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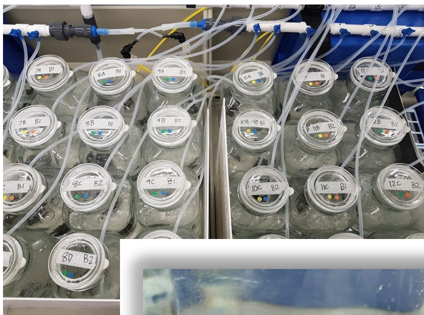
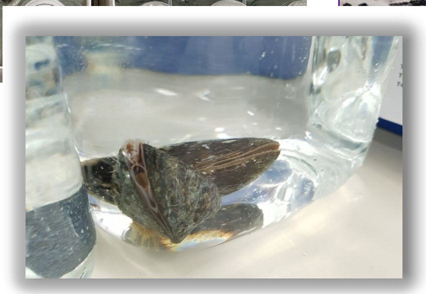
Contents





Despite covid-19, malacologists make their best endeavours. The mages above are from the Early Career Research Grant report of Alice Wilson McNeal on impacts of ocean acidification and pharmaceutical contamination on *Mytilus edulis* (see report on page 21).

The Malacological Society of London was founded in 1893 and registered as a charity in 1978

EDITORIAL

It is still the time of covid. As I write, English case numbers stand at a mean of 31698/day and deaths at a mean of 100/day over the last week. That is *circa*50000 extra deaths per year (compare this with approximately 3000 mortalities when the Twin Towers were felled in New York). While the hospital situation seems to have improved since the last issue of *The Malacologist*, many young and some old people are developing long covid, while the country struggles to keep on a 'normal', even keel, including for those pursuing the objectives of malacology, such as running meetings. Despite the difficulties, the President John Grahame hosted an excellent virtual meeting of the **AGM** and a **virtual conference on *Molluscs in Extreme Environments,*** held on the same day. The abstracts from the conference are presented on pages 34-43 this issue.

This issue also presents an invited article on the biology of the molluscan shell. This was my personal indulgence, since I had encountered the author, Alessia Carini, when she was a presenter in a quickfire session at the 2020 Forum. Some fifty years ago, I had researched the biochemistry of freshwater molluscan shells, so I was particularly intrigued to see how things had developed in the interim.

It is encouraging to the Society's efforts to be able to present several **Early Career Research Grant Reports,** including an account of Lukas Ostermair's work on *Molecular analyses of solenogaster midgut contents to determine food sources* , the report of Alice Wilson-McNeal on the *Impacts of ocean acidification and pharmaceutical contamination on Mytilus edulis,* and the report of Samuel Abalde on *Using shotgun sequencing for disentangling a taxonomic jumble: the case study of the skeneimorphs.*

There are two **book reviews**—firstly of the book *Molluscan genomics: broad insights and future directions for a neglected phylum by Angus Davison and Maurine Neiman* which summarises a recent Royal Society conference. Secondly there is a review of Peter Godfrey-Smith's book entitled *Other minds—the octopus and evolution of intelligent life.* The review also references a recent BBC documentary on octopuses.

Unfortunately, *The Malacologist* also carries **obituaries.** Here there are tributes to Brian Morton, Arie W. Janssen and Jack Burch.

Finally, this issue covers the formalities of the AGM, together with its associated virtual conference *Molluscs in Extreme Environments.* So, this turns out to be rather a large issue. Here's hoping that all our readers stay covid free and above all, safe.

Emeritus Prof. Georges Dussart
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TAXONOMIC/NOMENCLATURAL DISCLAIMER
This publication is not deemed to be valid for taxonomic/nomenclatural purposes [see Article 8b in the International Code of Zoological Nomenclature 3rd Edition (1985), edited by W.D. Ride *et al.*].

NOTICES

J Frances Allen Institute of Malacology Student Research Award

The Board of Directors of the Institute of Malacology, publisher of the academic journal *Malacologia*, is pleased to announce the recipients of the 2021 J Frances Allen Institute of Malacology Student Research Award, a newly created award to support field or laboratory research on molluscs conducted by a student enrolled in a degree-granting program. We received 17 outstanding proposals from undergraduate and graduate students representing nine countries. The proposals were reviewed by a committee of the IM Board and were evaluated on the quality, feasibility, and potential significance of the proposed research.

The first recipients of this award are:

- Nicholas Gladstone, Auburn University, USA: Re-evaluation of the phenotypic plasticity hypothesis in a freshwater gastropod complex using phylogenomics, population genomics, and morphometrics (Pleuroceridae: *Lithasia*)
- Noelia Sánchez, National University of La Plata, Argentina: Conoidean gastropods from unexplored Argentine deepwaters: the family Drilliidae
- Taro Yoshimura, The University of Tokyo, Japan: Sulfur detoxification by biomineralization in the hadal chemosynthetic bivalve *Axinulus hadalis* (Thyasiridae)

Please join me in congratulating the successful applicants. We wish them every success in completing their proposed research!

Ellen Strong
President
Institute of Malacology

The Octopus in My House

This is the title of a BBC programme about the relationship between a Professor and diver David Scheel and a wild octopus.

ON BBC iplayer—BBC Two - Natural World, 2019-2020, The Octopus in My House

See page 26 for a review of this programme.

Squid in Space

Images, selected by the Bailey-Matthews National Shell Museum's Curator and Science Director Dr. José H. Leal convey a range of the singular beauty in the world of molluscs. For more information visit the website at www.shellmuseum.org/in-focus

The tiny squid illustrated below were due to head into space on June 3, 2021, along with many other scientific experiments aboard SpaceX's 22nd cargo resupply mission to the International Space Station. The squid were part of the UMAMI study which examines the effects of spaceflight on interactions between beneficial microbes and their animal hosts. UMAMI stands for Understanding of Microgravity on Animal-Microbe Interactions. Microbes play a significant role in the normal development of animal tissues and in maintaining human health. The Understanding of Microgravity on Animal-Microbe Interactions (UMAMI) study uses bobtail squid and bacteria to examine the effects of spaceflight on interactions between beneficial microbes and their animal hosts. This type of relationship is known as symbiosis. Beneficial microbes play a significant role in the normal development of animal tissues and in maintaining human health, but gravity's role in shaping these interactions is not well understood. This experiment could support the development of measures to preserve astronaut health and identify ways to protect and enhance these relationships for applications on Earth. This investigation helps determine whether spaceflight alters the mutually beneficial relationship, which could support development of protective measures and mitigation to preserve astronaut health on long-duration space missions. The work also could also lead to a better understanding of the complex interactions between animals and beneficial microbes, including new and novel pathways that microbes might use to communicate with animal tissues. Such knowledge could help identify ways to protect and enhance these relationships for better human health and well-being on Earth as well.

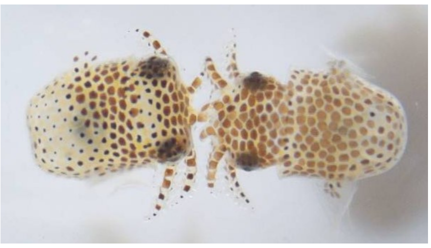


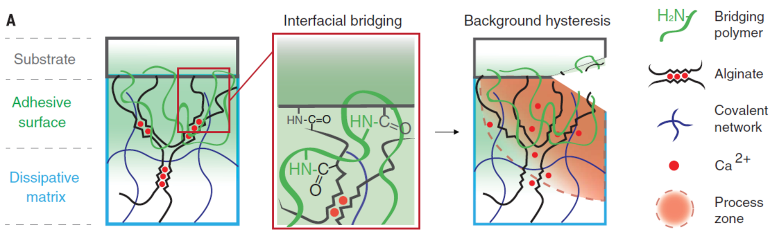
Image Credit: Courtesy of Jamie S. Foster

Yvette Smith May 26, 2021

Using slug slime to engineer adhesives for diverse wet surfaces

Abstract of the paper - Adhesion to wet and dynamic surfaces, including biological tissues, is important in many fields but has proved to be extremely challenging. Existing adhesives are cytotoxic, adhere weakly to tissues, or cannot be used in wet environments. We report a bioinspired design for adhesives consisting of two layers: an adhesive surface and a dissipative matrix. The former adheres to the substratum by electrostatic interactions, covalent bonds, and physical interpenetration. The latter amplifies energy dissipation through hysteresis. The two layers synergistically lead to higher adhesion energies on wet surfaces as compared with those of existing adhesives. Adhesion occurs within minutes, independent of bloodexposure and compatible with *in vivo* dynamic movements. This family of adhesives may be useful in many areas of application, including tissue adhesives, wound dressings, and tissue repair…..

From within the text - The design is inspired by a defensive mucus secreted by slugs (*Arion subfuscus*) that strongly adheres to wet surfaces. This slug adhesive consists of a tough matrix with interpenetrating positively charged proteins. Our tough adhesives are made up two layers: (i) an adhesive surface containing an interpenetrating positively charged polymer and (ii) a dissipative matrix (Figure). The adhesive surface can bond to the substratum through electrostatic interactions, covalent bonds, and physical interpenetration, whereas the matrix dissipates energy through hysteresis under deformation.



Reference

Li A., Celiz A.D., Yang J., Yang Q., Wamala I., Whyte W., Seo, B., Vasilyev N.V., Vlassak J.J., Suo Z, & Mooney D.J. 2017. Tough adhesives for diverse wet surfaces. *Science,* **357**: 378–381.

OctoCam is LIVE!

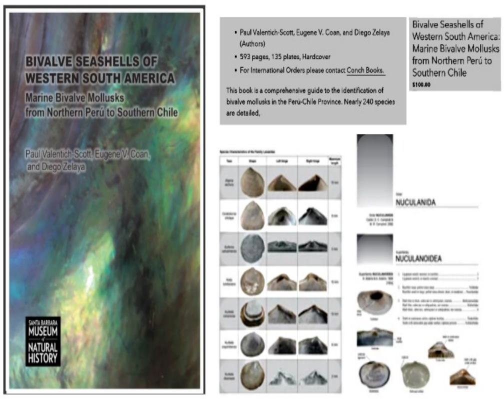
On April 30th, the Bailey-Matthews Shell Museum unveiled its live stream of OctoCam - an underwater camera that gives visitors a unique view into the nocturnal life of its Giant Pacific Octopus. To see the octopus live, plus highlight footage of its very active moments follow:-
www.shellmuseum.org/octocam

Dr. José H. Leal, Science Director and Curator
Bailey-Matthews Shell Museum
3075 Sanibel Captiva Rd. Sanibel, FL 33957, USA

Companions for the evening

Patricia Highsmith once went to a London cocktail party with a "gigantic handbag" that "contained a head of lettuce and a hundred snails" which she said were her companions for the evening.

New book on South American bivalve molluscs https://bit.ly/2HIPPj2



Gene Coan and **Paul Valentich-Scott** have completed the eastern Pacific marine bivalve series (https://bit.ly/2HIPPj2) and are making the combined bibliography for the three books available online. This includes over 7,600 references cited in their mongraphs. In addition, John Taylor and Emily Glover have shared the bibliography from their recent book on the Bivalve Family Lucinidae (https://bit.ly/3b1iSKg). This has added an additional 500 references to the bibliographies, including those on vent and seagrass communities. The database is accessible through an open-source freeware called Zotero (https://www.zotero.org). A free Zotero account should be set up if you wish to access this database. If you are interested in accessing this database, send your email address pvscott@sbnature2.org. You will need to send the email you used to set up a zotero account.

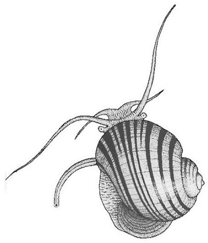
Paul Valentich-Scott, Curator Emeritus of Malacology
Santa Barbara Museum of Natural History
2559 Puesta del Sol, Santa Barbara, CA 93105
www.sbnature.org

Late evening work

The slugs and snails in my garden (particularly *Arion ater* and *Cornu aspersa*a) re bullies, homing in on weaker plants and stripping an individual plant of its leaves in a single night. Starting in March, and for several weeks, I go into the garden before bedtime with a torch, a jam jar and a plumber's glove, collecting slugs and snails from my seedlings. I put them in the freezer overnight to painlessly kill them, then bury the corpses deep in the compost heap. The first several nights, I get a jam jar full each night. The numbers decline as I make inroads into the population but I never get them all. Sometimes it seems there is the molluscan equivalent of a small sheep feeding at night on my flowers and veg.

GBJD

The Malacological Society of London's *Molluscan Forum*



Because of Covid-19, the Molluscan Forum will take place in a different format this year. We still plan to hold the event and will do so via an online platform (probably Zoom) on Thursday 18th November 2021.

As in previous years, for those wishing to offer a presentation, please fill out the attached registration form. For those just wanting to attend, please let me know so I can keep track of attendees. The **deadline for registrations and talk applications is October 1st 2021.** Presenters will be informed of successful applications soon after**.**

Registration is **free!**

In lieu of posters, we will instead have 5 minute (3 slide maximum) **Quickfire PowerPoint** presentations,

We hope these changes will still allow all those who wish to attend and present the chance to do so, even if we can't offer the customary wine reception!

For further details and an application form, see page 51.

The contact is Dr Phil Hollyman
British Antarctic Survey, Cambridge CB3 0ET
Email: phyman@bas.ac.uk

A climate-warming relevant snail joke from Tim Pearce

https://www.facebook.com/watch/?v=796957347660223

Molluscan genomics: broad insights and future directions for a neglected phylum

Royal Society Publishing has recently published a special issue of Philosophical Transactions B - *Theo Murphy meeting Molluscan genomics: broad insights and future directions for a neglected phylum* organized and edited by Dr Angus Davison and Dr Maurine Neiman. Articles can be accessed directly at www.bit.ly/PTB1825. If your institution does not give access to the full text, corresponding authors will probably be happy to send a pdf, or else contact Maurine or Angus. A print version is also available at the special price of £35.00 per issue, by contacting Debbie.vaughan@royalsociety.org
Dr Angus Davison, Reader and Associate Professor in Evolutionary Genetics
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University of Nottingham
Nottingham, NG7 2RD
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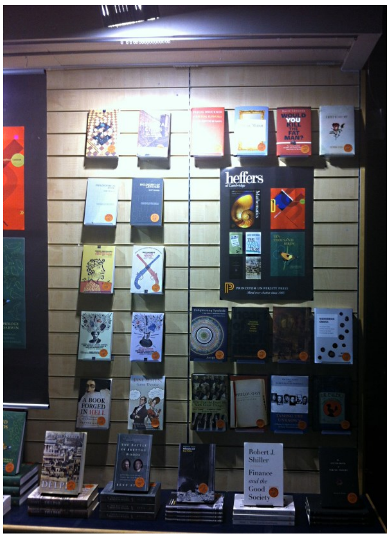
(This Royal Society special issue is reviewed on Page 25 of this issue of *The Malacologist*)

Spot the mollusc



Bailey-Matthews National Shell Museum

The Chiton and the Whelk

Museum's Senior Aquarist Carly Hulse took this great photo, at the Cold-water Touch Pool, of a Lined Chitons (*Tonicella lineata*) riding a Kellet's Whelk (*Kelletia kelletii*). The chiton needs hard substrata to live and feed on, and the whelk's shell serves that purpose.

Lined Chiton riding a Kellet's Whelk. Photo by Carly Hulse.

The whelk's right tentacle is touching the bottom of the aquarium. All molluscs in the Cold-water Touch Pool were obtained from the West Coast of the US, where the water temperature is in average at least several degrees cooler than the water temperature in Southwest Florida.
(with the permission of José H. Leal, Bailey Matthews National Shell Museum)

Mollusc conservation—Tentacle

The latest issue - number 29 - of Tentacle (the newsletter of the IUCN - Species Survival Commission - Mollusc Specialist Group) is now available on the web.
http://www.hawaii.edu/cowielab/issues.html

Tentacle is an on-line only publication, though of course you may print it for yourself if you wish.

Malacological cosmetic treatment as portrayed in the new TV series 'Murder in Mallorca'

Mollusc themed dinner plate from the Charente region of France

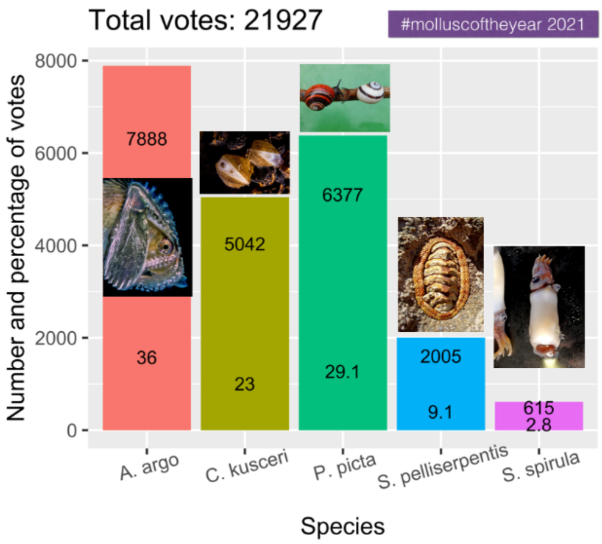
Article on the co-existence of *Crassostrea* and *Mytilus*

Ecological impacts caused by invasive alien species can be severe but may vary depending upon environmental conditions. Many European populations of the native mussel, *Mytilus edulis,* have been invaded by the Pacific oyster, *Crassostrea (Magallana) gigas*. Although widespread invasions have occurred, interactions between *M. edulis* and *C. gigas* have largely been investigated with regards to competition for space and food as well as effects on species assemblages. Experimental investigation of competitive interactions on physiological responses of the two species requires further exploration. To this end, we used a 12-month field manipulation experiment to examine growth rates, mortality and condition indices of the two species occurring in monospecific and heterospecific groups. Growth rates and mortality of both species were similar in monospecific and heterospecific groups, whereas condition indices were significantly reduced for both species in heterospecific groups. Growth rates and condition indices also differed amongst experimental sites, potentially due to differing water motion. Shell weight-length relationships did not explain the observed differences in condition for either species. Coexistence between the two species may occur but could be detrimental for both species. A preliminary viewpoint that water motion can mediate competitive interactions between these species is also provided.

