments have demonstrated that this value correlates with unloaded maximum shortening velocity, V_{max} , and it may therefore be an indicator of fiber types recruited *in vivo*. We hypothesized that the $t_{50\%P}$ would decrease with running speed, in proportion to the decrease in foot contact time. This hypothesis was not supported. Foot contact time decreased by approximately 50% across the measured speed range, from 37 ± 0.3 s at 1 m/s to 18 ± 0.3 s at 3.5 m/s, while $t_{50\%P}$ was independent of speed (0.14 ± 0.004 s at 1 m/s and 0.12 ± 0.004 s at 3.5 m/s, mean \pm s.d.). If our measure of rate of force development is a reliable indicator of the speed of recruited fibers, these results suggest that the correlation between foot contact time and recruited fiber type may not always hold within individual muscles. Supported by NIH grant AR46499.

8.4

ROBERTSON, B.; bruce.robertson@mso.umt.edu. University of Montana
A FRAMEWORK FOR UNDERSTANDING ECOLOGICAL TRAPS AND AN EVALUATION OF EXISTING EVIDENCE

When an animal settles preferentially in a habitat within which it does poorly relative to other available habitats, it is said to have been caught in an ecological trap. Although the theoretical possibility that animals may be so trapped is widely recognized, the absence of a clear mechanistic understanding of what constitutes a trap means that much of the literature cited as support for the idea may be weak at best. Here, we develop a conceptual model to explain how an ecological trap might work, outline the specific criteria that are necessary for demonstrating the existence of an ecological trap, and provide tools for researchers to use in detecting ecological traps. We then review the existing literature and summarize the state of empirical evidence for the existence of traps. Our conceptual model suggests that there are two basic kinds of ecological traps and three mechanisms by which traps may be created. To this point in time, there are still only a few solid empirical examples of ecological traps in the published literature, although those examples suggest that both types of traps and all three of the predicted mechanisms do exist in nature. Therefore, ecological traps are either rare in nature, are difficult to detect, or both. An improved library of empirical studies will be essential if we are to develop a more synthetic understanding of the mechanisms that can trigger maladaptive behavior in general and the specific conditions under which ecological traps might occur.

51.1

RODRIGUEZ-LANETTY, M., WEIS, V.M., PHILLIPS, W.S.; rodrigm@science.oregonstate.edu. Oregon State University
TRANSCRIPTOME ANALYSIS OF A CNIDARIAN DINOFLAGELLATE MUTUALISM REVEALS COMPLEX MODULATION OF HOST GENE EXPRESSION

Cnidarian dinoflagellate endosymbioses are one of the most important mutualisms in the marine environment. They form the trophic and structural foundation of coral reef ecosystems. Despite the prevalence of these symbioses, we still know very little about the cellular and molecular basis of the symbiosis. Through a comparative transcriptome analysis, we detected statistically significant differences in host gene expression profiles between sea anemones in a symbiotic and non-symbiotic state. The group of genes whose expression is altered is diverse, suggesting that the molecular regulation of the symbiosis is governed by changes in multiple cellular processes. Our data do not support the existence of symbiosis-specific genes involved in controlling and regulating the symbiosis. Instead, it appears that the symbiosis is maintained by altering expression of existing genes involved in vital cellular processes. In the context of cnidarian dinoflagellate symbioses, we discuss pivotal host gene expression changes involved in lipid metabolism, cell adhesion, cell proliferation, apoptosis, and oxidative stress. Specifically, the finding of key genes involved in cell cycle progression and apoptosis have led us to hypothesize that a suppression of apoptosis, together with a deregulation of the host cell cycle, create a platform that might be necessary for symbiont and/or symbiont-containing host cell survival. This first comprehensive molecular examination of the cnidarian dinoflagellate associations provides critical insight into the maintenance and regulation of the symbiosis.

18.2

ROLIAN, C.; rolian@fas.harvard.edu. Harvard University
COMPARATIVE GROWTH PLATE KINETICS IN RODENTS: INSIGHTS INTO THE EVOLUTION AND DEVELOPMENT OF LIMB LENGTH ALLOMETRY

The primate appendicular skeleton shows significant diversity in the proportions of fore- and hindlimbs. Humans have proportionately longer hindlimbs (intermembral index = 0.70), quadrupeds have limbs approximately equal in length (IMI=0.95), and brachiating apes have the longest relative forelimb length (IMI >1.20). These differences are thought to have evolved in response to selective pressures relating to the energetics and biomechanics of locomotion. However, the developmental mechanisms that selection acts upon to generate these interspecific differences have been poorly studied. For example, differences may be due to changes in rates affecting endochondral bone growth, or they may result from variation in the cellular properties of physal growth plates, such as the size and number of proliferative and hypertrophic chondrocytes. Here I present a rodent model to address these hypotheses, using cross-sectional ontogenetic series of two species, the house mouse (*Mus musculus*, n=14, IMI=0.73) and Mongolian gerbil (*Meriones unguiculatus*, n=16, IMI=0.63). In each individual, left limbs were used to determine bone growth rates; and right limbs were thin-sectioned for analysis of cellular properties in the growth plates of the proximal humerus, distal radius, distal femur, and tibia. Results indicate that differences in rates of chondrocyte proliferation are significantly correlated with interspecific differences in bone growth rates and interlimb proportions. Cellular properties of the growth plates do not contribute significantly to differences in growth or limb proportions between species or ontogenetic stages. These findings are discussed in the context of the developmental genetics and evolution of primate limb proportions.

41.4

ROSS, C.F.; rossc@uchicago.edu. University of Chicago
HOW DO PRIMATES CHEW HARDER?

Mammalian mastication is a rhythmic activity used to break down foods with a variety of material properties. How do mammals chew harder foods? Do they chew faster or slower? How do they modulate bite force? Corpus bone strain data were collected from seven species of primates (four anthropoids and three strepsirrhines) during mastication of a variety of foods. Chewing frequency, power stroke duration, strain magnitude and strain rate were calculated and the relationships between them were assessed. Chewing frequency did not vary consistently with food type, strain magnitude or strain rate. Strain magnitude varies as a function of strain rate. Chewing duty factor (percentage of cycle time taken up by power stroke) increases with chew frequency, but absolute power stroke duration does not vary with chew frequency. These data suggest that primates chew at species-specific frequencies governed largely by size, although there is variation. Increases in chewing frequency within a species are achieved by reducing the amount of time in opening and closing, while keeping power stroke duration relatively constant. Increases in corpus strain, i.e., bite force are achieved by increasing the rate at which bite force is exerted. These data suggest that the masticatory central pattern generator maintains a relatively constant chewing frequency and that bite force must be modulated within this framework by increasing the rate at which force is exerted. The strepsirrhines in this study were provided by the Duke University Primate Center.

66.4

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VARIATION IN SEAL CONSUMPTION BY BROWN HYENAS IN THE NAMIB DESERT ESTIMATED USING STABLE ISOTOPES

Coastal areas often receive substantial inputs of energy and nutrients from the ocean, and these allochthonous inputs can be important for terrestrial consumers. The Namib desert is a hyper-arid desert with very low primary productivity, but the highly productive ocean along the coast of southwestern Africa supports large, permanent colonies of seabirds and seals that can be an important food source for terrestrial consumers. We used stable isotope analysis to reconstruct the diet of brown hyenas (*Hyaena brunnea*) along the coast of the Namib desert, where the primary prey available are Cape fur seals (*Arctocephalus pusillus*). Stable-nitrogen and carbon isotope ratios of hyena hair were compared with samples collected from seals and other prey species. Hyena diets were influenced by proximity to seal colonies, with decreasing stable-nitrogen and carbon isotope ratios as distance from colonies and from the ocean increased. Age class also affected diet, with older hyenas consuming a greater proportion of marine-based foods. Since desert soils are so nutrient-poor, the nutrient additions from allochthonous marine inputs transported by brown hyenas could be an important resource for the desert ecosystem.

16.4

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GENETIC ANALYSIS OF THE INTERSECTION BETWEEN ECDYSONE AND INTRACELLULAR SIGNALING DURING *DROSOPHILA* LEG AND WING MORPHOGENESIS

Epithelial morphogenesis is a critical process in the metamorphosis of holometabolism insects, and the product of coordinated endocrine, paracrine, and intracellular signaling events. Our work, and the work of others, has revealed an intersection between the systemic steroid hormone 20-hydroxy ecdysone (ecdysone), and the intracellular RhoA signaling pathway in the developing leg and wing imaginal discs of *Drosophila melanogaster*. Imaginal discs are composed of single cell-thick epithelia that undergo extensive reconfigurations to form rudimentary adult organs at the onset of metamorphosis. Ecdysone directs all major post-embryonic developmental transitions in *Drosophila* by inducing concerted, tissue-specific cascades of gene expression. The mechanisms underlying how global ecdysone signaling induces tissue-specific responses are not well understood. RhoA is a highly-conserved intracellular regulator of changes in the cytoskeleton, transcription, cell growth, cell shape, and cell division at all stages of development. The ecdysone-inducible Stubble locus encodes a type II transmembrane serine protease that appears to link the ecdysone and RhoA pathways in leg and wing imaginal discs. Strong Stubble mutant alleles produce severe leg and wing malformations when homozygous or combined with mutant alleles of activators in the RhoA signaling pathway. We demonstrate that mutant alleles of known negative regulators of RhoA reduce the frequency and severity of malformations seen in RhoA/Stubble double mutants. Our data suggest that the Stubble gene functions as an ecdysone-induced trigger of intracellular RhoA signaling during the process of imaginal disc morphogenesis. This provides a model of how a global hormone signal can act through a ubiquitous intracellular signaling pathway to elicit appropriate tissue-specific responses.

3.1

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EFFECTS OF HIGH ALTITUDE DEVELOPMENT AND COLD ACCLIMATION ON SUMMIT METABOLISM AND ORGAN MASS IN THE DEER MOUSE, *PEROMYSCUS MANICULATUS*

A key to understanding putatively adaptive changes in metabolic rate is identifying causative changes in organ or organ system mass. Changes in summit metabolism (maximum oxygen consumption induced by cold; VO_{2sum}) that result from cold acclimation have been well documented, and seem intuitively adaptive in cold habitats. However, little attention has been paid to changes in organ mass (other than brown adipose tissue, BAT) that result from cold acclimation. In several vertebrates *in utero* development in a hypoxic environment (e.g. high altitude, HA) can alter organ growth and hence metabolic rate. To examine if visceral organ mass is correlated with VO_{2sum} and whether development at HA affects VO_{2sum} after subsequent acclimation to low altitude (LA), we studied three groups of deer mice, *Peromyscus maniculatus*: one born at LA (380 m) and two born at HA (3800 m) and acclimated to 380 m for several months. One group of HA-born mice was acclimated to 5°C for 8 weeks; control mice were housed at 23°C. After 8 weeks, VO_{2sum} was determined and each mouse was dissected. We used previously collected VO_{2sum} data from LA-born, cold-acclimated mice as a comparison. VO_{2sum} was 12-43% higher in cold-acclimated mice than controls, but was not affected by birth altitude ($p < 0.05$). VO_{2sum} was 28% higher in HA-born control mice than LA-born mice ($p < 0.05$). No organ mass was correlated with VO_{2sum} except testicle mass in cold-acclimated, HA-born males ($r^2 = 0.98$, $p = 0.02$). We can conclude that site of development influences metabolism to some degree and that no organ or organ system mass, other than BAT, appears to be strongly involved in regulating acclimatory changes in summit metabolism.

48.4

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EVOLUTION OF PHARYNGEAL GILL BARS IN THE DEUTEROSTOMES

Vertebrate pharyngeal gills contain structural elements that are cartilages elaborated from neural crest cells. The invertebrate chordate group, the Cephalochordates, also have pharyngeal gills containing structural elements, although the origin of these structures are not known. The other major invertebrate chordate group, the Tunicata, also have pharyngeal gills, but they do not have major structural elements within them. The chordates mentioned above are part of a larger monophyletic group, the Deuterostomes, which is a group that also contains the sister taxa echinoderms and hemichordates. The hemichordates, like their chordate relatives, also have pharyngeal gills supported by structural elements, very similar in shape and structure to those of cephalochordates. Since hemichordates and chordates possess pharyngeal gills, it is likely that the deuterostome ancestor also possessed pharyngeal gills and that these structures were later lost in echinoderms. We are investigating the structure and development of hemichordate gill bars and comparing them with cephalochordate and vertebrate gill bars. This study shows that the pharyngeal cartilage of hemichordates and cephalochordates are composed of fibrillar collagen and sulfated proteoglycans, similar to vertebrate pharyngeal cartilages. However, unlike vertebrate pharyngeal cartilage, hemichordate and cephalochordate pharyngeal cartilage is acellular and secreted from endodermally derived epithelia, as an extra-thickened basal lamina. This type of pharyngeal cartilage is likely the ancestral mode of constructing pharyngeal cartilage in the deuterostomes. The evolution of neural crest allowed the elaboration of these structures from a new cell population.

73.4

SAMARCO, T.J., TURINGAN, R.G.; tsamarco@fit.edu. Florida Institute of Technology

INTRASPECIFIC VARIATION IN SCALING OF PREY CAPTURE KINEMATICS IN THE TELEOST FISH, *Sciaenops ocellatus*

Body size influences the ability of an organism to function in its environment. Previous studies involving a wide range of body size of fishes revealed that feeding kinematics exhibit a constant scaling pattern through ontogeny. Here we present the first empirical analysis of variation in scaling coefficients of prey capture kinematics between larval and juvenile stages of a teleost fish. We recorded prey capture behavior using high speed videography in larval (2-8 mm SL) and juvenile (40-135 mm SL) red drum, *Sciaenops ocellatus*. Films were played back frame by frame to measure linear excursions (e.g., gape, hyoid depression, and premaxillary protrusion) from key feeding structures. Times to reach peak values of these kinematic variables were also recorded. All kinematic variables were \log_{10} transformed and plotted against \log_{10} transformed standard length of fish. Maximum gape, hyoid depression, premaxillary protrusion, and all timing variables showed major ontogenetic changes due to an increase in fish body size. Our analyses revealed two scaling patterns of prey capture kinematics; one for larval fish and one for juvenile conspecifics. Larval fish had shorter timing durations than expected based on the scaling patterns of juvenile fish. These results suggest that fishes undergo a major change in the nature of the relationship between prey capture kinematics and the physical environment from the larval to the juvenile stages of their life history.

37.3

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THE DYNAMICS OF UPPER RESPIRATORY TRACT DISEASE (URTD) IN MOJAVE POPULATIONS OF THE DESERT TORTOISE

Upper respiratory tract disease (URTD) has been identified as a possible cause for declines in densities of some populations of the Mojave desert tortoise (*Gopherus agassizii*). Samples of blood serum taken over the geographic range of the Mojave desert were analyzed to determine the presence of *Mycoplasma agassizii*, an established causative agent of URTD. To gain a deeper understanding of the epidemiology of this disease, a number of hypotheses must be considered in light of these new data: (H1) *M. agassizii* is an opportunistic pathogen which mainly causes outbreaks of disease when individual tortoises experience stress due to a variety of environmental factors, including anthropogenic disturbance, changes in diet, prolonged drought, frequent aggressive social interactions, etc. (H2) *M. agassizii* is an opportunistic pathogen which mainly causes outbreaks of disease in combination with the presence of other pathogens. (H3) *M. agassizii* has strains with a range of virulences, and outbreaks of disease are caused mainly by more virulent strains. These may have been introduced into populations by captive tortoises, evolve in denser populations due to higher transmission rates, or evolve in certain populations by chance. Virulence may also be context-dependent, if host populations display a range of inherent susceptibilities to URTD. (H4) The presence of *M. agassizii* alone is sufficient to cause disease in populations of desert tortoises. Although our current understanding of the range wide pattern of *M. agassizii* infection in tortoise populations lends support to some of these hypotheses, additional field data as well as controlled experiments are needed to distinguish accurately among these possible mechanisms of the epidemiology of URTD.

73.5

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EVALUATING THE IMPORTANCE OF NEW STRUCTURES VERSUS NEW MUSCLE ACTIVITY PATTERNS IN THE EVOLUTION OF A NOVEL FEEDING MECHANISM IN SALMONID FISHES

Understanding how new functions evolve within the framework of a tightly integrated system has been one of the greatest challenges to evolutionary biology. Yet new functions are one of the most important mechanisms by which organisms can expand their potential niche and increase the likelihood of survival. Clearly identifiable examples are rare in which both the anatomical structures and muscle activation patterns have lead to new functions. The feeding mechanism of salmonid fishes represents an excellent case study in which to approach these issues in an integrative way. Salmonids possess a modified anterior hyoid, the tongue bite that consists of an impressive set of teeth on the surface of the bony tongue and an opposing set of teeth on the roof of the mouth. I will present the results of a kinematic and electromyographic study of feeding in the rainbow trout, *Oncorhynchus mykiss*. This tongue-bite system is used in a novel feeding behavior termed raking that is used to shred and disable prey following capture, and is distinct from other feeding behaviors analyzed. It is notable that when compared to the strike, differences in muscle activity pattern associated with this new raking behavior are relatively minor, primarily involving the jaw closing adductor mandibulae muscle. These minor changes have resulted in an entirely new feeding behavior that I predict have increased the feeding success of these fishes.

S7-1.5

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APPLYING THE CONCEPT OF METAMORPHOSIS TO THE CRUSTOSE-TO-ERECT THALLUS TRANSITION OF MACROALGAE

Metamorphosis is broadly defined as a more or less radical morphological change between two multicellular life stages within an organism life phase, often marking the transition from pre-reproductive to reproductive stages. It involves structural re-organization and major physiological changes, generally under the control of endogenous and exogenous factors, often resulting in changes in habitat use. This concept has been applied to the crustose-to-erect thallus (hereafter CET) transition of some red algae and this study evaluates the tenability of such hypothesis. In contrast to the metamorphosis of some invertebrates, the CET transition of red algae does not involve radical morphological changes nor complete morphological remodeling; it may be restricted to only one of the two life phases in species with alternation of generations and often involves only slight microhabitat changes. On the other hand, the CET transition may separate pre- and reproductive stages, the onset of the morphological change (e.g. axis differentiation) appears regulated by endogenous signals (growth factors) and the axial growth is affected by genetic and environmental factors. Furthermore, equivalent processes exist in green and brown algal species and paleontological data on taxa with reliable fossil records (e.g. coralline algae) suggest a later evolutionary origin for erect axes from species previously conformed only by crustose morphologies. Thus, the CET transition of red algae partially approaches the broader concept of metamorphosis, it is taxonomically widespread, within each group it seems to be evolutionary derived and it allows separation of functions within the plant, the crustose base holding the often limiting substratum and erect axes maximizing propagule production and dispersal.

24.1

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WAS THE FISH SPECIFIC GENOME DUPLICATION THE CAUSE OF THE HIGH DIVERSITY OF TELEOST FISHES?

During the past few years a number of genomic studies have corroborated the idea that a duplication of the entire genome happened in the ancestor of teleost fishes. Comparing the high species diversity as a whole of the teleostean clade when compared to the pre-teleostean actinopterygian lineages (approx. 25000 teleost species, versus a few dozen actinopterygian species), several authors have claimed that the high diversity of teleost fishes is due to this fish-specific genome duplication, even though no causal mechanism for this has ever been proposed. These claims, however, do not take into consideration many recent and even not-so-recent advances in phylogenetic and paleontological studies of actinopterygian fishes. In fact, as I will show, 1) most pre-teleostean lineages have in the past been much more species-rich than they are now; 2) most teleostean diversity is found within two clades that originated at least 100 million years after the fish-specific genome duplication; 3) the origin of both these clades likely coincides with the invasion of new environments; and 4) the diversification of these lineages was probably mostly due to ecological factors, such as the availability of new food sources (i.e., after the evolution of herbivory). While the fish-specific genome duplication may have provided the genetic basis that allowed the diversification of teleost fishes to occur, possibly through the development of preadaptive morphological or physiological features, there is as yet no evidence that the fish-specific genome duplication was the cause of such diversification.

S3-1.1

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CHANGING LOCOMOTORY SPEED IN A MOLLUSK: FROM NEURONS TO MECHANICS

The change from slow to fast swimming in the pteropod mollusk *Clione limacina* has been described at the circuit and cellular levels. Thus far, we can relate neuronal activity to increases in locomotor system cycle frequency and appendage muscle force both for increases in muscular force within slow swimming and in the change from slow to fast swimming. We are coupling our electrophysiological analyses with kinematic analyses of wing movements for slow and fast swimming, and with new investigations into mechanisms of modifying wing stiffness, to provide a bridge between neuronal and mechanical aspects of locomotory speed changes.

72.8

SCALES, J.A., BUTLER, M.A.; jscales2@utk.edu. University of Tennessee
FORCE PRODUCTION DURING ACCELERATION IN GRAVID IGUANAS

Many animals carry high reproductive loads, yet must maintain locomotor performance despite this burden. One aspect of locomotor performance that is considered important to fitness is acceleration. Green iguanas (*Iguana iguana*) are burst locomotors, carry a high reproductive load, and still are able to match the acceleration of normal iguanas. How do they do this? We compare the force production of individual hind and fore limbs during acceleration in gravid, early post-gravid and recovered green iguanas. Iguanas were induced to run down a 6 m trackway, and video and force measurements were recorded from individual footfalls as iguanas accelerated over a force plate. These data will be used to test whether iguanas are generating more braking forces when gravid, whether force production can be matched to mass gain during gestation, or iguanas may be generating force more economically by adjusting limb posture to align with ground forces.

55.3

SCHAEFER, J.T., KOOB, T.J., LONG, JR., J.H.; jschaefer@uci.edu. University of California, Irvine, Shriners Hospital for Children, Tampa, Vassar College

BENDING MECHANICS OF ELASMOBRANCH VERTEBRAL COLUMNS

The waveform of sinusoidally swimming elasmobranchs depends, in part, on the flexural stiffness of the body, which in turn is presumed to be a function of the material and structural properties of the axial skeleton. We use dynamic three-point bending tests at biologically relevant amplitudes and frequencies to measure the mechanical properties of vertebral columns from three species (*Sphyrna tiburo*, *Carcharinus plumbeus*, *Rhinoptera bonasus*). Two of these species (*S. tiburo*, *C. plumbeus*) swim in an axially-undulatory manner while *R. bonasus* uses pectoral fin oscillations for propulsion. Vertebral morphology varied in length/diameter aspect ratio and amphicoel volume. Stiffnesses were similar between species and through the length of the column, except in *R. bonasus*. Shear rate had little effect on stiffness of the column. As bending amplitude increased, there was a disproportional increase in force required to bend the column. This was inferred to be the point at which the intervertebral ligaments dominated beam stiffness. This project is supported by NSF grant DBI-0442269.

75.5

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BIOMIMETIC VERTEBRAL COLUMNS OF VARIABLE STRUCTURE AND MECHANICAL PROPERTIES

In order to analyze the mechanical design of vertebral columns (VCs), we built artificial VCs that mimic aspects of the morphology and mechanics of the VC of elasmobranchs. Specifically, we varied two properties of the biomimetic VCs: (1) degree of concavity of the amphicoelous vertebral centra and (2) the shear strength of the intervertebral connective tissues. We determined the biomimetic VCs dynamic mechanical properties in lateral bending, using a three-point bending machine operating over a range of physiologic curvatures and frequencies. Both amphicoel geometry and stiffness of the intervertebral gel affect the flexural stiffness of the biomimetic VC; those with higher shear strength gels bend more like a traditional beam. The magnitude of the stiffening effect of amphicoel morphology is attenuated by higher stiffness intervertebral gels. We then compare the effects of these changes to known structural parameters of extant elasmobranch vertebral columns. This project is supported by NSF grant DBI-0442269.

S2-2.3

SCHILLING, T.F.; tschilli@uci.edu. University of California, Irvine
CRANIOFACIAL DEVELOPMENT AND EVOLUTION IN GNATHOSTOMES

The skull and jaws were key innovations in vertebrate evolution. Much of this skeleton has a unique embryonic origin from cranial neural crest cells, unlike the more posterior axial and appendicular skeletons which are derived from mesoderm. How does the embryonic origin of a skeletal element, versus the environment in which it differentiates, determine its morphology and function? Our lab is taking a genetic approach to these issues in zebrafish, and comparing the results with embryos of agnathans and other gnathostomes to identify conserved and divergent genetic pathways. AP-2 transcription factors are required for development of the pharyngeal skeleton, and our analyses of AP2-deficient zebrafish has revealed multiple roles for these factors in early neural crest development. Many of the skeletal defects in embryos lacking a functional AP-2 alpha (*tfap2a*) are due to intrinsic requirements within neural crest cells themselves, and we have identified a novel target of *tfap2a* called *inca* (induced in neural crest by AP-2) that regulates neural crest morphogenesis. In contrast, *tfap2b* (mutated in some forms of Char syndrome in humans) is required for skeletogenesis but is not expressed in neural crest, only in the epidermis. Epidermal grafts from wild-type donors rescue skeletal development in *tfap2b*-deficient animals, illustrating the important role that the epidermis plays in modulating skeletogenesis. We have recently shown that the formation of distinct joints between apposing skeletal elements in the jaw also depends on signals from the overlying epidermis. All vertebrate embryos show similar patterns of early neural crest migration, suggesting that differences between species result from dramatic differences in later events such as shifts in the localization and interpretation of signals from adjacent epithelia.

67.6

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THE GENETIC POPULATION STRUCTURE OF CARIBBEAN POPULATIONS OF THE BANDED CORAL SHRIMP *STENOPUS HISPIDUS*

The extreme biphasic life-history of the red banded coral shrimp *Stenopus hispidus* presents an opportunity to examine the population genetics of an evolutionarily successful, circumtropical lineage. Patterns of DNA polymorphism in *S. hispidus* from populations in Puerto Rico, Belize, and Panama have been investigated. Gene flow analysis of three mitochondrial genes (Cytochrome b, Cytochrome c Oxidase Subunit I, and 12sRNA) suggests a single, cohesive, Caribbean-wide population. Interestingly, an excess of rare mutations was detected. Excessive numbers of new mutations suggest specific scenarios consistent with patterns of genetic variation expected from an expanding, or recently expanded, population.

46.5

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OVERLAPPING AND DISTINCT FUNCTIONS OF THE DUPLICATED ZEBRAFISH INSULIN-LIKE GROWTH FACTOR-1 RECEPTOR (IGF-1R) GENES IN EARLY DEVELOPMENT

The process of gene duplication is a major contributor to the genetic diversity of vertebrate genomes, and the driving force behind a complicated process of functional gene evolution, involving both the acquisition of new functions and the rearrangement of ancestral functions. Deciphering whether a pair of duplicated genes have acquired new functions, or subdivided their ancestral functions, is an important but challenging question. Among vertebrates, the zebrafish is well suited for investigations into this question because of its versatility, and because it possess a large number of duplicated genes. Previous studies have shown that there are two structurally distinct and functional insulin-like growth factor 1 receptor (*igf1r*) genes in zebrafish, in contrast to the presence of a single *IGF1R* gene in mammals. *IGF1R*-mediated signaling is an evolutionarily ancient signaling pathway that plays fundamental roles in regulating growth, development, metabolism, and longevity. In this study, we tested the hypothesis that gene duplication has led to the functional divergence of zebrafish *igf1ra* and *igf1rb* in development using a MO-based loss-of-function approach. Our results indicated that *igf1ra* and *igf1rb* are not redundant genes, as both are essential for zebrafish viability and somatic growth and development. Although *Igf1ra* and *Igf1rb* demonstrated a large degree of functional overlap with regard to cell differentiation and survival in the eye, inner ear, and heart, they also demonstrated functional distinction involving a greater requirement for *Igf1rb* in spontaneous muscle contractility and motoneuron axon formation. These findings provide novel insights into the functional evolution of the *IGF1R*/insulin receptor gene family.

4.4

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DEVELOPMENTAL PLASTICITY VS. PHYLOTYPIC CONSTRAINTS DURING EARLY EMBRYOGENESIS OF ZEBRA FISH, *DANIO RERIO*

During the phylotypic stage vertebrate embryos pass through a period of morphological similarity. In zebra fish, *Danio rerio*, multiple correlations among characters stabilize morphology during the phylotypic stage, but a considerable degree of phenotypic variability can still be observed (coefficient of variation for morphometric measurements > 4 %). Here, we studied zebra fish embryogenesis under different experimental conditions to see if besides the morphological similarity, developmental plasticity is limited during the early developmental period. Eggs of zebra fish were raised at different temperatures (24°C, 27°C, 30°C) and different salinities (10mosmol/200mosmol). The size development of the maximum diameter of the eye, the length of the embryo, the size of somites, the inclination of somites, the size of otic vesicle, the maximum diameter of the yolk sac of individual embryos were documented at 12, 15, 18 and 24 hours post fertilization. Embryos grew faster at higher temperatures, but were smaller in overall size and somite size at the same developmental stage. The size of eye, otic vesicle, and the inclination of somites were not affected by temperature or salinity. Only the yolk sac decreased in higher salinity. This effect can most likely be associated with the reduced osmotic pressure. Analysis of variance (one-way ANOVA) showed that internal constraints are effective for most of the observed characters. Limited plasticity was only detected in the overall size of the embryo and the somites, but not in other organs. We conclude that developmental plasticity is also reduced during the phylotypic stage.

57.9

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THE EFFECT OF INTERTIDAL THERMAL ENVIRONMENTS ON SURVIVAL AND GROWTH: A COMPARISON BETWEEN AN INVASIVE AND NATIVE MUSSEL SPECIES

The harsh and dynamic conditions of the rocky intertidal zone present an excellent system to examine how physiological constraints may contribute to species distribution patterns. Here, we use two mussel species, *Mytilus galloprovincialis* and *M. trossulus*, to address the role that both aerial and emersion temperature plays in such patterns. On the west coast of the United States, *M. galloprovincialis* was introduced ~100 years ago into Southern California replacing the endemic mussel, *M. trossulus*, they currently overlap in distribution in Central California. Laboratory experiments were completed under simulated intertidal conditions in both 18°C and 12°C water. Within each water temperature regime, four aerial exposure treatments were constructed including hot, warm, cool and no aerial (i.e. subtidal) exposure. In 18°C water survival was low for *M. trossulus* and high for *M. galloprovincialis* regardless of aerial exposure treatment. In contrast, aerial exposure affected survival of both species in 12°C water, although survival rates were lower for *M. trossulus* than *M. galloprovincialis*. This effect was only seen in mussels collected during the winter and was not observed in summer collected mussels. Additionally, growth was negatively affected by aerial exposure in both mussel species. Growth was higher in *M. galloprovincialis* than *M. trossulus*. Data indicate that *M. galloprovincialis* survival and growth are higher in all conditions tested when compared to *M. trossulus*. This may be a significant explanation for why this species has successfully invaded several locations around the world.

22.1

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TIMING OF REPRODUCTION AND FOOD SUPPLEMENTATION: ARE HIGH LATITUDE SPECIES LESS RESPONSIVE THAN LOW LATITUDE SPECIES TO NON-PHOTIC CUES?

Food supplementation usually advances the timing of egg laying in birds. A meta-analysis of 34 food supplementation studies suggests that high latitude species are less responsive to food supplementation than lower latitude species. As the length of the breeding season varies with latitude, it may be that species at high latitudes with a short season rely largely upon photic cues. In contrast, lower latitudes have a longer suitable period at which breeding can occur and this may lead species to be more responsive to supplementary cues, thus assuring suitable conditions for rearing young. Studies by Wingfield et al. (1996, 1997, 2003) suggest a physiological underpinning to this reduced responsiveness to supplementary cues in high latitude species. Given 1) temperature increases resulting from global climate change are most pronounced at high latitude and 2) the apparent reduced plasticity to respond to these changes in high latitude species, one might predict that these species will have difficulty synchronizing reproduction with a resource base that will emerge earlier than usual. Should global climate change advance the time when the critical resources for the rearing of young are available, high latitude species may not have the plasticity to adapt to the change in the time when conditions are optimal for breeding. As Visser et al. (1998) note in their studies of breeding of great tits, decoupling of resources and breeding may be in part because the sites from which birds migrate do not reflect the environmental changes that have occurred on the breeding grounds. Even if they could respond to the earlier emergence of resources, they might not arrive from overwinter sites early enough to take advantage of the earlier resource availability.

47.2

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MOLECULAR AND MORPHOLOGICAL EVOLUTION IN SIPUNCULAN WORMS

Sipuncula are not only a key group in protostome evolution but they are also used as bio-indicators for marine pollution and as model systems in physiological studies. A stable phylogenetic framework is necessary to interpret results of these studies in an evolutionary context. Here we present our findings on the intra-phyletic relationships of the Sipuncula. Our analyses are based on four gene regions as well as 58 morphological characters. We sequenced the complete gene for 18S rRNA and obtained partial sequences for 28S rRNA, Histone H3 and the mitochondrial cytochrome c oxidase subunit I. The datasets were analyzed separately and in combination. First, we analyzed the data under direct optimization with the program POY. Subsequently, we used the implied sequence alignment resulting from the POY analysis and performed an analysis with Bayesian statistics under mixed models for the different data partitions. For the stem regions of the 18S rRNA, we applied a doublet model that accounts for correlated substitutions in the complementary strands of the ribosomal molecule. Both analyses support the monophyly of the Sipuncula and most of the same clades within the Sipuncula. They also agree that a clade containing the genera *Sipunculus* and *Xenosiphon* is the sister group to all other Sipuncula. They differ with respect to the relationships among the remaining clades but whereas the deep nodes in the POY analysis generally show jackknife support below 50%, most of the deep nodes in the Bayesian analysis are supported by 100% posterior probability. In conclusion, the direct optimization approach has been extremely useful for handling sequences of unequal length and generating conservative phylogenetic hypotheses. The application of mixed models in the Bayesian analysis greatly improved the resolution in the deep nodes.

35.4

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SEX-SPECIFIC VARIATION IN RINGTAILED LEMUR *LEMUR CATTAL* OLFACTORY COMMUNICATION

Prosimians are unique among primates in their reliance on complex olfactory cues as a primary mode of social signaling. Scent marking may serve to demarcate territories, maintain dominance hierarchies, and advertise reproductive state. Male *Lemur catta* use species-specific brachial, antebrachial, and scrotal glands to scent mark, whereas females employ labial glands. We suggest that different glands convey different types of information. This hypothesis is corroborated by variation in the chemical composition of gland secretions and seasonal variation in gland usage, as revealed by GC/MS and behavioral observation, respectively. To determine if an animal's reproductive and/or dominance status is encoded in, or influences response to, a particular type of secretion, we conducted behavioral choice tests on 8 adults (4 M; 4 F) during the breeding and non-breeding seasons, using odor samples collected in both seasons from all 4 glands (n = 16 unfamiliar donors). Behavioral responses (approach, sniff, lick, and scent mark) to all odors were stronger in males than in females. Males preferentially investigated female odors, but responded differently across glands (e.g. licking labial, sniffing antebrachial, and scent marking brachial odors). The differing patterns of sniffing and licking suggest that volatile and nonvolatile fractions of scent marks convey different information. Males also licked and scent marked odors from dominant donors more so than from subordinates. Conversely, females responded almost exclusively to female odors, and were influenced by their own reproductive state and by that of the scent donor. These data support functional differences between glands, suggesting that scent marking in males serves in intrasexual competition, whereas female marking is a form of reproductive competition and sexual advertisement.

5.4

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SEASONAL AGGRESSION IN FEMALE SIBERIAN HAMSTERS (*PHODOPUS SUNGORUS*)

Most seasonally breeding species demonstrate a suite of adaptations including reproductive regression and increased territorial aggression in short winter-like compared with long summer-like day lengths. For example, male Siberian hamsters (*Phodopus sungorus*) held in a short days (LD 8:16) express heightened levels of territorial aggression independent of gonadal steroid hormones. Similar findings have been reported for both male and female Syrian hamsters. Virtually nothing is known, however, regarding seasonal aggression in female Siberian hamsters. Thus, the present study was undertaken to determine if females, like males, express increased levels of aggression under short-day winter-like conditions. Specifically, females were individually housed in either short- (LD 8:16) or long-day (LD 16:8) photoperiods for 10 weeks. Assessment of aggression was accomplished by placing a long-day-housed female intruder in the home cage of a test animal and recording latency to attack as well as number of attacks. Prior to testing, estrous cycle stage was determined in long-day animals via vaginal cytology and females were tested during both the Diestrus I and Proestrus stages and matched with intruders in the same estrous stage. Short-day animals showed significantly higher levels of aggression than did long-day animals, and estrus stage did not affect aggression in long-day females. These results support previous findings of increased non-breeding aggression and suggest that gonadal steroids do not likely mediate short-day aggression. Collectively, these results suggest that endocrine regulation of seasonal aggression may be similar between the sexes.

53.4

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TIMING OF FLEDGING, BODY CONDITION, AND CORTICOSTEROID BINDING GLOBULIN IN LAYSAN ALBATROSS

Fledging is a major life transition for birds, moving from the safety of a nest into an environment where they must find food and avoid predators. Timing of fledging can have significant effects on future survival and breeding success. Previous studies in several species have shown elevated plasma corticosterone (CORT) in the days before fledging, though the reason for this increase is not clear. Laysan Albatross *Phoebastria immutabilis* chicks have an extended post-hatching period of 165 days where they peak at a mass of 1 1/2 times the weight of an adult. However, as they approach fledging, chicks fast for days to weeks between feedings and drop significantly in mass while still putting energy into feather growth. We are currently investigating the interaction of several physiological and morphological factors influencing fledging. Initial results show that CORT increases as chicks approach fledging. Additionally, corticosteroid binding globulin (CBG) declines significantly before fledging. We found that binding protein levels are positively correlated with body condition as chicks fast longer and lose weight, their CBG levels fall. To test this relationship, we supplementally fed chicks for four weeks before fledging. Fed birds did not decrease in body condition, did not have the correlated decrease in CBG, and delayed fledging for an average of 9 days. Our study suggests that deteriorating body condition in fasting albatross chicks causes a decrease in CBG which, paired with an increase in CORT and a suitable level of wing development, prompts the chicks to fledge.

9.2

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HEART POSITION IN SNAKES, ONTOGENETIC SHIFTS AND
CORRELATION WITH OTHER ORGANS

It has been hypothesized for snakes that heart position is adaptively linked to habitat. From aquatic to terrestrial to arboreal habitats as snakes are more often vertically oriented, there is an increase tendency for their hearts to be positioned closer to the head. With a more anterior-positioned heart, adequate circulation can be maintained to the head when the body is positioned upright. Given the attention directed at the generality of this feature over a wide diversity of snake species, it has not been asked whether relative heart position varies ontogenetically or is linked to the position of other organs. For the semi-aquatic diamondback water snake (*Nerodia rhombifer*), the terrestrial sidewinder (*Crotalus cerastes*) and the semi-arboreal Burmese python (*Python molurus*), I measured the position of internal organs of neonate to adult individuals spanning respective 260-, 40-, and 600-fold range in body mass. For these snakes, the heart on average was positioned 19.5%, 38.0%, and 23.5% of snout-vent length from the snout, respectively. Each species exhibited a significant decrease in the relative position of the heart with body size, the shift equaling as much as 6% of SVL. Heart position was linked to the position of other organs intra- and interspecifically. Individual snakes whose hearts were positioned anterior or distal to a predicted location tended to have other organs positioned accordingly. Among three species, the more distal the heart is located, the further back are positioned the other organs, with a decrease in the distance relative to SVL between the heart and those organs.

23.6

SEPULVEDA, C.A., GRAHAM, J.B., BERNAL, D.; chugey@pier.org. Pflieger Institute of Environmental Research, Scripps Institution of Oceanography, University of Massachusetts, Dartmouth
SWIMMING PERFORMANCE STUDIES OF THE MAKO SHARK, *ISURUS OXYRINCHUS*

The mako shark, *Isurus oxyrinchus*, is an active epipelagic predator that has been shown to possess several adaptations for a heightened aerobic swimming performance. Although several studies have documented the degree to which the mako shark is specialized for fast, efficient locomotion, few studies have focused on live sharks, and metabolic measurements (indirect calorimetry or respirometry) are limited to only one individual juvenile. The present study used a large swim tunnel respirometer to measure the swimming metabolic rate of juvenile mako sharks under controlled conditions. This work tested the hypothesis that the mako shark has an elevated standard metabolic rate when compared to other active sharks swimming at the same water temperature. Swimming VO_2 and tail beat frequency were measured at $18 \pm 2^\circ\text{C}$ for 9 makos ranging in size from 70 to 95 cm fork length and 4.50 to 8.20 kg. The range of swimming speeds for which makos were tested was from 28 to 50 cm s^{-1} or 0.3 to 0.7 bl s^{-1} , and for all individuals replicate VO_2 measurements were made at each test speed. This paper reports on mako shark swimming metabolic rate, standard metabolic rate, tail beat frequency and for some individuals heart rate.

53.7

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AGE- AND SITE-SPECIFIC DECLINE IN IGF-I RECEPTOR EXPRESSION AND GROWTH PLATE ACTIVITY IN THE MOUSE HINDLIMB

The proximal and distal growth plates of the principal long bones do not contribute equally to their longitudinal growth. Most hindlimb elongation occurs at the knee (distal femur/proximal tibia), while the forelimb grows predominantly at the shoulder (proximal humerus) and wrist (distal radius/ulna). Much diversity in mammalian limb proportions is realized through these differences in local physis growth, but the mechanisms that underlie them remain unclear. We tested the hypothesis that expression of the insulin-like growth factor-I receptor (IGF-IR) is associated with differential growth in the mouse hindlimb. We evaluated IGF-IR expression in proximal/distal growth plates of the femur and tibia from 8, 16, and 28 day old mice using immunohistochemistry. Growth activity was assessed by size/morphology of the growth plate and PCNA staining for proliferation. IGF-IR and PCNA positive cells were counted and standardized as a proportion of the total chondrocytes in each growth plate. Cells expressing the IGF-IR declined considerably with age in the proximal femur and distal tibia (hip and ankle), but maximum expression was maintained in the distal femur and proximal tibia (knee) at all ages. PCNA expression similarly declined with age in the hip and ankle but remained high in the knee. Growth plate size decreased with age in all sites, but the absolute and relative decline in IGF-IR in the hips and ankles of older mice indicated a site-specific loss of IGF-I sensitivity in these less active regions. These results suggest that regulation of the IGF-IR may at least partially mediate differential long bone growth, thereby providing a local mechanism for altering skeletal proportions absent modification of systemic hormone levels.

S8-2.5

SHAFER, T.H.; shafert@uncw.edu. University of North Carolina, Wilmington
EXPRESSED SEQUENCE TAG SEQUENCING TO IDENTIFY GENES INVOLVED IN EXOSKELETON CALCIFICATION IN THE BLUE CRAB

A blue crab (*Callinectes sapidus*) expressed sequence tag project was designed for multiple purposes including the discovery of genes for cuticle proteins regulating calcification. One of the expression libraries sequenced was from hypodermal tissue, the epithelium that deposits the cuticle. The RNA used for cDNA synthesis was pooled from arthrodistal and dorsal hypodermis of both pre-ecdysis (D2) and 3-h postecdysis crabs. This ensured representation from both calcifying and non-calcifying cuticle regions and from cuticle layers deposited both before and after exuviation. The EST data have been mined for cuticle protein sequences. First, we searched for known cuticle-specific motifs, the Rebers-Riddiford chitin-binding sequence and a mineralized-tissue motif described by Andersen. Second, we checked the BLAST annotations and the GO analysis of the entire EST project for evidence of similarity to known (often insect) cuticle proteins. Finally, all crustacean cuticle protein sequences in NCBI were placed into an alignment-based dendrogram resulting in broad similarity groups. Then BLAST was used to search the EST data for significant homologies to each group. In all, the database appears to contain approximately 70 contigs or singlets representing transcripts of cuticle proteins. Forty-five distribute among ten clusters of very similar transcripts, possibly representing alternate splicing or recent gene duplications, while the rest share less similarity. We have obtained complete sequences for about 25 of the transcripts, and we are determining gene expression patterns across the molt cycle in calcifying versus non-calcifying cuticle regions. The combination of homology analysis and gene expression analysis allows us to infer possible functions in cuticle synthesis and calcification.

30.6

SHECHTER, A., YUDKOVSKI, Y., TOM, M., OPHIR, R., CHALIFACASPI, V., CHANG, S.A., CHANG, E.S., SAGI, A.; asafshe@bgu.ac.il. Ben Gurion University of the Negev, Israel, Israel Oceanographic and Limnological Research, University of California, Bodega Marine Laboratory
ECDYSTEROID-AFFECTED GENES IN ENDOCRINOLOGICALLY-INDUCED MOLT CYCLE OF THE CRAYFISH *CHERAX QUADRICARINATUS* THE USE OF A CDNA MICROARRAY

During premolt in arthropods a surge in ecdysteroid levels triggers a programmed gene expression pattern. To elucidate the pivotal role of 20-hydroxyecdysone (20E), initiation of the molting process has been experimentally induced in the crayfish *C. quadricarinatus* by either X-organ-sinus gland (XO-SG) removal or administration of exogenous 20E. A 4700 clone *C. quadricarinatus* cDNA microarray composed of hepatopancreatic transcripts was used during the premolt stage, which was precisely determined through X-ray digital imaging of the gastroliths and ecdysteroid levels. Since both treatments involved ecdysteroid elevation we assumed that genes which are similarly affected by both are suspected to be ecdysteroid triggered. Genes affected exclusively by XO-SG removal are suspected to be triggered by the absence of XO-SG borne neuropeptides. 200 clones showed significant changes in both treatments and were sequenced and annotated. Approximately 100 genes suspected as ecdysteroid-triggered were identified comprising of mostly transport proteins, peptidases and proteins related to chitin and carbohydrate metabolism. 144 clones showing significant changes exclusive to the XO-SG removal treatment were sequenced and annotated. Approximately 90 genes which their expression seems to be related to XO-SG neuropeptides are comprised mostly of integral membrane, nuclear and hypothetical proteins. 20-25% of the genes in both groups showed no similarity to any known genes from the database. This study opens a path for further functional genomic studies of specifically molt induced genes.

2.4

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FORAGING BEHAVIORS OF INSULAR COTTONMOUTH SNAKES

Florida cottonmouth snakes (*Agkistrodon piscivorus conanti*) exhibit significant variation of foraging behavior on a single island at Cedar Keys, Florida. Snakes in this population characteristically remain beneath avian rookeries where colonial nesting birds drop or regurgitate fish that are consumed (by snakes) as carrion. Observations and studies using radio telemetry indicate these snakes move little, having home ranges of 0.18 to 1.72 ha in area. Snakes typically scavenge at night, restricting movements largely to substrate beneath rookeries, but daytime feeding is sometimes observed. Rarely, it appears, snakes at the periphery of the island scavenge at the intertidal zone of beaches where dead fish may be washed ashore by tidal waters. Occasionally, snakes ingest marine debris, including marine plants, presumably due to presence of fish odors. In the laboratory we show that snakes will ingest marine algae that have contacted dead fish. In contrast with snakes at rookeries, snakes on half of the island where bird nesting is absent move over greater distances (e.g., 10.29 ha), feed on rats (*Rattus rattus*), and have lower body condition than snakes at rookeries (mean of 5.2 g/cm *vs.* 10.4 g/cm), presumably owing to lesser concentration of resources. Laboratory studies show that newborn snakes accept a wide range of prey items and do not appear to have innate preferences, similarly to snakes born on the mainland. Thus, insular cottonmouths benefit from resource subsidy brought to the island by nesting birds, and they also employ other foraging strategies when these resources are scarce or absent. Success of these snakes is important to bird rookeries owing to mutualism wherein cottonmouths deter potential avian nest predators.

S5-2.5

SHOOK, D., KELLER, R.; drs6j@virginia.edu. University of Virginia, Charlottesville
EVOLUTION OF VERTEBRATE MESODERM MORPHOGENESIS

The Chordate lineage shows a evolutionary trend from mesoderm internalization by budding off epithelial tubes, as in ascidians and amphioxus, to internalization by ingression, as in the amniotes. Urodele amphibians appear to be an interesting intermediate in this transition, using an epithelial folding mechanism to internalize axial mesoderm and using ingression through a bilateral primitive streak to internalize paraxial mesoderm. Medio-lateral and anterior-posterior mesoderm patterning through the chordates appears to be relatively conserved, as do the fundamental global morphogenic movements: epiboly, internalization, emboly, convergence and extension. What is not conserved is the initial embryonic architecture of the fertilized egg, and the specific cellular mechanisms used to drive mesoderm morphogenesis. Amphibians in particular, probably because of their broad range of reproductive strategies, show diverse embryonic architectures across their class and appear to use a broad range of cellular behaviors, making them an interesting comparative group. How then are conserved patterning mechanisms superimposed on divergent architectures and the cellular mechanisms used for rearranging them? If morphogenesis is a simple consequence of fate, then how has the patterning machinery evolved to accommodate a different starting point, and the use of different cellular mechanisms, to none-the-less wind up at a common end point? Or if morphogenesis is specified (at least somewhat) independently of fate, as at least two examples indicate, at what point in the developmental hierarchy does patterning diverge from morphogenesis? In either case, it appears that morphogenesis is far more labile than patterning.

40.3

SIDLAKUSKAS, B.L.; bls@uchicago.edu. University of Chicago and The Field Museum
UNEQUAL RATES OF MORPHOLOGICAL DIVERSIFICATION IN SISTER CLADES OF CHARACIFORM FISHES

Why have certain groups of organisms diversified greatly in morphology, while closely related groups have not? This study took advantage of a rare natural experiment to determine whether apparent differences in morphological diversity between the Anostomoidea and Curimatoidea, two sister clades of South American fishes with approximately equal species richness, should be taken as evidence that the tempo or mode of evolution has differed between them. Despite identical ages of origin and similar net speciation rates and geographic distributions, the morphological and ecological diversity of the Anostomoidea dwarfs that of the Curimatoidea. I investigated the source of unequal diversification in these fishes by combining simulations of cladogenesis with models of morphological drift in an empirically determined morphospace. Likelihood ratio tests showed with 90% confidence (using variance among species as the measure of morphological diversity) or 99% confidence (using volume of occupied morphospace) that the rate of morphological change per unit time in the Anostomoidea was likely to have been higher than that of the Curimatoidea. Variation in rates of speciation or extinction was not found to be a likely explanation of the observed difference in morphological diversity. Uniquely derived morphological and ecological features of these clades may have accelerated or decelerated the rate of morphological change, such as a marked lengthening of the quadrate that may have relaxed structural constraints on the evolution of the anostomid jaw.

76.2

SIEG, A., O'CONNOR, M.; aes48@drexel.edu. Drexel University
EXPLORING THE POSSIBLE RADIATIVE ORIGINS OF INTER-SPECIFIC METABOLIC ALLOMETRIES

The correlation between body size and a large suite of organismal characteristics has been a subject of much interest in the biological community; and, recently, the scaling of metabolic rate with body size has received renewed attention. The nearly ubiquitous pattern of metabolic allometry in extant organisms lacks a clear general mechanism or set of mechanisms. We examine the potential origin/modification of metabolic allometry via a simulated radiation of competing vertebrate taxa each with life history traits determined by a given allometric exponent. In our simplified model, we examine the outcomes of competition of individual organisms in a bounded homogenous environment with their daily activity, resource allocation rules and aging based on a selected set of metabolic allometries. The simulation consists of carnivorous and herbivorous animals that exhibit predator-prey relationships as well as competition amongst herbivores for available primary productivity. Individual taxa are defined based on body size ranges and allometry, and there are attendant rules within taxa for size at reproductive maturity and cost of growth and reproduction. Each individual makes activity and foraging decisions every fifteen minutes with consequent energy costs and probabilistic energy gains. Each day, energy is allocated amongst competing functions of maintenance metabolism, storage, and growth and reproduction depending on maturity. The animal also ages via an accumulation of free radicals depending on its metabolic rate that concomitantly increases its probability of dying of natural causes at the end of a simulated year. This simulation, carried out over many simulated years, predicts relative advantages for animals with differing metabolic allometries.

53.5

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CHARACTERIZATION OF AN ANCESTRAL TYPE II GnRH RECEPTOR: FUNCTION AND PHARMACOLOGICAL PROFILE OF THE SEA LAMPREY GnRH RECEPTOR

Neuroendocrine regulation of reproduction in vertebrates is regulated by gonadotropin-releasing hormone (GnRH). GnRH acts on gonadotropes located in the anterior pituitary via its receptor, a 7-transmembrane G-protein coupled receptor. The objective of this study was to describe the function and molecular evolution of the GnRH receptor through the characterization of the previously cloned sea lamprey GnRH receptor (Silver et al., 2005). The lamprey GnRH receptor was shown to stimulate both IP and cAMP when treated with either lamprey GnRH-I or -III; however lamprey GnRH-III is a far more potent activator of either system. Competitive binding analysis revealed that lamprey GnRH-III binds to the lamprey GnRH receptor with approximately 100 fold higher affinity compared to lamprey GnRH-I, suggesting lamprey GnRH-III is the native ligand for this receptor. Interestingly, chicken GnRH-II binds the receptor with equal affinity compared to lamprey GnRH-III. Truncation of the lamprey GnRH receptor C-terminal tail resulted in a decrease in second messenger production; however IP signaling was fully recovered by the tail-less mutant. Saturation binding assays using the wild type and mutant lamprey GnRH receptors indicated a decrease in K_d of the tail-less receptor, which is compensated by a significant decrease in ligand dependant internalization, contributing to the recovered signaling capacity. This unique lamprey GnRH receptor, with both high affinity for lamprey GnRH-III and chicken GnRH-II and ligand binding activity in the tail-less form may represent an important ancestral state which provides insight into the function and evolution of the vertebrate GnRH receptor family. (Supported by NSF 0421923 to SAS)

66.2

SINCLAIR, B.J., KLOK, C.J., TERBLANCHE, J.S., SCOTT, M.B., CHOWN, S.L.; celatoblatta@yahoo.co.uk. University Nevada, Las Vegas, Arizona State University, University of Stellenbosch, South Africa, University of Otago, New Zealand, University of Stellenbosch, South Africa
PHYSIOLOGICAL CONSTRAINTS ON THE SMALL-SCALE DISTRIBUTION OF THREE SPECIES OF ANTARCTIC COLLEMBOLA

We investigated the tolerance to cold, heat and desiccation of three species of Collembola, *Isotoma klovstadi*, *Cryptopygus cisantarcticus* (Isotomidae) and *Friesea grisea* (Neanuridae), at Cape Hallett, North Victoria Land, Antarctica. *C. cisantarcticus* was less tolerant of low and high temperatures and of desiccation than the other two species. We observed that the three species were spatially segregated, and this was borne out in a model of distribution from a systematic survey that incorporated spatial terms. Microclimate temperature recordings from representative microhabitats indicate that the habitat occupied by *I. klovstadi* has temperatures that regularly cross both the upper and lower survival thresholds of *C. cisantarcticus*, and we propose that the spatial segregation of the Collembola species at Cape Hallett may be mediated by their environmental tolerances.

52.8

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EVOLUTIONARY ORIGIN OF A BLUE OPSIN GENE DUPLICATION IN LYCAENID BUTTERFLIES

Duplication of opsin genes followed by functional diversification is the evolutionary mechanism that enabled invertebrates to gain trichromatic vision. Recently, a novel blue opsin duplication was found in the genus *Lycaena* that was not found in other closely related butterfly families. The spatial expression patterns of the two blue opsin genes in the *Lycaena* retina were also distinct from each other. In order to elucidate the relative timing of the duplication event, and whether it is widespread amongst lycaenids, we screened for the presence of blue opsin genes from cDNA libraries of butterflies belonging to other lycaenid subfamilies, Theclinae (*Satyrium behrii*) and Polyommatae (*Polyommatus icarus*). These data will be discussed in relation to site-specific and lineage-specific models of adaptive evolution and in relation to both spectral tuning and homology models of the closely-related proteins.

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ZOOPLANKTON ABUNDANCE AND DISTRIBUTION IN TIDAL
MARSHES IMPOUNDED FOR MOSQUITO CONTROL

Seventy-five percent of tidal marsh areas along the Indian River Lagoon (IRL) are impounded for mosquito control. Canals within these areas are habitat used as nurseries by juvenile fish, which in many cases feed on impoundment zooplankton. Our study examined the diversity, abundance, and distribution of zooplankton at six impoundments in the IRL representing a range of distances from a coastal inlet. We identified and counted zooplankton, then compared them between sites and also compared within sites between the culvert (impoundment entrance) and the heart (deeper into the impoundment). For overall impoundment numerical abundance of zooplankton (pooled), flatworms composed 44%, copepods 25%, nauplii 18%, rotifers 7%, veligers 3%, and all other organisms 3%. Zooplankton diversity varied between the heart and the culvert and we believe this is due to flow rates, with lower flows allowing higher diversity. Zooplankton also varied between sites, possibly due to the proximity of the coastal inlet. In both cases, patterns may be the result of hydrographic supply of zooplankton and the influence of water exchange through the coastal inlet (between site differences) or through the culvert (within site differences).