P. Joyce, D. Smyth, J. Dick & L. Kregting (2020)
Coexistence of the native mussel, *Mytilus edulis*, and the invasive Pacific oyster, *Crassostrea (Magallana) gigas*, does not affect their growth or mortality, but reduces condition of both species
Hydrobiologia https://doi.org/10.1007/s10750-021-04558-1(0123456789().,-volV)(01234567

Mollusc of the Year

This award was organised by the Senckenberg Research Institute, together with the LOEWE Translational Biodiversity Genomics centre, and Unitas Malacologica. There were over 120 nominations for any molluscan species from any marine, terrestrial, freshwater zone or from any country. The first, ever, international Mollusc of the Year award went to *Argonauta argo.* More than 21,000 votes were cast by the public, with *Argonauta* capturing 36% of the vote, followed closely by *Polymita pita,* and *Congeria kusceri* (see image below). Specimens of *Argonauta argo* from the nominating group, at Stazione Zoologica Anton Dohrn, Naples, Italy, have now arrived at the Senckenberg LOEWE Translational Biodiversity Genomics centre, where a team will sequence the complete genome during 2021. The organisers send a huge' thankyou' to all who nominated species, and all who voted! It is hoped to repeat the award next year. There is more about the competition here: https://tbg.senckenberg.de/mollusc/
Julia Sigwart



Decapitated sea slug grows a new body

Video at:-instagram.com/p/CMNQ_t0qOx7/?igshid=mn8no78cwweoscitechdaily.com

Sayaka Mitoh & Yoichi Yusa, 2021, Extreme autotomy and regeneration of the whole body in photosynthetic sea slugs. *Current Biology*, **31**: 5R233–R234, **DOI: 10.1016/j.cub.2021.01.014**

Cuttlefish exert self-control

The ability to exert self-control varies within and across taxa. Some species can exert self-control for several seconds whereas others, such as large-brained vertebrates, can tolerate delays of up to several minutes. Advanced self-control has been linked to better performance in cognitive tasks and has been hypothesized to evolve in response to specific socio-ecological pressures. These pressures are difficult to uncouple because previously studied species face similar socio-ecological challenges. Here, self-control and learning performance is investigated in the cuttlefish, an invertebrate that is thought to have evolved under partially different pressures to previously studied vertebrates. To test self-control, cuttlefish were presented with a delay maintenance task, which measures an individual's ability to forgo immediate gratification and sustain a delay for a better but delayed reward. Cuttlefish maintained delay durations for up to 50–130 s. To test learning performance, a reversal-learning task was used, whereby cuttlefish were required to learn to associate the reward with one of two stimuli and then subsequently learn to associate the reward with the alternative stimulus. Cuttlefish that delayed gratification for longer had better learning performance. These results demonstrate that cuttlefish can tolerate delays to obtain food of higher quality comparable to that of some large-brained vertebrates.

Schnell A.K., Boeckle M., Rivera, M., Clayton N.S. & Hanlon R.T. 2021. Cuttlefish exert self-control in a delay of gratification task. *Proc. R. Soc. B* **288**: 20203161. https://doi.org/10.1098/rspb.2020.3161

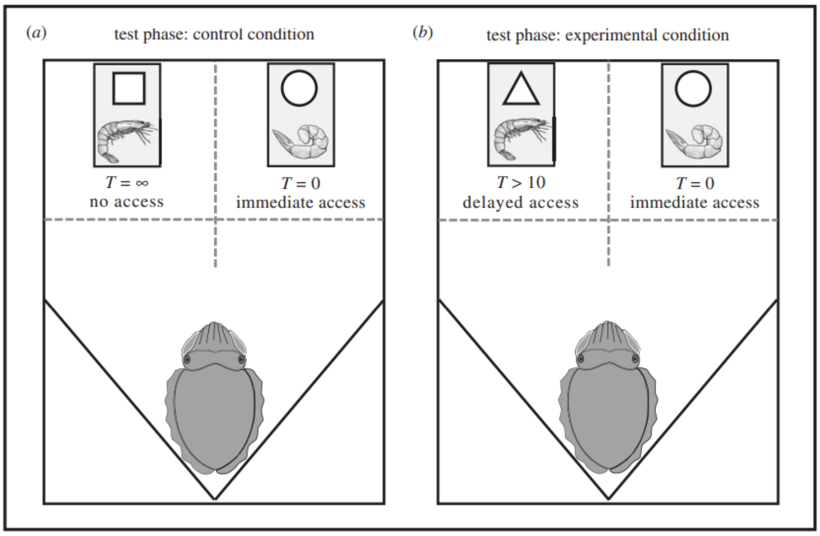


Figure 1. Schematic of the test conditions in the delay maintenance task: (*a*) control condition and (*b*) experimental condition. The different shaped visual symbols represent the time delays that were associated with each chamber. *T* represents the delay in seconds: $T = \infty$ represents a perpetual delay (a second film of clear Perspex obstructed access to the prey); $T = 0$ represents immediate access; and $T > 10$ represents delays ranging from 10–130 s. The immediate-release chamber ($T = 0$) was always baited with the less preferred prey whereas the delayed chambers ($T = \infty$ and $T > 10$) were always baited with the preferred prey. The dotted lines represent the decision point, where the cuttlefish makes a choice between the prey items on offer.

Slug (*Lehmannia nyctellia*) slides down a mucus thread like a spider on silk

Published:03 March 2021https://doi.org/10.1098/rspb.2020.3161

https://www.iflscience.com/plants-and-animal /World-First Sighting Of Slug Sliding Down Mucus Thread Like A Spider On Silk | IFLScience

A striped field slug (Lehmannia nyctelia) descending a mucus thread
ohn Gould & Jose W Valdez

Call for Applications: 2022 Conservation Leadership Programme (CLP) Team Awards

Funding opportunity for young scientists working in species conservation

The funding comes with a training opportunity for one team member to take part in a highly regarded course, usually held in Cambridge UK, although recently it has been held online.

Previous grants have tended to be awarded to bird, mammal and plant projects, so the competition is high. However, with a good project and clear outcomes, there is an chance for young invertebrate conservationists to make an application for a place. Projects working to resolve understanding of the status of *Data deficient species* can be equally valid as conservation assessments and recovery plans for threatened species. Freshwater spring snails, Cave invertebrates or species that exist in world heritage sites might be good candidates for projects.

https://www.conservationleadershipprogramme.org/our-projects/latest-projects-2021/

Successful candidates have the opportunity for follow-up funding for projects.

The Conservation Leadership Programme (CLP) is now accepting applications for our 2022 Team Awards. Future Conservationist Awards are worth up to $15,000 each and support projects in low- and middle-income countries and some high-income islands in the Caribbean and Pacific. Funding enables early-career conservationists to conduct scientific research, encourage and promote pro-conservation attitudes to better conserve and manage the natural world. Each project must have at least three members and all team members must have less than five years of paid conservation experience. Projects can last 3-12 months and must focus on a threatened species. In addition to project funding, CLP will invite one member of each award-winning team to their international training course where they will gain a range of conservation management and leadership skills as well as build their professional network.

The application deadline is 10 October, 2021.

For more information, including the eligibility criteria and detailed application guidelines, please visit our website. Applications must be submitted via the online platform (potential applicants will need to register to be able to complete the application form). Contact clp@birdlife.org with any questions.

Stuart.Paterson@fauna-flora.org>

16th Deep Sea Biology Symposium, Brest, France 12-17 September 2021

Welcome to the 16th edition of the Deep Sea Biology Symposium!

We are very excited about the opportunity to host the 16th Deep-Sea Biology Symposium in Brest, France between 12 and 17 of September 2021!

Brest's history has always been linked to the sea and the oceans. Nowadays, Brest has a leading position in European deep-sea science, technology and industry.

Ifremer has a long experience in deep-sea research and technology with a dedicated deep-sea department (Department of Physical Resources and Deep-Sea Ecosystems-REM), mainly investigating the deep-sea seafloor and the sub-seafloor, biodiversity and the dynamics of deep-sea ecosystems, and the interaction between the biosphere and the geosphere on scales ranging from bacteria to the glacial cycles.

The meeting includes special sessions on the impacts of deep sea mining and polymetallic mining.
Programme https://wwz.ifremer.fr/16dsbs/Program
Conference information https://wwz.ifremer.fr/16dsbs/Conference-Information

New book—Bivalve seashells of Western South America

- Paul Valentich-Scott, Eugene V. Coan, and Diego Zelaya (Authors)
- 593 pages, 135 plates, Hardcover
- For International Orders please contact Conch Books.

This book is a comprehensive guide to the identification of bivalve mollusks in the Perú-Chile Province. Nearly 240 species are detailed,

Bivalve Seashells of Western South America: Marine Bivalve Mollusks from Northern Perú to Southern Chile
$100.00

Carnivore Dilemma

Most bivalve molluscs are filter-feeders, straining water to get their food, usually microscopic plants. Exceptions to this include marine clams that prey on small creatures, such as crustaceans. Some of these clams, the septibranchs, use a flexible, muscular "wall", or septum, as a diaphragm pump that allows the animal to quickly and decisively suck prey in. The inch-long Specter Clam, *Dilemma spectralis* Leal, 2008 (below), a deep-sea dweller found off Vanuatu in the SW Pacific, is one of them. It is possible, given that *Dilemma* clams live permanently attached to rocks, that Specter Clams may use some form of chemical attraction to lure nearby prey.

Fig. 2 shows from left, a whole preserved clam, the clam with shell removed, and drawing (by Kimberly Nealon) showing the stomach with its crustacean food, in this particular case an isopod crustacean. The drawing also shows the *incurrent siphon*, or opening through which prey is ingested.

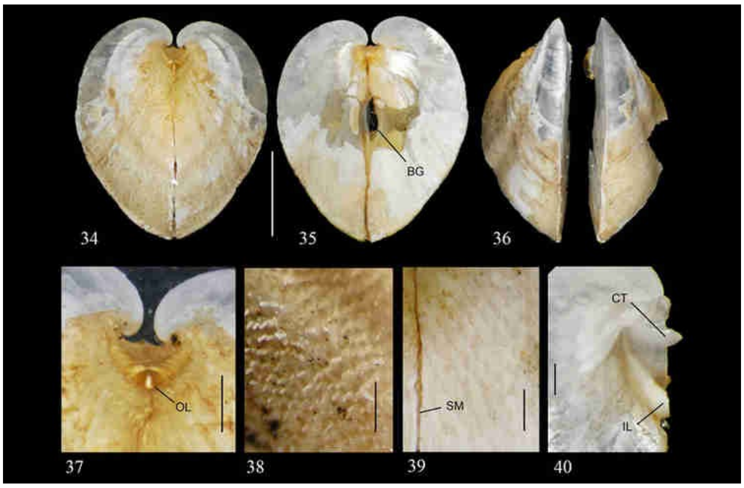


Fig. 1 ***Dilemma spectralis*, different views of an unusual shell. From the original species description.**

Fig. 2

Jose H Leal (2008) A remarkable new genus of carnivorous, sessile bivalves (Mollusca: Anomalodesmata: Poromyidae) with descriptions of two new species. *Zootaxa* **1764**:1-18

Invited article

Marine shells: the beauty and the resilience

Alessia Carini

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The University of Hong Kong,
Pokfulam Road, Hong Kong SAR
Email: acarini@hku.uk

People strolling along the beach have been collecting shells since prehistoric times and treasured them as beautiful, sometimes spiritual, marine tokens (Scales, 2015). Many public beachgoers who stumble upon empty shells do not realize that these are the washed-up legacy of living organisms. This could be because marine shells can resemble perfect pieces of elegant, stony, small (and occasionally large) rocks. They are indeed composed of a mineral analogous to limestone, yet, contrastingly, they can be shaped in extraordinary forms, and, as you know if you have ever cut your foot on the beach, of puncturing sharpness and strength. Marine shells recovered on beaches are often either the coiled exoskeletons of gastropods or the disjointed half of bivalve shells, and here I will mostly draw examples from the latter group.

Molluscs are the second species richest phylum in the world after the Arthropods and the class *Bivalvia* accounts for an estimated 10,000-20,000 extant species (Gonzalez *et al*., 2015). They are characterized by two tightly fastened valves, sometimes but not exclusively, symmetrical. Since their appearance in the Cambrian, around half a billion years ago, they have spread to an incredible number of different habitats, from the tropics to the arctic, from lakes to hydrothermal vents, and survived several catastrophic events in our Earth's history such as the Palaeocene-Eocene Thermal Maximum (PETM). The PETM was characterized by warming, acidification and hypoxia that lead to severe extinctions and changes in global ecosystems. Little lasting impact was sustained by molluscs however (Ivany *et al*., 2018). Simply, these unpretentious invertebrates are resourceful. The evolutionary success of the bivalves is the manifestation of small modifications to an already simple animal body plan (Plazzi *et al.,* 2011) and, importantly, the reason bivalves are traditionally thought to have been so successful is the secretion of the external shell (Clark *et al*., 2020).

The bivalve shell is a composite biomineral, incorporating mineral and organic components, and molluscs produce the highest diversity of biominerals of any animal group (Lowenstam & Weiner, 1989). The mineral of choice by the vast majority of bivalves is calcium carbonate ($CaCO_3$), which, in its abiotic form is typically unimpressive, not only in shape but also in mechanical properties. However, when moulded into a shell by a mollusc, it takes beautiful, complex, and mechanically superior forms. This is a good example of structural potential once biology and evolution join forces to create forms able to persevere for millions of years.

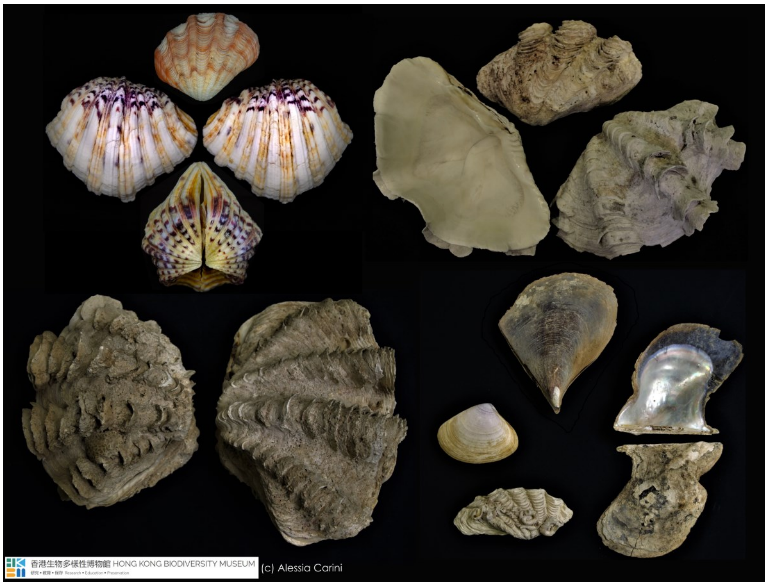

Fig 1. Some of the bivalve shells in the collection in the Hong Kong Biodiversity Museum. Shells are not to scale.

Evidence suggests that the molluscan shell evolved from an ancestor with a chitinous scaffold (Murdoc, 2020). Since eukaryotic cells have the inherent capacity to bind calcium ions and control their internal carbonate chemistry, accumulating ions for calcification simply exploited some ancient cellular features (Knoll, 2003). However, biomineralization is energetically costly, hence, there are metabolic constraints on organisms that limit the evolutionary potential-for skeletal components (Knoll, 2003; Schoeppler *et al.,* 2019).

Even so, for biomineralization to be so widespread, the benefits of having a shell must offset the metabolic costs, yet the energy spent to secrete a shell must be flexible as a response to the requirements by the external environment (Knoll, 2003). Ultimately, the evolutionary and metabolic constraints are the drivers for the diversity of structures that we see today. Intuitively, the bivalve shell functions as armour and structural support for the vulnerable, and, regrettably for the bivalve, tasty soft body for a predator. Nonetheless, bivalve shells can have several different functions other than structural ones.

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For example, several bivalve species live in intertidal regions where they are exposed to air or sediments for extended periods. In these scenarios, the shell prevents dehydration by locking tightly and retaining water. In some cases, shells can act as reservoirs and release ions to neutralize internal pH which quickly decreases due to excessive production of metabolic CO_2 (Lowenstam 1981).

The basics of shell formations are that calcium, carbonate and/or bicarbonate ions are extracted from seawater and concentrated in a confined space by the bivalve at a much higher level than the surrounding seawater. Isolation of this medium from the external seawater is necessary to facilitate and promote calcification. $CaCO_3$ is then deposited together with an organic fraction called the shell organic matrix. This matrix is extracellular, and it is typically composed of organic compounds such as polysaccharides (mostly chitin), proteins, and lipids. Pioneering research on bivalve shells and their organic matrices has been done since at least the 1800s. Other than geologists and palaeontologists, few chemists found interest in this biomineral . An exception was Edmond Fremy (1855), who, in his quest to describe as many as possible biominerals from the animal kingdom, came across molluscan shells, thanks to a collaboration with a certain M. Valenciennes (Fig. 2). After applying his standard decalcification protocol to marine shells, he obtained an insoluble, shiny organic substance he named *conchiolin* after its similarities with ossein. Conchiolin had, however, a different chemical behaviour from ossein, and he also points out the presence of a carbohydrate, chitin, a trait he found shells' share with arthropod exoskeletons and cnidarian skeletons. This is also one of the first times that researchers found how much these invertebrate exoskeletons have in common with human skeletons, a parallel that is still an active field of research (Loh *et al.,* 2021, Clark *et al.,* 2020).

Certaines espèces de coquilles, traitées par l'acide chlorhydrique, laissent un résidu d'une matière organique fort remarquable, d'un aspect brillant et feutré, insoluble dans l'eau, l'alcool et l'éther, et qui résiste à l'action des acides étendus : j'ai donné à cette substance le nom de *conchioline*. Elle a présenté la composition suivante :

Dosage de l'hydrogène et du carbone		*Dosage de l'azote.*	
Matière	0,208	Matière	0,270
Eau	0,111	Azote	0,04725
Acide carbonique	0,382		

	En centièmes.
Hydrogène	5,9
Carbone	50,0
Azote	17,5
Oxygène	26,6
	100,0

Fig. 2. Extract from Fremy, E. 1855. Roughly translated, Fremy reports that certain shells, when treated with acid, release a remarkable organic matter, of a shiny and felted appearance, insoluble in water, alcohol, and ether, capable of withstanding the extended action of acids. He names it conchiolin and then describes its organic composition This was probably the first ever description of conchiolin.

A lot of shell literature followed the work of Fremy, although some of this material is now difficult to access and often requires translations from different languages. Fast-forwarding to the 20th century, we see that renewed, international interest was developed in the 1960-80s. While the presence of an organic matrix within shells was well established, we see more and more attempts to characterize it in increasing detail. It was known that a large part of the shell organic matrix was composed of proteins, and with their amino acid characterization, Weiner & Hood (1975) provided evidence that shell proteins are rich in negatively charged amino acids. Weiner & Traub (1980) with their improved x-ray analysis of the insoluble protein fraction of the matrix confirmed that it displays similarities with silk fibroins and has a β-sheet conformation, probably in an antiparallel fashion. As new instruments emerged and were more widely accessible, Weiner, Talmon & Traub (1983) published the first analysis of organic matrices with electron diffraction patterns. Strikingly, the observations from these and many concomitant experiments, still make up a lot of the ground theory and assertions in the biomineralization field. At the same time, biomineralization scientists started to come together since at least 1970, when the first international symposium was held in Germany. An account of the progress since their second international meeting can be found in the Science bulletin from 1977, where Towe paints a rather negative picture (Fig. 3).