59.5

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DEVELOPMENTAL COSTS OF BEHAVIORAL PLASTICITY:
EXPLORATION DURING OVIPOSITION-CUE LEARNING IN
BUTTERFLIES (LEPIDOPTERA: PIERIDAE)

Why is there is variation in the degree of phenotypic plasticity within and among species? Somatic selection (e.g., trial-and-error learning) is a developmentally costly mechanism of plasticity as individuals must explore their environment, test a variety of phenotypes, and suffer time, energy, and exposure costs in the process. These costs may impose tradeoffs in the evolution of plasticity. Full-sibling families of *Pieris rapae* (Lepidoptera: Pieridae) were reared in a common environment and trained to one of two host plants that differed in color and leaf shape. Plastic families, relative to specialized families, were those where siblings learned to correctly land on only the host plant in both of the host plant environments. Naïve siblings of plastic families should be more likely to suffer 1) behavior-level costs in exploration of a diverse array of non-host plants of different colors and shapes, and 2) tissue-level costs in the amount of neural tissue dedicated to producing and learning a variety of behaviors (e.g., optic lobes, central body, mushroom bodies).

39.2

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TUBES SQUEEZE AND THE AIR FLOWS OUT: CORRELATED
PATTERNS OF CO₂ EMISSION AND TRACHEAL COMPRES-
SION IN THE BEETLE, *PLATYNUS DECENTIS*

Active tracheal compression is a prominent feature of internal dynamics in multiple species of insects. Although the kinematics for one beetle species have been described, the physiological function of tracheal compression in gas exchange has not been determined. Possible roles of this mechanism include to convectively transport air or to increase the local pressure within the tracheae; alternatively, compressions may be a secondary consequence of other physiological processes. To determine if compressions are associated with excurrent gas exchange in the ground beetle *Platynus decentis*, we used simultaneous flow-through respirometry and phase enhanced x-ray imaging at the Advanced Photon Source (ANL) to synchronously record CO₂ emission and observe changes in diameter of the major thoracic tracheae. Each observed tracheal compression (which occurred at an average frequency and duration of 15 per min and 2 s, respectively) was associated with a local peak in CO₂ emission rate, with the start of each compression occurring simultaneously with the start of the local rise in CO₂ emission. No such peaks were observed during inter-compression periods. Furthermore, these peaks were observed both prior and post x-ray beam exposure, indicating that active tracheal compression is a natural physiological process and not an artifact of x-ray irradiation. In one specimen, the volume of CO₂ emitted per peak was $0.0032 \pm 0.0006 \text{ mm}^3$, representing up to 30% of the emission volume at mid-peak. Although not unexpected, these data confirm that tracheal compression is indeed a gas exchange mechanism, and strongly suggest that internal convection is a major component of ventilation for *Platynus decentis* and other insects that employ this mechanism. Use of the APS was supported by the U.S. D.O.E., O.S., B.E.S., under Contract No. W-31-109-Eng-38.

42.3

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SEX-SPECIFIC EFFECTS OF YOLK ANDROGENS IN AMERICAN
KESTRELS

Female birds deposit high concentrations of androgen hormones into the yolks of their eggs as they are formed on the ovarian follicle. In several species, yolk-androgen concentrations increase with laying order within a clutch. This raises the possibility that embryonic and post-hatching effects of differential yolk-androgen deposition may modify the developmental hierarchy commonly observed among sibling nest-mates as a result of hatching asynchrony. In a few species, experimental elevation of yolk-androgen concentrations enhances nestling growth-rates, suggesting that in some cases, elevated yolk-androgen concentrations in later-laid eggs of a clutch might buffer the effects of hatching late. In the American kestrel (*Falco sparverius*), experimental elevation of yolk-androgen concentrations reduces nestling growth-rates. Thus, in this case, the natural elevation of yolk-androgen concentrations with laying order seems to augment the effects of hatching asynchrony. It is not surprising that the effects of yolk androgens on nestling growth may vary with species or context, because whether or not the parent would benefit from a sibling developmental hierarchy is likely to depend on environmental conditions and factors intrinsic to laying order and individual eggs, such as their sex. We used PCR and morphological traits to sex nestlings and found that experimentally elevated yolk-androgen concentrations reduced growth rates in male but not female nestling kestrels compared to controls. From a proximate perspective, such sex-specific effects of yolk androgens may be related to differences between the sexes in the expression of androgen receptors. From an ultimate perspective, these sex-specific effects may tune parental reproductive effort to differences between male and female offspring in their reproductive value.

9.3

SOTHERLAND, P.R., KILLPACK, T.L., SELBO, B.G., DZIALOWSKI, E.M.; paulsoth@kzoo.edu. Kalamazoo College, University of North Texas
A CHANGE OF HEART IN DEVELOPING BIRDS AT THE ONSET OF ENDOTHERMY

In pythons, postprandial upregulation of physiological systems is large, rapid, and correlated with a noticeable rise in standard metabolic rate. Cardiac hypertrophy of pythons in response to this increased metabolism led us to investigate whether a similar change in hearts of developing birds occurs with the abrupt increase in metabolism associated with onset of endothermy at hatching. We measured rate of oxygen consumption at 35 °C and 25 °C as well as body size and masses of heart and small intestine of parinate and neonate chickens. We obtained the same measurements on neonates maintained at 35 °C (normothermic) or 25 °C (cold-stressed) for two days post-hatching. Neonates manifested an endothermic response to low ambient temperature (parinates remained ectothermic) and had significantly larger hearts than parinates even though body masses of the two groups did not differ. During two days post-hatch, normothermic neonates maintained a progressively increasing and higher body temperature than cold-stressed neonates, whose body temperature decreased after one day post-hatch. Both groups of neonates decreased in dry body mass and residual yolk mass, while intestine dry mass increased in both groups. However, dry heart mass increased only in cold-stressed neonates. Normothermic neonates retained an endothermic response to acute cold-stress whereas cold-stressed neonates lost this response after two days of exposure to 25°C. These results support the notion that ontogenetic changes coinciding with the metabolic metamorphosis from ectothermy to endothermy in birds might be similar to changes associated with feeding in large snakes and to differences between adult ectotherms and endotherms.

21.6

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THE EVOLUTION OF HERBIVORE OFFENSE IN THE SEA:
TROPICAL VERSUS TEMPERATE HERBIVORES IN FEEDING
TOLERANCE FOR CHEMICALLY-RICH SEAWEEDS

The past 25 years of research on seaweed-herbivore interactions have witnessed remarkable advances in our understanding of seaweed defenses, the chemical and morphological mechanisms that seaweeds use to protect themselves from being consumed by their herbivores. In contrast, we have relatively less information on herbivore offense, the traits that allow herbivores to increase their feeding rates on seaweeds when this use benefits the herbivore. This lack of information impedes our ability to predict the course and rate of the evolutionary response to perturbation to seaweed communities, including increasingly prevalent blooms of noxious or introduced seaweeds. As an example, there is a mountain of evidence that tropical seaweeds produce greater types and quantities of seaweed chemical defenses than temperate seaweeds. In contrast, there is little direct evidence on whether tropical herbivores have evolved greater feeding preferences for, and juvenile performance on, tropical seaweeds relative to temperate herbivores. I use a combination of field-sampling, laboratory rearing assays and DNA phylogeography to directly compare the genetically-based feeding responses of tropical and temperate populations toward chemically-rich tropical seaweeds. If I find that tropical populations have evolved greater feeding tolerance, then this would be consistent with the notion that tropical seaweeds and herbivores are evolving in a diffuse coevolutionary manner.

HB.

SOWER, S.A.; sasower@cisunix.unh.edu. University of New Hampshire
HOWARD BERN LECTURE: INSIGHT INTO THE MOLECULAR
EVOLUTION OF GONADOTROPIN AND ITS RECEPTOR IN
THE HORMONAL REGULATION OF REPRODUCTION

Gonadotropin-releasing hormone (GnRH) is the central regulator of reproduction in all vertebrates. In response to GnRH, gonadotropins (GTHs) are secreted from the pituitary and stimulate gonadal steroidogenesis and gametogenesis. Lamprey hold a unique position between protochordates and gnathostomes and are the oldest extant lineage of vertebrates, the agnathans. Little has been known about their reproductive pituitary hormones even though lamprey have two GnRHs that have demonstrated functional regulation of the pituitary-gonadal axis. The current studies were undertaken to identify the GTH(s) and its receptor(s) in sea lamprey, *Petromyzon marinus*, to gain a further understanding of the origin and evolution of reproductive pituitary hormones and their receptors. A sea lamprey preGTH cDNA was cloned in which the GTH β consisted of 134 amino-acid residues. Phylogenetic analysis of the LH-FSH family showed that lamprey GTH β is a clear out-group to vertebrate glycoprotein hormones (LH, FSH, TSH) suggesting that there is a single GTH in agnathans representing an ancestral form of GTH. The cDNA of a functional glycoprotein hormone receptor (LGpH-R1) was also cloned from sea lamprey testes. The high expression of LGpH-R1 in the gonads and the high similarity with gnathostome gonadotropin receptors suggest that LGpH-R1 functions as a receptor for lamprey gonadotropin. The key motifs and characteristics of the identified glycoprotein receptor reveal a mosaic of features common to all other classes of vertebrate glycoprotein hormone receptors. These data will be discussed in relation to the co-evolution of the ligand and its receptor and proposed increased specificities of ligand (TSH, LH, FSH) and receptor interactions in gnathostomes compared to lower specificity of GTH and its receptor in agnathans.

34.1

SPAIN, D.D., PERALTA, M.; dspain@dominican.edu. Dominican
University of California
SINKING IN SAND - AN EXAMINATION OF BURROWING IN
SEA CUCUMBERS (HOLOTHUROIDEA: ECHINODERMATA)

There are over 1,400 species of sea cucumbers living in marine environments worldwide. Yet, there are few descriptions of the burrowing process of infaunal holothuroids. This study provides a detailed description of burrowing in the infaunal dendrochirotid, *Thyonella gemmata*. Specimens were placed in small plastic containers with sand or gravel and artificial seawater. Burrowing was recorded using both real-time and interval recording features on a Sony digital camcorder. Analysis of the recordings showed that specimens burrow by using peristaltic waves originating on opposite ends of the body. Burrowing was only initiated after the anterior and posterior regions of the body were elevated. Afterwards, peristaltic waves were initiated at both ends of the body and traveled towards the midsection of the animal. Thus, the midsection of the body was buried first with the remainder of the body gradually being pulled under the sediment. This analysis will be combined with descriptions of burrowing methods used by other sea cucumber species in order to generate a more comprehensive account of burrowing in infaunal holothuroids.

71.1

SPEAR, E., ELLIOTT, J.K., WYLLIE-ECHEVERRIA, S.*; jkelliott@ups.edu. University of Puget Sound, University of Washington
USING THE SULFIDE-OXIDIZING BACTERIUM *Beggiatoa* AS AN INDICATOR OF INHIBITING LEVELS OF HYDROGEN SULFIDE FOR *ZOSTERA MARINA*

Seagrass beds are important components of marine ecosystems, but they are in decline worldwide because of human activity. Environmental organizations are interested in identifying areas that are best suited for seagrass restoration. The objective of this study was to determine the distribution and abundance of the seagrass *Zostera marina* in relation to the distribution of the mat forming bacterium *Beggiatoa* spp., and the levels of sulfide and organic material (wood waste) in the sediment. Underwater videography and intertidal surveys were used to map the distribution and abundance of *Z. marina* beds and *Beggiatoa* in the nearshore area of Commencement Bay, WA, a location that has a long history of sawmill activity. *Z. marina* occurred from the intertidal to -6 m MLLW on sandy substrates in areas with low levels of sulfide (< 50 μM) and organic material (<5 % total volatile solids). Areas with high sulfide levels (> 200 μM) occurred where there were significant amounts of organic material in the sediments, which was found to be wood waste that had been discarded from sawmills that operated on the Tacoma waterfront between 1869-1977. *Z. marina* was absent from the intertidal and occurred at lower densities in areas with high sulfide levels. In contrast, the bacterium *Beggiatoa* was only found in areas where the sulfide levels were > 1000 μM and there were significant deposits of wood. Thus, the negative correlation between the distribution and abundance of *Z. marina* and *Beggiatoa*, suggests that the presence of *Beggiatoa* mats could be used as a biological indicator of inhibiting levels of hydrogen sulfide in the marine environment. Sulfide is a phytotoxin, and high levels in sediments have been linked to seagrass die-offs in Florida Bay. This study exemplifies the need to examine the ongoing effects of past human disturbances and suggests that restoration of the nearshore habitat in Commencement Bay will require the removal of wood waste.

27.6

SPENCE, H.R., KNOWLTON, R.E., MERCHANT, H.C.; knowlton@gwu.edu. University of Massachusetts, George Washington University
A COMPARISON OF CRYPTIC SPECIES OF *ALPHEUS* (SNAPPING SHRIMP) FROM NORTH CAROLINA AND FLORIDA

Differentiating cryptic species of snapping shrimp (Alpheidae), despite their ubiquity and acoustic fame, is fraught with misidentifications and ambiguity. Much of this confusion is due to previous reliance on preserved specimens for morphological descriptions, and consequent omission of color and other information lost through preservation. In this research, live shrimp were studied to determine any differing developmental, behavioral, ecological and further morphological features that could be used to identify species and provide insight into their ecological roles. The two principal species examined were *Alpheus heterochaelis* Say, collected from Beaufort, North Carolina, and *Alpheus angulosus* McClure, collected from Jacksonville, Florida. The main new morphological difference found between *A. heterochaelis* and *A. angulosus* was color and length of the (second) antennal flagellum. The extended pattern of larval development, more typical of alpheids, was demonstrated by *A. angulosus*, in contrast to the abbreviated development of *A. heterochaelis*. Snapping frequency was not found to differ between the two populations. Sheltering behavior differed between species, with *A. angulosus* (from Florida) found under oyster shells more often than *A. heterochaelis* (from North Carolina). Paired interactive behavior experiments indicated that females spent more time than males occupying the shelter, regardless of species; in female-female pairings of same sized individuals, *A. angulosus* exhibited dominance over *A. heterochaelis*. The close morphological similarities of these two alpheid species, as well as *A. estuariensis* and others, underlines the importance of examining live animals to identify and differentiate them.

S4.7

SPONAUGLE, S., GRORUD-COLVERT, K.; sponaugle@rsmas.miami.edu. RSMAS, University of Miami
INFLUENCE OF EARLY LIFE HISTORY TRAITS ON RECRUITMENT SUCCESS AND EARLY SURVIVAL IN A CORAL REEF FISH

For organisms with complex life histories, life history traits of early stages may influence the survival of subsequent stages. We surveyed and collected 13 monthly cohorts of the reef fish, the bluehead wrasse, *Thalassoma bifasciatum*, from the Florida Keys to examine how variation in water temperature influences early life history (ELH) traits and juvenile recruitment. We also repeatedly sampled nine of the cohorts over sequential 3 d periods during the first 2 wks of juvenile life to determine whether early survival is related to particular ELH traits. Otoliths of new settlers were analyzed to obtain individual and cohort-specific data on ELH traits. Larval growth was directly related to water temperature, and fast-growing larvae in warm waters had shorter pelagic larval durations. Water temperature explained 61% of the variation in size of recruitment events, but only if four cohorts settling during the nearshore passage of mesoscale eddies were removed from the analysis. Eddy passage may disrupt the larval food supply or advect larvae out of the system. For successful recruits, cohort-specific survival on the reef was selective with respect to at least one ELH trait, but the traits and strength of selection varied among cohorts. Most frequently, survivors had wider otolith metamorphic band widths (thought to be a proxy for condition) and faster juvenile growth rates. These traits were also the most variable among new settlers, with variability decreasing with recruit age. Higher condition settlers were frequently, but not always, smaller at settlement. The variable pelagic life of *T. bifasciatum* may provide multiple ways to achieve a minimum settlement condition, thereby complicating selective mortality.

12.5

SPONBERG, S., SPENCE, A., FULL, R.J.; sponberg@berkeley.edu. University of California, Berkeley
TESTING NEURAL CONTROL MODELS FOR ANTENNA-BASED TACTILE NAVIGATION IN COCKROACHES

Navigation requires neural sensing of environmental features. Cockroaches use antennal tactile contact to track walls during running in low light environments. A kinematic response to wall turning occurs in as little as 40 ms (Camhi & Johnson, 1999). Neural signals encoding the change in wall orientation are mediated by mechanoreceptors located on the antenna flagellum. Simple biomechanical control models have shown that the cockroaches dynamic response to tracking a step change in wall angle is unstable if proportional information (distance from wall) alone is used (Cowan and Full, 2005). The model predicts that the rate of change of distance from wall (derivative information) is required from sensors. The simplest source of derivative control predicts a phasic response in antennal mechanoreceptors during an increase in bending - equivalent to a change in wall orientation. We recorded extracellularly from the antennal nerve of restrained Deaths head cockroaches (*Blaberus discoidalis*) using sharpened tungsten electrodes. The antenna was flexed both with a point deflection and using a mechanically actuated wall segment to simulate turns during running. We calculated the rms value of the net antenna nerve response to describe the power in the neural signal. Neural activity significantly increased during and immediately after the stimulus (Paired t-test, p-value <0.001). The post-stimulus signal power subsequently decreased from peak power indicating a phasic response. Our results confirm a phasic response in antennal mechanoreceptors demonstrating that derivative control information as predicted from the control model is available for use in cockroach navigation. Support by an NSF FIBR grant to R.J. Full and the Fannie and John Hertz Foundation.

12.1

SPRAYBERRY, J.D.H., DANIEL, T.; jdhenry@u.washington.edu. University Washington, Seattle

CONTROL OF LEFT-RIGHT STEERING IN *MANDUCA SEXTA*

Motor behaviors are influenced by the properties and constraints of the mechanical systems in which they operate. Hawkmoths feeding from moving flowers exhibit a visually guided tracking behavior. Given the visual stimulus of a flower oscillating left and right, we would expect a feeding hawkmoth to also fly left and right. Hawkmoths, like other lepidopterans, have an indirect flight mechanism in which two sets of power muscles (the dorsolongitudinals and the dorsoventrals) move the wings up and down by deforming the thorax. Subtle changes in wing kinematics, which are largely responsible for maneuvering, are controlled by steering muscles that alter the mechanical behavior of the thorax and wing hinge. These steering muscles consist of three functional groups: the axillary, basalar, and subalar muscles. We used EMG recordings from tethered *Manduca sexta* subjected to left-right visual motion stimuli to investigate the role of the subalar steering muscles in maneuvering flight. The subalar muscles demonstrate small but significant phase shifts in average timing of activation (1.1-6.2%) correlated with changes in horizontal motion. These phase shifts are very consistent within individuals, but the direction of phase shift varies between individuals. However, multiple motor forcing functions could result in similar cuticular deformations that are required for appropriate changes in wing kinematics. Our results indicate that the subalar steering muscles are likely involved in, but not the sole controllers of, left-right maneuvering.

75.4

STANDEN, E.M., LAUDER, G.V.; standen@fas.harvard.edu. Harvard University

HYDRODYNAMICS FUNCTION OF DORSAL AND ANAL FINS IN TROUT (*SALVELINUS FONTINALIS*)

Fish fins produce moments around the fish's body that potentially contribute to thrust and stability. The dorsal and anal median fins are located above and below the rolling axis of the fish and oscillate during locomotion, which suggests they produce rolling moments on the fish's body. How moments produced by dorsal and anal fins affect fish stability is not well understood. Previous flow visualization experiments have shown that the dorsal fin produces large lateral jets above the fish's rolling axis possibly causing rolling instabilities during swimming. The location and structure of the anal fin suggests it may counteract the forces produced by the dorsal fin. To date, anal fin wake structure has not been described. In this study we use particle image velocimetry to visualize the wake structures of dorsal and anal fins of brook trout (*Salvelinus fontinalis*). Using two parallel light sheets with high-speed digital cameras filming each sheet simultaneously we assess the kinematics of the dorsal and anal fins as well as the timing, magnitude and direction of forces produced by these fins during swimming. We find that the anal fin is producing large lateral jets of similar magnitude and direction to the dorsal fin. We hypothesize the timing, direction and magnitude of dorsal fin jets are balanced by anal fin jets to minimize rolling perturbations experienced by fish.

28.3

STAYTON, C.T.; tstayton@bucknell.edu. Bucknell University
IS CONVERGENCE SURPRISING? A SIMULATION STUDY USING A BROWNIAN MOTION MODEL OF EVOLUTION AMONG QUANTITATIVE CHARACTERS

Convergence, the independent evolution of similar phenotypes among distantly related species, is often taken as evidence of adaptation in response to similar selective pressures. However, some degree of convergence is expected given a large enough sampling of species; this is true even if evolution in quantitative character space is random. The amount of convergence expected for a given data set under such random evolutionary processes is usually unknown, as simulation studies of convergence are rare. Thus, researchers currently lack an appropriate null model for evaluating the significance of convergent patterns, or even a baseline for determining whether their study system might show a surprising (i.e., greater than expected) amount of convergence. In this exploratory study, I develop an operational metric of convergence, and explore the average amount of convergence that is produced in randomly generated (Brownian motion model) phylogenies. Monte Carlo simulations are used to assess the effects of phylogeny size and balance, as well as number of variables and variance structure within the data set, on the expected amount of convergence. In comparing these randomly-generated data sets to a real data set consisting of shape measurements on a sample of lizard skulls (including a case of convergence between among herbivorous lizards), I find that large amounts of convergence, equal to those observed in empirical data sets, can be generated by random evolution in character space.

35.2

STEFFEN, J.E., SIEFFERMAN, L.; steffje@auburn.edu. Auburn University

SPECTRAL PROPERTIES OF THE DEWLAPS OF FLORIDA BROWN ANOLES, *NOROPS SAGREI*

Male and female Brown Anoles (*Norops sagrei*) possess a throat fan, or dewlap, that is purportedly used for communication between conspecifics in courtship and territorial interactions. To humans this dewlap appears red-yellow-orange on the lateral portion and yellow on the leading-edge portion of the dewlap. This coloration is thought to result from the deposition of pterin (red-orange) and carotenoid (yellow) pigments. Because squamates can perceive coloration in both the ultraviolet (UV) and the human-visible range, we used UV-vis spectrometry to objectively measure coloration from both the lateral and midline region of dewlaps of male and female *Norops sagrei*. The lateral (red-orange) portion of the dewlap reflected light predominantly in the human visible wavelengths (400-700 nm), whereas the dewlap leading-edge (yellow line) was comprised of spectral peaks in both UV and visible wavelengths (300-700 nm). Principal Components Analysis of the spectra data indicate that brightness (PC1) and chroma (PC2) contribute the greatest amount of variance in spectral measurements for both the lateral (red-orange) and the leading edge (yellow) portions of the dewlap. We found significant sexual dichromatism from both the leading-edge and lateral portions of dewlaps. For both portions of the dewlap, males were darker (PC1) and more chromatic (PC2) than females, suggesting greater pigment deposition in males than females. These differences are discussed in light of chromatophore deposition and sexual selection.

S8-1.4

STILLMAN, J.H., TERANISHI, K.S.; stillmaj@sfsu.edu. Romberg Tiburon Center, San Francisco State University, University of Hawaii at Manoa
TRANSCRIPTOME CHANGES DURING THERMAL ACCLIMATION, ACCLIMATIZATION, AND STRESS IN PORCELAIN CRABS

The thermal phenotype of an organism (*i.e.*, heat tolerance, cold tolerance, eurythermality) is an essential determinant of performance across thermal environments and in response to thermal stress. We are working to understand the mechanistic bases of thermal phenotype by analysis of correlated changes between transcriptome profiles and cardiac thermal performance of thermally acclimated porcelain crabs, *Petrolisthes cinctipes*. Crabs were acclimated for 28 days to 8°C or 18°C, at which time cardiac upper and lower thermal performance limits significantly differ. On day 29, crabs were swapped between 8°C and 18°C. Transcriptome profiles were generated from crabs sampled during days 27-31 of the experiment using cDNA microarrays of 13,824 cloned ESTs from *P. cinctipes*. R/maanova was used to identify ESTs that had significantly different expression profiles between pre-swap and 12h intervals post-swap. Following transfer of 8°C-acclimated crabs to 18°C, 4957 ESTs had significant changes in expression. In contrast, 1400 ESTs had significant changes in gene expression following transfer of 18°C acclimated crabs to 8°C. Only 300 ESTs were identified as having significant changes in expression in both groups of crabs, indicating that different sets of genes are involved in achieving warm and cold acclimation states. Functional characterization of genes expressed in both groups of crabs as well as those expressed only during warm or cold acclimation is underway. I will also present an overview of our studies to examine variation in thermal phenotype in an ecological context by examination of acclimatization across natural thermal gradients as well as responses to thermal stresses common in intertidal zone habitats. Supported by NSF IOB 0533920 and DOE JGI CSP2006.

S2-2.6

STOCK, D.W.; David.Stock@Colorado.edu. University of Colorado, Boulder
COMPARATIVE STUDIES OF TOOTH DEVELOPMENT IN TELEOST FISHES

My laboratory uses the zebrafish (Ostariophysi: Cypriniformes) as part of a three taxon statement for investigating the developmental genetic basis of macroevolution in the vertebrate dentition. Comparisons of gene expression, regulation and function are carried out with an additional ostariophysan, the characiform *Astyanax mexicanus* (Mexican tetra), and an acanthopterygian outgroup, the beloniform *Oryzias latipes* (Japanese medaka). These comparisons allow an analysis of several morphological transformations of the teleost fish dentition, with our current focus being the loss of cypriniform oral teeth. The most distinctive gene expression difference we identified between these species is the absence of expression from the zebrafish oral epithelium of three members of the Dlx family of transcription factors that are expressed in dental epithelium of the other two species. Reporter transgenic analysis of one of these genes, *dlx2b*, suggests that loss of its expression is the result of changes in *trans*-acting regulators. Two candidates for such regulators are the Fibroblast growth factor (Fgf) and Bone morphogenetic protein (Bmp) signal transduction pathways, as we and others have shown them to be upstream of epithelial Dlx expression. We have identified expression differences in Bmp ligands between the zebrafish and the other two species and are investigating individual Fgf ligands for similar differences. Experiments to rescue zebrafish oral tooth development by transgenic mis-expression are also underway and may shed light on whether the genetic changes involved in cypriniform tooth loss have constrained the evolution of feeding mechanisms in this group.

74.5

STONE, M.D., HELLGREN, E.C.; matt.stone@okstate.edu. Oklahoma State University, Southern Illinois University
THERMAL VARIATION IN THE MICROHABITAT OF THE TEXAS TORTOISE (*GOPHERUS BERLANDIERI*)

Texas tortoises potentially experience harsh thermal regimes during summer months. It is therefore likely that environmental temperature significantly influences activity patterns. Although thermoregulatory and heat exchange studies have been conducted on *Gopherus berlandieri*, few data exist concerning the thermal properties of their microhabitat. Moreover, development of miniature data loggers has facilitated the continuous tracking of temperature data in the field and reduced variance associated with one-point measurements. We continuously monitored the thermal properties of *G. berlandieri* microhabitat by affixing ibutton[®] (Dallas/Maxim Semiconductors) temperature data loggers to the carapace of 6 and 14 tortoises during the summer of 2005 and 2006, respectively. In 2005 temperature values were collected every 5 minutes for at least 60 days between May 25th and August 10th. In 2006 we monitored every 8 minutes between June 7th and August 9th. We also monitored ambient temperatures in the shade and sun from a Stevenson Screen. Preliminary data suggest that tortoises experience temperatures that are lower than ambient during daylight hours; however, tortoises generally experience temperatures higher than ambient between dusk and dawn. This suggests that *Gopherus berlandieri* may buffer temperature exposure by selecting microhabitat that reduces variation in temperature.

70.2

STORRS, S.I., SEMLITSCH, R.D.; sisk95@mizzou.edu. University of Missouri
IS HERMAPHRODITISM NATURAL IN AMPHIBIANS? A CASE OF CONTAMINATED CONTROLS

Is hermaphroditism natural in amphibians? Preliminary histological data from an outdoor mesocosm study suggest that a female biased sex ratio and abnormal gonads in control animals may be the result of contamination. The experiment was initiated to examine the effects of atrazine (0, 3, 30, 100 ppb) on gray treefrogs (*Hyla versicolor*) in Missouri. Twice during the experiment, water in high density polyethylene cattle watering tanks (with and without animals) and water used to fill the tanks was sampled for an MCF-7 human breast cancer cell bioassay. The results of the assay demonstrate that water in the tanks was very estrogenic and resulted in cell growth equivalent to that of estradiol concentrations as high as 1×10^{-10} M, while that from the hose used to fill the tanks was negative. Water was also sampled from the tanks to examine nominal atrazine concentrations (0, 3, 30, 100 ppb) which correspond to estimated concentrations of 0.10 ± 0.07 , 3.56 ± 0.49 , 31.69 ± 11.63 , and 117.83 ± 19.84 ppb (mean \pm SD). Contamination of outdoor mesocosms may lead to false indications that hermaphroditism is a natural phenomenon in amphibians. Background levels of estrogenic activity in experimental waters should be tested to ensure true controls. These data are important in light of the recent focus on atrazine exposure of amphibians.

25.1

STORZ, B.; bstorz@bio.fsu.edu. Florida State University
POLYPHENISM, PLASTICITY, AND CANALIZED RAPID DEVELOPMENT; MODIFICATIONS OF THE DEVELOPMENTAL PROGRAM IN SPADEFOOT TOADS

Is there a common means by which a developmental program is modified via polyphenism, plasticity, or canalization, or do these modifications of the developmental program represent fundamentally different processes? New World spadefoot toads are an excellent system in which to study this question because they have evolved three apparently adaptive strategies for developing in ephemeral ponds: polyphenism, larval period plasticity, and canalized rapid development. Morphological analyses of *Spea multiplicata* polyphenism, *Spea hammondi* larval period plasticity, and *Scaphiopus* evolution of canalized rapid development suggest that the modifications leading to these developmental phenomena are occurring at different points of the developmental cascade. Both larval period plasticity and the evolution of canalized rapid development almost certainly occur(ed) because of changes in timing of the hypothalamuspituitarythyroid axis maturation and thyroid hormone release. Polyphenism, in contrast, occurs by way of trait specific modifications rather than an entire shift in somatic tissues, which suggests that the modifying activity for polyphenism occurs at the specific tissue level rather than earlier in the developmental cascade.

8.2

STRATHMANN, R.R., HYSERT, A., FOLEY, R.; rrstrath@u.washington.edu. University of Washington, Friday Harbor
FOOD LIMITED GROWTH, PLASTICITY IN LOSS AND GAIN OF METAMORPHIC COMPETENCE, AND RECRUITMENT OF THE CYPHONAUTES LARVA OF A BRYOZOAN

The cyphonautes larvae of bryozoans have a low capacity for clearing food from suspension. As predicted, they starved at concentrations of food that supported growth of sea urchin larvae. Nevertheless, these bryozoans developed from egg through metamorphosis in 4 weeks at 14°C when food was abundant in laboratory cultures. The cyphonautes larvae also tolerated extended starvation at low concentrations of food. The internal sac (a rudiment of postlarval juvenile structures) shrank in starved larvae, which lost competence for metamorphosis, but the larvae regrew the internal sac and regained competence when fed. Thus the larvae can use the juvenile rudiment as a nutrient reserve when food is scarce and grow it back when food is abundant. The four week planktonic period in laboratory culture was close to the time lag between larval abundance and zooid density in P. Yoshiokas study of a population off southern California, but a similar time lag did not occur in the population near the Friday Harbor Laboratories. Peak densities of reproductive adults occurred in the summer, larval abundance declined to low densities of precompetent larvae during the autumn and winter, then abundant competent larvae appeared from an unknown source and settled at high densities in the spring. Extreme plasticity in size and age of reproduction was confirmed: first reproduction occurred a month after settlement in colonies with only about 20 zooids when space for growth was limited.

36.5

SULLIVAN, L.E., COCROFT, R.B.; LauraSullivan@mizzou.edu.
University of Missouri-Columbia
THE INFLUENCE OF POPULATION DENSITY ON MATE-FINDING TACTICS AND THE STRENGTH OF SEXUAL SELECTION IN *ENCHENOPA BINOTATA* TREEHOPPERS (HEMIPTERA: MEMBRACIDAE)

Within species, mating systems and the strength of sexual selection will vary in time and space depending on variation in resource distribution, population density and operational sex ratio. In many cases, male mate-finding tactics vary in concert with these factors. However, the hypothesis that this variation in mate-finding tactics is adaptive has seldom been tested. We tested this hypothesis experimentally in a species in the *Enchenopa binotata* complex of treehoppers, which are small, sedentary, phloem-feeding insects. These treehoppers communicate with substrate-borne vibrational signals, and have two common mate-finding tactics: stationary chorusing and active searching. We manipulated the density of experimental populations, and then measured lifetime mating success of marked individuals whose mate-finding tactics were followed over the course of the mating season. We released the treehoppers into large outdoor enclosures to create high-density (40 males/40 females) and low-density (10 males/10 females) conditions. We marked individuals to track their movements and mating behavior. The location and behavior (including courtships and matings) of each treehopper was recorded every 90 minutes during daylight hours. The movements of the males were used to categorize their mate-finding tactics as either chorusing or active searching. Our results suggest that there is a large opportunity for sexual selection in this species. The influence of population density on the strength of sexual selection and on the fitness payoffs of different male mate searching tactics will be discussed.

72.7

SULLIVAN, C.; csullivan@oeb.harvard.edu. Harvard University
VARANUS, *ALLIGATOR*, AND THE DIVERSITY OF NON-PARASAGITTAL LOCOMOTION

The American alligator (*Alligator mississippiensis*) and the savannah monitor (*Varanus exanthematicus*) both hold the femur in an abducted, "sprawling" posture during terrestrial locomotion. However, despite sharing this non-parasagittal mode of walking, the two taxa differ substantially in their hindlimb kinematics. Analysis of the 3-D movements of the limb bones, using light and cineradiographic video footage, shows that *Alligator* is capable of greater femoral adduction than *Varanus*. Furthermore, even fully abducted strides performed by *Alligator* are in many ways kinematically closer to adducted *Alligator* strides than to strides by *Varanus*. Regardless of femoral adduction, *Alligator* exhibits relatively little lateral deflection (yaw) of the pelvis, and the extensor surface of the crus remains directed almost ventrally until very late in the stance phase. In *Varanus*, by contrast, yaw often exceeds 25° and the crus has a strong tendency to rotate laterally (in an absolute frame of reference) as the femur retracts. The difference in crural rotation is related to the ankle structure of each taxon, since *Alligator* has a posteriorly aligned calcaneal tuber whereas the calcaneum of *Varanus* bears a posterolateral flange. Crural rotation in *Varanus* brings the flange close to a parasagittal plane, and helps the flange to increase the moment arm of M. peroneus longus as this muscle resists the flexor moment produced about the ankle by the ground reaction force. Particularly when extinct forms are considered, documented differences in the hindlimb osteology of various non-parasagittal taxa imply a high level of kinematic diversity. The ancestral archosaur ankle, from which the crocodylian pattern ultimately arose, probably bore a closer functional resemblance to *Varanus* than to *Alligator*, based on the presence of lateral or posterolateral calcaneal flange.

45.2

SUMIDA, S.S., NORIEGA, K., FISK, J.; ssumida@csusb.edu. California State University San Bernardino, Atomic Monkey Digital Modeling
DEVELOPING A DIGITAL ATLAS OF A CENTROSAURINE CERATOPSIDIAN DINOSAUR FOOT USING NEARLY COMPLETE AND ARTICULATED MATERIALS

A nearly complete right hind limb of a centrosaurine ceratopsian dinosaur from the Sage Creek Locality of the Late Cretaceous (Campanian) Dinosaur Park Formation of southern Alberta provides important information regarding the structure and function of the pelvic limb in this group. As the preservation of complete and articulated manual or pedal components of the appendicular skeleton is rare in ceratopsians, the inclusion of a nearly complete right pes in the Sage Creek centrosaurine has the potential to add important information to our understanding of morphology of the centrosaurine pes, hind limb posture, and realistic range of locomotor behavior. The elements of the right foot indicate that metatarsals I-IV were closely packed and tightly bound. Fortuitous preservation of metatarsals I and II, and complete preparation of metatarsal IV indicate that the metatarsals articulated with one another medio-laterally with high congruence, creating a very tight union and allowing little if any splay. Each of the completely prepared elements was subjected to three-dimensional digital scanning, creating: (1) a digital atlas of the specimen elements, and (2) providing a means to more readily test differing hypotheses of pedal morphology and posture.

62.1

SWARTZ, S., GALVAO, R., IRIARTE-DIAZ, J., ISRAELI, E., MIDDLETON, K., ROEMER, R., TIAN, X., BREUER, K.; sharon_swartz@brown.edu. Brown University
UNIQUE CHARACTERISTICS OF AERODYNAMICS OF BAT FLIGHT: EVIDENCE FROM DIRECT VISUALIZATION OF PATTERNS OF AIRFLOW IN THE WAKES OF NATURALLY FLYING BATS

The interaction of animal wings with the surrounding fluid is similar to, but quite distinct from, that of the wings of human-engineered aircraft. All animal fliers move their complex, deformable wings, via more or less complicated motions, to produce lift and propulsion. To understand the mechanistic basis of bat flight, we must have detailed information regarding flight forces. One means to achieve this is to employ quantitative flow visualization methods to the structure of the wake footprint left behind flying animals. To visualize and quantify the structure and behavior of the wakes of slow forward flight in *Cynopterus brachyotis*, we employed Particle Image Velocimetry (PIV). By adapting this technique to naturalistic flight in these bats, we successfully obtained the first detailed, 3D documentation of the structure of bat flight wakes. PIV clearly demonstrates that these wakes differ significantly from those of non-flapping models similar in size and shape to bats, and from those of both flying birds and insects. Bat flight wakes are complex in structure, with many small-scale flow structures in addition to regions of concentrated vorticity. Wake structure changes dynamically over the course of the wingbeat cycle, but does not conform to any published models of flight gaits.

52.7

SWEENEY, A., DES MARAIS, D.L., BAN, A., JOHNSEN, S.; ams27@duke.edu. Duke University
EVOLVING REFRACTIVE INDEX: HOW LENS PROTEIN EVOLUTION CONTRIBUTED TO HIGH-RESOLUTION SQUID VISION

A lens with a graded refractive index is necessary for high-resolution animal vision. This graded refractive index is produced by a concentration gradient of a few kinds of protein. Here, using a synthesis of protein biochemistry, molecular phylogenetics, structural biochemical modeling, molecular dynamics and optical modeling, we show how the radiation and electrostatic evolution of squid lens proteins have likely been major contributors to the evolution of a high-resolution lens in squid eyes. Lenses of the squid *Loligo opalescens* are built primarily of lens-specific proteins that resulted from the extensive genetic radiation of an ancestral liver enzyme. There are two major clades within this lens-specific radiation; one of them has extremely high average net charge, and has experienced strong positive selection in the *Loligo* lineage. These two clades differ in both their electrostatic properties and in other amino acid polymorphisms that may promote the folding and stability of proteins in the highly charged clade. The exterior of the lens, with a low refractive index and low protein concentration contains more highly charged proteins than the interior of the lens that has a high refractive index and high protein concentration. Molecular dynamics and optical scattering models using our lens protein electrostatics, concentration and distribution data show that the evolution of variable electrostatic properties in lens proteins likely promotes the transparency and stability of *Loligos* high-resolution lens.

3.4

SZAFRANSKA, P.A., ZUB, K., KONARZEWSKI, M., SPEAKMAN, J.R.; pszafran@bison.zbs.bialowieza.pl. Mammal Research Institute Polish Academy of Sciences, University of Bialystok, University of Aberdeen
A POSITIVE ASSOCIATION BETWEEN RESTING AND FIELD METABOLIC RATES IN WEASELS

A positive association between resting (RMR) and field metabolic rate (FMR) is one of the most important notions of mammalian energetics. It has not, however, been convincingly demonstrated, especially on intra-specific level. To test this, we measured RMR and FMR in male weasels *Mustela nivalis*. These small predators are characterized by a considerable variation in body mass (range 40g–150g) and high metabolic rates. Their FMRs (measured by doubly labelled water technique) were strongly depended on daily activity time (estimated by radiotracking), and significantly varied among seasons. Weasels had highest body mass-corrected FMR in spring, intermediate in summer, and lowest in winter. The pattern of annual changes of mass-specific RMR was similar. In consequence, we found a high, positive correlation between mass-specific FMR and RMR. Furthermore, we also demonstrated a high within-individual repeatability of body mass-corrected RMR in an annual cycle. We suggest that an increase of the activity time during reproductive season (spring and summer) was reflected by an increase of FMR, which in turn incurred an increase of RMR. In winter, weasels restricted their energy expenditures by minimizing hunting time and staying in well insulated nests. This type of behavior allowed them to maintain low RMR.

30.4

TAMONE, S.L., THOMTON, J.D.; sherry.tamone@uas.alaska.edu. University of Alaska Southeast, University of Alaska Fairbanks, Alaska Sea Life Center

EYESTALK ABLATION OF FEMALE DUNGENESS CRABS *CANCER MAGISTER* YIELDS DIVERSE RESULTS DEPENDENT UPON PHYSIOLOGICAL STATE

The crustacean eyestalk is the source of numerous neurohormones that regulate important physiological processes such as reproduction, growth, metabolism, and coloration. Neurohormones are synthesized in the X-organ and stored in the sinus gland within the eyestalk of crustaceans. Eyestalk ablation (EA) is a technique used to manipulate the physiology of crustaceans by removing the influence of the eyestalk hormones. Induction of vitellogenesis is known to occur upon EA in studied crustaceans since specific regulatory inhibitory hormones are removed. Eyestalk ablation is commonly used to induce molting due to the removal of molt inhibiting hormone, which stimulates the secretion of molting hormones (ecdysteroids) that promote ecdysis. In a group of mature female non-ovigerous Dungeness crab, *Cancer magister*, EA resulted in either vitellogenesis or ecdysis, but not both. Increases in the yolk protein, vitellogenin (Vg) could be measured after EA in four of the five crabs manipulated. Vitellogenesis was measured using SDS-PAGE followed by silver staining. Levels of Vg increased 6.2 ± 1.1 fold. In a single female, ecdysteroids initially measured at 35 ng/ml (intermolt levels) increased one week post ablation (78 ng/ml) and peaked 47 days prior to ecdysis (2590 ng/ml). The length of premolt period was 167 days and the change in ecdysteroids was not significantly different from those measured in control animals undergoing ecdysis in the laboratory. Non-ovigerous control females did not undergo vitellogenesis during the duration of the experiment. Current studies are investigating whether EA of post molt mature females or ovigerous females will induce ecdysteroid synthesis or Vg synthesis.

6.3

TANKERSLEY, R.A., WINDSOR, J.G., HANSELMAN, J.A.; rtankers@fit.edu. Florida Institute of Technology, Melbourne
INSTEP: ENHANCING SCIENCE EDUCATION THROUGH GRADUATE STUDENT-TEACHER PARTNERSHIPS

In an effort to enhance science instruction in K-12 schools, Florida Tech has developed a new partnership between students, researchers, and high school teachers in Brevard County, FL. The Integrated Science Teaching Enhancement Partnership (InSTEP) is part of the NSF's Graduate Fellowships in K-12 Education (GK-12) Program and is designed to foster student interest in science while boosting teacher confidence in science content and inquiry-based instruction. Each year, eight graduate students from Florida Tech's science departments (Biology, Chemistry, Marine and Environmental Systems, and Physics) are matched with eight Brevard County high school Integrated Science (IS) teachers to design and pilot a series of learning modules linking core IS content areas Earth science, biology, chemistry and physics. Using ocean exploration as a common theme, the program takes advantage of Florida's extensive coastal resources and student awareness of local ocean-related issues. Modules are based on state and national curriculum standards and include demonstrations and inquiry-based activities that rely heavily on instructional strategies that encourage experimentation and problem solving. Through their participation in the program, Fellows learn valuable teaching, communication and classroom management skills and gain a heightened awareness of their ability to enhance K-12 education. Teachers improve their understanding and mastery of science concepts and content, increase their comfort with inquiry-based techniques, and develop a greater appreciation for the interdisciplinary nature of the IS curriculum. Students have an opportunity to interact with scientists and career role models and develop a deeper understanding of the scientific process and the relevance of science to local issues.

51.8

TARRANT, A.M., CORTÉS, J., BEZY, B., JOHANNING, K.J., CHIANG, T.C., VARGAS, J.A., MCLACHLAN, J.A.; atarrant@whoi.edu. Woods Hole Oceanographic Institution, University of Costa Rica, San Jose, University of New Orleans, Tulane University, New Orleans
IDENTIFICATION AND EXPRESSION PATTERNS OF NUCLEAR RECEPTORS IN THE CORAL *POCILLOPORA DAMICORNIS*

Reef-building corals and other cnidarians must regulate diverse physiological processes including intracellular symbiosis, calcification, and synchronous reproduction. These processes are poorly understood at a molecular level, and the potential for signal disruption is unknown. Nuclear receptors are transcription factors that regulate diverse aspects of animal development, differentiation and physiology. In this study, three nuclear receptor cDNAs were cloned from *P. damicornis*. PdNR1 and PdNR7 are putative homologs of the tailless (subfamily 2E), and COUP-TF genes (subfamily 2F), respectively. The third cDNA, PdNR6 cannot be unambiguously assigned to a known nuclear receptor subfamily. Expression of PdNR1, PdNR6 and PdNR7 transcripts was quantified by real-time qPCR in *P. damicornis* samples collected from Culebra Bay, Costa Rica in December 2004, June 2004 and March 2005. Expression of all three nuclear receptors and the stress-inducible heat shock protein 70 was elevated in samples collected in March relative to samples collected in December and June. Similar induction was not observed in two housekeeping genes (β -actin and 28S rRNA). Manipulative experiments are in progress to determine the effects of physical stressors on nuclear receptor expression. Future characterization of the function of these nuclear receptors will provide insight into evolution of bioregulatory pathways and a basis for investigation of signal disruption in corals. Funding provided by the Caribbean Marine Research Center CMRC-03-NRAA-01-04A (NOAA/NURP) and the Costa Rica-USA Foundation.

7.2

TAYLOR, J.R., WHITTAMORE, J.M., WILSON, R.W., GROSELL, M.; jtaylor@rsmas.miami.edu. RSMAS, University of Miami, Exeter University, UK
POSTPRANDIAL ACID-BASE BALANCE IN FRESHWATER AND SEAWATER-ACCLIMATED EUROPEAN FLOUNDER

Intestinal HCO_3^- secretion and resultant carbonate precipitation are important in the hydromineral balance of all fishes sampled to date in hyperosmotic conditions. Furthermore, intestinal $\text{Cl}^-/\text{HCO}_3^-$ exchange plays an important role in maintaining postprandial hydromineral balance. Digestion is a nearly constant occurrence in the natural existence of most animals and greatly modifies physiology, but surprisingly its effects in fishes have been largely ignored by comparative physiologists. This study is the first to investigate the effects of feeding on acid-base balance in seawater and freshwater acclimated euryhaline fish. Using European flounder, *Platichthys flesus*, we found that base efflux is maximal 6-12 h post feeding regardless of salinity and is of greater magnitude in seawater-acclimated flounder than in freshwater flounder. In freshwater flounder, Cl^- uptake was measured and does not match the magnitude of base efflux, suggesting that mechanisms additional to $\text{Cl}^-/\text{HCO}_3^-$ exchange contribute to branchial postprandial base output. Ammonia flux measurements revealed an ammonia efflux of similar magnitude in both salinities, but with maximal output occurring during the first 6 h post-feeding in seawater-acclimated fish and between 6 and 12 h post-feeding in freshwater flounder. This ammonia efflux counters the base efflux in seawater fish, yielding no distinct net acid-base disturbance. Based on our findings of similar ammonia efflux but reduced base output in freshwater flounder, the possibility of a postprandial alkaline tide was investigated at both salinities, but no evidence for disturbed acid-base balance was observed. (Supported by JEB/CoB and SEB travel awards to J. R. Taylor and by NSF-IBN 0416440 to M. Grosell).

34.10

TAYLOR, J.R.A., KIER, W.M.; jataylor@email.unc.edu. University of North Carolina, Chapel Hill
MECHANICAL PROPERTIES OF A CRAB SKELETON FOLLOWING MOLTING

Molting involves significant changes in the structure of the exoskeleton as the old one is shed and a new one is secreted. The flimsy new cuticle takes several days to harden and during this time crabs rely on a hydrostatic skeletal support system. This change from a rigid to a hydrostatic support mechanism implies correlated changes in function, and thus mechanical properties, of the cuticle, from primarily resisting compression and bending to resisting tension. This study was designed to describe changes in the mechanical properties of the cuticle following molting and to test the hypothesis that changes in the cuticle mechanical properties reflect the shift in skeletal support mechanism. The cuticle of the Blue crab, *Callinectes sapidus*, was examined at the following postmolt intervals: 1 hour (soft stage), 12 hours (paper stage), and 7 days (hard stage). Samples of cuticle were removed from the claw and the tensile strength was tested using an Instron. Soft stage cuticle had a maximum tensile breaking strength of 14 MPa, which was less than the paper stage cuticle (30 MPa) but greater than the hard stage cuticle (8 MPa). These data illustrate significant changes in mechanical properties of the cuticle as a consequence of the molt cycle. Currently, flexural stiffness is being tested in a 3 point bending apparatus and we predict that the hard stage cuticle will be orders of magnitude stiffer in bending than the paper and soft stage cuticle. The mechanical properties of the cuticle appear to correlate with the function of the cuticle in support; tensile strength is most important for hydrostatic support and flexural stiffness is most important for rigid support. Funded by NSF IBN-972707 and DARPA N66001-03-R-8043.

25.5

TAYLOR, S.M., GRACE, M.S.*; mgrace@fit.edu. Florida Institute of Technology
EVOLUTION AND ECOLOGY OF VISION: DEVELOPMENT OF PHOTORECEPTOR ARRAYS IN ELOPOMORPH FISH

The Atlantic tarpon (*Megalops atlanticus*) and the speckled worm eel (*Myrophis punctatus*) belong to the teleost subdivision Elopomorpha, an assemblage of four orders grouped primarily on the basis of remarkably similar larval form. As adults, however, tarpon are large visually-guided surface predators while speckled worm eels are small nocturnal burrowers that rely primarily on chemoreception for feeding. Because these species exhibit dramatic morphological and behavioral divergence during development, we hypothesized concomitant changes in retinal structure and function in support of species-specific life history changes. We studied ultrastructure, opsin content, and rod and cone distributions in these two species at four developmental stages: premetamorphic pelagic larval, settlement/metamorphosis, postmetamorphic juvenile, and adult. Prior to metamorphosis, both species had rod-dominated (but duplex) retinas, in stark contrast to pure-cone or cone-dominated retinas of most teleosts. In larval tarpon, cone opsin was present only in the mid-temporal region; in larval eels, only in the ventral region. During and post-metamorphosis, tarpon rods and cones became more differentiated, and exhibited distinct distributions. In the worm eel, rod and cone opsins were present at metamorphosis, but the two cell types were morphologically indistinct. During subsequent development, worm eel retinas contained only rhodopsin, and all photoreceptors were morphologically rod-like. Our results show that the Elopomorpha may be united on the basis of shared larval retinal organization in addition to overall form, and that development of the Elopomorph retina is dramatically different from that in most teleosts. Furthermore, our results show that retinal organization changes dramatically in concert with changing habits and habitats.

31.3

TERANISHI, K.S., STILLMAN, J.H.; kteranis@hawaii.edu. University of Hawaii at Manoa, Romberg Tiburon Center, San Francisco State University
SEASONAL VARIATION IN HEPATOPANCREAS TRANSCRIPTOME PROFILES FOLLOWING HEAT STRESS IN THE PORCELAIN CRAB, *PETROLISTHES CINCTIPES*

How organisms respond to thermal stress in their natural habitat is a function of thermal acclimatization state. Here, we have investigated seasonal differences in transcriptome responses to acute thermal stress in one population of the intertidal porcelain crab, *Petrolisthes cinctipes*. In winter and summer 2005, crabs were collected from the field site at Cape Arago, Oregon where n=6 crabs were immediately dissected and additional crabs were taken to the laboratory and divided into 2 groups. One group was subjected to a 4h thermal ramp to 30°C, and the other group was held at a constant temperature (10-12°C) during the 4h treatment. Following the 4h treatment, crabs were placed into a recovery tank (10-12°C) and n=5 crabs from each group were sampled after 6h. For each crab sampled, hepatopancreas tissue was dissected immediately into RNA tissue protect (Qiagen), RNA was purified using Qiagen RNeasy spin columns, and reverse transcription was used to synthesize amino-allyl cDNA. Amino allyl cDNAs were labeled with Cy3 or Cy5 dye and hybridized on microarrays using a dye-swap design for each season. The microarray used for this study was printed from a 13,824-clone cDNA library created from a range of *P. cinctipes* tissue types (including whole crabs, and tissues from gill, heart, muscle, nerve, and hepatopancreas) from crabs exposed to a range of thermal conditions. Fluorescence data were log transformed and normalized using the Loess function. MAANOVA in R was employed to identify genes that had significantly different expression profiles between field acclimatized, thermally stressed and control crabs between seasons. This research was supported by a NSF Graduate Research Fellowship to KST and NSF IOB-0533920 and JGI CSP to JHS.

S8-2.6

TERWILLIGER, N.B., RYAN, M., PHILLIPS, M.; nterwill@darkwing.uoregon.edu. University of Oregon
CRUSTACEAN HEMOCYANIN GENE FAMILY: OXYGEN PROBES OF THE GLOBAL GENE SCENE

Global expression profiling simultaneously monitors vast numbers of genes in an organism, and it identifies groups of co-regulated genes. The principles of molecular recognition at the genomic and proteomic levels were developed for single gene analysis, and data analysis of global expression profiling requires knowledge of gene families and products. Oxygen delivery in decapod crustaceans is provided by hemocyanin (Hc). The Hc gene family, like hemoglobin, has undergone a process of gene duplication and divergence. These events have resulted in a Hc molecule composed of multiple subunits with a functional spectrum of homeotropic and heterotropic responses to allosteric effectors, metabolites and environmental factors. Other duplication events have resulted in new proteins with marked changes in function, as evidenced by phenoloxidase, cryptocyanin, and insect hexamerins. Continuing investigations at the gene family level in concert with genomics and proteomics will provide new insights into crustacean physiology. We have determined the cDNA sequences of all six subunits that compose the Hc molecule in the adult Dungeness crab, *Cancer magister*. The subunits are the products of six separate genes. Analyses of protein and gene structures of these Hc subunits confirm the clustering into two motifs. Hc genes 1 and 2 are tandemly linked on the same chromosome and have one intron. Genes 3,4,5 and 6 have an additional intron. The exon-intron pattern in *C. magister* will facilitate Hc gene structure comparisons in the Arthropoda and other phyla. Analyses of upstream regulatory regions of the Hc genes in conjunction with ongoing development and construction of a *C. magister* microarray will yield insights into transcriptome changes during development, molting and environmental stress. Supported by NSF 9984202.

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NEURAL SUMMATION IN NIGHT FLYING SWEAT BEES

Megalopta are neotropical sweat bees that forage during only two time windows: after sunset and before sunrise. Thick forest canopies and the quick onset of darkness at tropical latitudes leave bees in profound darkness for these trips—20 times dimmer than starlight. Other insects that fly in this environment, such as moths, invariably possess superposition eyes, which increase light capture several hundred fold. All bees, however, have apposition eyes. Nonetheless, *Megalopta* survey the visual scene on exit, fly off to forage, and return to the entrance of a small stick hidden in a forest littered with similar sticks. The implication is that they perform difficult visual tasks despite the low signal to noise ratios produced by such darkness. With limited optical options, *Megalopta* may use neural mechanisms to improve signal to noise ratio. We investigated the theoretical effects of spatial and temporal pooling as they apply to bees in their natural habitat. Although sacrificing acuity, we found they could extend reliable vision to much lower light intensities. Further, the optimal summation was a close match to estimates derived from physiological, cellular, and behavioral data. We propose that neural mechanisms are critical to *Megalopta's* ability to forage in the dark, and allow them to exploit the night habitat, visually hidden from predators, and with reduced competition from other bees.

57.1

THOMAS, F.I.M., BADGLEY, B.D., YUND, P.O., GRABOWSKI, R.C.; fthomas@cas.usf.edu. University of South Florida, University of New England

LINKING FIELD MEASUREMENTS OF HYDRODYNAMIC CONDITIONS TO THE FERTILIZATION OF THE GREEN SEA URCHIN *STRONGYLOCENTROTUS DROEBACHIENSIS*

The immediate transport of gametes away from free spawning invertebrates is determined by hydrodynamic conditions. In relatively benign flows gametes are retained on or near the spawning animal. In rougher flows gametes are quickly advected away from the spawning adult and diluted in the water column. Because the probability of fertilization is higher for gametes retained near the adult compared to those advected away, determining the range of flows that organisms experience in the field is essential to analyzing fertilization success in these animals. Animals are likely to spawn over a range of hydrodynamic conditions due to large scale differences in wave and current conditions and the location of specific animals relative to structural elements within the habitat. Therefore, to predict fertilization success in a location, it is necessary to link the flow conditions experienced by individuals to measurements of wave and current measurements made at larger scales. In this study, we measured the hydrodynamic conditions above adult green sea urchins, *Strongylocentrotus droebachiensis* and related these measures to water column measurements of velocity, turbulence, and wave height. These field measurements were then combined with laboratory data on fertilization as a function of local hydrodynamics to make predictions about the expected fertilization success of urchins under a range of hydrodynamic conditions.