No overlaying mechanism is observed, and scientists are baffled by the immense number of structures, their complexity, and the absence of an observable common underlying mechanism. Recent biomineralization review papers similarly state that, despite the newest developments in the field, the complex variety of three-dimensional shell morphologies is largely unexplained (Clark *et al*., 2020). While this is true, the fact is that the field of biomineralization has greatly grown, several scientific groups from all over the world revolve around it, innumerable datasets have been collected and ever more structures have been investigated. Flourishing information and the development of ever more advanced equipment has led to even further investigations opening new debates and reshaping questions.

The main organ in charge of the complex biomineralization apparatus is the mantle. The mantle is a relatively thin tissue that overlays both valves and stretches as needed to tackle multiple tasks within and outside of shell formation. There is also evidence that other cells could be involved in biomineralization in different species (see for example Sillanpää *et al*., 2016), however, the mantle remains the best studied. Gene expression analyses of mantle tissues have greatly increased the amount of information we possess on molluscan biomineralization. Nevertheless, the picture remains puzzling, and this is in part due to the enduring neglecting of molluscan genomes as well as the fast evolutionary speed of biomineralization genes which make phylogenetic comparisons difficult especially when no dominant molluscan model species has yet emerged. However, a renewed effort is now being put into expanding our databases and more information is flowing in, thanks to international collaborations (Davison & Neiman, 2021). It has been repeatedly observed that there are high rates

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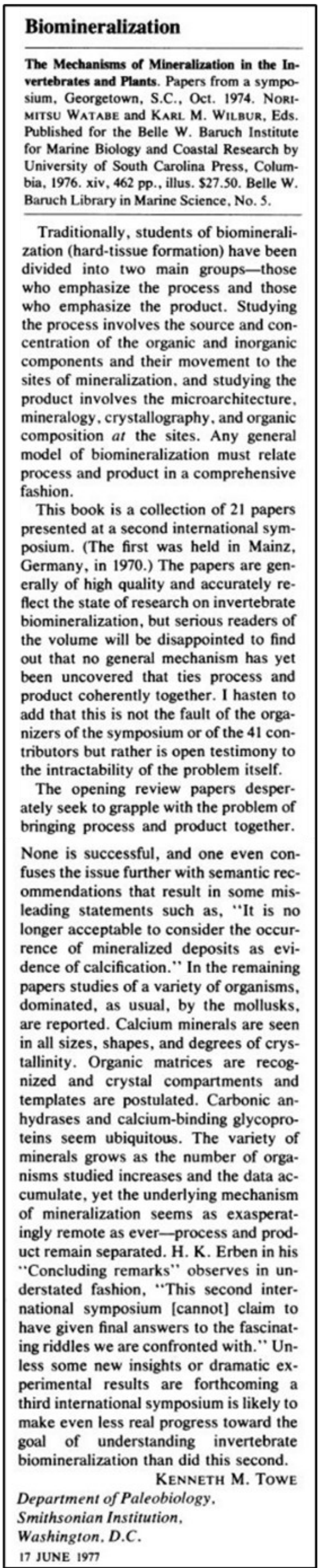

Biomineralization

The Mechanisms of Mineralization in the Invertebrates and Plants. Papers from a symposium, Georgetown, S.C., Oct. 1974. NORIMITSU WATABE and KARL M. WILBUR, Eds. Published for the Belle W. Baruch Institute for Marine Biology and Coastal Research by University of South Carolina Press, Columbia, 1976. xiv, 462 pp., illus. $27.50. Belle W. Baruch Library in Marine Science, No. 5.

Traditionally, students of biomineralization (hard-tissue formation) have been divided into two main groups—those who emphasize the process and those who emphasize the product. Studying the process involves the source and concentration of the organic and inorganic components and their movement to the sites of mineralization, and studying the product involves the microarchitecture, mineralogy, crystallography, and organic composition *at* the sites. Any general model of biomineralization must relate process and product in a comprehensive fashion.

This book is a collection of 21 papers presented at a second international symposium. (The first was held in Mainz, Germany, in 1970.) The papers are generally of high quality and accurately reflect the state of research on invertebrate biomineralization, but serious readers of the volume will be disappointed to find out that no general mechanism has yet been uncovered that ties process and product coherently together. I hasten to add that this is not the fault of the organizers of the symposium or of the 41 contributors but rather is open testimony to the intractability of the problem itself.

The opening review papers desperately seek to grapple with the problem of bringing process and product together.

None is successful, and one even confuses the issue further with semantic recommendations that result in some misleading statements such as, "It is no longer acceptable to consider the occurrence of mineralized deposits as evidence of calcification." In the remaining papers studies of a variety of organisms, dominated, as usual, by the mollusks, are reported. Calcium minerals are seen in all sizes, shapes, and degrees of crystallinity. Organic matrices are recognized and crystal compartments and templates are postulated. Carbonic anhydrases and calcium-binding glycoproteins seem ubiquitous. The variety of minerals grows as the number of organisms studied increases and the data accumulate, yet the underlying mechanism of mineralization seems as exasperatingly remote as ever—process and product remain separated. H. K. Erben in his "Concluding remarks" observes in understated fashion, "This second international symposium [cannot] claim to have given final answers to the fascinating riddles we are confronted with." Unless some new insights or dramatic experimental results are forthcoming a third international symposium is likely to make even less real progress toward the goal of understanding invertebrate biomineralization than did this second.

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17 JUNE 1977

Fig 3. Review of papers published after the second biomineralization symposium (Georgetown, USA, 1974). Printed in *Science* 196 (4296) pp 1311.

of lineage-specific gene co-option and loss from mantle tissues, rapid evolution of coding sequences (Aguilera, McDougall & Degnan, 2017), and extensive duplication of shell matrix protein families (Miyamoto *et al.,* 2013, Takeuchi *et al.,* 2016). Since molluscs produce the highest diversity of biominerals of any animal group, the evolvability of the mantle could provide a molecular explanation for this (McDougall & Degnan, 2018). Whether this confers any selective advantage to molluscs, however, or whether it is a byproduct of the molecules necessary for shell assembly, is not known (Kocot *et al.,* 2016). Exploring these questions would be key to understanding the adaptation potential for this group in the face of rapid environmental change.

The complexity behind shell formation is further enriched when we include increasing evidence for epigenetic post-transcriptional regulation of biomineralization processes through microRNAs (Zheng *et al.,* 2016) and long noncoding RNAs (Zheng *et al*., 2020). In addition, the Mediterranean mussel genome has been reanalysed and has been found to contain an unexpectedly high number of dispensable genes for an animal (Gerdol *et al.,* 2020). Dispensable genes are characteristic of microorganisms such as bacteria, and they are correlated with the ability to respond to selection and inhabit new niches, something that bivalves, which (1) survive in extreme environments, (2) are often exposed to highly fluctuating environments and (3) can be cosmopolitan, have in common with microorganisms. This feature is likely to be found in other bivalves with invasive species traits. All of these observations are important to link the thought of a shell as a solid, rock-like immutable structure and the fact that a great diversity of bivalve and molluscan shells exists, not only between but also within species. For example, the plasticity of shell formation is particularly evident in certain groups such as cementing oysters that create shells so polymorphic that often, species identification based on shell morphology is impossible (Xia, Yu & Kong, 2008). Contrary to all predictions, mussels have been reported to quickly modify their shell structure to adapt to changes in the environment and predation pressure (Telesca *et al*., 2020). It has also been suggested that rapid responses to environmental stress are facilitated by maintaining high genetic diversity in the brooding population (Bitter *et al.,* e2019). In fact, mussel larval shells size can be sustained even in very low pH seawater through fitter genotype and phenotype selection (Bitter e*t al.,* 2019). Therefore, the lack of observations of a clearly defined biomineralization genetic tool and common shell architecture, even within closely related species, is not all that surprising. Clearly, their genetics offer a unique of opportunities for us to learn about plasticity and evolutionary biology.

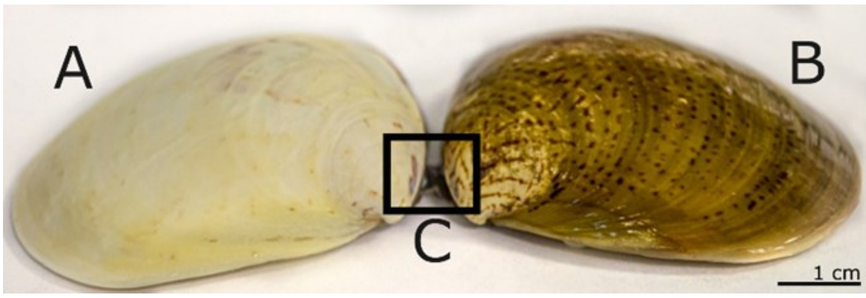

Fig. 4. Adult hard clam shell (*Meretrix* sp.). A) Bare valve after removal of the periostracum, B) valve with original periostracal cover and C) shell ligament.

The making of the bivalve shell begins very soon after fertilization. Bivalves are spiralian animals that undergo unequal embryonic cleavage until bilateral cleavage of dorsal cells triggers the establishment of the unique doubling of the dorsal shell (Kin *et al.,* 2009). It is believed that the bivalve cleavage pattern is highly conserved, and that canalisation of development is key to the establishment, and maintenance, of the bivalve body plan (Kin *et al.,* 2009). A series of cell signalling will initiate the formation of the so-called *shell field*—an early organic matrix,

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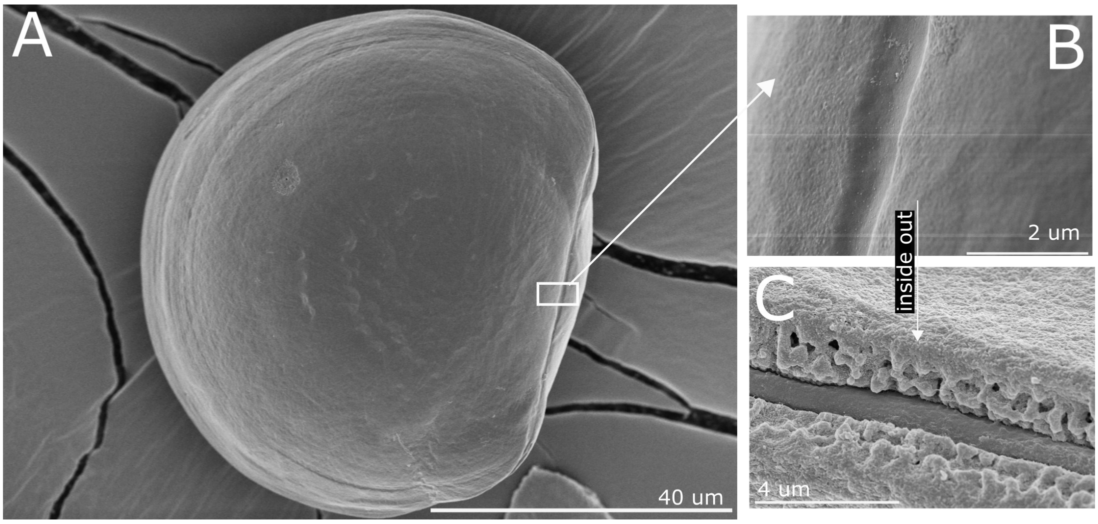

Fig. 5. Example of a bivalve larval shell imaged using scanning electron microscopy. A) Entire Hong Kong oyster larval shell. B) Details of the larval ligament structure from outside the shell and C) view from inside.

which flattens the trochophore larva into a version of the bivalve body frame with which we are familiar (Fig. 5A). Mineral deposition co-occurs upon the organic matrix and at high rates, relatively much higher than in adult counterparts. The bivalve larva mass has been observed to be 90% shell which needs to be deposited by relying mostly, if not exclusively, on the energy provided by the maternal oocyte (Waldbusser *et al.,* 2013). The first bivalve larval shell, which is called a D-shell, is similar among different species with very divergent adult shell morphology. Differently from the settled, mature versions of the bivalve shells with which we are familiar, the larva in its shell is microscopic, free-swimming, and in many species, fully planktonic. Despite all these differences and metabolic challenges, the larval shell already includes all of the features that will also make up the adult shell: distinct layers of $CaCO_3$, hinge ligament, periostracum, and a diverse organic matrix proteome.

The periostracum and the ligament are hardened organic layers, mostly proteinaceous. These structures are visible in the first larval shell (Fig. 5 and 6) and are retained and further developed in the adult counterpart (Fig. 4). Ligament formation is initiated by specialised cells during larval development after valve partitioning (Mouëza *et al.,* 2006) and supports bivalve motility throughout its life. The ligament maintains its elasticity while keeping the valves tightly sealed yet flexible, and is a composite of crystals and an unusual combination of proteins (Suzuki *et al.,* 2019). Similar to a tough insect cuticle, these structures are sclerotized, probably through quinone tanning of soluble proteins (Waite, 1977) and they are produced by the mantle like the rest of the bivalve shell. By contrast with the ligament, the periostracum is not mineralized, although intraperiostracal calcification is not uncommon in adult bivalves (Checa & Harper, 2014). As most clearly observed by transmission electron microscopy, the periostracum encloses the newly formed larval shell from hinge to mantle edge and it is the first observable part of the larval shell (Mouëza *et al*., 2006). One of the prime functions of the periostracum is to provide waterproof support and a substratum for the growth of the outer shell layer (Taylor & Kennedy, 1969). An external organic layer is necessary to isolate the calcification space to create that highly concentrated fluid for $CaCO_3$ deposition and to avoid immediate shell dissolution. The periostracum layer is the key player in more corrosive waters such as polar, subpolar, and low-salinity environments (Telesca *et al.,* 2019). In these habitats, mussels within the same species modulate shell formation by secreting a thicker periostracum and a less calcified shell as compared with their lower latitude relatives (Telesca *et al*., 2019).

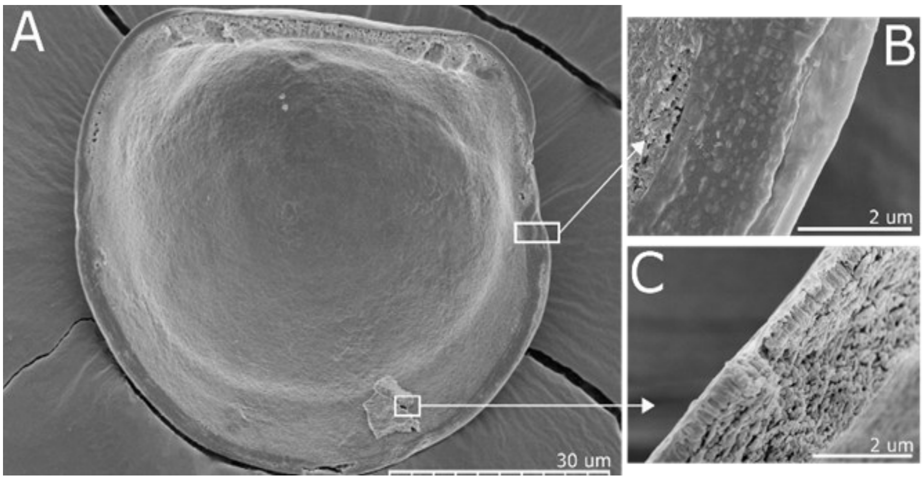

Fig. 6. Bivalve larval shell example imaged using scanning electron microscopy. A) View inside a larval shell valve. B) Details of the larval periostracal cover and C) view of larval shell layers from a broken shell fragment.

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Another adaptation is to increase the organic component within the shell itself. It has been suggested that shells have become more calcified and less organic over time, possibly due to the high metabolic cost of secreting the organic matrix (Palmer, 1992). Therefore, this is not necessarily the best approach to produce more functional shells, at least not on an evolutionary time-scale. It was also proposed that the introduction of calcite to replace aragonite was a cheap innovation for protection from dissolution as *calcite* is less soluble than *aragonite.* These are the two main $CaCO_3$ polymorphs assembled by bivalves: aragonite is harder and stronger, but it is also more soluble than the "cheaper" calcite. It is widely accepted that the primitive molluscan shell was wholly aragonitic (Taylor, 1973). While the bivalve larval shells are all still composed of aragonite, many adult bivalves, such as mussels, include a calcitic layer right under their periostracum. Since this layer would be more at risk of interacting with seawater especially during early deposition, it could indeed be beneficial against dissolution. Whilst aragonite is a more soluble polymorph, there is little evidence that aragonite layers are more soluble than calcitic ones in cold waters (Harper, 2000), but several studies on the effect of decreased pH show a more pronounced negative effect on aragonitic layers as compared to calcitic ones (reviewed in Byrne & Fitzer, 2019). It has been argued, therefore, that aragonitic shells were difficult to maintain and secrete during highly corrosive ancient calcite seas and that during these times the acquisition of a calcitic shell layer was advantageous (Harper, Palmer & Alphey, 1997). Reversing mineralogy is a costly business (Porter *et al*., 2010) and, therefore, the layer might have been maintained since.

When rapid calcification is required, as during embryonic development or new edge growth, granular homogenous structures are observed (Schoeppler *et al*., 2019). As the granular layer grows, the number of crystal nucleation centres decreases and the $CaCO_3$ layers transition in a predictable manner to columnar and then nacreous following a directional solidification model (Schoeppler *et al*., 2019). Nacre, mother of pearl, is easily the most commonly known structure, for its beautiful appearance and commercial value (Fig. 7). Not surprisingly, it has also been the model biomineralization structure in molluscan shell studies. A well-known nacreous material is also the oyster pearl, which is essentially an inside-out shell, with the periostracum at its centre (McDougall *et al*. 2021). Pearls are arguably the most impressive piece of biomaterial produced by molluscs, and the most valuable (at least from a human perspective). Other than its beautiful appearance, nacre is known for being the strongest of all molluscan microstructures (Checa, 2018). Nacre's architecture can absorb 1–3 times more mechanical energy than prismatic calcite and monolithic aragonite before total failure (Gim et al., 2019). Nacre also contains a large proportion of organics, compared to other layers, and these can help restrict crack propagation both within and between tablets, sustaining the overall architecture and allowing further structural loading (Gim *et al*., 2019).

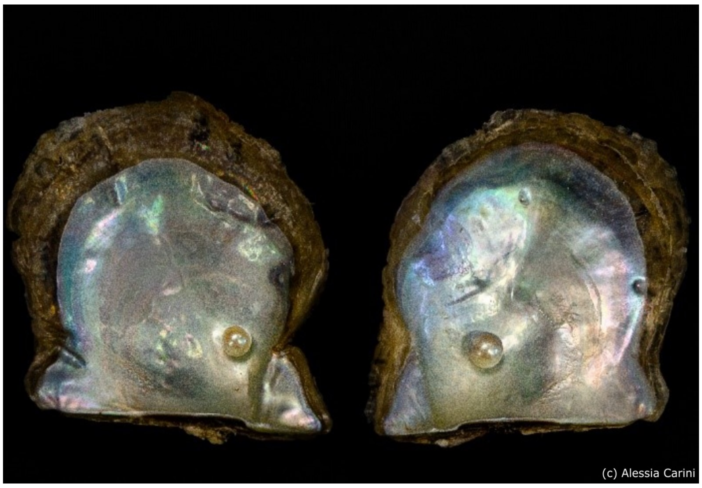

Fig. 7 Mother-of-pearl comprising nacre

Similar sequences of different shell layers are found in calcitic oyster shells, from outer prismatic to the inner foliae layer which is an analogue to nacre. Nacre has evolved multiple times in different lineages (Jackson *et al*., 2010) following the *directional solidification* model. These microstructural sequences, based on thermophysical, and chemical laws, appeared repeatedly during evolution (Checa, 2018: Schoeppler *et al.,* 2019). An example is that calcitic foliae have developed independently in bivalves and gastropods, even though they form a weaker structure than nacre (Checa, 2018). While the large number of microstructures produced by molluscs is impressive, how have bivalves created just the right environment, for their assembly if the $CaCO_3$ abiotic version is so uncomplicated and seawater conditions unfavourable? The answer seems to be that the physical and chemical boundaries for shell secretion are controlled by the direct action of the mantle and then remotely through the secretion of the extracellular conchiolin.