9.4

THOMPSON, J.T., SZCZEPANSKI, J.A., BRODY, J.H., CRESCENTI, L.M.; joe.thompson@sju.edu. St. Joseph's University, Philadelphia, PA

ONTOGENY OF ISOMETRIC FORCE PRODUCTION BY THE CIRCULAR MANTLE MUSCLES OF LOLIGINID SQUIDS AND CUTTLEFISHES.

Thick filament length in the mantle muscles that provide power for jet locomotion (i.e., the circular muscles) increases significantly during the growth of loliginid squids and some cuttlefishes. This trend holds for both the superficial mitochondria rich (SMR analogous to vertebrate red muscle fibers) and central mitochondria poor (CMP analogous to vertebrate white muscle fibers) circular muscles. The ontogenetic increase in thick filament length may affect the mechanical properties of the circular muscles. The contractile properties of striated muscles, such as the obliquely striated circular muscles of the mantle, depend on the lengths of the thick filaments and sarcomeres, the load on the muscle, and the rate of cross-bridge cycling (e.g., Josephson, 1975). Thick filament length is inversely proportional to shortening velocity and is directly proportional to peak isometric tension (e.g., Josephson, 1975). Assuming all else is equal, we predict that the circular muscles of newly hatched animals will produce lower peak isometric tension than the circular muscles of juveniles and adults. We performed a set of preliminary muscle mechanics experiments at 20°C on three species of loliginid squids (*Lolliguncula brevis*, *Loligo pealei*, and *Sepioteuthis lessoniana*) and two species of cuttlefishes (*Sepia officinalis* and *Sepia pharonis*). We found peak isometric tension (brief tetani, 50Hz, 100ms) of between 230 and 300 mN/mm² (N=12) in juveniles and subadults but only 170 to 200 mN/mm² (N=8) in hatchlings. The preliminary results are consistent with the prediction that peak isometric tension should increase during ontogeny in the species we studied.

S4.5

THORNBUR, C.S.; thornber@uri.edu. University of Rhode Island

FUNCTIONAL PROPERTIES OF ALGAL LIFE CYCLES

Many species of algae have complex, multiphasic life cycles. These species contain multiple independent, free-living stages that they either obligately or selectively cycle between. The inherent complexities of these life cycles provide unique opportunities for investigating the ecological dynamics and tradeoffs between the different stages. All stages must be able to successfully survive and reproduce for the species to persist. However, some species have heteromorphic life cycles, in which the two phases occupy ecologically distinct niches (e.g. an upright blade vs. a flat crust). Other, closely related species have isomorphic life cycles, in which the two phases are assumed to be occupying the same ecological niche. This latter assumption has been infrequently investigated; I focus upon the relationship between isomorphic haploids and diploids of the red alga *Mazzaella flaccida*. Although these individuals appear morphologically similar, and occur together in the same habitats year-round, they were found to differ markedly in their reproductive capacity, as well as in their palatability to common intertidal herbivores. These results can explain the apparent demographic overabundance of *M. flaccida* haploids in many populations and provide insights into the evolution and maintenance of isomorphic life cycles.

67.5

TIBBELS, A.E., MORENO, A., MCCRACKEN, G.F.; atibbels@utk.edu. University of Tennessee, Instituto Tecnológico de Cd. Victoria
LOCAL SCALE POPULATION STRUCTURE OF THE COMMON VAMPIRE BAT (*DESMODUS ROTUNDUS*)

We examined mitochondrial genetic variation of common vampire bats (*Desmodus rotundus*) in western Tamaulipas, Mexico. The Sierra Madre Oriental Mountains, of Tamaulipas, are dissected by steep ridges and narrow valleys. Each valley is cut by an active creek, with farms and potential bat roosts distributed therein. Populations of *D. rotundus*, were sampled to characterize demographically significant units, as determined by the scale of genetic structure. We sequenced the hyper-variable mitochondrial control region from approximately 100 individuals, collected from 10 locales within Tamaulipas. *Desmodus rotundus* commonly forms polygynous mating groups of one adult male and a small number of females. Females typically remain in natal roosts, while juvenile males disperse to other colonies. Long distance dispersal in *D. rotundus* is uncommon. We hypothesize that there will not be significant structure among populations within valleys, but significant matrilineal structure across populations of different valleys.

6.4

TIMMERMAN, B.E., STRICKLAND, D.C.; timmerman@biol.sc.edu. University of South Carolina
CAN PEER REVIEW IMPROVE FRESHMAN LAB REPORTS AND DOES EXPERIENCE WITH PEER REVIEW IMPROVE STUDENTS SCIENTIFIC REASONING SKILLS?

One of our departmental curriculum goals is for students to be able to think like scientists, but we are unable to provide individual research opportunities for 1000+ majors. We hypothesize that incorporating formal peer review into core courses provides sufficient intellectual stimulation to cause an increase in students scientific reasoning skills over time while still being a manageable innovation on this scale. Using a web-based freeware program, our large introductory courses (400+ students per course per semester) and sophomore lab courses (100-150 students) have incorporated formalized peer review of written lab reports into their regular curricula over the last two years. Data indicate that undergraduates provide consistent feedback (overall scores had an average std dev of 15%, n=335). The quality of the feedback is higher when phrased as a question (5.1 ± 2.7 pieces of useful feedback) rather than as a comment (2.4 ± 1.7) (n=61), but writers find comments easier to incorporate. A detailed analysis of the strengths and weaknesses of student papers (content accuracy, quality of hypotheses, data interpretation, degree to which conclusion are based on data, etc.), peer feedback, and resulting changes in final papers will be presented. In addition, a previously published multiple-choice test of scientific reasoning ability has been administered over a range of courses. Correlations between increases in scientific reasoning skill and increasing experience with peer review (as opposed to increasing academic experience in general) will also be presented. Initial results suggest that a single experience with peer review improves student scientific reasoning scores by 8% and that all quartiles of student performance see equivalent gains.

43.2

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EFFECT OF WING DESIGN ON WAKE STRUCTURE IN SMALL FLYING BIRDS

Two species, rufous hummingbird (*Selasphorus rufus*, 3 g) and zebra finch (*Taeniopygia guttata*, 16 g) represent opposites with regard to wing design and kinematics among small birds. The hummingbird has pointed wings of high aspect ratio, and the finch has rounded wings of low aspect ratio. Across all flight speeds, upstroke : downstroke span ratio is greater than 95 % in the hummingbird and less than 20 % in the finch. We used digital particle image velocimetry (DPIV) to investigate the aerodynamic consequences of these interspecific differences in design. We measured circulation in the wake as the animals flew at speeds from 4 to 12 m/s in a variable-speed wind tunnel. Upstroke aerodynamics were distinct between species. At mid-upstroke, hummingbird wings shed a counter rotating vortex pair that was due to the ending and starting of lift production on the distal wing during early upstroke and late upstroke, respectively. The vortex pair indicates thrust production at the expense of weight support. This is a novel mechanism for matching pressure drag during forward flight; previously, it was thought the hummingbird would suffer negative thrust during upstroke. In contrast with the hummingbird wing, the finch wing does not shed substantial vorticity during upstroke. Using body lift, the finch induces downward velocity to the air flowing over the body, and this downwash is continuous throughout the entire wingbeat cycle. In the hummingbird, induced downwash through most of the wingbeat reverses to upwash during late upstroke. Our results confirm that wing design has a dramatic effect upon aerodynamics, and they improve understanding of the predictive limitations of purely kinematic data. NSF IBN-0327380

52.6

TODT, C., TYLER, S.; christiane.todt@umit.maine.edu. University of Maine, Orono
COMPARATIVE STUDIES ON THE PHARYNX SIMPLEX OF ACOELA

The homology of pharynges within the mostly pharynx-less Acoela has been a matter of discussion for decades, and still the basic question of whether a pharynx is a primitive trait within the Acoela and is homologous to the pharynx of other turbellarians is unanswered. Nemertodermatida, the sister group to the Acoela, lack a true pharynx, as does *Paratomella*, by some considered the most basal of acoels. Other candidates for this basal position, including Solenofilomorphidae, Hofsteniidae, and Proporidae, have well developed pharynges. We present the first comparative study of the pharynx simplex in these groups using transmission electron microscopy and fluorescence staining of musculature in the mouth and pharynx as well as conventional histological techniques. Among three species of the Solenofilomorphidae, characters relating to position of the mouth, presence and elaboration of sphincter muscles, presence of pharyngeal glands, and ultrastructure of epitheliosomes proved to be variously species- and genus-specific. For comparisons to other acoel families, arrangement of pharyngeal muscles and their connection to body-wall musculature, ultrastructure of receptor cells, and morphology of a non-ciliated glandular region in the posterior pharynx provided better insights. Our results show major differences of these characters among the studied species of Solenofilomorphidae, Hofsteniidae, and Proporidae. This confirms the great variability of pharynx morphologies in the Acoela and points to an independent evolution of pharynges within these families.

S8-1.3

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FUNCTIONAL GENOMICS OF ENVIRONMENTAL ADAPTATIONS IN MARINE CRUSTACEANS

The expression of genes in response to changes in salinity and temperature is being examined in our laboratory through the generation of expressed sequence tags and subsequent microarray analysis. Using the traditional gene-by-gene approach and quantitative PCR, the expression of ten different genes has been monitored in gills and other tissues of crabs and lobsters challenged with an environmental stimulus. For example, in the European shore crab *Pachygrapsus marmoratus* acclimated to normal seawater, salinity dilution leads to rapid up-regulation of transporter and heat-shock protein mRNA levels in all gills tested. In contrast, salinity increase produces an up-regulation of transporter gene expression only in gill number 7 (of 9). Current expressed sequence tag (EST) and microarray programs are developing tools for the global analysis of changes in gene expression. Starting with mixed tissue cDNA libraries normalized to reduce the abundance of highly expressed messages, we have produced 4,604 ESTs for the American lobster *Homarus americanus* and 5,362 ESTs for the green shore crab *Carcinus maenas*, available for searching at www.ncbi.nlm.nih.gov. Clustering has identified 3,773 unique sequences for *H. americanus* and 1,928 unique sequences for *C. maenas*. Oligonucleotides based on these ESTs are being arrayed for studies of transcriptome changes following environmental perturbation. In addition, the ESTs are being used directly to identify specific targets for further study, including the recent characterization of a zinc transporter in gills of *C. maenas*. Supported by NSF (DBI-0100394 and IBN-0340622) and NCRP (1-P20-RR16463).

S1.8

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IMMUNE CELL-ENDOTHELIAL CELL INTERACTIONS IN THE BOVINE CORPUS LUTEUM

Early embryonic mortality accounts for a substantial portion of reproductive failure in agriculturally important livestock, including the dairy cow. The maintenance of early pregnancy requires a fully functional corpus luteum that is not susceptible to regression following fertilization, yet the cellular mechanisms of luteal regression are not clearly understood. Immune cell accumulation within the corpus luteum at the time of luteal regression is a well-documented phenomenon in a variety of species. In the dairy cow, immune cell accumulation precedes luteal regression by several days and coincides with an increase in the expression of monocyte chemoattractant protein-1 (CCL2), suggesting that immune-mediated events promote the onset of tissue destruction. Our laboratory has shown that endothelial cells comprising the corpus luteum are a primary source of CCL2 secretion. Moreover, we know that although uterine-derived prostaglandin F₂-alpha (PGF) initiates luteal regression in the cow, PGF does not directly provoke CCL2 secretion by luteal endothelial cells. Instead, it is proposed that PGF-induced luteal regression requires the cooperative interaction among immune cells, endothelial cells, and the steroidogenic cells within the corpus luteum to promote CCL2 secretion, enhance immune cell recruitment, and eliminate luteal tissue. This presentation will focus on proposed interactions between immune cells and endothelial cells derived from the bovine corpus luteum that result in enhanced CCL2 expression and the elaboration of other inflammatory mediators (e.g., cytokines, endothelin-1) that perpetuate luteal regression. Our long-term goal is to obtain fundamental knowledge of immune-endocrine interactions regulating the function of the corpus luteum and thereby formulate methods to improve estrous synchronization and fertility in cattle.

49.6

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A MYSTERY SOLVED: HOW THE EGYPTIAN FRUIT BAT ABSORBS SUGAR

Two decades ago D.J. Keegan reported findings on Egyptian fruit bats (*Rousettus aegyptiacus*, Megachiroptera) that were mysteriously at odds with the dogma about how glucose is absorbed. Keegan's in vitro tests for active transport by bat intestine were all negative, although he used several tissue preparations and had positive control results with laboratory rats. Because glucose absorption by bats is nonetheless efficient, he observed that it seems necessary to postulate that the rapid glucose absorption from the bat intestine is not through enterocytes but must occur between these cells (*S. Afr. J. Sci.* 80 (3):132). Thus, we predicted that absorption of nonactively-transported water soluble compounds would be more extensive in these bats than in rats, and would decline with increasing MW as predicted for sieve-like paracellular absorption. Bats were captured in Beer Sheva, Israel, and rats were studied in Madison, WI. Using a standard pharmacokinetic technique, we gavaged or injected the relatively inert carbohydrates L-rhamnose (MW = 164 Da) and cellobiose or lactulose (MW = 342 Da), and actively transported 3-O-methyl-D-glucose (3OMG), and subsequently measured the appearance of probes in blood to calculate fractional absorption (F). As predicted, F declined with increasing MW in both bats (rhamnose, 62 ± 4%; cellobiose, 22 ± 4%) and rats (rhamnose, 24 ± 2%; lactulose, 10 ± 2%), but was significantly higher in the bats, indicating higher paracellular absorption. Absorption of 3OMG was high in both species (respectively, 91 ± 2% vs. 92 ± 5%). We estimate that Egyptian fruit bats rely on passive, paracellular absorption for about 2/3 of glucose absorption, much more than in non-flying mammals but similar to birds. Supported by NSF IBN-0216709 to WHK.

49.5

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CARBOHYDRATE ABSORPTION IN MIGRATING BLACKCAPS, UPON ARRIVAL AND AFTER REFEEDING, AT A STOPOVER IN SOUTHERN ISRAEL

Small birds in migratory flight catabolize fat and apparently some protein as well, including gastrointestinal tract (GIT) tissue. The smaller guts, along with mucosal structural changes, probably reduce the capacity for mediated nutrient uptake and increase intestinal permeability. When refueling at a stopover, a bird's body mass (*mb*) increases in 2 phases: 2-3 days of slow lean mass increase including GIT, followed by rapid fat gain. We hypothesized that in phase 1 of *mb* increase, blackcaps (*Sylvia atricapilla*) that have crossed the Sahara and Sinai deserts would have lower active uptake and higher paracellular, passive uptake of water soluble nutrients. To test this we measured absorption of sugars in newly arrived and refed blackcaps in Eilat, Israel. Refed birds were kept in an aviary at the capture site, fed *ad libitum*, and tested after 5 d. Fractional absorption of actively transported 3-O-methyl D-glucose was lower in newly arrived than in refed birds, indicating reduced active absorption in the former. An index of paracellular permeability, the ratio of the fractional passive absorption of a large paracellular probe (cellobiose, 342 Da) to smaller ones (rhamnose or arabinose, 164 and 150 Da, respectively), attests to higher permeability in new arrivals. Further, fractional absorption averaged across all passive, paracellular probes, in refed birds was 74% of that in new arrivals. Higher paracellular uptake during refueling at stopover can compensate for the reduced active nutrient uptake capacity of the GIT, but it could also expose birds to higher levels of toxins in their food. Supported by NSF IBN-0216709 to WHK.

76.9

TRACY, C.R., CHRISTIAN, K.A., BETTS, G., TRACY, C.R.; chris.tracy@cdu.edu.au. Charles Darwin University, University of Nevada Reno
INTERACTIONS BETWEEN WATER BALANCE, TEMPERATURE REGULATION AND ARBOREALITY IN FROGS

Many amphibians evaporate water freely across their skin. This creates a challenge to thermoregulation: how to simultaneously regulate water and temperature balances when thermoregulatory behaviors may simply result in changes in rates of water loss rather than changes in body temperature. The apparent conflict between predictions based upon the physics of heat exchange, and observations of apparent thermoregulatory behaviors (e.g. basking), and physiology (e.g. increased water loss at high temperatures) has resulted in a debate for many years. It is likely that frogs with extreme resistance to water loss have the capacity to thermoregulate and to be partially emancipated from the need to find free water, and therefore have the means to become arboreal. Controlling rates of desiccation in frogs appears to be accomplished by three mechanisms: (1) having cutaneous resistance to water vapor transport (e.g. *Litoria bicolor*), (2) having a large body size which effectively reduces the surface area to volume ratio, and thus, reduces the rate of dehydration (e.g. *L. caerulea*), and (3) behavioral or ecological selection of wet environments (such as rainforests or stream sides; e.g. *Platymantis vittensis*). We have developed biophysical models to calculate water loss in frogs in relation to cutaneous resistance to water vapor loss and body size, and the simulations from this modeling shows that it is possible to achieve the same resistance to loss of hydration level by having a high cutaneous resistance, or by having large body size. This is consistent with the hypothesis that there is more than one means by which the ability to avoid desiccation can evolve, thereby providing potential for thermoregulation.

S9-2.4

TRACY, C.R., NUSSEAR, K., ESQUE, T., ZIMMERMAN, L., DEAN-BRADLEY, K., CASTLE, K., ESPINOZA, B., TRACY, C.; dtracy@biodiversity.unr.edu. University of Nevada, Reno, USGS, Colorado State University, California State University Northridge, Charles Darwin University

OVERVIEW OF CONSERVATION PHYSIOLOGY

The field of physiological ecology has evolved greatly over the most recent 20 years, and increasingly, the field has migrated from being a stand-alone discipline to deriving its importance in evolutionary biology (as we try to understand the mechanisms underpinning adaptation), and in conservation biology (as we try to apply physiological properties and processes as predictors of management efficacy). Effective use of physiological information in conservation biology requires extensive understanding of the ways in which fitness is enhanced by physiological properties and processes as well as the relationship between fitness and differences in environments including environments modified by humans. The use of evolutiono-environmental modeling to assess optimality of physiological adaptations in relation to environmental challenges represent an approach to how conservation physiology has, and should, develop. Questioning how social interactions among individuals can change physiology in ways that make individuals more vulnerable to disease in stressful environments also demonstrates how the complexity of physiological processes can predict the efficacy of conservation planning to benefit species. The area of conservation physiology will become pivotally important to conservation as we treat conservation challenges with hypothesis-based approaches to understand the direct and indirect physiological links to environments very different from those in which species have evolved.

31.4

TRANT, J.M., PLACE, A.R.*; place@umbi.umd.edu. University of Maryland Biotechnology Institute, Baltimore
PRODUCTION AND ANALYSIS OF NORMALIZED CDNA LIBRARIES FROM BLUE CRAB (*CALLINECTES SAPIDUS*) ENDOCRINE TISSUES

In order to protect and propagate economically important species of crustaceans (such as the Blue Crab), an understanding of the physiology of molting and reproduction is critical. Our ultimate goal is to devise molecular methods to predict and manipulate these processes in an aquaculture environment. Towards this end, we have generated normalized, unidirectional cDNA libraries of the Y-organ (produces ecdysone which regulates molting), neuroendocrine tissues (X-organ, brain, and thoracic ganglion), and the hepatopancreas (digestive gland where vitellogenesis and xenobiotic metabolism occurs) in order to provide a resource for molecular probes and for gene discovery. Normalization (Trimmer-Direct; Evrogen) of the cDNA libraries (Creator SMART; Clontech) reduced the complexity of each library (826,000, 618,000, and 154,000 cfu, respectively) but the analysis of the first 1,000 clones from the Y-organ shows a redundancy of only 10%. Over 62% of the clones were tentatively identified in GenBank and the remaining 17% are potential new gene products. Only 10% of the sequence data were considered unusable (empty vector, bad sequence, or short insert). These first 1,000 clones yielded 4 cDNAs representing 3 cytochromes P450 putatively responsible for ecdysone synthesis and 3 different 7-pass transmembrane receptors. Plasmids from over 11,000 colonies (at least 5,000, 5,000, and 1,000 respectively) are being sequenced and subjected to BLAST analysis. Current efforts are focused on the clones representing steroidogenic enzymes and membrane receptors of the Y-organ and members of the CHH family of hormones from the neuroendocrine library. The hepatopancreas will be fully explored in the near future. The results will be posted on the World Wide Web.

51.9

TRESPALACIOS, D., BEULIG, A.; beulig@ncf.edu. New College of Florida

CORAL LUMINESCENT BANDING AS ENVIRONMENTAL INDICATOR IN BOCAS DEL TORO, PANAMA

Coral luminescent banding is explored as a potential environmental indicator in the region of Bocas del Toro, Panama. The luminescent banding pattern in two specimens of *Porites astreoides* taken from Almirante Bay in Bocas del Toro was examined to determine: 1) if there was a general banding pattern observable within a single cross section of coral, 2) if the banding patterns on cross sections from different corals taken from the same reef system exhibit a similar pattern, 3) if coral banding patterns can be effectively related to rainfall and river run off data. Bocas del Toro can be representative of many reef ecosystems in the wider Caribbean and also of reef ecosystems adjacent to growing coastal communities in developing countries. Reef ecosystems in the Bocas Archipelago are under stress from a variety of anthropogenic activities, and have witnessed severe decline over the last 15 years. The possible causes for reef decline are considered. In particular, problems of excessive resource use and sedimentation appear to have the greatest effects in Almirante Bay, in Bocas. Coral luminescent banding is presented as a possible methodology to derive information about environmental conditions over time. It is an especially attractive technique for use in these areas because it is a relatively easy and inexpensive method of constructing environmental records. It is readily accessible to those areas that need it the most.

27.3

TRIPP, E.A.; erin.tripp@duke.edu. Duke University
NOTHING HAPPENS ONCE: SYSTEMATICS AND PARALLEL EVOLUTION IN THE SPECIES-RICH GENUS RUELLEIA (ACANTHACEAE)

The genus *Ruellia* (Acanthaceae) comprises ca. 300 species, is largely herbaceous, and is primarily tropical or subtropical in distribution. *Ruellia* is ecologically and evolutionarily interesting because of its diversity in floral and vegetative morphology, habit, and reproductive strategies. Using Bayesian and parsimony methods, molecular phylogenetic analyses of 200 spp. of *Ruellia* and 45 additional taxa in tribe Ruellieae were conducted to test the monophyly of the genus, elucidate patterns in biogeography, and reconstruct the evolution of pollination syndromes, breeding systems, and plant habit. While the monophyly of *Ruellia* has been historically doubted, results from this study indicate that the genus is indeed natural and nested within Ruellieae. The geographic distribution of basal lineages of the genus as well as neighboring outgroups suggest an out-of-Madagascar scenario for its origins, with dispersal to and radiation in Central and South America. Hummingbird pollination has evolved at least 7 times, hawkmoth pollination 5 times, and bat pollination at least 3 times. Cleistogamy, or the production of closed, obligately self-fertilizing flowers, has evolved at least 4 times. This reproductive strategy may facilitate population establishment and growth following a dispersal event. Both liana and tree habits have evolved multiple times. Bat pollination is often associated with one of these habits and may have evolved as a consequence of more aerial flower production. Finally, floral resupination, or the twisting of flowers during development that in *Ruellia* results in an upside-down orientation of reproductive parts, is also documented for the first time in this genus. It has evolved multiple times, often in association with bat pollination. The ability of species of *Ruellia* to exploit a wide range of niches, pollinator communities, and reproductive strategies probably helps explain its diversity and widespread distribution.

39.4

TRUEBLOOD, L.A., SEIBEL, B.A., GILLY, W.F.; truell@mail.uri.edu. University of Rhode Island, Stanford University
BREATH HOLDING SQUID: PHYSIOLOGICAL CONSTRAINTS ON VERTICAL MIGRATIONS OF *DOSIDICUS GIGAS*

Squids found in shallow waters have been shown to have high oxygen demands and limited oxygen transport capacity. As a result, such species are thought to be intolerant of waters with low oxygen content. However, our submersible observations and telemetry data demonstrate that one active shallow squid, *Dosidicus gigas*, migrates diurnally between the well-aerated shallow waters and mid-depths (300-600 m) where oxygen content is less than 1% of air saturation. Metabolic and enzymatic measurements show that *D. gigas* routine metabolic rate is substantially higher than species of squid living permanently in oxygen depleted water. *D. gigas* is presumably unable to support its metabolism aerobically in this environment. Possible alternatives include sustained anaerobiosis, metabolic suppression, or some combination of these strategies for survival in this oxygen minimum layer until its nightly return to shallower waters.

S6-2.2B

TUBLITZ, N.J.; tublitz@uoneuro.uoregon.edu. University of Oregon
MECHANISMS UNDERLYING PEPTIDE MEDIATED NEUROPLASTICITY: A SPINELESS APPROACH IN MOTHS, FLIES AND CEPHALOPODS.

This talk discusses 4 separate mechanisms underlying peptide mediated neuroplasticity that have evolved in several invertebrates. The first is at the cellular level in the moth *Manduca sexta*. *Manduca* has a set of larval neurons that express a subset of cardioacceleratory peptides (CAPs). During metamorphosis these neurons undergo a complete transformation, changing their physiological, biochemical and morphological properties. This cellular alteration is hormonally-triggered by the insect steroid hormone 20-OH ecdysone. CAP expression in other neurons is also significantly altered during metamorphosis. The second example of peptide mediated plasticity is at the biochemical level and involves evolutionary variation in CAP signaling pathways in three different insect species. With others, we have demonstrated that the neuropeptide CAP2b causes differential effects on the Malpighian tubules in the fly *Drosophila melanogaster*, the bloodsucking bug *Rhodnius prolixus* and the moth *Manduca sexta*. This talk will focus on the species-specific differences in the biochemical pathways causing this functional diversity. A third example of peptide-mediated plasticity is at the developmental level in *Drosophila*. Two CAPs, CCAP and CAP2b, are expressed in the mesodermally-derived midline mesoderm cells (MMCs) of *Drosophila*. The MMCs extend a neuronal-like process, express neuronal markers, have voltage-dependent channels, and contain bioactive CAPs. These data suggest that the MMCs act as neurosecretory cells despite their non-neural origins. The final example of peptide mediated plasticity is at the system level, centering on the control of body patterning behavior in cephalopods. Several basic principles will be discussed to set the stage for the following talk by Dr. Poh Kheng Loi on the neural regulation of body patterning behavior in cephalopods.

60.4

TURNER, A.C., DASARI, S., COOPER, R.L.; RLCOOP1@pop.uky.edu. LaFayette High School, Lexington, University of Kentucky, Lexington
INFLUENCE OF THE DOPAMINE AND SEROTONERGIC SYSTEM ON PHYSIOLOGY, DEVELOPMENT AND BEHAVIOR OF *DROSOPHILA MELANOGASTER*

The dopamine and serotonergic system in the nervous tissue is known to play a vital role in development and behavior in simple to complex animal models. Previously we showed the physiological sensitivity of exogenous application of serotonin (5HT) and dopamine on sensory-CNS-motor circuit in a semi-intact preparation of *Drosophila* 3rd instar larvae. Feeding p-CPA (a blocker of 5HT biosynthesis pathway) from 1st to 3rd instar resulted in slowing of the growth compared to controls. The rate of body wall and mouth hooks movements are reduced in p-CPA fed larvae compared to controls. HPLC analysis shows a reduction in 5HT in the larval CNS of animals fed p-CPA. Animals were also fed AMVT (a blocker for dopamine production). When AMVT is given to first and second instar larvae, a concentration of 0.0005g/0.5ml water resulted in death, even when the second instar larvae were administered the drug for twelve hours then non-tainted food. All the animals died within 24 hours of first being exposed to AMVT. When 3rd instar larvae were fed the drug they lived. The third instar larvae have a higher tolerance of AMVT than earlier stages of larvae and when fed the drug. Time to pupation was not altered in 3rd instars, but they died readily if stressed by heat or physically. Immunocytochemistry staining is also being used to confirm the HPLC results and localization of drug effects. Funded by KY Young Researchers Program, University KY (A.C.T) Dept. of Biology G. Ribble Fellowship (SD) & NSF-IBN-0131459 (RLC).