As observed by Fremy in 1855, molluscan shell conchiolin includes a polysaccharide, chitin. Chitin is frequently used by organisms for structural support and probably contributes to the mechanical strength of the shell (Chan *et al*. 2018). Not all shells show evidence of chitin however, and therefore, the abundance and role of chitin in molluscan shells have been debated. When present, it associates with proteins and the mineral phase. For example, in the pearl oyster, crystal defects become larger as chitin fibres are degraded by chitinolytic enzymes (Kintsu et al., 2017), and in the Eastern oyster when the mineral phase or proteinaceous fractions are dissolved, the chitin fibrils growth is stunted (Chan *et al.,* 2018). There is evidence for chitin presence in the bivalve larval shell as well, where it strongly interacts with proteins (Weiss & Schönitzer, 2006).

Shell matrix proteins have received the most attention in recent years, probably due to advances in mass spectrometry. Models based on molluscan nacre proposed that the bulk of shell proteomes is composed of silk-like proteins with gel-like properties that are interspersed within the mineral tablets (Addadi *et al*., 2006). Indeed, several protein sequences similar to silk have been extracted from bivalve shells and often possess chitin-binding domains. It is reasonable to conclude therefore, that silk-like proteins and chitin provide structure to the matrix and the shell. In addition to silk-like proteins, classical models also include negatively charged proteins which have long been hypothesised to interact with positively charged calcium ions and therefore playing an active key role in biomineralization (Weiner & Hood, 1975).

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In addition to these components, it is well established that shell proteomes are characterized by repetitive, low complexity domains that have a biased composition and evolve rapidly by continual recruitment, deletion, and duplication (McDougall, Aguilera & Degnan, 2013).

Most studies regarding the characterization of the shell organic matrix have focussed on nacre. We know from several proteomic studies however, that different mineral layers can have large differences in their shell proteomes (eg. Marie *et al.,* 2012). Further, shell proteomes vary strongly with ontogeny (Zhao et al., 2018) and environmental fluctuations (Arivalagan *et al*., 2020). While proteins are estimated to only account for 1-5% of the shell weight, shell proteomes are quite diverse, and proteomics studies have accumulated a high number of sequences that often do not trace back to any known protein or function. However, functional studies have provided evidence for some long-hypothesized functions of soluble SMPs such as crystal nucleation (Feng *et al.,* 2009), CaCO3 phase determination (Suzuki *et al.,* 2009), initiation and inhibition of calcification (Sikes *et al.,* 2000) and controlling crystallization patterns (Checa *et al.,* 2016). Other than I improving the structural properties of bivalve shells, playing an active role in calcification and bivalve shell evolution, the organic matrix moulds the bivalve shell into a biochemical barrier for the animal. The identification of shell proteins with immunology-related domains used to be troubling, as they are associated with cellular functions and, were therefore, thought to be contaminants. The frequent identification of proteases, metalloproteinases, and protease inhibitors from shell proteomes, even after harsh biomineral cleaning, has now produced new scope for shell studies in the light of biochemical defence against pathogens. These expanding datasets and observations require new, updated, comprehensive models for the bivalve shell matrix that, while consolidating the traditional, well-established knowledge, also appreciates the novelty and nuances of newer findings.

The fact remains that after decades of research, we are still baffled by these invertebrates' resilient creations. The mechanical superiority of these shells offers great opportunities for us to create new bioinspired materials (Clark *et al.,* 2020) and to explore their value for human health, with applications in wound healing, tissue engineering, and bone regeneration (Loh *et al.,* 2021). Bivalves, and in particular their shells, are ecosystem engineers as they reshape their environment and create new homes to countless creatures while also providing an effective natural carbon sink (Fig. 8).

Clearly, bivalve shells are more than just relics on the beach, but issues such as overconsumption, habitat loss, pollution, and climate change, to name a few, put at risk many of these species and their highly specialized shells. Even if it were not for our own consumption, health benefits, or ecological roles, understanding shell formation is important to the safeguarding of the incredible shell diversity that has fascinated geologists, biologists, chemists, and the public alike and, importantly, their millennia of natural history.

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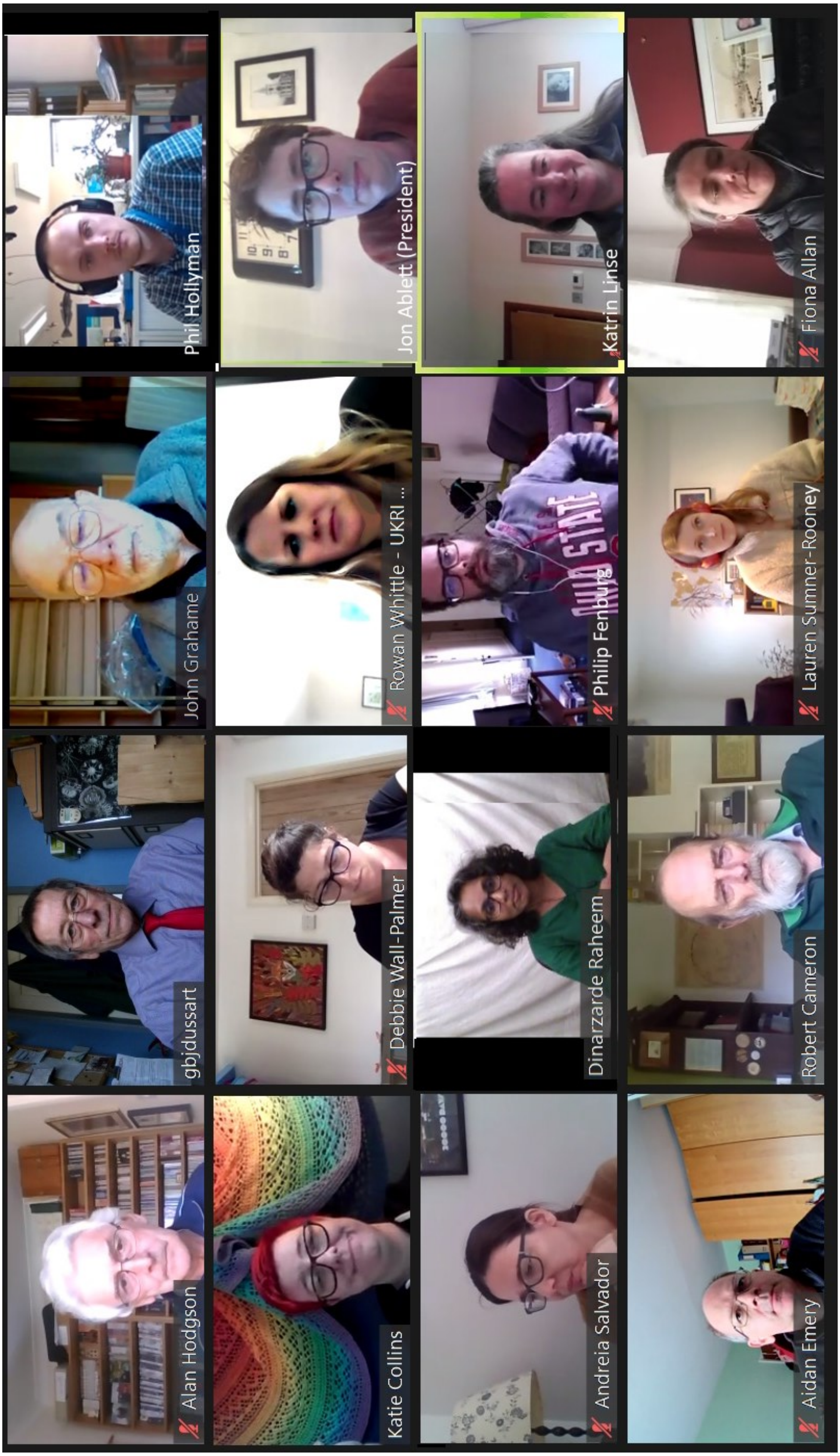
Fig. 8. Examples of ecological functions served by bivalve shells such as rock oysters. Oyster reefs create habitats for other species such as gastropods, chitons, crustaceans, and algae. Oyster reefs change the structure of rocky shores and the oysters, therefore, are ecosystem engineers. Location: Lantau Island, Hong Kong.

Editors note ~ This review was solicited from Alessia Carini after she presented a paper at the Malacological Forum. I suggested the review because I have a special interest in the subject of conchiolin, since I had analysed the amino acid composition of several species of freshwater gastropods in relation to water hardness for my doctoral thesis, presented in 1973.

INVITED ARTICLE—MARINE SHELLS

MEMBERS OF COUNCIL AT THE VIRTUAL AGM



AGM meeting by Zoom 24 March 2021 - Council members

Early Career Research Grant Reports

Research financially supported by the Malacological Society of London

Taking advantage of contamination: Molecular analyses of solenogaster midgut contents to determine food sources

Franziska S. Bergmeier (on behalf of Lukas Ostermair)

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In 2018, The Malacological Society of London provided an early career research grant to Lukas Ostermair to support his master thesis. We are very excited that results of this project are now published as a Correspondence piece in *Current Biology*.

In his master's thesis, Lukas tested a molecular approach to investigate the food sources of Solenogastres, a class of worm-shaped and shell-less molluscs. Traditionally, anthozoan cnidarians were proposed as the main food source of these marine molluscs, as undigested cnidocysts were often found during histological investigations of the midgut (Salvini-Plawen 1981), or based on live feeding observations of large-sized species (e.g. Sasaki and Saito 2005). For this project, gut contents were indirectly sequenced from genomic DNA extracts of almost 200 specimens of deep-sea Solenogastres assigned to more than 60 species, constituting their currently known diversity the deep Northwest Pacific (Bergmeier et al. 2019). We used a universal primer pair targeting the nuclear 28S rRNA region and took advantage of a known amplification problem in solenogaster nuclear genes (i.e. their complex secondary structures usually hamper standard PCRs and instead result in contaminations amplified from gut contents (Okusu and Giribet 2003; Meyer et al. 2010)).

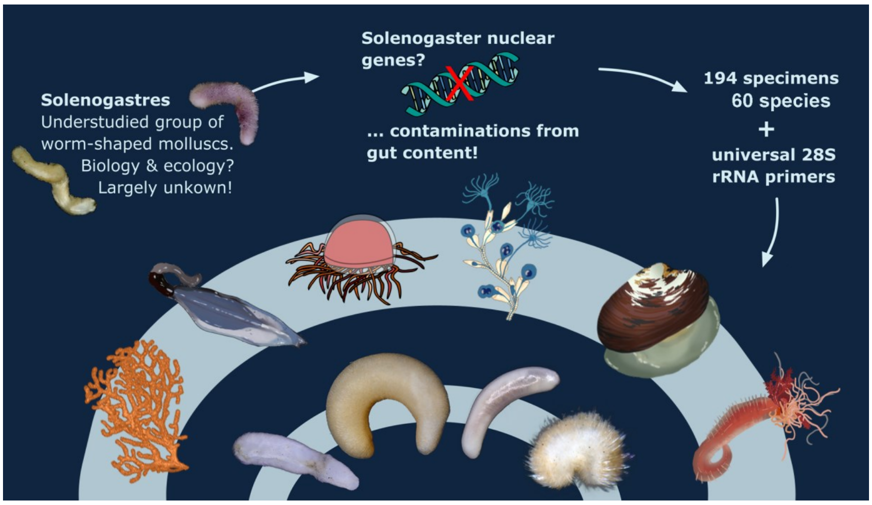
This indirect sequencing of gut contents allowed us novel insights into the feeding ecology of these molluscs. In short, we discovered more than 26 food sources from four different phyla. In addition to cnidarians and annelids, the studied Solenogastres also prey on nemerteans and bivalve molluscs. The majority of investigated solenogasters species seem to have highly specific prey preferences, feeding only on a single food source. Surprisingly, a generalist feeding strategy was only documented in one species. Cnidarians still constitute the most common food source in Solenogastres, but in addition to anthozoans and hydrozoans, some species also prey on benthic siphonophores or scavenge on jelly-fall.

Finally, we plotted these food sources onto a phylogeny of the investigated solenogaster species and discussed the findings in an evolutionary context. The experimental procedures of this project are detailed in the Supplemental information of the publication.

We would like to thank *The Malacological Society* for funding this student project, which resulted in this study on solenogaster food sources and allowed us to gain a better understanding of what's on the menu for these enigmatic molluscs.

The publication is available from the journal's homepage through a subscription or we will happily share it via e-mail (franzi.bergmeier@gmail.com):

Bergmeier FS, Ostermair L, and Jörger KM (2021). Specialized predation by deep-sea Solenogastres revealed by sequencing of gut contents. *Current Biology* 31(13): R836-R837, https://doi.org/10.1016/j.cub.2021.05.031.



Graphical summary of the research project. Inner blue semicircle with some of the investigated Solenogastres species; outer blue semicircle with some of the sequenced food sources (from left to right: Alcyonaceae (Cnidaria), Monostilifera (Nemertea), Trachymedusae (Cnidaria), Leptothecata (Cnidaria), Nuculanida (Mollusca), Terebillida (Annelida)).

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Author's note

In 2018, my student Lukas Ostermair received a junior research grant for his master's thesis. We now have finally published the results as a Correspondence piece in *Current Biology*. I would like to thank the Society again for their support, especially in relation to young students.

EARLY CAREER RESEARCH GRANT REPORT

Mussels under threat: combined impacts of ocean acidification and pharmaceutical contamination on *Mytilus edulis*

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Alice Wilson-McNeal conducting some muddy fieldwork in the Exe Estuary, UK.

Ocean acidification, the "evil twin" of global warming, is known to be a threat to calcifying molluscs (Gazeau *et al.,* 2013). Increasing atmospheric carbon dioxide is absorbed by the oceans, decreasing seawater pH and reducing the bioavailability of carbonate ions which are key for calcifiers to build shells and skeletons. In addition, the changes in carbonate chemistry induced by ocean acidification have the potential to change the chemical behaviour of marine contaminants. The associated reduction in seawater pH can alter the bioavailability and toxicity of ionisable organic contaminants to marine organisms. Species which lack the ability to maintain their extracellular acid-base status in ocean acidification conditions, such as the blue mussel *Mytilus edulis*, may be particularly at risk from this; their internal carbonate chemistry mirrors that of the surrounding seawater, and therefore chemical changes to pollutants could also take place inside their bodies, resulting in altered toxicity effects (Lewis *et al*., 2016).

Research into these potential interactions between ocean acidification and contaminant toxicity for mussels and other molluscs is lacking, despite their potential susceptibility. I designed an experiment to test the hypothesis that the limited ability of *M. edulis* to regulate its acid-base status in response to ocean acidification will cause predictable changes to the toxicity of contaminants. In the experiment, individual mussels were exposed to one of two pharmaceutical drugs at present-day seawater pH and carbon dioxide concentrations, or at simulated pH and carbon dioxide concentrations predicted to be present in the oceans by the year 2100 according to the Intergovernmental Panel on Climate Change. Based on their chemical behaviour, we predicted the toxicity of one of these drugs should increase in this ocean acidification scenario, whereas the toxicity of the other should decrease. We measured haemolymph carbonate chemistry to measure the strength of the mussels' response to ocean acidification, metabolic rate and ammonia excretion rates to investigate energetic effects, and antioxidant activity and oxidative stress as measures of drug toxicity. The combination of these endpoints would give us an overall picture of the mussels' general health status as well as the specific effects of the drugs in ocean acidification conditions.

Mytilus edulis in experimental tanks.

The experiment was set up in March 2020 but we couldn't access our labs or wild mussels due to the covid pandemic. The Malacological Society graciously offered to extend the duration of the grant, and we were able to postpone the work until restrictions were eased. In the meantime, we marine biologists had to get creative with working from home. I took the opportunity to read more literature than at any other time during my PhD, and came across an additional assay for when we got back into the labs. This assay would give us a greater understanding of the neurophysiological effects of the pharmaceutical drugs.

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Once we were able to get back into the lab, socially distanced of course, it was a race against time to have the work completed before the mussels' spawning season as this would interfere with their normal physiology. We collected almost one hundred mussels from the Exe estuary and transported them back to the Exeter University aquarium facility. After some fine-tuning of carbon dioxide concentrations in the tanks and confirmation of the experimental doses of the drugs, mussels were finally added to their tanks in September 2020 – six months later than planned. After two weeks we were able to explore the effects of each of the six treatments to the mussels. Whilst changes in acid-base physiology caused by ocean acidification appeared to affect the toxicity of the two drugs, this was not as clear-cut as we had expected. Some parameters were affected far more than others, and the drug which was expected to become less toxic in ocean acidification conditions had greater effects on some endpoints. The mussels' physiological responses to ocean acidification probably influenced the toxicity of the contaminants, but the exact mechanisms are not fully understood.

Experimental tanks aerated with an air/CO_2 mix to simulate end-of-century ocean acidification conditions.

We are indebted to the Malacological Society of London for providing an Early Career Research Grant to conduct this research. This enabled the purchase of additional chemicals to run liquid chromatography-gas spectroscopy analysis of seawater chemistry to validate the findings and additional equipment for experimental work using carbon dioxide. Thank you to my supervisors Dr Ceri Lewis and Dr Rod Wilson for their guidance in writing the grant proposal and designing the experiment, and to Katherine Colvin and Will Davison for their assistance with field and laboratory work. This work was also supported by the University of Exeter Vice Chancellor's Scholarship for Postgraduate Research. We hope to publish the results from this research this year.

Measuring ecotoxicological parameters in the lab.

Using shotgun sequencing for disentangling a taxonomic jumble: the case study of the skeneimorphs

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Introduction

The Gastropoda comprise the most diverse class of Mollusca, including between 40,000 to 150,000 species adapted to live in all environments. This astonishing diversity has hindered a comprehensive understanding of their evolutionary history, leading to multiple alternative classifications [1] and the subsequent creation of taxonomical categories that do not represent natural groups.

The family Skeneidae Clark W., 1851 represents an extreme example of such taxonomic conundrum. This family traditionally includes hundreds of species in dozens of genera that are characterized by a minute shell (usually 0.8–2 mm) without nacre, a rhipidoglossate radula and a multispiral operculum [2]. However, more detailed morphological and molecular studies have proved their polyphyletic nature and the name "skeneimorphs" was claimed to be more accurate for these snails [3]. For instance, although the family Skeneidae has been assigned to the superfamily Trochoidea [4], some specimens should be considered members of the superfamily Seguenzioidea [3], and there are even cases of former skeneimorphs that belong to the subclass Heterobranchia [5].