55.2

TYTELL, E.D.; tytell@fas.harvard.edu. Harvard University
MEDIAN FIN FUNCTION IN BLUEGILL SUNFISH, *LEPOMIS MACROCHIRUS*: STREAMWISE VORTEX STRUCTURE DURING STEADY SWIMMING

Flow patterns in the transverse plane were examined at a range of positions around bluegill sunfish, *Lepomis macrochirus*, from the trailing edges of the dorsal and anal fins to the near wake. Simultaneous particle image velocimetry and kinematic measurements were performed during swimming at 1.2 body lengths per second to describe the streamwise vortex structure, to quantify the contributions of each fin to the vortex wake, and to assess the importance of three-dimensional flow effects in swimming. Sunfish produce streamwise vortices from at least eight distinct places, including both the dorsal and ventral margins of the soft dorsal and anal fins, and the tips and central notched region of the caudal fin. Vortices from the dorsal and anal fins persist into the wake, and do not differ significantly in circulation from the two caudal fin tip vortices. Because the circulations are equal and the length of the trailing edge of the caudal fin is approximately equal to the combined trailing edge length of the dorsal and anal fins, I argue that the two anterior median fins act like a second tail, producing a total force that is comparable to that of the caudal fin. Additionally, while the posterior half of the caudal fin and the dorsal and anal fins add vortex circulation to the flow, the peduncle and the anterior caudal fin appear to absorb it. Kinematic measurements indicate that the tail is angled correctly to enhance thrust through this interaction. Integrating these measurements, a three-dimensional structure of the vortex wake is proposed. Finally, the degree to which the caudal fin acts like a idealized two-dimensional plate is examined, and the possibility of substantial losses from tip vortices is described.

70.1

URANO, A., MORIYA, S.; ABE, Shuiti; urano@sci.hokudai.ac.jp. Hokkaido University, Sapporo, Research Development Center, Nisshinbo, Chiba, Hokkaido University, Hakodate
OLIGONUCLOTIDE DNA MICROARRAY FOR HAPLOTYPE ANALYSIS IN FIELD ENDOCRINOLOGY

Wild animals of the same species often form a mixed population of individuals from different stocks. Analyses of endocrine parameters, such as the contents of hormones and their plasma levels, in individuals require identification of their genetic stocks, otherwise mislead incorrect conclusions. Oceanic salmon in the Bering Sea contain large mixed populations, in which origins of fish varied from Asia to North America. Identification of their natal country is thus crucial for understanding of endocrine mechanisms of their migratory behavior. We therefore developed a method in which oligonucleotide DNA microarray is used for detection of nucleotide sequence variations in the 5' half of the mitochondrial DNA control region of chum salmon. The method includes 1) immobilization of 17 to 20 mer synthetic oligonucleotides, which contain the previously identified polymorphic site sequence, on a slide glass pre-coated with poly-carbodiimide resin, 2) hybridization of biotinylated PCR products spanning the 5' variable portion with a DNA microarray, and 3) coloring of hybridization signals by a conventional ABC method, and comparison of scanned signal images on a computer. All processes of hybridization and detection could be completed within eight hours, so that we obtained the result even during a few week research cruise. Since the present oligonucleotide microarray method can be carried out without any specialized laboratory equipment, it will be a rapid and accurate means for genetic stock identification of animals in the field.

11.3

UYENO, T.A., KIER, W.M.; uyeno@bio.unc.edu. University of North Carolina, Chapel Hill
THE MUSCLE ARTICULATION IN POLYCHAETES AND CEPHALOPODS: JOINTS MADE OF MULTIFUNCTION MUSCLE

Joints allow relative movement between rigid structural elements (termed links). There are two categories found in animals: sliding and flexible joints. Sliding joints (e.g. vertebrate articulated joints) transmit compressional forces directly between contacting links. The shape of the contact surfaces and their connective tissue capsules limit the degrees of freedom and range of motion. Flexible joints include a pliable connection between two links that allows motion. These joints are normally loaded in tension because compressional forces buckle the connection. This study focuses on a form of flexible joint first identified in the *Octopus* buccal mass: the muscle articulation. Here, muscle and connective tissue form the connection between links. The soft tissues move and transmit compressional forces between the links and create pivot areas. Thus, with appropriate neural control, a greater diversity and complexity of joint movement may be possible. The pharyngeal bulb of the polychaete *Nereis* also appears to possess muscle articulation characteristics. The curved jaws, used in burrowing, feeding, and fighting, are embedded in a complex mass of connective tissue and muscle fibers. The longitudinal, radial, and circumferential muscle fiber bundles and the connective tissue fiber sheaths of the bulb probably function as a muscular hydrostat. A previous morphological study assigned single functions to individual muscle fiber bundles. Our biomechanical analysis indicates, however, that the function of a given muscle bundle is context-dependent: both the morphology and preliminary observations of the jaws in use suggest that some fiber bundles may function as pivots and jaw openers or closers depending on the activity of other fibers. Thus, *Octopus* and *Nereis* jaws share the characteristics of muscle articulations and suggest that such multifunctional joints may be more common than previously recognized.

63.2

VAN WASSENBERGH, S., HERREL, A., ADRIAENS, D.; AERTS, P.; Sam.VanWassenbergh@ua.ac.be. University of Antwerp, Ghent University
TERRESTRIAL FEEDING IN THE EEL CATFISH, *CHANNALLABES APUS*

The air-breathing catfish *Channallabes apus* lives in the muddy swamps of tropical Africa. Stomach contents revealed that this species selectively feeds on (mostly terrestrial) Coleoptera. Although it was originally assumed that terrestrial insects are only taken when they had accidentally fallen into the water, recent aquarium observations have shown that these fish are actually capable of capturing prey on land. During aquatic feeding, this species uses considerable suction to draw prey towards the mouth. Once out of the water, however, a flow of air is unlikely to cause displacement of the prey. Consequently, the eel catfish is forced to apply an alternative prey capture strategy. To investigate what morphological and/or behavioural characteristics enable the eel catfish to feed terrestrially, high-speed video recordings were made of this animals remarkable feeding mode and compared to sequences of aquatic bottom feeding. During terrestrial feeding, the catfish lifts up the rostral part of the body and points the head downwards. The anguilliform body of *Channallabes apus* makes it possible to assume this posture without losing stability. Next, the jaws are placed onto the prey, followed by a substantial abduction of the hyoid and the pectoral girdle. After this, the mouth closes and the catfish returns to the water holding the prey between the jaws. So, despite the drastic mechanical differences of water *versus* air, kinematics of suction feeding are still applied terrestrially. Yet, given the catfishes characteristic posture when searching for food on land, these cranial kinematics do not prevent the animal to perform successful prey captures in this unusual environment.

54.6

VANDEN BROOKS, J.M.; john.vandenbrooks@yale.edu. Yale University
THE DEVELOPMENT OF *ALLIGATOR MISSISSIPPIENSIS* UNDER VARYING pO_2

Oxygen is the most important environmental component for all terrestrial aerobic organisms. Traditionally, the partial pressure of oxygen (pO_2) was thought to have varied little since its original rise during the Precambrian. Contrary to this, the Berner oxygen curve indicates a marked increase in pO_2 during the Permo-Carboniferous with an upper value of ~31% and a sharp decline at the Permo-Triassic boundary to below modern day levels. Such large scale changes in pO_2 would have had wide ranging effects on vertebrate evolution and development. To begin to examine the effects of varying pO_2 on vertebrate development and evolution, 750 *Alligator mississippiensis* eggs were raised under nine different pO_2 levels ranging from 16% to 35%. Temperature, humidity, and carbon dioxide were held constant. The results of this experiment demonstrate that pO_2 has an effect on growth rate, the timing of developmental events, bone density, phosphate concentration within the bones, and mortality rate in developing *Alligator mississippiensis* embryos. In addition, a threshold value of 27% oxygen was determined, beyond which increasing pO_2 has a deleterious effect on development. Up to this value, increasing pO_2 has a positive effect. This data was then applied to the fossil record. Some of the same trends seen in the *Alligator* experiment were observed in the fossil taxa that existed during the time of the hypothesized oxygen spike. This is the first step in understanding the complex interactions between pO_2 and vertebrate evolution and development.

72.2

VANHOOYDONCK, B., HERREL, A., IRSCHICK, D.J.; bieke.vanhooydonck@ua.ac.be. University of Antwerp, Belgium, Tulane University, New Orleans
EFFECTS OF SUBSTRATE DIAMETER ON ACCELERATION CAPACITY IN *ANOLIS* LIZARDS

Although lizards are often considered model systems for the study of locomotor performance and ecology, little is known about the effect of substrate characteristics (e.g. diameter, texture) on performance. This seems especially relevant in the context of unsteady locomotor behaviours, such as acceleration, as in nature lizards typically use short bursts of locomotion on a variety of substrates to escape predators and/or to capture prey. In this study, we measured acceleration capacity and running speed in three species of *Anolis* lizards on two dowels of different diameter. The species were chosen to represent three ecomorphs, differing in their natural substrate usage (i.e. trunk-ground, trunk-crown, twig). The trunk-ground anole, *Anolis sagrei*, showed the highest level of acceleration capacity followed by the trunk-crown anole, *A. carolinensis*. The twig anole, *A. valencienni*, performed poorest on both substrates. In all three species, acceleration capacity declined with dowel diameter. Sprint speed, however, was affected to a varying degree in the different species. Whereas sprint speed declined dramatically in the trunk-ground anole, no effect of dowel diameter on sprint speed was observed in the twig anole. Despite being the best accelerator, *A. sagrei* appears unable to continue to accelerate beyond the first step on the narrowest dowel. *A. valencienni*, on the contrary, manages to accelerate over several steps on both surfaces. Our data suggest that initial burst acceleration capacity might trade-off with stability on narrow surfaces thus compromising sprinting ability in *Anolis* lizards.

74.4

VEILLETTE, P.A., BREVES, J.P., REARDON, D.R., SPECKER, J.L.; pveillette@gso.uri.edu. University of Rhode Island
COMPENSATORY HYPERTROPHY IN FLOUNDER GUT

We investigated the osmoregulatory physiology of the marine teleost summer flounder (*Paralichthys dentatus*) that had a pathologically shortened gastrointestinal tract due to necrotizing enteritis. Evidenced by undisturbed content of moisture in muscle, survivors maintain salt and water balance despite missing most of their intestine. This is surprising because the intestine is the primary site for the obligatory uptake of water in order to prevent dehydration. Rates of fluid uptake (normalized to tissue weight) across all segments of the partial gastrointestinal tract (esophagus, stomach, and remnant intestine) were either less than or similar to rates from intact, healthy cohorts. In contrast, the average total weight (percent of body mass) of the stomach or remnant intestine was about double that of the stomach or intact intestine from healthy flounder. Consequently, when fluid uptake rate was normalized to body mass, total uptake capacity was similar for both groups. Adaptive hypertrophy of the stomach and remnant intestine likely restores functional capacity of the partial gastrointestinal tract to a magnitude sufficient to maintain water balance. These results further evidence a critical role of the intestine for osmoregulatory ability of teleost fishes in a marine environment. [Supported by NSF IOB 0220196]

40.4

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INTERZOOIDAL CONNECTION PREDICTS DIVISION OF LABOR IN COLONIAL MARINE INVERTEBRATES

Life is organized as a structural hierarchy manifesting division of labor among elements at each level. The evolutionary processes by which this structural hierarchy formed are not well understood. This study shows that the type of inter-zooidal connections within a marine invertebrate colony predicts presence of division of labor in that colony and suggests that division-of-labor plays a standardized role in hierarchy evolution. Higher levels of biological hierarchies form by the coalescence of lower levels: organelles combine to form cells, cells combine to form multicellular organisms, and multicellular organisms combine to form colonies or societies. Examination of transitional forms suggests that division of labor among morphological variants called polymorphs plays a crucial role in these coalescences. It is poorly understood why some biological collectives evolve division-of-labor systems, leading to higher hierarchical levels, while others do not. This is particularly perplexing among major colonial marine invertebrate groups, such as Cnidaria, Bryozoa and Urochordata, all of which contain both monomorphic and polymorphic subtaxa. Here a meta-analysis demonstrates that in all taxa, colonies with zooids connected by wide cavities are exclusively monomorphic, colonies with zooids connected by unobstructed tubes are either monomorphic or polymorphic, and colonies with zooids connected by tubes featuring valves or other restrictions are exclusively polymorphic. Thus, there appears to be a phylogenetically independent and rule-like correlation between the restrictedness of interzooidal connection and the presence of polymorphism. Given the close relationship between division of labor and biological hierarchies, the evolution of new levels of hierarchy may also behave according to general rules.

41.5

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ARE JAW-MUSCLE ACTIVITY PATTERNS CORRELATED WITH MASTICATORY APPARATUS MORPHOLOGY AMONG PRIMATE SPECIES?

A long-standing hypothesis in studies of primate mastication argues that morphological changes in the masticatory apparatus have evolved within a conserved behavioral framework. Thus, jaw-muscle activity patterns are thought to vary little across primate species with one pattern purportedly describing strepsirrhines and a second characterizing anthropoids. Until now, we have lacked sufficient *in vivo* data on jaw-muscle activity patterns during mastication to adequately test this hypothesis.

We compared the recruitment and firing patterns of the superficial and deep masseter as well as the anterior and posterior temporalis muscles to measures of jaw and tooth form in *Otolemur* sp., *Lemur catta*, *Propithecus verreauxi*, *Callithrix jacchus*, *Aotus trivirgatus*, *Macaca* sp., *Papio anubis* and *Tupaia belangeri*. The above hypothesis predicts little association between jaw-muscle activity and morphology.

Morphological estimates of relative symphyseal strength (Beecher, 1974) are significantly inversely correlated with the average working-to-balancing-side (W/B) ratio for these jaw muscles ($r_s = -0.93$) and the deep masseter W/B ratio ($r_s = -0.97$) across these species. Thus, primate species with relatively greater symphyseal strength estimates tend to increase the relative recruitment of their balancing-side muscles during mastication. Additionally, the timing of peak firing for the balancing-side posterior temporalis is correlated with the ratio of cristid obliqua length (as an estimate of molar shearing) and M2 crushing area suggesting that specific jaw-muscle firing patterns are linked to dental form and function.

Primate jaw-muscle activity patterns appear to be an integrated and evolving component of the masticatory apparatus. Supported by NSF.

56.2

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BIOBALLISTICS: THE SCALING OF PRELAUNCH ACCELERATION AND SUBSEQUENT TRAJECTORIES

Biological projectiles, from spores to leaping mammals, range over 100,000-fold in length. If force available varies with length squared and projectile mass with length cubed, then acceleration should scale inversely with length. Thus the prodigious accelerations of small ones (approaching 1,000,000 g) come as no surprise. The scaling of acceleration suggests constant stress and a limit on performance based on the strength of available materials, not on the outputs of biological motors. The smaller the projectile, the more its trajectory reflects a drag-dominated rather than a gravity-dominated world; a scaling index based on that shift can predict ranges and optimal launch angles. Borellis adage that (drag aside) animals of any size should jump to about the same height ignores prelaunch energy storage. While the rule turns out to be remarkably general, its applicability has quite a different basis.

57.3

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INFLUENCES OF FLOW AND FEEDING ON COLONY ORGANIZATION IN A BRYOZOAN

The bryozoan *Membranipora membranacea* has been an excellent system for studying the mechanistic basis for integration in colonial animals. Colonies of *M. membranacea* feed by pumping seawater through the colony and capturing food particles from the current of seawater. The seawater flows back out of the colony at regularly spaced openings (chimneys) that are produced by the morphological modification of many individuals, some of which degenerate and stop feeding. Previous results indicate that fluid flow controls the position of chimneys as they form: chimney formation is induced by increased excurrent flow speed at the colony edge. However, once formed, the chimneys do not appear to respond to modifications to the flow, suggesting that fluid flow may influence chimney morphology over a narrow developmental window. Excurrent flow speed could influence chimney formation directly, but it might also influence chimney formation indirectly by affecting the local feeding rate. Preliminary results suggest that food concentration influences chimney size, but not chimney spacing. Colonies grown at either high or low food concentrations produced larger chimneys than colonies grown at an intermediate food concentration, but chimney spacing was similar in all three treatments. These results suggest that both excurrent flow speed at the colony edge, and food concentration are important in organizing these colonies, but that flow is more important in determining the pattern of colony integration than feeding.

60.5

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NEURAL PLASTICITY IN HIBERNATION

Hibernators provide a uniquely informative system for studying neural structural plasticity because these animals exhibit an extreme spectrum of neural activity, virtually ceasing electrical activity as body temperature drops during torpor. We investigated whether changes in neural activity over the course of a torpor bout in adult hibernating golden-mantled ground squirrels are associated with corresponding changes in neural structure. Neural activity is known to influence parameters of neural structure such as dendritic arbors and spines, but malleability of neural structure is thought to be limited in adulthood. We detailed the time course of neural structural changes over the course of a torpor bout in disparate regions of the brain. Squirrels were sacrificed at several time points in torpor, and neurons were imaged by injecting Lucifer Yellow into cortical, thalamic, and hippocampal neurons in fixed slices. Cell body size, dendritic length and complexity, and spine density all decrease by 20-30% during torpor. The majority of decrease occurs during entry into torpor, and the majority of the recovery takes place within 2 hours of arousal induction. These rates of structural change are among the most dramatic found in nature, suggesting that adult mammals are capable of greater neural plasticity than previously thought.

20.3

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ONTOGENETIC PATTERN OF INTRACELLULAR CORTICOSTEROID RECEPTORS IN WHITE-CROWNED SPARROW NESTLING BRAIN

During the first stages of life, some species show a lack of reactivity to various stressors, failing to elicit glucocorticoid secretion. This is called the stress non-responsive period, which has been well documented in rats. It is thought to be adaptive, allowing organs to mature without glucocorticoids retarding growth. Previously, we have shown that altricial white-crowned sparrow nestlings also show a stress non-responsive period: handling stress did not increase total corticosterone during the first 3 days of 10-day nestling period. This lack of reactivity may be regulated at multiple physiological levels; here we focus on neural corticosteroid receptors. We investigated changes in the two intracellular corticosteroid receptors (the high-affinity mineralocorticoid receptor MR, and the low-affinity glucocorticoid receptor GR) with age. Brains were obtained from three age groups (1-3, 4-6, and 7-9 days post-hatch) of free living Nuttalls white-crowned sparrow nestlings. We found that while GR showed no change in receptor number with age, MR had a trend in decline with age. The age group showing the non-responsive period also had the highest number of MR. These results suggest 3 points: 1) the non-responsive period seen in the youngest age group of this species may be caused by MR-mediated negative feedback, 2) different ontogenetic patterns of MR and GR may result in differential set-point (threshold) for the negative feedback causing contrasting sensitivity to a stressor with age, and 3) MR and GR numbers may be controlled separately during development. We are also currently investigating whether affinities of these receptors for corticosterone change with age.

15.10

WALGUARNERY, J.W.; jwalguar@utk.edu. University of Tennessee, Knoxville
NONRANDOM PATTERNS OF SEX DETERMINATION IN *ANOLIS* LIZARDS

Despite the general selective advantage afforded parents investing equally in sons and daughters, deviations from random sex determination do occur and can provide important insight into reproductive adaptation. Recently it was discovered that individuals of the lizard, *Anolis carolinensis*, a taxon widely described as a model in reproductive behavior and ecology, sequentially alternate the sex of successive offspring, a pattern not previously known to occur in any species. Of female lizards collected from a population in Columbia County, Georgia, a majority alternated the sex of consecutive offspring, significantly more so than expected by chance. However, my own research on *A. carolinensis* collected in Duval County, Florida indicated no deviation from randomness in sex of consecutive offspring and conclusively rejected the hypothesis of even a weak tendency to alternate sex. Since neither the physiological mechanism of sex alternation nor a selective advantage of this unique pattern is yet known, it had not been possible to determine from existing data whether this disparity was due to unmeasured differences in the environment and condition of the animals or whether it indicated a genetically constrained reproductive strategy of limited geographic range. As a preliminary study of the geographic and phylogenetic distribution of this novel pattern, I simultaneously examined additional series of offspring produced by female *A. carolinensis* from populations in Georgia and Florida as well as series of offspring produced by a congener, *A. sagrei*. The results of these data indicate that a pattern of sequential alternation of offspring sex is not characteristic of the genus *Anolis*, nor even inherent to the reproduction of *A. carolinensis*, and suggest a need for further research into the conditions leading to nonrandom sex determination.

1.4

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DO FASTER STARTS INCREASE THE PROBABILITY OF EVADING PREDATORS?

Nearly all fish evade predation strikes by rapidly accelerating out of the strike path, a behavior called the fast-start evasion response. The many studies investigating correlates of fast start performance assume that faster starts increase the probability of evasion. We tested this faster-start hypothesis by measuring the effect of acceleration ability on evasion outcome (success, failure) in guppies evading the strike of a natural predator, the pike cichlid. Four parameters affected evasion outcome, two parameters important to the predator-prey interaction but not to the faster-start hypothesis: 1) the time required to reach the prey by the striking predator (measured by the initial distance between predator and prey and strike velocity), 2) the evasion path of the prey relative to the strike path of the predator, and two parameters relevant to the faster-start hypothesis: 1) the ability of the prey to generate rapid tangential acceleration (measured by net distance traveled, maximum velocity, and maximum acceleration), and 2) the ability of the prey to rapidly rotate during the initial stage of the fast start. On average, a one standard deviation increase in fast start performance increased the odds of surviving a predation strike 2.3 fold. These results support the assumption that faster starts increase the probability of successfully evading a predation strike.

20.4

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BASELINE AND STRESS INDUCED CORTICOSTERONE LEVELS IN FEMALE AND MALE SIBERIAN HAMSTERS DEPENDS ON PAIRING TYPE AND PARENTAL STATUS

The Siberian hamster, *Phodopus sungorus*, forms loose monogamous pairs during breeding. However, it appears that females provide the majority of the parental care as observed in both nature and captivity. Here we show how baseline and stress-induced corticosterone levels in Siberian hamsters change after pairing and giving birth. When both male and female hamsters were housed in same sex pairs (prior to breeding initiation) baseline corticosterone levels were low, and only moderate increases in corticosterone were observed after a capture stress protocol. After being moved to mixed-sex pairs and allowed to interact for 7 days (i.e., attempt matings), in females, both baseline corticosterone and the magnitude of the corticosterone stress response increased significantly as compared to previous same-sex housing levels. In contrast, baseline levels in males remained similar as when paired with other males, although the stress response increased considerably. Finally, after raising pups for 7 days, baseline corticosterone remained high in females, but a capture stress elicited no further increase in corticosterone. In males, baselines were lower than in females, but capture stress levels similarly showed no significant increases. It was not surprising that female hamsters, chief care-givers in the nest, showed elevated baseline corticosterone as energetic demands increased due to raising young. Similarly, their blunted stress response is a likely mechanism to avoid the high reproductive cost of a flight response when young are present. For males that provide little parental care, the only strong modification of corticosterone was elicited during they period they were actively devoting energy towards mating.

69.1

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LEATHERBACK TURTLES AS OCEANOGRAPHIC INDICATORS: STABLE ISOTOPE ANALYSES REVEAL A TROPHIC DICHOTOMY BETWEEN OCEAN BASINS

Oceanographic sampling is often limited to local “snapshots” of complex, transient and widespread phenomena. Migratory pelagic animals can provide important integrated information about broad-scale oceanographic factors to improve understanding of complex ocean processes and their effects on marine biodiversity. Leatherback turtles (*Dermochelys coriacea*) are long-lived, migratory reptiles and are specialist predators for gelatinous prey. In addition, differences in morphometrics, reproductive output, and population trends exist between inter-basin leatherback populations, and could be due to differential resource availability on foraging grounds. Therefore, we analyzed stable carbon and nitrogen stable isotopes ratios $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ of tissues from nesting leatherback populations from the eastern Pacific and North Atlantic Oceans to establish differences between oceanographic processes in both basins. While $\delta^{13}\text{C}$ signatures were similar between eastern Pacific and North Atlantic leatherbacks, reflecting the pelagic foraging strategy of the species, eastern Pacific leatherback $\delta^{15}\text{N}$ signatures were significantly enriched relative to North Atlantic leatherback $\delta^{15}\text{N}$ signatures. This $\delta^{15}\text{N}$ discrepancy reflects inter-basin differences in nitrogen cycling regimes and their influence on primary productivity being transferred through several trophic levels. These results demonstrate intriguing potential for combining high-order marine consumer movements, habitat preferences, and stable isotope signatures with ocean sampling to elucidate interactions between oceanographic processes and marine biodiversity.

S1.10

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THE IMMUNE SYSTEM OF ELASMOBRANCH FISHES

Reports that elasmobranchs (sharks, skates, and rays) may have a low incidence of disease has stimulated interest in understanding the role of their immune system in this apparent resistance. Although research in this area may potentially translate into applications for human health, an initial understanding of the basic components of the elasmobranch immune system is essential. As in higher vertebrates, elasmobranch fishes possess thymus and spleen, but in the absence of bone marrow and lymph nodes, these fish have evolved unique lymphomyeloid tissues, namely epigonal and Leydig organs. TCR genes and genes associated with T-cell development are expressed in the elasmobranch thymus, implicating this tissue as a primary source of T-cells. Expression of immunoglobulin genes is more complex, with simultaneous expression of these genes in spleen, epigonal and Leydig organs suggesting multiple sites for B-cell development. The presence of rearranging antigen receptor genes along with recombinase-activating genes and polymorphic MHC genes that encode for antigen presentation structures suggest that elasmobranchs are the earliest phylogenetic group to possess the components necessary for an adaptive immune system. Ongoing studies to identify immune regulatory factors in the media conditioned by short-term cultures of epigonal cells have resulted in the isolation of bioactive compounds with potent growth inhibitory activity against several mammalian tumor cell lines and may represent novel cytokines with potential applications for human health.

13.2

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EFFECTS OF FORE-AFT BODY MASS DISTRIBUTION ON ACCELERATION

A quadrupeds ability to apply propulsive ground reaction forces (GRF) and accelerate rapidly may be limited by 1) muscle power, 2) foot traction, and 3) ability to counteract the nose-up pitching torque due to propulsion. If foot slippage or pitching moments play a major role in limiting maximum acceleration, then fore-aft body mass distribution should strongly influence a quadrupeds ability to accelerate. Despite this, quadrupedal mammals vary greatly in their fore-aft body mass distribution from the front heavy American bison to the hind-weighted jackrabbit. We investigated the effects of fore-aft mass distribution on acceleration by comparing the mechanics of accelerating dogs with and without 10% body mass added in saddlebags just in front of the shoulder girdle or directly over the pelvic girdle. Dogs were videotaped and their GRFs measured during the initial pushoff and first two strides on a sandpaper coated trackway. During initial pushoff, dogs hindlimbs applied the greatest peak propulsive forces and force impulses with caudal weights, whereas, in step two, these forces were greatest with cranial weights. Unweighted dogs applied greater peak vertical and propulsive forces during step one than during initial pushoff. Propulsive forces during pushoff appeared to be limited by substrate friction. If dogs leg muscles exerted their maximum power during pushoff dogs could not have applied greater peak propulsive forces in step 1. Caudal weights led to greater hindlimb normal force and decreased the potential for foot slippage. In the second step, where cranial weights increased dogs propulsive forces, propulsive force production was likely limited by a nose-up pitching torque. Cranial weights increased the propulsive forces dogs could apply while the net GRF remained in line with the center of mass.

70.4

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DIET AFFECTS THE ADRENOCORTICAL FUNCTION IN NORTHERN FULMARS (*FULMARS GLACIALIS*)

Previous studies have shown that variations in corticosterone secretion in birds might reflect either changes in physiology between different life-history stages or fluctuations in food resources. The objective of this study was to test whether corticosterone secretion in northern fulmars is determined by age, reproductive stage or changes in the diet. We compared baseline and acute stress-induced levels of corticosterone and diets in chicks and adult fulmars breeding on three largest colonies in the North Pacific. We found that corticosterone levels vary inter-annually, among colonies and between incubation and chick-rearing. However, there was no consistency in both inter-annual and inter-seasonal patterns of corticosterone secretion among colonies or between age categories. Qualitative inferences of the diets from fatty acid signature analyses suggest that all differences in corticosterone secretion might be explained by changes in the diet composition. These results suggest that the adrenocortical function of northern fulmars reflect changes in food resources rather than physiological changes in birds among different life-history stages.

12.2

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DYNAMICS OF HAWKMOTH ANTENNAE: FINITE ELEMENT ANALYSIS OF ANTENNAL MECHANICS

All moving systems require sensors that encode their motions. Sensing body rotation is particularly important in flight control and both visual and exteroceptive (e.g. halteres) systems have been implicated as key modalities regulating flight paths, at least in Diptera species. While halteres are heralded as outstanding sensors in this regard, far less is known about rotational sensors in non-Dipteran insects. We have suggested that the antennae can serve this role in Lepidoptera. To explore this issue we used the hawkmoth *Manduca sexta* as a model system. We measured the vibrational motions of antennae during free hovering flight to determine the magnitude of tip motions. We then measured the mechanical properties of antennae (their flexural stiffness) and used these data to estimate the forces required to produce observed tip motions. Armed with mechanical and morphological properties, we developed a dynamic finite element model of an antenna subject to a combination of vibrations with varying levels of rotational precession about an orthogonal axis. Our results show that (a) the predicted motions match those we have observed and (b) the observed vibrational motions generate a rotating pattern of strain at the antennal base. We further explored how the flexural stiffness of antennae affect the patterns of strain at the antennal base by varying flexural stiffness over several orders of magnitude. Simulation results show that for a particular driving frequency, there is a unique value for stiffness that leads to peak strain in the antennal response to rotation. This suggests that filtering of vibrations can be tuned by the flexural stiffness of antennae.