Molecular studies could help us overcoming this situation. In particular, mitochondrial genomes have been widely used to infer the evolutionary history of different gastropods, and to define a robust classification of these groups [e.g. 6]. In the summer of 2017, I visited the lab of Professor Yasunori Kano (University of Tokyo) aiming to amplify the complete mitochondrial genomes from several species of skeneimorphs from his collection. However, the low amount of DNA (due to the size of these snails), the lack of specific primers (given their polyphyletic origin) and the quality of the probably fragmented DNA, hindered my approach. The main goal of this project was to overcome these limitations by establishing a new methodological pipeline, sequencing low coverage genomes from three skeneimorph species. This would be instead of using the traditional PCR-based approach.

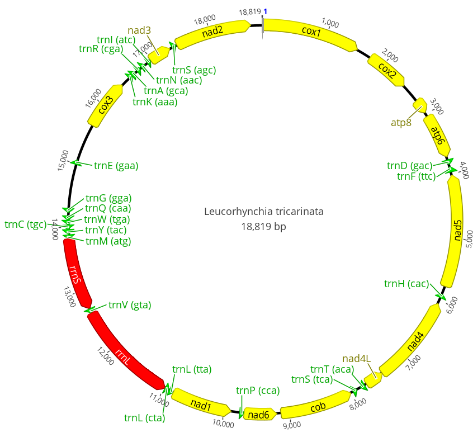

Figure 1 – Annotated mitochondrial genome of *Leuchorhynchia tricarinata*. Diagram generated with Geneious.

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Materials and Methods

Three species were selected: *Dillwynella vitrea, Leucorhynchia tricarinata*, and *Protolira thorvaldssoni*, collected between 2003 and 2012 and preserved in 100% ethanol. Total genomic DNA was extracted from whole specimens using the Qiagen DNeasy Blood & Tissue Kit. Samples were then sent to Macrogen, where an indexed library per sample was constructed using the TruSeq Nano DNA Kit and sequenced in an Illumina NovaSeq platform with a sequencing depth of 30GB.
Raw reads were corrected for potential sequencing errors using Rcorrector [7], adapters were removed using Trimmomatic, and reads were quality trimmed using Prinseq v.0.20.4 [8]. Mitochondrial genomes were assembled using NOVOPlasty v.4.2 [9] and annotated by comparison with other Vetigastropoda genomes. Additionally, in order to assess the minimum sequencing depth required to recover complete mitochondrial genomes, reads were randomly sampled to generate 2, 5, 10, 15, and 20GB files. All reads were mapped to the assembled mitochondrial genomes using Bowtie2 v.2.2.6 [10] to separate the nuclear reads, which were then assembled using SPAdes v.3.14.1 [11]. Genome completeness was assessed using BUSCO v.3.0.2 [12].

Results and Discussion

Mitochondrial genomes have been widely used for inferring phylogenetic relationships within Gastropoda, and have helped in the definition of several trochoidean families [6, 13]. Based on this experience, mitogenomes were chosen to study the polyphyletic Skeneidae and identify those species that could belong to different families, but the traditional PCR-based approach was largely unsuccessful. Genome skimming techniques allow the assembly of complete or nearly-complete mitochondrial genomes and the annotation of nuclear markers just from DNA extractions, and it has been successfully used in other contentious groups [14].

Between 144 and 211 million reads were generated per species. The complete mitochondrial genome from *L. tricarinata* (Fig. 1) and *P. thorvaldssoni* were recovered. The mitogenome of *D. vitrea*, however, was not circularized. Instead, two fragments of 14,400 and 3,300 bp were assembled. Successive attempts improved this result, although a small fragment between the *trnD* and the *trnS* genes was still missing. During the quality control of the extraction, the Macrogen lab team detected a high degradation in this sample, which could explain this result. All mitochondrial genes could be annotated however, proving the reliability of this approach for assembling and annotating the (nearly) complete mitochondrial genome of these minute skeneimorphs.

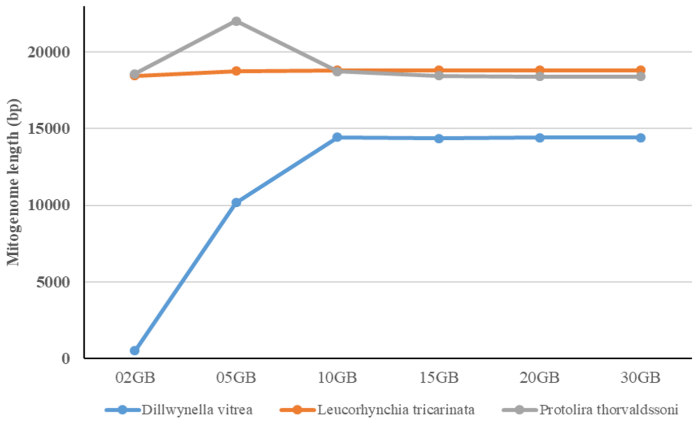

Figure 2 – Sequence lengths of the mitogenomes assembled at different sequencing depths for the three species: *Dillwynella vitrea* (blue), *Leuchorhynchia tricarinata* (orange), and *Protolira thorvaldssoni* (gray).

Aiming to identify the minimum sequencing depth required the assembling of a complete skeneimorph mitogenome. Different depths were simulated by randomly sampling 6, 16, 33, 50 and 67 million reads for each species. For *L. tricarinata* and *P. thorvaldssoni* , virtually no differences were found among attempts, as the complete mitochondrial genome was recovered in all cases. Small variations in length were detected however, due to the differences in the assembly of the repetitive control region (Fig. 2).

By contrast, *D. vitrea* was more troublesome, as at least 10GB were necessary to replicate the results of the full dataset. Based on this experience, DNA quality (or integrity) seems to be an important factor for recovering a complete mitochondrial genome, although this limitation can be bypassed by increasing the sequencing effort [15].

Although most of this work was focused on mitogenomes, a big portion of the nuclear genome was also assembled (Table 1), representing between one third and a half of the vetigastropod *Haliotis rufescens* genome [16]. All three genomes were highly complete, with more than 65% of the metazoan BUSCO genes present in all cases. As expected for a genome assembled from short reads, they are highly fragmented, with the highest N50 of the three in 13,923bp, as reported for other species [e.g. 17].

Table 1: Basic statistics of the assembled nuclear ge-

	D. vitrea	*L. tricarinata*	*P. thorvaldssoni*
Total length (bp)	838,389,779	627,445,078	511,601,414
Number of contigs	737.371	264,380	376.317
Largest contig (bp)	148.918	367.191	232,540
N50	3.154	13.923	2.873
BUSCO (C/P/M)*	35.9/30.6/33.5	82.2/12.5/5.3	44.7/31.6/23.7

*Percentage of C = Complete; P = Partial; M = Missing genes

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Future work

This project was conceived as a proof of concept to evaluate the performance of genome skimming for studying skeneimorph gastropods. After these successful results, this protocol will be now extensively applied to other skeneimorph samples, aiming to identify highly divergent lineages that might represent independent families. Thus far, one of the goals included in the proposal was inferring the phylogenetic position of the Skeneidae within Trochoidea. However, the inferred tree topology was highly variable depending on the analysis. This project will surely benefit from an increased taxon sampling.

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Book reviews

Molluscan genomics: broad insights and future directions for a neglected phylum

Angus Davison and Maurine Neiman

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Genome sequencing seems now so commonplace, a critical part of the Covid-19 response, embedded in personal healthcare, and the reporting of genome sequencing of 'newsworthy' organisms, that it would be understandable if the general public held the misperception that genome sequencing was trivial, with the science at a stage where any organism could have its entire genome sequenced quickly, cheaply, with apparently little effort. It is preaching to the converted to argue that molluscs display a wide variety of phenotypes of interest addressable through genomic methods. Why then are, particularly high-quality molluscan genomes, under-represented in genome databases, how can this be changed, and what even can we learn from molluscan genomes? This special issue of *Philosophical Transactions of the Royal Society*: 'Molluscan genomics: broad insights into future directions for a neglected phylum' reports on a meeting, 'Pearls of wisdom: synergising leadership and expertise in molluscan genomics' held in 2019 and considers, in a series of 14 papers, particular aspects of, or challenges to, molluscan genomics. From technical difficulties in extracting the high molecular weight DNA necessary for genome sequencing (molluscs seem to have evolved a number of characteristics which make this extremely difficult), right through to front-end database availability of genomes accessible by all, and from the current knowledge of epigenetic modification of genomes through to the state of play of molluscan phylogenomics.

The introductory paper to the volume by Angus Davidson (University of Nottingham) and Maurine Neiman (University of Iowa), the meeting conveners, sets the scene for these diverse papers, explaining the current state of play of molluscan genomics and the (quirky) history and rationale for this conference.

Adema reviews difficulties with extracting high quality molluscan DNA, something anyone studying molluscan genetics will be abundantly aware of. This article clearly presents the issues affecting extraction e.g. mucopolysaccharides and pigments, and difficulties with qualitative assessment of molluscan genomic DNA, an article I am sure will be extremely useful to all undertaking such procedures.

We sit at an exciting juncture where not only are large national (e.g. Darwin Tree of Life project) and international efforts underway to sequence the genomes of all species but individual labs can feasibly sequence whole genomes. In recent years the Oxford Nanopore Technologies (ONT) sequencer, a device that in its simplest form is a small USB powered sequencer, has been demonstrated to be deployable anywhere from field diagnostic laboratories in Liberia to the International Space Station. However, the latest iterations of this and the bioinformatics methodology to deal with these data make it usable in any laboratory for genome sequencing. Sun *et al.* take molluscan ONT data and benchmark a range of assembly pipelines offering advice for the optimum methods dependent on the size and heterozygosity of your molluscan genome.

To be useful, molluscan genomes must be accessible, not just as raw data available only to those with the necessary bioinformatic skills, but through freely accessible online genome databases. Caurcel *et al.* present MolluscDB (https://molluscdb.org/) an access route for both currently available and future mollusc genome assemblies. Whole genomes represent a rich dataset for phylogenetics and molluscan phylogenetics (with contentious evolutionary relationships, particularly within classes) may benefit greatly from the large datasets genomics can provide. Sigwart *et al.* consider where research activities should be directed in future years to optimise the utility of these, noting not that although most molluscan diversity remains unsampled, current genome sequences are typically from recently derived taxa and future efforts must concentrate on early diverging branches and groups with poor sampling (e.g. Aplacophora, Schaphopoda, Polyplacophora).

Whole-genome sequencing data opens up a swathe of opportunities for understanding the driving forces of speciation. Chueca *et al.* use data from two species of the terrestrial pulmonate *Candidula* to dissect the role, and extent of gene flow, to understand ecological speciation in these snails.

Whole mitochondrial genomes have been attainable for longer than whole (nuclear) genomes, although they now can be extracted from whole genome data. Ghiselli *et al.* review the current knowledge on the gene content and organisation of molluscan mtDNA and the utility of these sequences in a phylogenetic context.

The term 'model organism' is widely used in biology. In their paper, Davison and Neiman discuss why there are no molluscan model organisms and what criteria must be met for any mollusc to be regarded as such, including the genomic and genetic resources necessary.

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Other papers are perhaps more relevant to those interested in molluscan molecular genetics. Rosani *et al.* review current knowledge concerning molluscan miRNAs (non-coding regulators of gene expression) and Männer *et al.* consider a potential epigenetic regulator of gene expression, methylation, inferring methylation patterns across 140 molluscan species. Calcino *et al.* show that molluscan genomes not only show evidence of hemizygous regions (with large chromosomal sections differing in presence/absence) but that these regions typically contain genes involved in transposition, DNA repair and stress response. Other structural variation is detectable in oyster (*Crassostrea virginica*) genomes (Modak *et al.*). These duplications contain either genes or exons and are hypothesised to underpin this species' adaptive and evolutionary success. McCartney utilises genomics and classical genetics to locate and study the genes involved in byssus production from a *Dreissena polymorpha* genome assembly, comparing byssus proteins with those from quagga and blue mussels. Molluscs of aquacultural importance are perhaps over-represented in the (limited) available genomes. Potts *et al*. discuss how genomic data and technologies may aid in improvements to disease resistance including how genomic data can be interrogated for suitable loci for CRISPR modification. Finally, Seppälä *et al*. discuss the adaptive evolution of the gastropod immune response, reviewing the studies on this and discussing how genomic, or more particularly transcriptomic data may provide insights into this.

This volume is therefore not just a collection of papers detailing molluscan genomes, but a state-of-the-art summary, offering suggestions, both technical and reflective for how to move forward. Whilst it will, unsurprisingly, be likely of most interest to those directly involved in genomics (and not just of molluscs), it contains a variety of papers of interest to many broad molluscan interests, and demonstrates the utility of genomic data to throw light on important questions in molluscan biology.

Dr Craig Wilding
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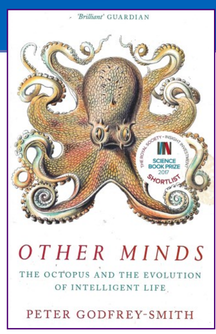
Book and film

Other minds; the Octopus and the evolution of intelligent minds

by Peter Godfrey Smith (2018). Pubished by William Collins, London ISBN: 978-0-00-822629-9

BBC iPlayer - Natural World - 2019-2020: The octopus in my house

Presented by Professor David Scheel



Peter Godfrey Smith (PGS) begins the book by describing 'Octopolis', an octopus 'city' over which he scuba dives on a shallow sea floor on the east coast of Australia. Octopolis is a habitat to which the author returns several times during the narrative. It is a rather strange biotope, in that octopods are not usually social animals.

The author takes an evolutionary approach to the question of how sentience, intelligence and consciousness fit into the physical world. As a philosopher, he wants to know how it feels to be an animal such as a cephalopod – "If we want to understand other minds, the minds of cephalopods are the most other of all" emphasising that "this is a philosophy book as well as a book about animals and evolution".

Early in his narrative, PGS describes what is meant by 'seeing' for a bacterium, including both the seeing its environment and seeing its bacterial colleagues. The relevance of this to malacology is that, for example Hawaiian squid host bacteria in their body. The bacteria produce light through a quorum-sensing mechanism, and the host squid incorporates the process into its development of camouflage.

Two possible narratives for the development of multicellularity are discussed, comprising sponges and comb jellies. The author observes that Ediacarans in the Precambrian beds near Adelaide may have had little to do with each other "munching on the mat (of) filtered food from the water … hardly interacting at all", since there is little evidence of predation. It seems that at this time, the nervous system was used for coordination rather than the sensori-motor control as used for, for example, in the processes of defence or attack. PGS then nicely obfuscates his own argument by raising the issue of jellyfish stings. Who was being stung, and why?

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The Cambrian metazoan explosion is described as a process of animals being "involved in each other's lives". Through natural selection and evolution this leads to the production of eyes, antenna and claws, The book is peppered with nuggets of biology - for example box jellyfish can navigate, moving at three knots, by watching external landmarks on the seashore. Eventually, complex, active bodies arise in only three taxa, these being the chordates, arthropods and cephalopods. The writing is both poetic and enigmatic in places, for example "until in one example of this sensory and behavioural entangling, a rubber encased mammal and a color changing Cephalopod find themselves staring at each other in the Pacific ocean" PGS moves on into the evolution of molluscs, pausing on *Nautilus* as a lone survivor with 200 million years of heritage.

Homing in on the Cephalopods, PGS observes that they evolved to "smart". He examines the mismatch between experiment and anecdote as a familiar problem in animal psychology, but it is particularly relevant to octopus behaviour. He describes experiments and observations on the extraordinary behaviours of cephalopods in the open sea, in Octopolis and in the laboratory.

Mammal brains can be mapped but it is difficult when the octopus has most of its neurons in its arms. Because of recurrent neural connections, octopuses have a form of short term memory in the arms. Nevertheless, in experiments, the octopus uses its eyes to guide its arms through a maze to a reward. The arms may also have sufficient independence to do some local exploration, self-motivated by the arms. PGS asks why an octopus has as many as 0.5 billion neurons and investigates ideas of primate behaviour developed by Katherine Gibson in the 1980s. Gibson firstly identified food gathering that requires little manipulation, for example a frog catching an insect. Secondly there is extracted foraging where choices are made within the context, for example removing food from protective shells. In relation to this, PGS reconsiders the evolution of nervous systems, contrasting sense or in motor views with action-shaping views, suggesting that the first nervous systems were primarily for coordination within the organism. He suggests the octopuses central nervous system imposes a top down order but also allows turned each arm to be an intermediate scale actor. Thus, the octopus has a kind of mixed (nervous) economy. The outcome is that it is not clear to us where the brain ends in an octopus, since the nervous system runs throughout a body which has "no parts, an old joints, no natural angles".

What it feels like to be another organism in its world is then considered. He investigates the ideas of consciousness, discussing issues such as perceptual constancy (how an object remains recognisable of the same object as the viewpoint changes) and nervous integration in a range of taxa, concluding that brain activity which leads to visual experience causes the building of an inner model of the external world in the nervous system. In exploring consciousness, the author takes the example of pain, noting that some animals don't seem to feel pain. For example, they don't groom or protect an injured part of the body but just continue with whatever they were doing. He points out that subjective experience comes from the modulation of the nervous system, that is, from registering things that matter and not just merely running the nervous system. In developing this argument, PGS invokes the work of Dehaene, Barrs, Millner and Goodale, seeing consciousness as a useful term for subjective experience that is "unified and coherent in various ways". He takes the special case of the octopus, describing a range of experiments which reinforce the idea that octopuses have delegated a certain amount of local control to their arms. At this point, PGS again wonders what it would be like to be an octopus. For the octopus nervous system, PGS accepts the metaphor that it may resemble jazz improvisation, where the final result emerge as out of a continued give and take of musical information between the players.

The colour changes of the giant cuttlefish is next for consideration. PGS is puzzled by the metabolic cost of the immensely expressive colour changes in an animal that apparently does not have colour perception, and in relation to cephalopod camouflage asks "How can you match colors you cannot see?" The relationship between colours and behaviour of shapes is explored; for example, when are a cuttlefish holds its arms up like horns, in an aggressive gesture. Many of these engaging examples of relationships between the observer and the Cephalopod take place in Octopolis and PGS describes examples of the animals exhibiting blatant curiosity, with associated colour changes. As a general biologist, I was pleased to see that PGS includes an analysis of the mechanisms of these colour changes. The descriptions in the book are eloquent but to really assimilate what is happening, I recommend the BBC video available at
BBC iPlayer - Natural World - 2019-2020: The Octopus in My House

Here, David Scheel Professor at Alaska Pacific University spends a year in a personal relationship with an octopus in an Octopolis in the USA. Finally in relation to colour, PGS concludes that colour changes in the giant cuttlefish are an inadvertent expression of the animals inner processes; he offers colour plates in evidence and again, his thesis is efficiently supported by the BBC film documentary.