22.2

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LIZARD LIFE HISTORY STRATEGIES AND POPULATION DYNAMICS UNDER A REGIME OF PULSED RESOURCES

How organisms of varied life history strategies integrate ephemeral pulses of resources to optimize reproductive effort at seasonal and annual time scales is unresolved and critical to our understanding of animal reproduction and subsequent population dynamics. Resource pulses such as rain in arid ecosystems drive seasonal vegetative growth patterns and the dependent population dynamics of herbivorous consumers. The bottom-up effects, however, of these pulsed resources on reproduction and population dynamics of secondary consumers is neither explicitly correlated nor well understood. To examine these dynamics we use a fifteen year dataset of quarterly lizard and arthropod trapping at the Jornada LTER in the arid Chihuahuan desert of southern New Mexico. Our analyses show emergent patterns of lizard populations, secondary consumers in this system, at seasonal and annual timescales as a function of species specific life history strategies.

17.6

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REEVALUATING CLAIMS OF ECOLOGICAL SPECIATION IN *HALICHOERES BIVITTATUS*

Rocha et al. (2005) hypothesize cryptic speciation across an ecological gradient in the Slippery Dick wrasse (*Halichoeres bivittatus*), a widely distributed marine fish that occurs from Brazil to the southern United States. This hypothesis is based on a study of geographic variation in the mitochondrial cytochrome B gene, which exhibits a deep phylogenetic break between northern and southern lineages. Where these lineages come into contact in Bermuda and the Florida Keys spatial haplotype segregation exists on a local scale, with significant differences in haplotype frequencies between habitats separated by as little as 2 km. It was also reported that no obvious morphological differences exist between the putative species in question, although no morphological measurements have been made. I present new molecular and morphological data from specimens collected in the Florida Keys, northern Florida, the Bahamas, and Belize. Molecular data from samples taken from a broad range of habitat types in the central Florida Keys is used to assess the degree of habitat segregation, and the addition of sequences from other loci and more distant locales allows further examination of the nature of the divergence seen in cytochrome B. Measurements of jaw adductor muscle mass are also presented along with an analysis of the degree to which this morphological variable correlates with ancestry and habitat type. The hypotheses of cryptic speciation and ecological differentiation are reexamined in the light of these analyses.

S2-1.7

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DEVELOPMENT OF THE LATERAL LINE SYSTEM IN TELEOST FISHES: ZEBRAFISH AND BEYOND

The lateral line system of teleost fishes provides many opportunities for the investigation of fundamental questions in evolutionary developmental biology. The lateral line system is composed of, not a bilateral pair of cranial sensory organs, but a spatial array of neuromast receptor organs on the head and trunk. In adult fishes, cranial neuromasts are enclosed in lateral line canals that are integrated into a subset of dermatocranial bones, and as such are also a component of the cranial skeleton. Lateral line development commences during embryogenesis with the migration of placode-derived cells from which neuromasts differentiate, and continues through the larval stage (over many weeks) with neuromast maturation and the morphogenesis of the lateral line canals. Neuromast differentiation and distribution, on the trunk has been studied in zebrafish and a handful of other species (e.g., medaka, blind cave fish), and the contributions of this work to our understanding of pattern formation and cell migration will be briefly reviewed. We have compared the pattern and timing of neuromast maturation and the morphogenesis of canal segments in species in 4 teleost clades: Ostariophysi (zebrafish), Scorpaeniformes (greenling), Pleuronectiformes (flatfish) and Perciformes (several cichlids). The unusual morphology of canal neuromasts in zebrafish, and the asymmetry of neuromasts in flatfish, suggest how the pattern and timing of hair cell proliferation during neuromast maturation can be easily altered to generate the diversity of neuromast morphologies documented among teleost fishes. We have also shown that while the pattern of lateral line canal development appears to be conserved, the order and timing of development of individual canal segments is likely the origin of much of the variation in the cranial lateral line canal system among fishes.

73.9

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GILL SPECIALIZATIONS OF THE SHORTFIN MAKU, *ISURUS OXYRINCHUS*, A LAMNID SHARK

The tunas (family Scombridae) and the lamnid sharks (family Lamnidae) demonstrate a remarkable convergence for high performance swimming. Increased aerobic muscle power, continuous swimming, and regional endothermy, characteristic of these two groups, mandate the specialization of respiratory structure and function to meet increased oxygen demands. This study provides the first comprehensive analysis of lamnid gill structure in comparison to that of tunas. Vascular plastic replica casts of mako shark gills reveal microvascular modifications to increase lamellar gas transfer. Mako lamellae have diagonal blood-flow channels (previously documented only in tunas and billfishes) that are thought to manage blood pressure drop across long lamellae. Blood is delivered to these oblique channels through an additional outer marginal channel on the lamellar lateral edge, and blood is collected by inner marginal channels. Mako diffusion distances are also quite short; lamellar thickness and lamellar wall width (the blood-water barrier distance) are comparable to measurements obtained for tunas and are among the smallest recorded for comparably sized fish. These microvascular specializations were not found in the blue shark (a non-lamnid). This study also confirms that mako gill surface areas are greater than non-lamnid shark species, but significantly less than those of tunas. The basic elasmobranch respiratory design (which exhibits a much more tortuous water pathway than that of teleosts) may limit lamnid gill surface areas and serve as a bottleneck preventing these sharks from reaching the scope of sustainable aerobic performance achieved by tunas.

45.3

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A REASSESSMENT OF THE SYSTEMATICS OF RAUISUCHIDS AND POPOSAURIDS (ARCHOSAURIA: CRUROTARSI)

The systematics of poposaurid and raiusuchid archosaurs is not well understood, particularly in relation to crocodylomorphs. The monophyly of both groups has also been questioned by several authors. Confusion stems in part due to a lack of complete descriptive work on key taxa. The terms poposaurid and raiusuchid are often used interchangeably in the literature, further confusing the taxonomy of these animals. New work on *Postosuchus* and a new specimen of *Poposaurus* help to polarize characters for a phylogenetic analysis. A data matrix of 34 characters for several selected Triassic taxa commonly referred to as poposaurids and raiusuchids, along with phytosaurs, aetosaurs and crocodylomorphs was used to present a new hypothesis of relationships. The data was analyzed in a bootstrap analysis with 100 replicates using a branch-and-bound search of PAUP. A strict consensus cladogram was produced indicating that poposaurids and raiusuchids are both monophyletic groups with crocodylomorphs more closely related to raiusuchids than poposaurids.

49.3

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USE OF DIETARY SUGAR BY HUMMINGBIRDS AS REVEALED BY STABLE ISOTOPE AND RESPIRATORY ANALYSIS

Hummingbirds are noted for their high foraging frequencies, their primarily nectar-based (sugar) diet, and their capacity to routinely display RQ values near 1.0. These observations led Suarez, et al. (1990, Proc. Natl. Acad. Sci., USA 87: 9207-9210) to propose that hummingbirds are able to fuel most or all of their metabolism during foraging with recently ingested sugars. We tested the hypothesis that broad-tailed hummingbirds (*Selasphorus platycercus*) rely upon direct oxidation of diet-derived sucrose to fuel flight when allowed free access to sugar water. Hummingbirds were maintained on a diet containing beet sugar, leading to carbohydrate and fat stores with $^{13}\text{C}/^{12}\text{C}$ isotope ratios characteristic of this C3 plants. Following a fast, hummingbirds were then given access to a feeder containing a solution containing cane sugar, i.e., from a C4 plant source. The feeders were fitted with a mask to allow flow through respirometry. By subsampling and analyzing the $^{13}\text{C}/^{12}\text{C}$ ratio of CO_2 expired while birds fed and comparing these values with RQ values, we determined that the hummingbirds began oxidizing sucrose from the C4 plant source within a few minutes after their first meal and could support most of their hovering metabolism with recently ingested sugar. This is the first report of a vertebrate fueling high metabolic rates during exercise mainly with dietary sugar.

15.9

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HERITABILITY OF LIPID RESERVES IN GRAY TREE FROG METAMORPHS

Condition-dependence has emerged as an important assumption in models of sexual selection and life history evolution. Condition has been defined as a measure of physiological state that reflects the ability of an organism to acquire, store, and/or use resources to enhance its fitness. Under condition-dependence, genetic variance in condition should contribute to the evolvability of traits that are limited by condition. Although condition is difficult or impossible to measure directly, and attempts to do so are often contentious, fat reserves can provide a meaningful proxy. I investigated genetic variation in condition by measuring fat reserves at the end of the metamorphic transition for gray tree frogs (*Hyla chrysoscelis*). Two measures of fat reserves—whole body lipid content and lipid mass as a percentage of dry mass—showed significant heritability in each of two experimental environments. The heritability of lipid reserves may help explain how variation in performance at metamorphosis is translated into variation in sexual displays and other fitness-related traits in adulthood. Although measuring fat reserves requires destructive sampling, both measures of lipid content were phenotypically correlated with body size and age at metamorphosis, traits that are widely used in amphibian ecology. The genetic correlation between lipid reserves and metamorphic size and age remains to be tested. A significant genetic correlation would validate the use of these non-destructive measures as estimates of condition at metamorphosis. In addition, the strong phenotypic correlation between mass at metamorphosis and percent lipid content reflects increased allocation to energy storage at larger body size. This increased allocation to storage offers a possible mechanism linking metamorphic performance traits to fitness later in the life cycle.

69.5

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FECUNDITY AND REPRODUCTIVE ENERGETICS IN THE CHESAPEAKE BAY BLUE CRAB, *CALLINECTES SAPIDUS*

The blue crab, *Callinectes sapidus*, has historically been a major fishery in the Chesapeake Bay. Both fishery dependent and independent data indicate that the population declined abruptly in the mid-1990s and has remained low, which has raised concerns about the health of the Bay population. Fishery independent observations also indicate that the mean carapace width of mature female crabs in the Bay has declined. Previous reports found a significant relationship between size and fecundity for mature females in this population. This was similar to allometric relationships reported for other brachyuran crustaceans. Fecundity estimates for the spawning stocks of 2002–2005 indicate that individual female fecundity was an order of magnitude lower than previously reported. This suggests that the allometric size/fecundity relationship is no longer valid for this population. The production of fewer eggs per mature female, along with a decline in spawning stock size, suggest a major change in population fecundity. Alternative non-allometric regulation has been examined. The current gonadal index was similar to data from the early 1980s. This indicates that each individual is still producing a consistent amount of ovarian tissue. Lack of sufficient energy resources to produce the maximum number of eggs would be a strong alternative control factor. One likely extrinsic source for the fecundity changes is reduced prey availability, which has been documented throughout the Bay. The allocation of resources was examined by determining the lipid and protein concentrations of the hepatopancreas, ovaries, and eggs of mature females. Quantitative differences in lipid types in these tissues were also examined.

S4.9

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AVAILABILITY OF DISSOLVED ORGANIC MATTER (DOM) REDUCES CARRYOVER PERFORMANCE CONSEQUENCES FOR THE MARINE BRYOZOAN *BUGULA NERITINA*

For marine invertebrates with complex life-cycles physical stresses during the larval stage can often have dramatic and long-lasting effects on post-metamorphic performance. The cheilostome bryozoan *Bugula neritina* is an ideal model system for investigating such carryover performance consequences. For *B. neritina* an extended larval swimming phase results in post-metamorphic individuals that are on average smaller and slower growing, causing a decrease in the production of offspring over a given time period when compared to individuals that develop from larvae that do not undergo protracted larval swimming. We sought to determine if the availability of dissolved organic matter (DOM) could offset the known carryover effects that result from extended larval swimming by comparing the performance of animals in the presence and absence of DOM during larval swimming and metamorphosis. Indeed, for nearly a century researchers have investigated the uptake and utilization of dissolved organic matter (DOM) by marine invertebrates however the extent to which DOM transport contributes to the overall growth, reproduction and survival of animals remains largely unknown. Animals in a DOM-enriched condition had a higher rate of successful metamorphosis when compared to animals in the DOM-reduced condition. In addition, animals in the DOM-enriched condition had larger post-metamorphic size compared to animals in DOM-depleted seawater. The results from these experiments in conjunction with known carryover consequences for *B. neritina* suggest that the ability to utilize DOM during swimming and metamorphosis may ultimately result in increased reproductive fitness.

4.5

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ENVIRONMENTALLY CAUSED CHANGES IN ASEQUAL REPRODUCTION RATES IN TWO INVASIVE SEA SQUIRTS: *BOTRYLLUS SCHLOSSERI* AND *BOTRYLLOIDES VIOLACEUS*

An increase in global ocean temperatures over the last century has coincided with an increase in invasive species. Ascidians have been particularly successful as invaders and are now dominant space holders in benthic communities throughout the world. A potential cause of this dominance may be increasing water temperatures in coastal areas leading to greater asexual and sexual reproductive rates. Two species of interest in the Gulf of Maine are *Botryllus schlosseri*, a non-native established ascidian, and *Botrylloides violaceus*, an invasive species first noticed in the 1980s. In order to assess the relationship between increasing water temperatures and invasive ascidian success, we examined the impact of various temperatures on reproductive rates in *B. schlosseri* and *B. violaceus*. Settlement panels were deployed in Salem Harbor Massachusetts, Portsmouth Harbor New Hampshire, and Damariscotta River Maine, three sites of differing annual temperature ranges. We reared colonies of both species in the laboratory at 5°C, 10°C, 20°C, and 25°C while documenting both the growth rates of colonies and time of initial larval recruitment in the field. Asexual reproductive rates were quantified as the duration of the asexual zooid replacement cycle and the increase in number of zooids per replacement cycle. Initial recruitment was first noted in Salem Harbor and subsequently in Portsmouth and Damariscotta. *Botryllus schlosseri* had greater asexual reproductive rates than *B. violaceus* at 10°C, while the reverse was true at 20°C. This variation in asexual reproduction of colonial tunicate colonies suggests that environmental factors may play a large role in determining species suc-

cess.

73.7

WESTNEAT, M.W.; WESTNEAT@FMNH.ORG. Field Museum of Natural History

BIOMECHANICAL MODELS OF FEEDING IN FISHES: TESTING FOR CONVERGENCE IN FUNCTIONAL DESIGN

Fishes use a sensational diversity of jaw mechanisms to capture and ingest their food. One of the hallmarks of this diversity is the complexity of the kinetic fish skull, which can have more than 20 mobile skeletal elements driven by numerous muscles. This complexity has often led to compelling examples of both divergence in form and function as well as convergence in design and behavior. How do we test for functional convergence in biomechanics? How do we define functional characters and determine when they are convergent or redundant? This study expands previous lever and linkage modeling and outlines more comprehensive models for analysis of fish feeding. Software for analysis of cranial levers and linkages allows for simulation of structure-function relationships in a wide range of taxa. Simulations show that structural changes in four-bar linkages map to unique sets of primary functional variables (vector direction and magnitude of motion) with little or no redundancy. A survey of skull mechanical designs throughout the phylogeny of fishes reveals that evolutionary changes in feeding mechanisms of fishes are accompanied by a wide range of strategies for transferring force and motion. Examples are described in which jaw functions have diverged due to linkage changes, and in which other morphology is modified but linkages remain static. A protocol for defining convergent and divergent functional characters is proposed. Linkage modeling leads to several conclusions regarding the use of lever and linkage theory: (1) Coordinate based shape analyses can yield functional insight using mechanically relevant landmarks; (2) The geometry and physiology of muscles are critical to accurate estimations of lever and linkage function; (3) Multiple mechanical variables and levels of design should be considered when defining convergent or redundant biomechanical systems.

58.2

WETHEY, D.S., GILMAN, S.E., HELMUTH, B.S., HILBISH, T.J.; wethy@biol.sc.edu. University of South Carolina, Columbia, University of Washington, Friday Harbor

ECOLOGICAL HINDCASTING OF BIOGEOGRAPHIC RESPONSES TO CLIMATE CHANGE IN INTERTIDAL ECOSYSTEMS

Intertidal organisms are often assumed to live close to their thermal limits, and have emerged as potential early indicators of the effects of climate change on natural ecosystems. We have developed mechanistic simulation models for body temperatures of intertidal mussels and barnacles, using climate data from local weather stations and weather satellites, in conjunction with tide predictions and satellite-derived solar radiation. The models of body temperature are typically accurate to within 2°C of temperatures measured with biomimetic temperature loggers. Simulations were carried out on continental geographic scales, in order to examine the climatic influences on current biogeographic limits of intertidal species. We also used 1960s climate records to hindcast past thermal environments near historical geographic limits. Results indicate changes in geographic limits of some species since the 1960s are due to intolerance of climatic conditions.

10.1

WHITMAN, B.A., BREUNER, C.W., DUFTY, A.M.; bawhitman@gmail.com. Boise State University, University of Texas at Austin

INVESTIGATOR HANDLING, STRESS, AND NESTLINGS: SHOULD WE BE CONCERNED?

It is well established in the mammalian literature that early developmental environment and experiences can have profound and lasting consequences. For example, neonatal stressors can alter gene expression to increase glucocorticoid receptors in the hippocampus, thus sensitizing the glucocorticoid negative feedback mechanism. In addition, the hippocampus may be organized as a preemptive modulator of the glucocorticoid stress response; i.e., pre-negative feedback mechanism dampening. We set out to explore this phenomenon in an avian species, the American kestrel (*Falco sparverius*). Using daily handling (15 min./day) from hatching to 25 days post-hatch as a chronic neonatal stressor, we tested the idea that repeated handling will modulate the development of stress responsiveness. Previous work has shown that daily neonatal handling attenuated the glucocorticoid stress response to a novel stressor and increased glucocorticoid receptors in the hippocampus in rat pups. We implemented a standard capture and restraint protocol on day 26 post-hatch, with blood samples taken at: T0, T5, T15, T30, and T60. Baseline glucocorticoid levels did not differ between handled and control groups. At all other sampling points handled birds had significantly lower glucocorticoid titers. Corticosterone binding globulins were also measured, with handled birds having lower levels than controls. Moreover, estimates of free CORT were made. Brain samples were collected; however, analysis of glucocorticoid receptors has yet to be performed.

71.4

WIDDER, P.D., BIDWELL, J.R.; widder@vt.edu. Virginia Polytechnic Institute and State University, Oklahoma State University
TADPOLE SWIM SPEED AND ORGANOPHOSPHATE PESTICIDE EXPOSURE

While methods exist to verify exposure of amphibians in natural populations to agricultural chemicals through the use of physiological biomarkers, the ecological relevance of changes in these parameters is unknown in amphibians. We examined the relationship between changes in tadpole cholinesterase (ChE; a common enzymatic biomarker of exposure to OP pesticides) and measures of growth and swim speed in four native North American species of anurans (*Hyla chrysoscelis*, *Rana sphenoccephala*, *Acris crepitans*, and *Gastrophryne olivacea*). We used four environmentally realistic levels (1, 10, 100 and 200 µg/l) of a commonly used organophosphate pesticide (OP), chlorpyrifos, and examined tadpole response at the conclusion of four days of exposure. We further examined if the presence or absence of pond sediment influenced tadpole responses, and in two species we examined how longer exposure (twelve days) influenced response. We found species-specific differences in response to the pesticide, with *H. chrysoscelis* and *G. olivacea* being more sensitive than the other two species. Furthermore, we found the presence of sediment to influence response, although effects were not consistent among species. Given these differences, we recommend exercising caution when making generalizations across different anuran taxa regarding pesticide exposure response.

76.3

WIERSMA, P., MUNOZ-GARCIA, A., WILLIAMS, J.B.; wiersma6@osu.edu. Ohio State University
DO BASAL METABOLIC RATES OF TROPICAL BIRDS SUGGEST A LOW PACE OF LIFE?

The effects of extrinsic factors on life-history trade-offs may result in a slow to fast pace of life continuum. Tropical and temperate climates are supposed to generate contrasting extremes along this continuum, with typically long lifespans, slow reproduction and low energy metabolism in the tropics. As part of an integrated, multidisciplinary project, comparing life-history parameters and physiological trades between tropical and temperate birds, we measured basal metabolic rates (BMR) of a range of tropical species. Supposedly, tropical birds have lower energetic demands as a result of a less demanding environment (e.g., favourable thermal conditions, high food availability, long breeding season). This would give rise to lower BMR values, according to the idea that BMR reflects the size of the exercise and digestive organs. We caught birds in 2004 and 2005 around Gamboa, Panama, mostly in low-land, secondary rainforest. A first comparison between our data and published allometric relationships did not reveal a difference between tropical and temperate bird species lighter than 138 g. In addition, we measured Total Evaporative Water Loss (TEWL) and body temperature (T_b) as components of heat loss and BMR. Furthermore, variation in BMR will be linked to variation in habitat preference and life-styles (as defined by, e.g., diet and foraging mode).

75.6

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University of California, Los Angeles
HOW PORCUPINEFISH (*DIODON HOLOCANTHUS*) SWIM: BIO-MECHANICS AND KINEMATICS

The Porcupinefish (*Diodon holocanthus*), is a circumtropically distributed marine fish that lives on coral reefs and in other shallow-water environments. It can reach a substantial size (50 cm+) and bears many long spines along its body that become erect when the fish inflates itself as a defense. The Porcupinefish has a repertoire of at least three swimming gaits. Experiments in our water tunnel show that the Porcupinefish is a rigid-bodied MPF swimmer at all speeds. The gait changes occur over relatively narrow ranges of speed and involve changes in the patterns of the fins used, their synchrony with other fins, and their fin-beat amplitudes and frequencies. Additionally, it shows unusual stability at all swimming speeds (very small recoil movements in three dimensions). These characteristics allow the Porcupinefish to hover and to swim stably in potentially turbulent habitats.

58.1

WILLIAMS, J.D., MCDERMOTT, J.J., BOYKO, C.B.; biojdw@hofstra.edu. Hofstra University, Hempstead, Franklin and Marshall College, Lancaster, American Museum of Natural History, New York
A WORLD-WIDE REVIEW OF HERMIT CRAB PARASITES

Although the symbiotic relationships between commensal and mutualistic species associated with hermit crabs have been reviewed and studied in some detail, hermit crabs also host a variety of parasites that are generally poorly known. We present a preliminary review of the protozoan, fungal, and metazoan parasites associated with paguroids worldwide. Our analysis shows that approximately 115 parasite species, representing 8 phyla, are found with over 100 hermit crab hosts. Endoparasites, ectoparasites, mesoparasites, and parasitoids are harbored by hermit crabs. The phylum Arthropoda contains two major groups of hermit crab parasites, the mesoparasitic barnacles (Rhizocephala) and ectoparasitic isopods (Bopyridae) that are the most abundant groups of hermit crab parasites with 19 and 74 taxa, respectively. Parasitic isopods are approximately evenly split between species that inhabit the branchial chamber (36 taxa) and those that attach to the abdomen (38 taxa) of hosts. While rhizocephalans and bopyrids utilize hermit crabs as their definitive hosts, species in other groups (e.g., Cestoda, Trematoda, Acanthocephala, and Nematoda) infect hermit crabs as intermediate hosts. The best-studied hermit crabs are those from Europe (e.g., *Pagurus bernhardus*, *P. cuanensis*, *P. prideauxi*) that harbor 7-10 different parasites along their ranges. Individual hermit crabs from all other geographic regions are known to harbor 5 or less parasites; however, this disparity in number of parasites per host may reflect limited sampling. The biology and life-history of selected parasites of hermit crabs will be explored, including information based on recent investigations of bopyrids associated with hermit crab hosts from the Indo-Pacific.

76.7

WILLIAMS, J.B., OSTROWSKI, S.; williams.1020@osu.edu. Ohio State University, University of Lyon
HETEROOTHERMY OF FREE-LIVING ARABIAN SAND GAZELLES (*GAZELLA SUBGUTTUROSA MARICA*) IN A DESERT ENVIRONMENT

One mechanism, thought to be important in reducing evaporative water loss among large desert ungulates, is heterothermy, the storage of body heat during the day and dissipation of this heat at night, thereby reducing evaporative water loss in maintenance of Tb. Mitchell and colleagues have criticized early studies of heterothermy because test animals were captive and did not have the opportunity to behaviorally thermoregulate. They concluded we believe that the high Tbs displayed in some heat-exposed antelope, and invoked in support of adaptive heterothermy, are experimental artifacts arising from depriving the animals of their natural local climate and of thermoregulatory behavior. To test whether desert ungulates employ heterothermy, we have continuously measured the Tb of free-living Arabian sand gazelles (*Gazella subgutturosa marica*), a small desert antelope (12-20 kg) that lives in the deserts of Saudi Arabia, during both winter and summer. We found that the mean daily Tb varied by $2.6 \pm 0.8^\circ\text{C}$ during summer, but only by $1.7 \pm 0.3^\circ\text{C}$ during winter. Tb increased during day by more than 2°C when $T_a > T_b$ and declined when $T_a < T_b$ at night. Correlations between daily variation of Tb and mean, maximal T_a s were significant in summer, but not in winter. Heat storage was 81.4 kJ day^{-1} in summer and 56.4 kJ day^{-1} in winter. To dissipate this amount of heat by evaporation would require $33.9 \text{ milliliters H}_2\text{O day}^{-1}$ in summer and $23.5 \text{ milliliters H}_2\text{O day}^{-1}$ in winter. Sand gazelles provide a clear example of a small desert ungulate employing heterothermy to reduce evaporative water loss.

10.3

WILLIAMS, C.T., KITAYSKY, A.S., BUCK, C.L.; fncwt@uaf.edu. University of Alaska Fairbanks
ADRENOCORTICAL ACTIVITY IN TUFTED PUFFIN NESTLINGS VARIES WITH GROWTH RATES AND FLEDGING BEHAVIOR

Birds modulate the hypothalamus-pituitary-adrenal axis (HPA) in response to changes in life and changes in nutritional status. Baseline levels of corticosterone (cort) and the adrenocortical response to acute stress in semi-precocial nestlings of some species negatively correlate with nutritional status. Conversely, species that are subjected to extended periods of chronic food restriction in their life histories may down-regulate the adrenocortical stress response to avoid the deleterious effects of long-term exposure to elevated levels of cort. Tufted puffin chicks routinely experience variable food availability; therefore, we hypothesized that the adrenocortical response of wild puffin chicks would negatively correlate with nutritional status. We also predicted puffin chicks would modulate plasma cort levels as they approached fledging, a major transitional period in the life of birds. We measured growth rates, baseline cort (<3 min post capture), and adrenocortical stress response (subsequent samples at 10, 30, and 50 min) of 30 and 40 day-old free-living puffin nestlings during a season with high reproductive success and above-average rates of growth. Plasma cort concentrations at 10 min. negatively correlated, whereas cort levels at <3, 30, and 50 min. rates were not significantly correlated with growth rates. Baseline levels of cort in puffin nestlings increased more than 3-fold as chicks approached fledging age. These results suggest that puffin nestlings modulate adrenal sensitivity but not capacity in response to changes in food intake. High levels of cort in fledging-age puffins likely acts to promote mobilization of stored energy reserves needed as chicks transition from the nest to the marine environment where they are completely self-reliant.

66.1

WILLIAMS, R.L., JOHNSON, K.B.; rwilliam@marine.usf.edu. University of South Florida, Florida Institute of Technology
SEASONAL VARIATION, DIET AND PREY SELECTION OF THE CTENOPHORE *MNEMIOPSIS LEIDYI* IN A SUBTROPICAL ESTUARY

Published studies suggest mechanisms controlling blooms of the ctenophore *Mnemiopsis leidyi* vary relative to latitude and, in some estuaries, their presence reduces zooplankton standing stocks. It has been proposed that, in temperate estuaries, temperature controls the ctenophores presence, while food availability has more influence in estuaries of the Gulf of Mexico. We examined abundance, diet and prey selectivity of *M. leidyi* in a subtropical estuary on the eastern coast of central Florida. The Indian River Lagoon (IRL) holds an intermediate position relative to estuaries where *M. leidyi* blooms have been mainly studied; we hypothesized patterns of bloom control and ecological effects would be intermediate as well. Replicated plankton tows were collected weekly for one year, and twice weekly when *M. leidyi* was present, to sample the zooplankton community and quantify potential prey. Separate tows were used to determine *M. leidyi* abundance; to conduct gut content analysis, ctenophores were collected individually while submerged *in situ*. Prey for which *M. leidyi* displayed the strongest preference were pollen, juvenile flatworms, barnacle nauplii and bivalve veligers. In contrast, protists, polychaete metatrichophores, and copepod nauplii were generally selected against. *M. leidyi* were present in the study area from January to March and neither temperature nor food availability controlled the timing or size of the bloom. Examination of size class data reveals the ctenophore population likely did not originate in the waters of the study site, but was instead transported from a neighboring nursery site. The mechanisms of control behind *M. leidyi* blooms in this intermediate subtropical estuary do not cleanly fit the proposed latitudinal patterns.