The book now enters a more philosophical vein, passing from Hume to Vygotsky via Darwin. The relationships between speech and thinking in humans is explored by reference to the psychologists' use of the concepts of System I (thinking uses habits and intuitions) and System II (which is slower, users proper rules of reasoning, and tries to look at things from several angles, being "ponderous and powerful"). At this point, I notice a comment I have written on a page in the book "*has he abandoned the cephalopods now?"* but this is not a negative criticism. PGS can't stop being a philosopher and so, he makes an excursion into thinking about one's own thoughts. As this stimulating chapter ends, the author brings his readers back to the molluscs.

The short life of a cephalopod allows PGS to start wondering why anything gets old and dies, and he discusses the possibility that the death of aging individuals saves resources for the young, thereby benefitting the species. The evolutionary principle of mutation-selection balance is examined, including the logic that individuals who live long and without deleterious mutations are likely to have more offspring. By contrast, everyone will carry some mutations and it will appear to an observers that they have been programmed to decline. PGS develops his argument by considering semelparous and iteroparous life cycles. Semelparous organisms have-big bang reproduction, producing offspring in a single short season. Iteroparous organisms produce several generations over a more extended period. Female octopuses are an extreme case of semelparity since they die after a single pregnancy.

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First encounter

Exploration of a relationship

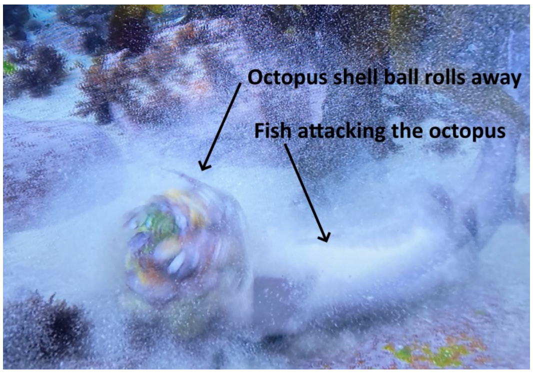
The den

A bitten off arm regrows

A child gets involved

As a protection, the octopus forms a ball, armour plated with shells

It is investigated by a predatory fish…...



...and in a blur, rolls away in its armour.

Some still images from The octopus in my house

In the final chapter PGS returns to Octopolis, recounting days when he would see more than a dozen octopuses roaming, grappling or just sitting in an area a few metres in diameter. In an observation supported by the BBC documentary, he engagingly describes a Nosferatu pose where a startled octopus colours itself black and raises a dark cloak of mantle forward, over its head. PGS wonders how Octopolis could originats, and comcudes that it is caused initially by octopuses eating scallops and leaving their shells as debris. In a positive feedback loop, this debris allows other octopuses to dig out further stable dens so that the environment comprises more and more of the shells themselves, in a case of ecosystem engineering. All this seems to lead at Octopolis to an unusual social life of high densities and continuous interaction.

Finally, PGS summarises his argument in relation to the cephalopods and extends it into the negative impacts humans activities have on oceans. The film also ends on a pensive note, when the main cephalopod protagonist comes to the end of its natural life. Its death evidently deeply affects its human companion.

I found the book and the film created a thought-provoking synergy, and I strongly recommend both to anyone who nurtures an interest in molluscs.

Reviewer - Georges Dussart

Annual report of Council for 2021/202

delivered by the President, John Grahame at a Virtual Annual General Meeting

MEMBERSHIP– no report

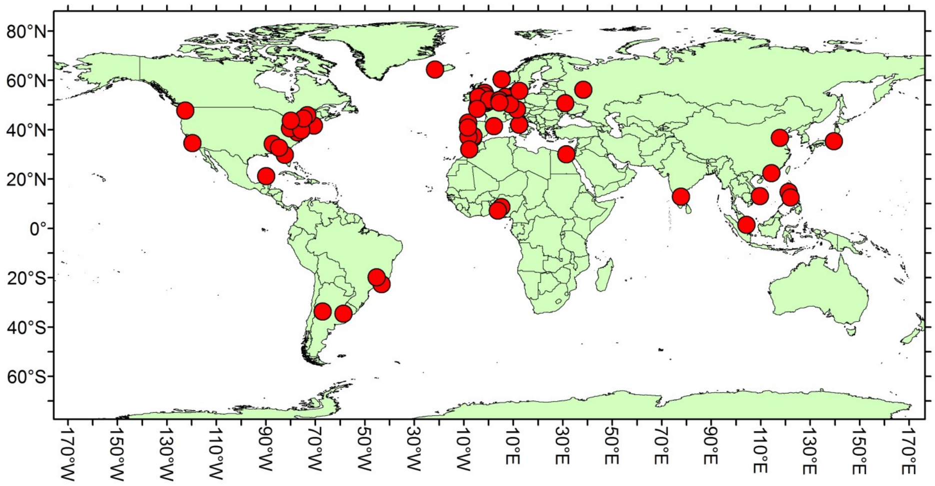
FINANCE for the financial year ending 31st December 2020 (reported by Katrin Linse).
Significant activities
In 2020 the Malacological Society of London had proposed meeting at the Marine Biological Association in Plymouth on "Limpets 2020" that had to be cancelled with a week's notice due to Covid-19, and the annual Molluscan Forum for Young Scientists was held virtually. The Society published the members' bulletin "The Malacologist" and in cooperation with Oxford University Press the "Journal of Molluscan Studies".
Public benefit
The charity's objects are for the public benefit because increasing public knowledge is required as molluscs form an important part of the global biodiversity and ecosystem stability which can have effects on human health and are a human food source.

ACHIEVEMENT AND PERFORMANCE
Charitable activities
In 2020 the main charitable activities were the funding of eleven research projects, of which nine claimed the grants (total cost of £13,342.25), eight to young researchers and malacologists in non-permanent positions and one to senior researchers, the support of 3 students and young researchers to attend conferences and training courses, an activity highly impacted by Covid-19 as the Society usually supports around 20 scientists here.

FINANCIAL REVIEW
The finances of the Malacological Society have been pleasing during 2020 with an overall gain of £52263. This gain is explained by a gain in the Fixed Interest and Investment funds and lower awards and meeting expenditure.
Our investments had an overall gain of £28,997 (comparing market value at 31 December 2020 with market value at 31 December 2019), with the COIF Investment Fund making a gain of £25,132 and the COIF Fixed Interest Fund a gain of £3,865. During 2020, no funds were transferred from the current account to savings accounts.
Separately, the profit-share from the publication of the Journal of Molluscan Studies in 2020 provided the Society with most of its income contributing £49,396. The Editor of the Journal, Dr Dinarzarde Raheem, and the Assistant Editors are to be commended for their hard work contributing to the publication of our scientific journal. In addition, sales of the digital archives provided £506.50 of income.
In 2020, more funds were used for research awards, being £13,342k in 2020 compared to £8,696k 2019, while travel awards remained similar, but there was reduced spending on Council meeting and Forum travel awards as meetings after January 2020 were virtually. The Society (MSL) spent less money in 2020 compared to 2019, this was mainly based on less expenses paid for meetings and to the JMS editor for attendance expenses Malacological conferences to promote our journal and network with potential assistant editors and authors.

MEETINGS
The AGM
The 127th AGM was held as a virtual meeting *via* Zoom, on the 4th of June, the same day as the June Council but as a separate meeting. Very unfortunately it was not only delayed by problems arising from the Covid-19 pandemic, but also was unaccompanied by any malacological presentations because the anticipated Limpets 2020 meeting was necessarily cancelled at very short notice.

The Molluscan Forum **reported on by Phil Hollyman**
The annual molluscan forum was held on the 19th of November 2020, for the first time this meeting was hosted virtually *via* Zoom. Over 170 people registered in advance for the event, representing about double the delegates of recent in-person meetings. The shift to a virtual platform had a clear impact on accessibility for international delegates, improving the ability of many people to attend and present.



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This year also saw the introduction of quick-fire talks in place of poster sessions, giving each speaker five minutes and two slides to present their findings. Overall there were 50 applications for full and quick-fire talks, which were presented during three full and three quick fire sessions throughout the day. **The Oxford prize, awarded annually for the best early career talk, was given to Lauren Eggleton (Sheffield University) for her talk titled: 'A Sticky Situation: Investigating the Contradictory Nature of Gastropod Mucus'.**

PUBLICATIONS

***The Malacologist* reported on by Georges Dussart**

In the 2020-2021 operating year, two issues of The Malacologist were posted to the website.

The August issue always includes the President's report of Council, which summarises the activities of the Malacological Society of London over the previous year. Issue 75 (August) of The Malacologist was an extended edition of 53 pages; this pagination largesse was partly due to papers which discussed the future of the Malacological Society of London. There was also an unusually large number of research reports. An article by Robert Cameron on The future of the Society and the Journal of Molluscan Studies in the age of Open (and digital) Access led to articles by Trevor Parry Giles (Crafting a new normalcy) and Robert Harington (Why scholarly societies are vitally important to the academic ecosystem). The research reports included Cryptic and invasive freshwater Galba snails by Pilar Alda, Towards a first molecular phylogeny of Caecidae micro snails by Christina Egger et al., Preliminary data on the biodiversity of solenogasters in the China Sea by M. Carmen Cobo, BrdU-based sperm-labelling protocol in a hermaphroditic freshwater snail species by Yumi Nakadera et al. and Physiological performance of an invasive freshwater gastropod under elevated CO2-induced acidification by Andrew A. David. As always, it was gratifying for the Society to receive a report from an Annual Award winner, in this case Samuel Abalde's report on Phylogenomics and comparative transcriptomics of West African cone snails. The issue also included a book review and two memoria (John Allen and Ron D'Or). Finally, the issue included an invited article from Jake Goodall et al. entitled Emerging from the shell: development of the common whelk as a novel model of phenotypic variation. The invitation arose from a series of Forum presentations given on this subject by the Icelandic group.

The February issue (76) of *The Malacologist* had, as its core, the abstracts of the Molluscan Forum for 2020. This 41-page issue included two research grant reports. Kiran Liversage et al. reported on Intertidal molluscs on the ecologically dynamic Saurashtra peninsula (Gujarat, India) and the report from Eduardo Sampaio, concerned Disentangling multi-partner effects on collaborative hunting between octopus and fishes. As increasingly happens for research reports, this report was associated with video recordings. The issue included an essay from Council member Robert Cameron which summarised his experience of academic publishing over the past decades; Robert intriguingly entitled the essay Tales from the Palaeolithic. Robert's essay was prompted by the termination of paper-printing of the Journal of Molluscan Studies (JMS); paper issues are now replaced by digital-only access. This event also prompted the article written by Alan Hodgson, another Council member, From print to on-line, a historical review of the Journal of the Malacological Society of London which reviewed the history and editorship of the JMS since its inception. A further contribution by Council members in this issue was the position paper from Lauren Sumner-Rooney on Diversity, Equality and Inclusion in the Malacological Society of London prompted by the 'Black Lives Matter' movement.

The Malacologist continues to present a useful synoptic view of malacology, especially amongst young researchers. The Malacologist has an ISSN number (ISSN 1759-1406) and is therefore citable, so it is in the interest of awardees to present reports on their Society-funded research or travels.

***The Journal of Molluscan Studies* reported on by Dinarzarde Raheem**

The ISI impact factor for the *Journal* in 2019 increased to 1.461 (compared with 1.345 in 2018, 1.483 in 2017, 1.250 in 2016 and 1.185 in 2015). The *Journal* stands at number 63 in the ISI list of 168 zoological journals (it was 65 out of 170 in the previous year). Our chief competitor, *Malacologia*, had a remarkably high impact factor of 13.50 in 2019, reflecting the fact that during the two-year citation window there has been just a small number of citable items in this journal, of which one (Bouchet *et al.*'s 2017 classification of gastropod and monoplacophoran families) has been cited nearly 300 times. The *Journal* continues to be truly international in terms of the geographical distribution of its authors; for volume 85 (2019) the corresponding authors represented 19 countries (of which the leaders were 16% Germany and 13% Japan). The average publication time from receipt to Advance Access publication was 10.4 weeks for 2019.

Circulation for the Journal in 2020 was 55 institutional (of which 36 were online-only and 19 print-only) and 156 membership subscriptions (compared with 30 and 157 respectively for 2019). In addition, a further 2,530 institutions have electronic access to the Journal through publishers' collections (includes migrated figures; compared with 2,348 in 2019).

The new pricing structure has been fixed for 2021. The Journal moved to being online only from January 2021, with the cost for an online-only subscription set at £552. Please see https://academic.oup.com/mollus/subscribe for more information.

Volume 86 (2020) contained 45 papers, research notes and review articles, totalling 434 pages (the preceding volume totalled 452 pages). In total, 127 manuscripts were submitted in 2020 (an increase of 8.5% on the 117 in 2019) and the acceptance rate was 33%. The image of the chiton *Chiton albolineatus* on the cover of Volume 87 was kindly donated by Douglas J. Eernisse.

Our board of Associate Editors is now: Coenraad Adema (immunology, genomics, parasitology), Thierry Backeljau (molecular phylogenetics and genetics), Liz Boulding (population and reproductive biology), Robert Cameron (ecology and genetics of terrestrial gastropods), Richard Cook (agricultural malacology, physiology, feeding behaviour), Simon Cragg (life histories, sense organs), Mark Davies (marine ecology and behaviour), Dan Graf (freshwater bivalves), John Grahame (population genetics, morphometrics), Liz Harper (marine bivalves), Gerhard Haszprunar (microanatomy, 3D reconstruction, minor molluscan classes), Bernhard Hausdorf (terrestrial gastropods), Michal Horsák (ecology and biogeography of

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terrestrial gastropods), Yasunori Kano (systematics of vetigastropods, tropical ecology), Joris Koene (reproductive behaviour of gastropods), Manuel Malaquias (opisthobranchs), Peter Marko (marine biogeography and phylogenetics), Pablo Martín (freshwater ecology, life history), Ellinor Michel (ecology, freshwater gastropods), Jeff Nekola (community ecology of terrestrial gastropods), Nicolas Puillandre (neogastropods), Ellen Strong (freshwater and marine caenogastropods), Janet Voight (cephalopods), Janice Voltzow (microscopic anatomy), Heike Wägele (opisthobranch biology), Tony Walker (biochemistry, immunology, cytology), Suzanne Williams (molecular phylogenetics and genetics), and Yoichi Yusa (general ecology and behaviour). Nerida Wilson has temporarily stepped down from the editorial board.
I would like to thank all the members of the editorial board, those members of the international malacological community who have contributed to the review process, the staff of Oxford University Press, particularly Cailin Deery and Jan Webster, and the production teams at Aptara Incorporated (led by Akash Mahajan) and SPi Ltd, Philippines (led initially by Mackie Fernandez and latterly by Ronel Mirano and Erica Fajardo), for their work on behalf of the *Journal*.

WEBSITE reported on by John Grahame and Tom White
Stefan Senk (http://www.senktec.com/stefan-senk/), who built the current website, is in the process of making some much needed revision and overhaul of it. John Grahame has started up the learning curve of editing the site, to bring its content up to date. This is very much a work in progress.

FACEBOOK & TWITTER reported by Chong Chen and Lauren Sumner-Rooney
The Facebook page continues to be a useful and well-used part of our Web presence. It has proved particularly valuable in communicating information the Society wishes to publicise quickly.
This year we have also set up a Twitter account to enhance communication. This has also proved successful – set up in July 2020, it has attracted 383 followers with 64.4K views of Tweets.
If you have suggestions / comments on these pages, please do not hesitate to contact Chong Chen, *Facebook Manager* or Lauren Sumner-Rooney, *Twitter Manager*.

AWARDS (reported by Jonathan Ablett)
Overall, the Society is very pleased with the number of applications that it receives for Travel Awards and Research Grants however the number of applications received for Travel Awards was severely reduced due to the current global health situation. The schemes seem to be achieving their global aim to enable young scientists to engage in malacological research activity both in the laboratory/field and at meetings. Citable reports from researchers, funded through both schemes, appear in *The Malacologist*.
The Society aims to make the following awards annually.
Travel Awards - at least 5 each of up to £500 for Society members, £300 for non-members
Research Grants - at least 5 each of up to £1500
Application forms and guidance notes for both schemes have been updated recently and can be downloaded from The Society's website.

Travel Awards
In 2020 there were 2 rounds of Travel Awards, June and December. Due to the global Coronavirus pandemic the Society only received 1 application for awards to travel and was able to fund this request. All Travel Award applications are reviewed by an Awards Committee. The Society is pleased to have announced the following awards.

June Travel Awards
No applications received and no awards made.

December Travel Awards
Hannah Lee (Heriot-Watt University)
£300 for attendance at 'NORA 4 (Native Oyster Restoration Alliance)' Middelburg (The Netherlands), 4th – 6th May 2021

A total of **£300** was allocated by The Society for Travel Awards. All applicants have been notified of the outcome. Note that this amount does not necessarily reflect actual 'spend' as occasionally students withdraw from the intended visit.

Research Grants for 2020 - Senior Research Grants & Early Career Research Grants
The society award both Senior Research Grants and Early Career Research Grant. Early Career Research Grants are conferred on students and researchers without professional positions, but without regard to nationality or membership of The Society. Senior Research Awards are aimed at established researchers in professional positions, but without regard to nationality. Applicants for Senior Research Awards must be members of The Society. Early Career Research Grants will be reviewed by MSL council members and Senior Research Grants will be reviewed by a Reviewers Panel including both council and non-council members invited for that purpose.
4

Early Career Research Grants
By the closing date of 15th December 2020, the Society had received 10 applications from workers from 10 institutions in 6 different countries. In general, the scientific quality of the research projects submitted was excellent.
On behalf of the Society, I would like to formally thank the members of the Grants Review Panel for their hard work in reviewing all applications. The Panel has agreed the following awards, in alphabetical order.

A. Bhosale (Foundation for Biodiversity Conservation, India), **£1500**
'A survey of the land-snail fauna of the northern Western Ghats, India'

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A. Buckner (University of Lincoln, UK), **£1255**
'Immnological respond of *Glaba truncatula* when infected with *Fasciola hepatica'*
C. Drerup (Cambridge University, UK), **£1500**
'Adaptions to visually challenging environments in cuttlefish'
H. Lipae (University of the Philippines Los Baños, Philippines), **£1500**
'Diversity and Community Assembly of Camaenid Land Snails in Karsts on Luzon Island'
L. Martin (Institute of Marine Sciences, University of Portsmouth, UK), **£1500**
'Laboratory testing of the efficacy of novel furfurylation treatments and naturally durable, tropical hardwood species against settlement by larvae of the shipworm, *Lyrodus pedicellatus* and other teredinid molluscs.'
O. Ojeda (University of Málaga, Spain), **£1250**
'Molluscan fauna of mud volcanoes of the north-eastern Gulf of Cádiz: biodiversity and eco-biological aspects.'
K. Zając (Jagiellonian University, Poland), **£1500**
'Removing taxonomic obstacles in the genus *Deroceras* by means of integrative redescriptions of selected taxa.'

Therefore **7** Research Grants have been funded at a total cost of **£10,005.** The success rate was **70%**. The Grants Review Panel would like to emphasise that the quality of all applications was high and that it funded as many excellent projects as possible. Applicants have already been formally notified of the outcome of their application.

Senior Research Grants
By the closing date of 15th June 2020, the Society had received only 1 application for the Senior Research Grants. On behalf of the Society, I would again like to formally thank the members of the Grants Review Panel for their hard work in reviewing all applications. The Panel has agreed the following award:
Dr Andrew David (Clarkson University, USA)
£923.42 'Testing the efficacy of a popular synthetic molluscicide (Niclosamide monohydrate) for controlling invasive mystery snails (Mollusca: Viviparidae) in North America).

The Annual Award
The Society received no nominations for the 2020 Annual Award.

The Oxford Prize for Malacology
The Oxford Prize for Malacology is awarded annually for the best presentation at the Molluscan Forum, is generously supported by Oxford University Press, publisher of the Society's journal. The 2020 winner is Lauren Eggleton (University of Sheffield, UK) for her talk entitled 'A Sticky Situation: Investigating the Contradictory Nature of Gastropod Mucus.'

OFFICERS & COUNCIL
This has been my third and final year as President, and it has brought unique challenges. Council met on 22nd January 2020 in the Natural History Museum, aware of reports of a new respiratory virus which had emerged in China but not particularly perturbed by them. What may now seem like complacency would be short-lived. The lead up to our proposed AGM in the context of the proposed Limpets 2020 meeting became a time of increasing anxiety, culminating in the cancellation of the Limpets meeting and the postponement of our AGM. This eventually took place in June (see above) using the Zoom platform, a novelty for many though by no means all of us. One of the discussions was about the Forum, and although the pandemic situation appeared to be improving in June it seemed foolhardy to contemplate a physical Forum symposium for November. Therefore the Forum was moved to Zoom, and proved to be an outstanding success with a stronger international participation than ever (again, see above). Council meetings in June and October 2020 and January 2021 have been in Zoom, we have yet to see how things work in June 2021, and later. While we all long to meet physically again, the Zoom platform has allowed much easier access to meetings for geographically distant councillors, and this has been welcome.
Our *Journal* has moved to online only – a change which would have happened in the not too distant future anyway, but which was brought forward in response to pandemic difficulties. It's in good health and in the hands of an excellent Editor in Chief, Dinarzarde Raheem, supported by a team of Associate Editors. *The Malacologist* with Georges Dussart as editor continues to function as our interesting and wonderfully illustrated newsletter and reporter of the malacology we have supported through Awards. This past 12 months it has documented some of the changes made, as well as the challenges posed by Open Access publishing and Diversity / Inclusivity concerns.
There are changes to Council going forward. I'm delighted that Jon Ablett has been nominated as President, with Fiona Allan as Vice President, joining Phil Fenberg in that role. Heartfelt thanks to those who are standing down from Officer positions – Rowan Whittle as meetings Secretary (succeeded by Debbie Wall-Palmer), Jon Ablett as awards Secretary (succeeded by Lauren Sumner-Rooney), Tom White as membership Secretary (succeeded by Harriet Wood). Welcome to Andreia Salvador as Archivist – so no longer a "Void" in that role! There is no named officer for the Forum – should there be? – Phillip Hollyman has done a sterling job of navigating the Forum over the last two years.
I am grateful to all of Council, as well as those named, for the work you have put into making the *Society* vibrant and vital. The 'unique challenges' of 2020/21 have I think been met, thanks to your efforts and the support given to me – thank you for this. And in closing, a reminder: our most excellent and hard-working Treasurer, Katrin Linse, stands down this year. We need to identify her successor.

John Grahame, President MLS

See next page for the Council at March 2021, and nominations going forward to 2022: CONTINUED >

Year of existence	**2020-2021**	**2021-2022**
	127	**128**
President	John Grahame (3)	Jon Ablett (1)
Vice Presidents	Robert Cameron (3)	Fiona Allan (1)
	Phil Fenberg (2)	Phil Fenberg (3)
Ex officio		John Grahame (1)
Councillors	Debbie Wall-Palmer (1)	Alan Hodgson (2)
	Alan Hodgson (1)	Robert Cameron (1)
	Andreia Salvador (3)	Phillip Hollyman (3)
	Fiona Allan (3)	Aidan Emery (1)
	Phillip Hollyman (2)	Victoria Sleight (1)
	Lauren Sumner Rooney (2)	Katie Collins (1)
Co-opted	Aidan Emery	Rowan Whittle (1)
Journal Editor	Dinazarde Raheem	Dinazarde Raheem
Bulletin Editor	Georges Dussart	Georges Dussart
Treasurer	Katrin Linse	Katrin Linse (final year)
Membership Secretary	Harriet Wood	Harriet Wood (1)
Hon. Secretary	Rowan Whittle	Debbie Wall-Palmer (1)
Web manager	Tom White/Chong Chen	John Grahame (web)/Chong Chen (Facebook)
Awards Officer	Jon Ablett	Lauren Sumner Rooney (1)
Archivist	void	Andreia Salvador (1)

'Years' means 'years in post'.
These are limited as described in the objects of the Society

AGM virtual conference

Molluscs in marine environments

Welcomed by the President of the Society, John Grahame
Hosted on Zoom

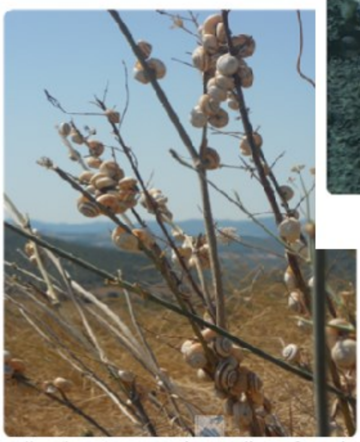
The Malacological Society of London

128th Annual General Meeting
and symposium, via Zoom, on the theme of

Molluscs in Extreme Environments

Wednesday 24 March 2012

Cocculina enigmadonta and *Lepetodrilus concentricus*
Kemp Caldera hydrothermal: Marum ROV



Cernuella virgata escaping soil-surface heat
Heinz-R Kohler *Ecology & Evolution*
doi.org/10.1002/ece3.5607

Registration was free
Harriet Woods handled registrations from Cardiff. Harriet.wood@museumwales.gov

Registration closed on Friday March 19th

organized by the Council, led by John Grahame, supported by
Phillip Hollyman, Katrin Linse, Lauren Sumner-Rooney and Harriet Wood'.

The evolutionary history of molluscs in vent and seep environments

Crispin T.S. Little

School of Earth and Environment, University of Leeds, Leeds, UK
E-mail earctsl@leeds.ac.uk

Molluscs are abundant constituents of modern hydrothermal vents and hydrocarbon seep (aka. methane or cold seeps) sites and this is partially because of the adaptation of many taxa to a symbiotic relationship with chemoautotrophic bacteria in their gills or oesophagus. The taxonomic diversity of molluscs in chemosynthetic environments tends not to be high, but is dominated rather by a few groups, for example bathymodiolin and vesicomyid bivalves, and provannid gastropods. Molecular divergence estimates indicates that some of these diverse taxa are relatively recent arrivals in chemosynthetic environments during the Cenozoic era, and this is supported by their fossil record. However, other groups are older, with Mesozoic origins. Molluscs are present in Palaeozoic vent and seep sites, but these belong to mostly extinct groups, showing that molluscan adaptation to, and extinction within chemosynthetic environments occurred regularly throughout Earth history.

The author sampling fossils from an early Cretaceous seep deposit in Svalbard.

Articulated solemyid bivalve in seep carbonate, early Cretaceous, NE Greenland. Handlens = 1.5 cm diame-

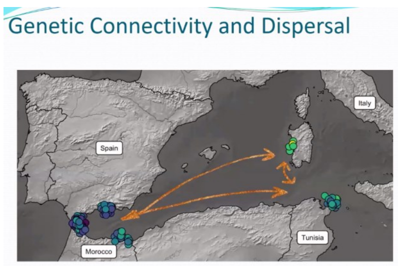
The author (seated with yellow helmet right centre) with students in an open mining pit, Cyprus, from where vent

Saving species from extinction one species at a time

Darren Fa

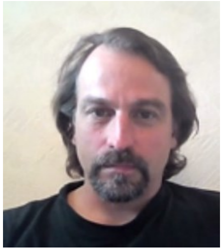
University of Gibraltar, Europa Point Campus, Gibraltar GX11 1AA
Email - darren.fa@unigib.edu.gi

Darren Fa described the taxonomy, distribution and ontogeny of the endangered limpet *Patella ferruginea*. He identified the distributions of patellids and mytilids across the straits of Gibraltar and discussed the effects of tidal amplitude on P.ferruginea and its local ecotope, including on artificial habitats such as boulder armour used to protect against shore erosion. Conservation efforts were discussed in relation to preferred *P.ferruginea* habitats in the straits. Individual animals were translocated to more benign habitats, with good results for percentage survival compared with resident populations. Fa discussed the possible extension of the species back into the Mediterranean and the importance of stepping stone populations creating genetic connectivity in this process.



Snails in space: a study of vestibular system plasticity

Nikolay Aseyev
Institute of Higher Nervous Activity and Neurophysiology
Russian Academy of Scientists, Moscow, Russia
E-mail: aseyev@ihna.ru



In 2005 NASA and the Russian space agency, Roskosmos, contacted our lab with an invitation to conduct a flight study of gravitational physiology relevance on board an upcoming unmanned satellite Foton-M2. A separate Russian laboratory had to withdraw from participation because of technical reasons. A vice director of the Institute of Biomedical Problems of the Russian Academy of Sciences knew the situation and began to initiate a potential collaboration of NASA scientists and our laboratory . Time was short, the payload had to be less than 2 kgs in weight, and the project could not interfere with any other projects or the spacecraft. Most importantly, the project had to have clear scientific merit. The head of my lab, Pavel Balaban, had the resources on hand, an energetic and enthusiastic team, and accepted the challenge. Because of the success of the Foton-M2 mission we were invited to participate in the Foton-M3 and Bion-M1 missions.

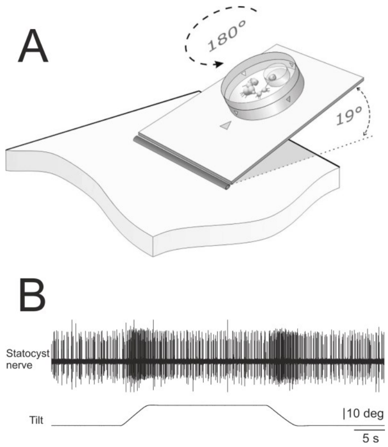
We quickly designed the experiments on our model subject, land snail *Helix lucorum*. These snails are very hardy and resilient, and can survive several weeks without food and water – the conditions expected on the satellite. The weight of the adult snail is about 25 grams, so we were able to launch a reasonably large group of our snail astronauts. Our expectations were correct, and in all three of our orbital missions, we observed no mortality in snails.

The goal of the project focused on the adaptation of the vestibular system of snails to near weightlessness conditions on orbit. We used a systems approach to study the vestibular system employing a wide arsenal of methods. In contrast to marine cephalopod and pteropod mollusks, which use the vestibular system to orient themselves in 3D space, land snails use their vestibular system for vertical movements during the day-night cycle and adapting themselves to circadian temperature changes. Also, the land snails use their vestibular sense for detecting dangerous stimuli, and its activation can mean either the snail is in a fall or under attack from a predator.

In our study to rule out the known confounding factors of an orbital flight and habitat confinement we used 4 groups of additional controls, with different factors controlled, such as temperature, light cycle, food deprivation, congestion and overloading during landing, which was controlled in ground-based control by short centrifugation of snails with 10G.

Our lab participated in 3 flight missions. The logistics of sample return after landing back to our lab was under development by the two space agencies and out of our control. The Foton-M2 snails arrived at the lab after 40 hrs post-landing on commercial airplane routes. This delay obscured our ability to detect with confidence the snails' response and adaptation to microgravity. Two consequent missions used private aircraft directly from the nearest airport to Moscow, cutting the time to 10-14 hrs post-landing, and thus were more successful. Our story is based on the results of these two missions. Most of the data came from the last mission on the 30-day Bion-M1 satellite, where our space collaborators and we took into account the mistakes of the earlier missions.

First, we filmed the negative gravitaxis behavior of the ground control and postflight snails. A snail reacts decidedly when its head is directed downward along the vector of gravity such as an opposed head-down tilt, akin to us pitching face forward to the ground, and turns itself in the opposite direction. Then we analyzed the video records and measured the time parameters of the gravitaxis reaction, also the tentacle withdrawal reflex, which was a proxy for a defensive behavior to dangerous vestibular stimulus. In postflight snails, we found significantly shorter latency of the T0 phase of the reaction, simply the time when snails completely retract their tentacles, reflecting an interpreted characteristic of fear they feel. Significant differences between groups were also found in T0 and T4 phases for the length of the tentacles, but not for the angle between tentacles. We made correlation analyses of all measured parameters and found that snails that were slow in the first phases of gravitaxis response were slow in late phases as well. In addition, the correlation of duration of the phases and tentacles length in postflight snails is more correlated with the weight of the animal. The last finding is not surprising, since postflight snails for a month appeared not to feel the weight of their shells.



To translate the observed postflight behavioral characteristics of the snails with the underlying neural commands, we dug deeper into the vestibular sense organs of snails, the statocysts. This is paired organ, like the gravity-sensing otolith organs (utricle and saccule) we have. The equivalent angular acceleration sensors of the semicircular channels we possess are lacking in the snails. The statocyst contains an inertial mass of calcium carbonate grains or statoconia in the form of aragonite surrounded by mechanosensing hair cells and supporting cells. The number of hair cells in this snail species is only 13 cells, which are primary receptor neurons.

Vestibular adaptation to spaceflight can occur in the peripheral organ itself or in the neural connectivity or both. A popular hypothesis of vestibular changes occurring as the result of exposure to orbital flight, and often discussed in the literature, is an increase in inertial mass in an attempt to restore the "weight" of the statoliths. We used scanning electron microscopy in several postflight snail statocysts to compare with the superficial structure of two control statocysts and found no significant differences at this level of examination. This pointed more to plasticity associated with the sensory neurons

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At the 2013 timeframe of the Bion-M1 mission, new high-throughput sequencing techniques became available to researchers, and thus we attempted to study the transcriptomes of statocyst, which is challenging due to the small amount of RNA in this 13-cell organ and lack of genome data for this snail. Finally, we (with our collaborators) had success and found that different peptides are differentially expressed in postflight and control groups. For one of the more diverse neurotransmitter receptors, glutamate, we also found a significant difference between flight and their ground counterparts.

We then did physiological experiments in snail statocysts. We recorded the static nerve activity during tilts on postflight and control animals. Later we were able to make a detailed analysis of the records. In the static nerve, neural responses of statocyst are visible, and we were able to distinguish responses of one hair cell from the other by action potential or spike parameters.

In all three missions, the spontaneous or normal background activity of statocysts didn't change in postflight animals in comparison with control. The total response activity in the static nerve was significantly higher in the postflight group at some time points. In the two successful missions with different duration of exposure to near weightlessness, we conducted comparable protocols and concluded that the time of neural adaptation to microgravity is less than 12 days (the duration of the shorter mission). The postflight snails of Bion-M1 satellite were prepared for recording over a relatively long period of time, about 6 hours. If we split the postflight group into early and late recordings, the critical time point is 20h after landing, when we clearly see the readaptation of statocyst to normal gravity. We then reanalyzed our data from the previous mission, split the postflight snails of the Foton-M3 satellite, and found the same picture there. The earlier we recorded the neural statocyst activity to perturbation stimuli after landing, the greater were the responses. We made the same comparison on the level of single hair cells, sensitive to the preferred direction of the stimuli. We found an even more profound effect of increased responses on postflight statocysts than in total activity. A very similar critical time point of readaptation to normal gravity after landing was found in studies of vertebrate animals and human astronauts, suggesting a common neuronal basis of vestibular system adaptations.

Are some chitons extremophiles, or mere opportunists on the fringe of hostile deep-sea habitats?

Douglas J. Eernisse
California State University, Fullerton, USA
Email: deernisse@fullerton.edu

Eight chiton species were identified in samples from a methane seep off Costa Rica. They are already known from whale-falls, seamounts and other deep sea samples. Douglas J. Eernisse posed several questions (see Fig. 1). Some chiton species were large, reaching several centimetres in length (Fig. 3) . One of the species*, Placiphora velata*, is an ambush predator and behaves like a Venus Flytrap. Eernisse concluded that seep habitats provided opportunities for generalist deep sea species, though some of the genera are know to inhabit shallow seas; there is still much to learn about chitons.

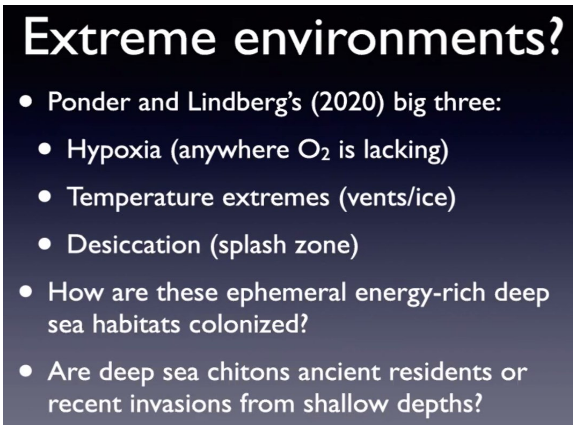


Figure 1

Figure 2

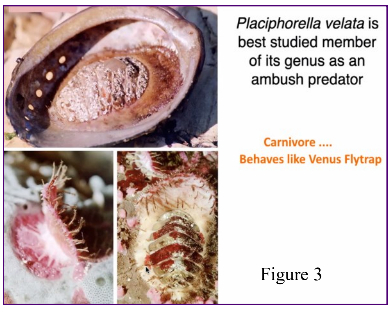


Figure 3

Solar radiation stress in terrestrial snails — from thermodynamics to microevolution

Heinz-R. Köhler, Institute of Evolution and Ecology, University of Tübingen, Germany

Heinz-R. Köhler [1], Rita Triebskorn [1], Ulrich Gärtner [2], Henri A. Thomassen [1], Yvan Capowiez [3], Christophe Mazzia [4], Thomas Knigge [5] and the 2018 Theba Survey Consortium [6]

[1] Institute of Evolution and Ecology, University of Tübingen, Tübingen, Germany
[2] Faculty of Engineering, Esslingen University of Applied Sciences, Esslingen, Germany
[3] INRA, UMR 1114, Avignon, France
[4] IMBNE, UMR 7263, AMU, CNRS, Université d´Avignon, Avignon, France
[5] UMR-I 02 SEBIO, Université du Havre, Le Havre, France
[6] Z. Arad, T. Backeljau, J.K.Y. Burmester, Y. Capowiez, L.J. Chueca, M. Coelho da Silva, M.S. Davies, L. Favilli, J. Florit Gomila, J. Heller, T. Knigge, H.-R. Köhler, S. Krais, A. Lobo da Cunha, G. Manganelli, S. Mazzuca, T. Monsinjon, C. Moreira, G. Moreno-Rueda, A. Piro, T. Prieto, J. Quintana Cardona, E. Rolan-Alvarez, B. Rowson, M.J. Saffrey, L. Sawallich, M. Schilthuizen, H. Schmieg, A.E. Staikou, H.A. Thomassen, G. Tomás Faci, R. Triebskorn

Email: heinz-r.koehler@uni-tuebingen.de

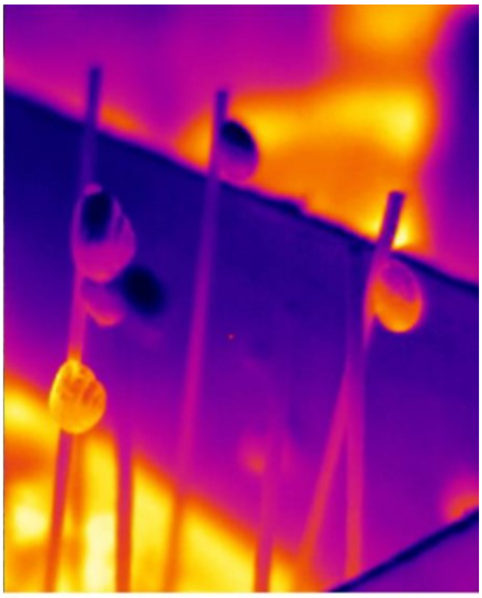
AGM CONFERENCE—MOLLUSCS IN EXTREME ENVIRONMENTSMS

Land snails, especially in Mediterranean and arid climates, are sometimes exposed to very strong solar radiation. Nevertheless, some species living in these habitats occur in exceptionally high individual densities, suggesting effective adaptations of these animals to heat and drought stress. In addition, these snails may include highly polymorphic species, in which individuals can differ considerably in the pigmentation of their shells. In this context, adaptation mechanisms on the biochemical, physiological, behavioural and morphological levels and their microevolutionary implications can be elucidated by a combination of laboratory, semi-field and field studies.