58.5

WILSON, N.G., HALANYCH, K.M.; wilsong@auburn.edu. Auburn University
UNDERESTIMATES OF ANTARCTICAS BIODIVERSITY: PHYLOGEOGRAPHY OF THE ANTARCTIC CRINOID *PROMACHOCRINUS KERQUELENSIS*

Antarcticas geographical and thermal isolation has led to high levels of endemic species. Although groups such as the pycnogonids and serolid crustaceans are well-known to have undergone major radiations in the Antarctic, the majority of other invertebrate groups are thought to have low numbers of representative species, although these are often endemic to the region. The Antarctic featherstar, or crinoid, *Promachocrinus kerguelensis* is such an example, with comprehensive morphological work recognising only one valid species, circum-Antarctic in distribution. The use of molecular data has refined our ability to detect cryptic species (although the definition of species will always remain somewhat arbitrary); we can now easily detect clades with different evolutionary trajectories. If *Promachocrinus kerguelensis* is indeed a single, widespread species, we might also expect to see the influence of the Antarctic circum-polar current on the directionality of gene flow. Here we investigate the genetic diversity in populations of a widespread, monotypic species of crinoid. *Promachocrinus kerguelensis* shows distinct genetic structure and subdivision, consistent with a radiation of multiple species. We suggest that this unrecognised pattern may be also present in other circum-Antarctic species, thus obscuring the real diversity occurring in Antarctica.

46.4

WISE, S.B., STOCK, D.W.; sarah.wise@colorado.edu. University of Colorado at Boulder
BONE MORPHOGENETIC PROTEIN EXPRESSION, REGULATION, AND FUNCTION IN TELEOST TOOTH DEVELOPMENT AND EVOLUTION

Bone morphogenetic proteins (Bmps) have been shown to be important in tooth development in the mouse and the evolution of dentition in rodents and birds, but little comparable data is available from teleost fishes. Teleost teeth vary greatly in location, number, and shape, both within individuals and between species. To determine whether Bmps affect this variation, we examined the expression of *bmp2a*, *bmp2b*, and *bmp4* during tooth development in the zebrafish and the Mexican tetra (*Astyanax mexicanus*). Both species possess pharyngeal teeth, while oral teeth are found only in the latter. All three genes are expressed in developing teeth of both species, with overlapping but distinct patterns. While few differences were found between oral and pharyngeal teeth, none of the genes is expressed in the toothless oral region of the zebrafish. Examination of an outgroup species, the Japanese medaka (*Oryzias latipes*), indicated that the zebrafish condition is derived, suggesting that Bmps may have been involved in the evolutionary loss of teeth in the zebrafish lineage. We also found evidence for a difference in Bmp function between the zebrafish and the tetra using morpholino-based gene knockdown. Specifically, *bmp4* is necessary for pharyngeal tooth development in the zebrafish, but not in the tetra. Finally, we are investigating the regulation of Bmp expression to understand the mechanism of oral expression loss in the zebrafish. To date we have investigated one candidate pathway, Fibroblast growth factor signaling, and have found dental expression of *bmp2a* and *bmp4* to be downstream of this process in the zebrafish. We conclude that Bmps have diverged in expression and function during evolution of teleost teeth, with some changes correlated with morphological divergence and others not.

57.5

WOLCOTT, T.G., WOLCOTT, D.L., KAMYKOWSKI, D., WATERS, L.; tom_wolcott@ncsu.edu. North Carolina State University
PLANKTON MIMICRY: FAKE DINOFLAGELLATES TO HELP UNDERSTAND REAL RED TIDES

Our robot plankter has been redesigned to permit study of motile algae as well as zooplankton. Presently it is being trained to behave like a dinoflagellate to elucidate how behavior interacts with physical oceanography in the genesis, transport, and eventual dissipation of red tides. It senses time and environmental variables: depth, temperature, salinity, photosynthetically-active radiation (PAR), and vertical velocity relative to the surrounding water and to the surface. It responds by migrating vertically according to known or theoretical behaviors of the organism under study. In its first field deployments it has successfully migrated according to the programmed profiles, calculated physiological variables (photosynthesis, respiration, nutrient uptake, cell C and N pools), and logged environmental and physiological data. An integrated GPS receiver, activated during short hops to the surface, has logged positions along the trajectory, obviating the need to follow each unit via its ultrasonic pinger. A VHF radio beacon, encoding the current GPS position, allowed location and retrieval of units from up to 6 km distance. We anticipate full-scale deployments in Gulf of Mexico red tides next year, using behavioral models that allow physiological state, as well as time, light and temperature, to modulate vertical swimming behavior.

Supported by EPA.

22.5

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MIGRATION OF FEMALE BLUE CRABS FROM MATING AREAS TO SPAWNING GROUNDS

To elucidate how adult female blue crabs migrate from oligo- and mesohaline areas in which they mature and mate, to the euhaline areas where they begin producing broods, we have been fitting them with both simple ID tags and electronic dataloggers over several years in both Chesapeake Bay and North Carolina waters. The overall pattern, revealed by conventional mark-recapture techniques, is that females generally do not migrate promptly after mating. Most from upper Chesapeake Bay and the tributaries of Pamlico Sound (NC) remain near where they mated for the remainder of the summer, departing in Sept./Oct. and migrating seaward over the next several months. In the Chesapeake they often are recaptured along the deeper channels. Electronic CTD dataloggers, deployed (and recovered) in much smaller numbers, show that Chesapeake crabs often descend into the deepest channels of the Bay but may also travel in the shallows of the submerged floodplain. Patterns are variable; several females from the lower Bay (York River), and a few from the upper Bay, have not shown such dramatic movements out into the spawning grounds where we expected recaptures by the winter dredge fishery. After overwintering (> 6 months), they were recaptured within a few hundred meters of their release sites. Females in Pamlico Sound are so mobile (at least in dry years) that the NC spawning sanctuaries appear to be ineffectual. The probability of females being caught by the fishery is similar whether they are tagged on the western shore of the sound or in a sanctuary at an Outer Banks inlet to the sea. Conservation measures evidently must be site-specific. Supported by NOAA.

37.6

WOODHAMS, D.C., RAMSEY, J.P., ROLLINS-SMITH, L.A.*; louise.rollins-smith@vanderbilt.edu. Vanderbilt University Medical Center
EFFECTS OF COLD TEMPERATURE ON ANTIMICROBIAL PEPTIDE SYNTHESIS AND RELEASE IN NORTHERN LEOPARD FROGS, *RANA PIPIENS*

Amphibians inhabit both warm and cold temperature habitats. One important innate immune defense is antimicrobial peptides produced and stored in granular glands in the skin. Little is known about the effects of temperature on the ability frogs to release antimicrobial peptides or renew their stores of antimicrobial peptides following discharge. To examine this question, warm frogs (*R. pipiens*, 23°C) were placed at 4°C for 4 weeks and peptides were induced under cold conditions. The amount of peptides collected and the anti-chytrid activity of the peptide mixtures was equivalent to those of warm-temperature frogs. This demonstrates that peptide secretion capacity was not inhibited. MALDI-TOF MS showed a similar pattern of peptides present in the cold-adapted frogs as those present in the warm frogs. Next, 10 frogs were depleted of skin peptides by injection of 40 nmole/gbw NE. Some were kept at room temperature, and others were placed at 4°C. After 35 days, peptides were induced again. The warm frogs were able to recover and synthesize new peptides; however peptide synthesis in the cold-adapted frogs was reduced. Using MALDI-TOF MS, we also analyzed the profile of skin peptides released by leopard frogs as they emerged from natural hibernation (4-10°C) in the spring. We observed that the full set of peptides was present in hibernating frogs and was approximately equivalent to that of lab-acclimated frogs. Taken together our results suggest that cold conditions may temporarily interfere with new peptide synthesis after depletion and could influence the capacity of cold frogs to resist infection. [Support NSF IBN-0131184; DEB-0213851].

3.6

WOODS, H.A.; art.woods@mail.utexas.edu. University of Texas, Austin
CAUSES AND CONSEQUENCES OF TEMPERATURE-OXYGEN INTERACTIONS IN METABOLISM

Biochemical reaction rates change more with temperature than do physical rates such as diffusion. Consequently, organisms exposed to rapid or high-magnitude temperature variation may experience profound variation in relative oxygen supply and demand. This problem is faced by all ectotherms that depend on oxygen diffusion which includes a larger range of taxa than is often appreciated. I will illustrate this issue with recent work from my lab on terrestrial insect eggs and marine opisthobranch egg masses. Insect eggs and marine egg masses are obviously different, in size, physiology, and habitat. Yet, for both, high temperature gives internal oxygen pressures low enough to limit rates of metabolism and development. Together with other similar data from the literature, my results suggest that temperature-oxygen interactions are pervasive, constituting a fundamental physiological reality for most organisms. This observation suggests several broad questions, which I will touch on briefly: What common constraints emerge from temperature-oxygen interactions? What means do different taxa use to mitigate constraints? Are there fundamental differences in how terrestrial and marine systems deal with oxygen deprivation? And how does differential temperature sensitivity affect the evolution of metabolic systems?

34.2

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CATERPILLAR CALISTHENICS: DYNAMICS OF A SLOW, STRETCHY MUSCLE DURING STRAIN CYCLING AND SIMULATED NATURAL CRAWLING

Caterpillars are soft-bodied terrestrial climbers that accomplish a wide variety of complex movements with several hundred muscles and a relatively simple central nervous system. The muscles show some characteristics of supercontracting muscles, and during crawling cycle through strains up to 30% of resting length. We examined the ventral interior lateral muscle (VIL) of final instar *Manduca sexta* larvae. VIL contracts slowly, taking 1-1.5 s to reach tetanic peak force. In passive sinusoidal strain cycling over 20% of resting length, peak force was a log function of cycling frequency ($r^2 = 0.99$), indicating viscoelasticity. After linear stretching from 90 to 110% of resting length, force immediately began to decay exponentially, with slower decay of force associated with slower lengthening; the time constant of the decay was a log function of strain rate for rates from 0.1 to 2 lengths s^{-1} ($r^2 = 0.94$). Unlike insect wing muscles during flight, VIL does not undergo a sinusoidal strain cycle during crawling; rather, the muscle is at resting length for most of the cycle, with a linear shortening and re-lengthening occupying about 45% of cycle duration. EMG recordings show that VIL stimulation occurs at the initiation of shortening and ceases when the muscle is about 54% re-lengthened. In vitro preparations were subjected to strain cycling and stimulation similar to that of natural crawling. The stimulation phase, together with the slow development of force during stimulation, contribute to a clockwise work loop, indicating that during crawling VIL functions as a brake rather than as an actuator. The high working strain range, slow contraction, and viscoelastic properties of caterpillar muscle may be important elements of passive control during caterpillar locomotion.

S9-2.3

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CONDITION INDICES FOR CONSERVATION: NEW USES FOR
EVOLVING TOOLS

Biologists have developed a wide range of morphological, biochemical and physiological metrics to assess the energetic status or health of individual animals. These metrics have proven useful to address questions in life history, ecology and resource management of game and commercial animals. We review the application of condition indices for conservation studies. We focus on measures that quantify fat reserves, known to be critical for energetically challenging activities such as migration, reproduction and survival of periods of scarcity. Standard methods measure or score fat content, or rely on a ratio of body mass rationalized by some measure of size, usually a linear dimension such as wing or total body length. Higher numerical values of these indices are interpreted to mean an animal has greater energy reserves. Thus, condition indices can provide predictive information about habitat quality and reproductive output which in turn helps managers with conservation assessments and policies. We review the current debate about the measurement methods and statistical approaches that are useful and valid for computing condition indices and discuss these indices in the context of dynamic physiological models that compute body composition. The underlying physiological regulatory systems that govern the allocation of energy and nutrients among compartments and processes within the body are poorly understood especially for field situations and await basic data from advanced telemetry systems. For now, standard physiological condition indices can provide supporting evidence and mechanistic linkages for population studies that have traditionally been the focus of conservation biology.

68.2

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MODELING NAVIGATION IN THE SEA SLUG *TRITONIA*
DIOMEDEA: STRATEGIES FOR FINDING ODOR SOURCES IN
VARIABLE FLOW

Animals navigate by integrating multiple environmental sensory cues to produce directed locomotion. From analysis of crawling patterns in the field and laboratory experiments, we know the nudibranch mollusc *Tritonia diomedea* uses a combination of odor cues and flow direction to guide navigation relative to targets of interest (prey, predators, and mates). However, it is not clear what navigational cues are used in the absence of odors. Theoretical considerations suggest a range of crawling strategies may be optimal depending on flow variability and how long ago odors were last detected. I use a simple numerical model of *T. diomedea* movements to explore the slugs navigational options. Using real current data and locomotory parameters from field observations, I compare the success of different strategies at finding odor sources. In particular, I test the possibility that the slugs magnetosensation might help them find odor sources following changes in current flow. These results will help guide both neuroethological and behavioural experimentation, contributing to a more complete picture of how mechanosensation, chemosensation, and possibly magnetosensation are integrated to produce directed locomotion in *T. diomedea*.

S5-2.4

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THE EVOLUTIONARY ORIGINS OF CARDIAC CHAMBERS

We suggest cardiac chambers evolved from anterior-posterior patterning of invertebrate peristaltic pumps, which lack efficient coordination between inflow/outflow. Strong evidence implicates retinoic acid (RA) signaling in this process. In amniotes, a caudorostral wave of the RA-synthetic enzyme RALDH2 patterns the cardiac field into inflow/outflow. The wave forms by a dynamic pattern rather than cell migration and studies in amphibians and fishes indicate it is ancestral in vertebrates. Cephalochordates, utilize 4 smooth muscle-powered vessels to drive their circulation. Urochordates centralized circulatory work in pump powered by striated muscle and encased in pericardium. Likewise, vertebrates concentrated work in the striated muscle-powered, pericardially-enclosed heart. In the traditional phylogeny similarities between urochordate and vertebrate pumps reflect inheritance of characters in the chordate ancestor. Thus, urochordates maintained the striated pump, cephalochordates regressed to a decentralized, smooth muscle system, while vertebrates developed chambers. Alternative phylogenies grouping urochordates with vertebrates provide solutions for pump similarities in these taxa, and suggest the rudimentary design of cephalochordates is primitive rather than regressed. Thus, the urochordate/vertebrate ancestor concentrated circulatory work in a striated, pericardially-enclosed pump. Urochordates further centralized circulatory work eliminating auxiliary pumps. Vertebrates created chambers, while maintaining redundancy in accessory pumps present in many species. While it is premature to decide between scenarios, the study of chordate RALDH2 expression patterns may shed light on how vertebrate hearts evolved from chordate pumps.

S6-1.1B

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MULTIPLEXED FUNCTION IN SEROTONERGIC NEURONS OF
GASTROPOD MOLLUSCS

A group of serotonergic neurons is highly conserved in cerebral ganglion lobes of opisthobranch and pulmonate gastropods. Known as the As1-4 group in *Pleurobranchaea californica* and the DSI neurons in *Tritonia diomedea*, these neurons were first discovered to be elements of the escape swimming motor networks. Subsequent studies in different labs showed that their functional roles were multiplexed. These cells act in defensive withdrawal, avoidance and orienting turning, and in locomotor command. Knowledge of the circuit and behavioral contexts within which they act can suggest the evolutionary history of acquisitions of function in these neurons. In particular, studies of the sensory and motor pathways that mediate the computations of turn responses to specific appetitive or noxious stimuli provide a highly ordered framework with predictive power for inferring evolutionary history.

54.10

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ONTOGENY OF LIMB BONE GEOMETRY AND BONE STRENGTH IN AN ARBOREAL PRIMATE (*CEBUS ALBIFRONS*)

In numerous mammalian taxa, limb bone cross-sectional dimensions tend to be relatively greater early in life and decrease with negative allometry over postnatal growth. Greater cross-sectional dimensions increase bone strength, allowing young mammals to maintain adequate safety factors in spite of reduced mineralization and more erratic locomotion. However, by focusing on primarily precocial and terrestrial taxa, previous studies have likely undersampled the full range of life history variables and locomotor behaviors that may influence long-bone growth in mammals. This study examined ontogenetic changes of limb bone cross-sectional properties in an arboreal primate, the white-fronted capuchin monkey (*Cebus albifrons*). As primates, capuchin monkeys are a relatively altricial taxon that moves and forages almost entirely an arboreal environment. Due to the three-dimensional nature of arboreal locomotion, loading regimes may be more varied and unpredictable than during terrestrial locomotion, perhaps necessitating different scaling patterns during postnatal growth. Cortical diameters, second moments of area and section moduli (a measure of bending strength) of the humerus and femur were measured in a longitudinal radiographic series of five male capuchin monkeys spanning the first five years of life. Relative to body mass, femoral dimensions scaled with significant positive allometry, differing from the trend observed in ontogenetic studies of other mammals. Humeral dimensions scaled isometrically. These data suggest that arboreality and terrestriality may exert contrasting pressures on long bone growth in mammals. Detailed studies of locomotor ontogeny in capuchin monkeys and other are required to further clarify the observed scaling patterns.

25.3

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THE RELATIONSHIP OF EMBRYONIC FACIAL SIZE TO ADULT FACIAL LENGTH

Facial length is an evolutionarily labile trait in mammals whose expression has numerous functional implications. There are many possible developmental mechanisms for variation in this trait, including responses to hormones or mechanical loading during ontogeny, patterns of postnatal growth, and initial size of the embryonic anlage. Here we test the hypothesis that embryonic facial size is correlated with adult facial length in strains of mice which are known to vary in this trait. The sample consists of facial landmarks in adults (90 days) and embryos (11 days postfertilization corrected for number of tail somites) of several strains of mice. Crania of adult mice were scanned using a μ CT and then landmarked in three dimensions using ImageJ. Embryos were scanned either as above or by photographing in lateral and frontal view and then landmarking in two dimensions. Geometric morphometrics was used to quantify, compare, and visualize shape variation between strains. Sizes of the facial prominences and adult facial length were calculated from the landmarks. Support for this hypothesis indicates that processes affecting embryonic maxillary mesenchymal proliferation rate are potential targets for evolutionary transformations associated with increases or decreases in the length of the face. Results from this analysis have important implications for the evolution of both reductions and increases in facial length (e.g., in humans and papionin primates, respectively).

S7-2.5

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LAMPREY METAMORPHOSIS AND A THEORY ON THE EVOLUTION OF ADULT LIFE HISTORY TYPES

Lampreys, as agnathans, have a direct lineage to the most ancient of vertebrates. Although the other extant agnathan, the hagfish, has direct development, all lamprey species have a free-living larva that undergoes a true metamorphosis into a juvenile. Two adult life histories, nonparasitic and parasitic, are seen among the 38 extant lamprey species with 20 of these being nonparasitic, the more recently evolved adult life history. Paired species, with a nonparasitic and parasitic member, have arisen from a parasitic ancestor. Recent findings of hormone profiles during metamorphosis, the existence of a certain degree of plasticity in the timing of development in wild populations, and the ability to induce precocious metamorphosis have allowed some speculation on both the evolution of metamorphosis as a developmental strategy and the evolution of adult life history types. An attempt will be made to explain the evolutionary origins of the unique thyroid hormone involvement in lamprey metamorphosis. Recent results comparing profiles of the hormone, gonadotropin-releasing hormone, and the prohormone, proopiomelanocortin, during metamorphosis and sexual maturation in a parasitic and nonparasitic species will be integrated into a view of how adult life history is directed during these developmental events. Many of the answers to questions on the control and evolution of metamorphosis in lampreys may be found among organisms that shared their time of origin and their long evolutionary history.

S4.3

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MULTIPLE PATERNITY AND SUBSEQUENT FUSION/REJECTION INTERACTIONS IN A COLONIAL ASCIDIAN

The production of genetically variable offspring is a central function of sexual reproduction. The genetic composition of offspring subsequently affects many processes that operate on adults. Although much work has considered the costs and benefits of sexual vs. asexual reproduction, studies of the consequences of variation among sexually produced broods have been largely lacking. For free-spawning marine invertebrates, fertilization processes control the genetic diversity of offspring. Each egg can potentially be fertilized by a sperm from a different male, and hence levels of multiple paternity within a brood are an index of genetic diversity. Determinants of multiple paternity have not yet been explored, but variation is expected based on the interaction of mating systems with environmental conditions and population parameters. For sessile, colonial invertebrates, one important adult process that may be affected by the genetic composition of offspring is the fusion with or rejection of conspecific colonies. Colonies contact in the course of asexual growth, and are often related because of philopatric larval dispersal. Allorecognition systems that dictate fusion vs. rejection are under genetic control, so variation in multiple paternity within a brood should influence fusion rates. We have been exploring the possible relationship between multiple paternity and subsequent fusion/rejection interactions in a colonial ascidian (*Botryllus schlosseri*). Microsatellite assays of embryos brooded by colonies in natural populations indicate substantial variation in levels of multiple paternity. Fusion tests among recruits collected from settlement plates adjacent to maternal colonies were used to assay fusion frequency. Results may indicate the need to consider fertilization processes to fully understand adult fusion/rejection dynamics.

72.6

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EFFECT OF REPRODUCTIVE BURDEN ON ENDURANCE IN
SIDE-BLOTCHED LIZARDS

In most taxa studied to date, reproductive burden has been reported to reduce locomotor performance. However, many of these studies classified subjects as simply either gravid or non-gravid, and did not consider the different stages of reproduction. By conducting a mark-recapture study of side-blotched lizards (*Uta stansburiana*) in eastern Oregon, we were able to collect females with no follicles, enlarged follicles, yolked eggs, or shelled eggs. Endurance trials (time to exhaustion) were performed using a motorized treadmill moving at 0.2 m/s. During May and June of 2005, endurance trials were performed on 169 females. After the effects of body length were taken into account using statistical residuals, endurance times of non-gravid females (raw mean \pm 1 S.E.M.: 216 ± 8.7 s; $n = 45$) were statistically indistinguishable ($P > 0.05$) from reproductive females with enlarged follicles (219 ± 12.5 s; $n = 49$) as well as females with yolked eggs (205 ± 11.9 s; $n = 25$). However, non-gravid females had significantly greater endurance than females with shelled eggs (196 ± 12.7 s; $n = 25$; $F = 4.0$; $P = 0.04$). This corresponds to a 9.3 % reduction in endurance capacity. Thus, the trend toward increasing reproductive burden does not significantly impair locomotor performance until just prior to oviposition. In the lab, we also measured endurance within 24–48 h of oviposition. Post-reproductive females (225 ± 19.2 s; $n = 25$) recovered their endurance capacity to levels indistinguishable from non-reproductive females very rapidly, suggesting that the major burden of reproduction is biomechanical. Assuming decreased endurance increases the risk of mortality in the wild, the major risk of mortality associated with reproductive burden should occur very transiently just prior to egg laying.

17.5

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GENETIC DIVERGENCE WITH DEPTH AND DISTANCE IN A
DEEP-SEA BIVALVE, *DEMINUCULA ATACELLANA*

Evolutionary origins are obscure for the diverse and highly endemic fauna of deep-sea soft-sediment environments. Current knowledge of geographic patterns of genetic variation in the deep sea, information fundamental to inferring population differentiation and speciation, is limited in its scope and scale. Utilizing museum-based collections, we characterized genetic variation in *Deminucula atacellana*, a protobranch bivalve widespread at bathyal and abyssal depths throughout the Atlantic Ocean. Samples were obtained from 18 localities across three hydrographic basins: North American, West European and Argentine. For 130 individuals a hypervariable region of mitochondrial 16S rDNA was amplified by PCR and direct sequenced. Twenty-one haplotypes were identified that, with several important exceptions, were unique to each basin. Overall gene diversity was high, population structure was pronounced, and highly significant geographic associations were detected with nested clade analysis. Four major clades were identified corresponding with geography and depth. Significant genetic variation occurred from basin to basin but the greatest levels of divergence were found among populations at different depths within the same basin. Large genetic divergence was not accompanied by morphological differentiation. Isolation by distance probably explains inter-basin or horizontal variation whereas depth-related or vertical differences may reflect historical patterns of colonization or selective environmental gradients driving speciation.

54.8

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DIETARY CONSISTENCY AND THE CANALIZATION OF SKULL
GROWTH

Forces generated by biting and mastication influence mammalian skull shape and are also thought to influence its variability. As a result, eating soft food reduces growth, and reportedly alters skull proportions and elevates craniofacial variability. However, even dramatic differences in dietary consistency might have little or no impact on skull shape, as we found in a prior analysis of deer mice (*Peromyscus maniculatus bairdii*) who were fed either hard laboratory chow or a gruel made from that chow. To explain that lack of impact, we postulated that these active animals, observed to gnaw their cages and bedding, might thereby compensate for any reduction in forces generated by feeding. If that is the case, we might expect that eating soft food would have no impact on skull variability either. However, that nonnutritive compensatory gnawing might be fairly idiosyncratic, and therefore fail to maintain the normally low level of variance. To determine if variance is any more affected by diet than the average skull form, we first reanalyze the impact of diet on that average, taking advantage of recent progress in morphometrics, and then compare variance in skull size and shape. We confirm diet has no significant effect on average skull shape, but it does have a very slight impact on size, at least in ventral view; skulls of the hard-diet group are larger in ventral view (albeit by only 2.5%). Contrary to expectations, the group fed hard chow is more, rather than less variable, in skull size, but, as expected, is less variable in skull shape. Taken together, that greater variability in skull size and lesser variability in skull shape, suggests that the forces generated by biting and mastication effectively canalize skull shape even in the face of elevated variation in size.

47.4

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MITOCHONDRIAL GENOMES OF THREE TEREPELLIFORMIA
ANNELIDS

Sequencing of complete mitochondrial genomes has become a useful tool for inferring animal phylogeny. Complete mitochondrial DNA (mtDNA) sequences have been determined for many invertebrate species and partial sequences for hundreds of others. Since the rate of gene arrangement of mtDNA varies among different lineages, gene order may provide resolution at differing taxonomic levels. To further understand the phylogenetic potential of complete mitochondrial genome sequence data in Annelida (segmented worms), we obtained mitochondrial genome data for three Terebelliformia worms (*Echysippe vanelli*—Ampharetidae, *Pista cristata*—Terebellidae and *Terebellides californica*—Trichobranchidae) and combined these with available GenBank data. The goal of this work is to elucidate phylogenetic relationships among the 5 recognized families within Terebellidormia: Alvinellidae, Ampharetidae, Pectinariidae, Terebellidae and Trichobranchidae. Sequence results show similar gene arrangement in these three taxa to annelid genomes reported previously, suggesting the gene order is conserved across Annelida. Thus, gene trees, rather than gene order, is being used to determine Terebelliformia relationships.

30.3

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CHARACTERIZATION OF A VITELLOGENIN GENE AND THE ENDOCRINE REGULATION OF VITELLOGENESIS OF THE BLUE CRAB, *CALLINECTES SAPIDUS*

Vitellogenesis and vitellogenin (Vg) uptake by oocytes are crucial for ovarian development and successful reproduction in many nonmammalian species. Crustacean vitellogenesis has long been suggested to be regulated by the XO-SG endocrine system. The blue crab female reaches puberty after a terminal molt, which is usually accompanied by mating. Previous studies indicated the ovary as the site of vitellogenesis^{1,2}. However, by isolating and characterizing cDNA of the blue crab Vg gene we have found that the hepatopancreas, not the ovary, is responsible for vitellogenesis. This was confirmed by Northern blot analysis and immunohistochemistry. Using 5-3RACE, the full length of 7.8 Kb Vg cDNA was amplified from the hepatopancreas. *Callinectes* Vg gene, like those from other crustaceans, possesses typical motifs such as cleavage and phosphorylation sites and shares 80% of sequence homology with Vg cDNA of *Charybdis feriatus*³. In order to understand the regulation of vitellogenesis of the blue crab, we monitored hemolymph Vg levels and gene expression in the hepatopancreas during ovarian development using a competitive ELISA and QRT-PCR, respectively. Hemolymph Vg and ovarian morphology indicate that the female undergoes a short spontaneous vitellogenesis, which is independent of mating. *In vitro* incubation of hepatopancreas explants with CHH and MIH neuropeptides, farnesoic acid and ecdysteroids showed that the XO-SG endocrine system may play an important regulatory role in vitellogenesis of the blue crab. Further investigation of the endocrine regulatory mechanism of female blue crab reproduction is in progress. 1. Lee CY & Watson D. J Exp Zool. 1995. 2. Lee RF & Walker A. J Exp Zool. 1995. 3. Mak et al. Ann N Y Acad Sci. 2005.