Our work concentrates on helicoid species, particularly on the highly polymorphic species *Theba pisana*. Using high-resolution thermography, µMRT, flow modelling, respirometry, biochemistry and field-based microcosms our team addresses the following questions: Under which conditions do land snails predominantly suffer from thermal stress and how can they limit it? Are different pimentation patterns actually biologically relevant in this context? Which conditions overstrain the capacity of biochemical and physiological defence mechanisms? Is there a thermal selection pressure on more intensely pigmented morphs and, if so, under which climatic conditions? And does this have implications for the future distribution of the species and phenotypic variation of *T. pisana* at the continental scale in the context of climate change?

In the year 2017, we installed 54 open-top chambers close to Avignon, Southern France, and investigated about 11,000 individuals of *T. pisana* (*Ecology & Evolution* **11**: 1111-1130 [2021]). In 2018, we conducted a Europe- and Middle East-wide survey, which brought together >30 colleagues providing more than 19,000 *T. pisana* individuals from 172 sites which we used for pigmentation analysis and spatial modelling of morphs. Our studies revealed the particular importance of climatic parameters for the evolution of morphological variation across the Mediterranean and all of Europe, and models allow predictions of the future continent-wide distribution of this species and its morphs as a result of expected environmental warming.

Open-top chambers on the INRA campus, Avignon.



Thermal imaging of *T. pisana* escaping from the hot soil.

Quickfire presentations—

These were the MSL's solution to the problem of not being able to have a poster exhibition. Each on-line presentation was for 5 minutes. If no abstract is here, no abstract was made available. Images are screen grabs from the talks, or were supplied by the presenters.

Victor Kang

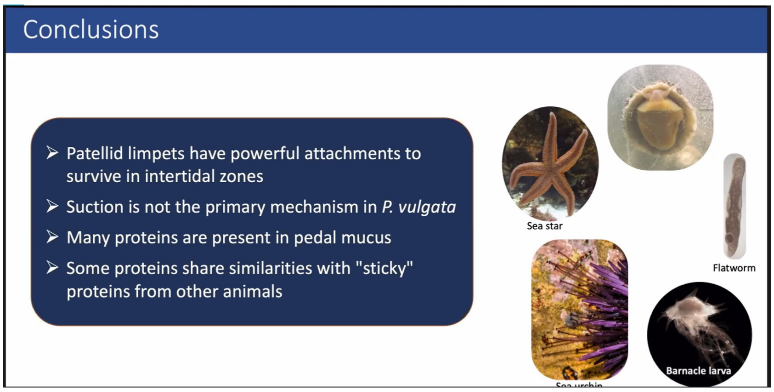
Postdoctoral researcher
Evolutionary biomechanics group
Department of Bioengineering,
Imperial College, London
k.kang@imperial.ac.uk>

***Patella vulgata* adhere with such strength that an individual can easily withstand the weight of a large rock.**

A method was devised in this study to collect limpets with minimal damage to their soft bodies. Here the attachment organ - the pedal sole - is shown on a recently detached specimen, where several unfortunate barnacles were also detached in the process.

Limpet feeding on algae growing on the shell of its neighbour

A rare sighting of a limpet actively moving. Unlike barnacles and mussels, which remain permanently attached as adults, limpets often move around to feed. This specimen was photographed mid-transition from a glass plate to the aquarium



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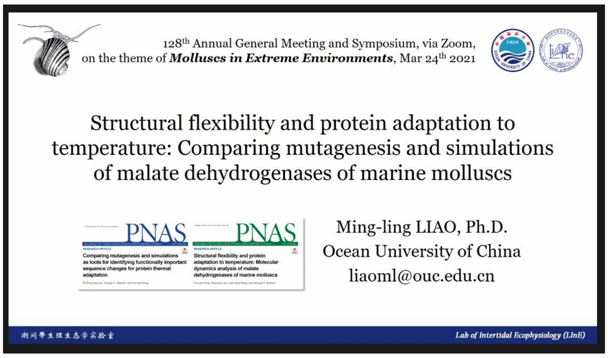

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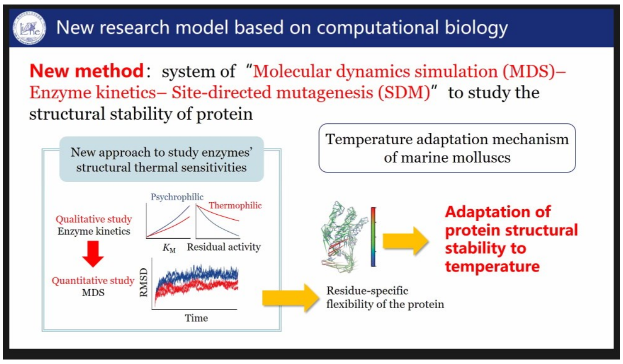

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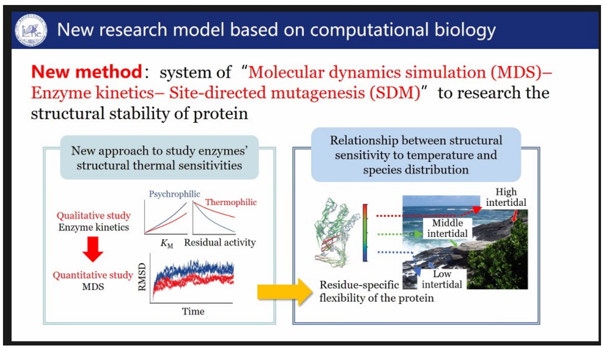

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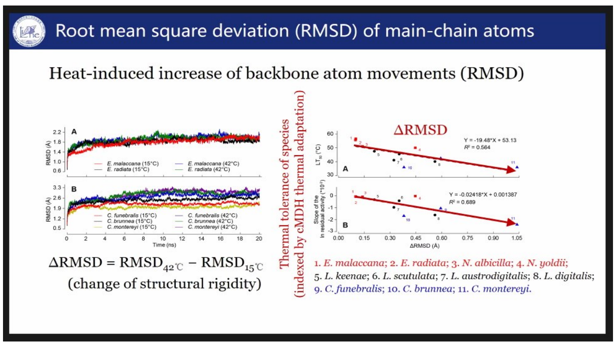

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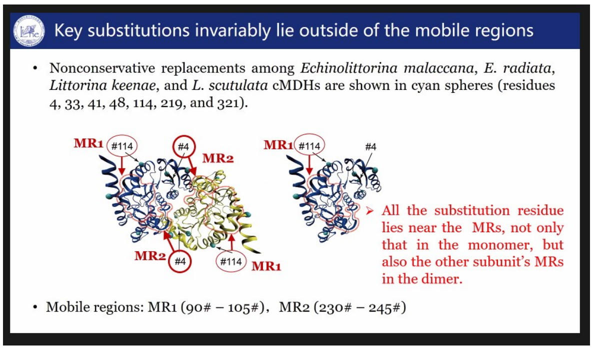

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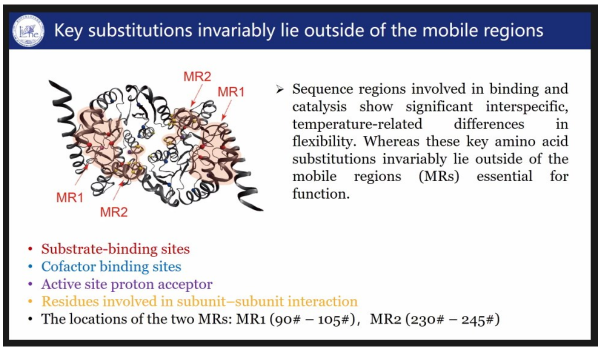

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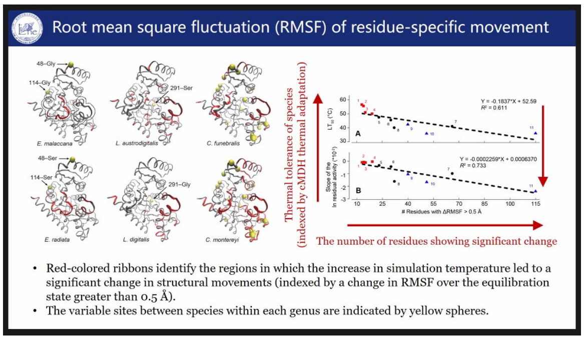

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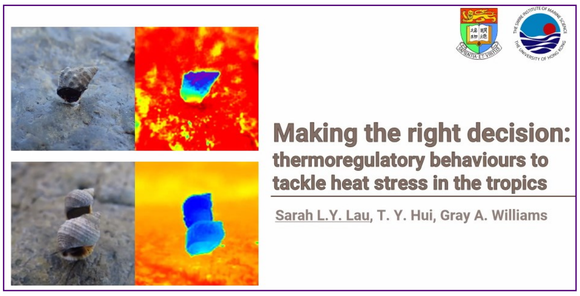

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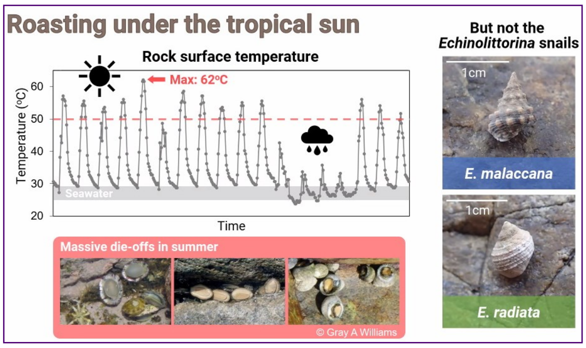

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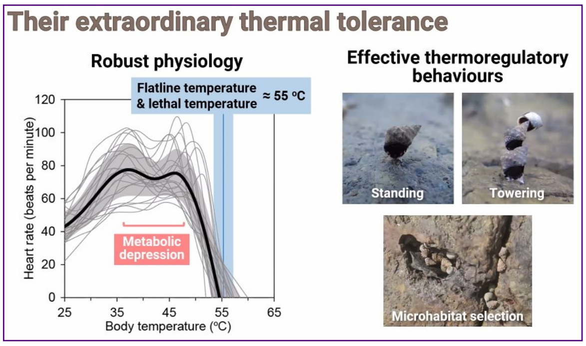

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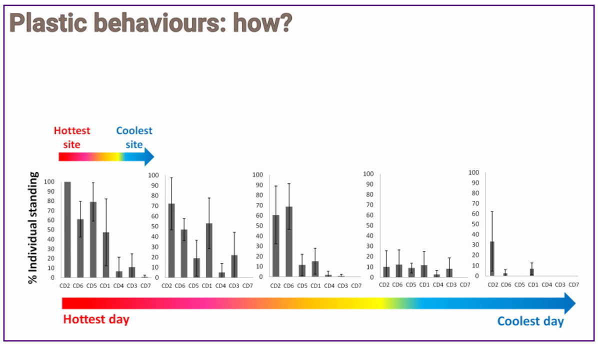

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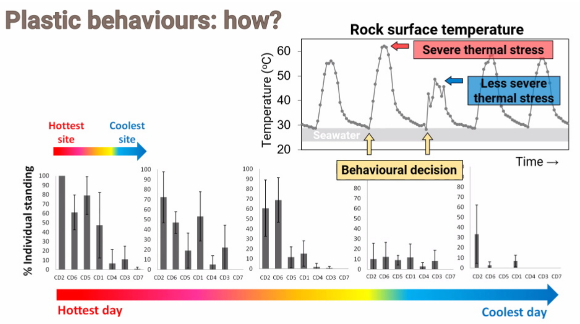


5

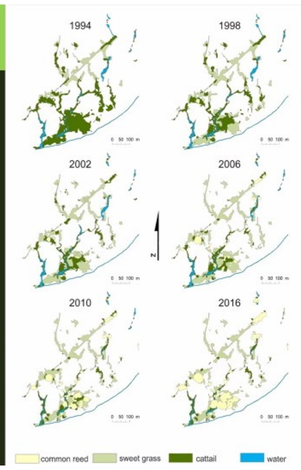
Study area – the Inland Delta of Nida river

A very **diverse environment** with a large number of old riverbeds at different stages of succession.

Dynamic hydrology, numerous floods and varied topography - **high variability of vegetation** in time and space.

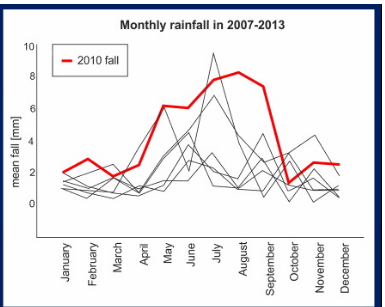
One of about 40 sites of *V. moulinsiana* currently known in Poland.

Natura 2000 protected area (PLH260003 "Ostoja Nidziańska").



Flood 2010

- Heavy rainfalls from May to September
- Rising water level in the Nida river
- Wetland was flooded from May to September

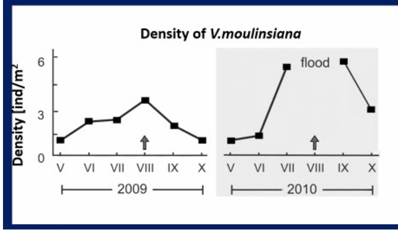


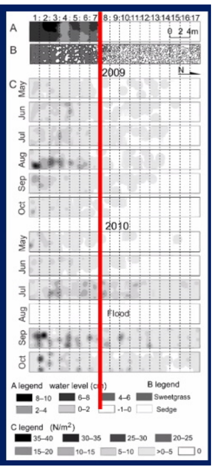
	May	June	July	August	September	October
2009	50	55	59	42	48	69
2010	97	69	65	-	75	-
2011	42	47	-	-	-	-

Groundwater level [cm] measured above the ground surface on the test plot

Flood 2010

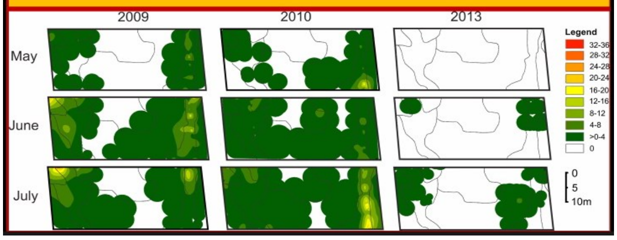
- Positive effect of flood on snails density.
- **Changes in distribution** during the flood: the population occurred in less preffered habitat as much as in the preferred one.





Fire 2012

- The population survived the fire but with the sharp decline in number.
- First sign of population slow recovery – over 1 year after the fire.
- After the fire, the snail occurrrence was limited to its preffered habitat (overgrown with sweet grass with standing water).
- The manuscript is under consideration in International Journal of Wildland Fire.

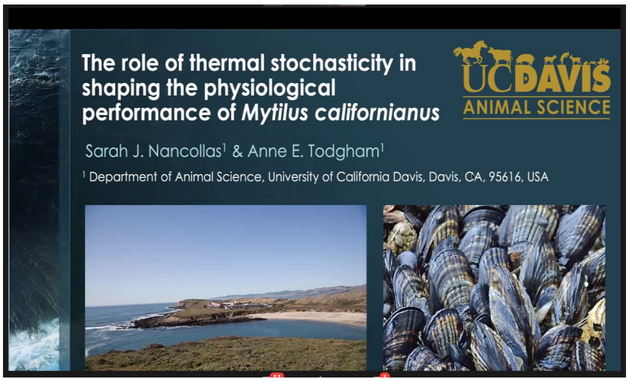


Mowing 2013

- Mowing was the final nail in the coffin for this population.
- Mowing does not appear to be too severe as long as the swath is left on the place.

Variable	Natural habitat						Mowed habitat						
							Swath						Stuble
	Σ	Min	Max	Mean	SD	Median	Σ	Min	Max	Mean	SD	Median	Σ
N_{all}	**205**	1	35	6.86	7.29	4.5	**20**	0	7	0.67	1.42	0	**0**
N_{alive}	**106**	0	17	3.53	4.39	2.5	**6**	0	1	0.2	0.41	0	**0**

- In the case of 2mm snail species, **removing the swath = removing the snail.**
- **The population became extinct after this series of catastrophic events.**



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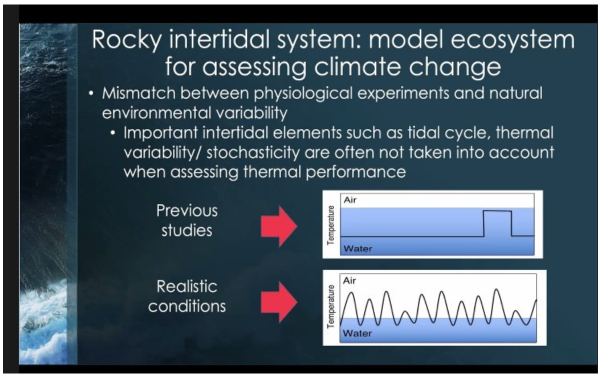

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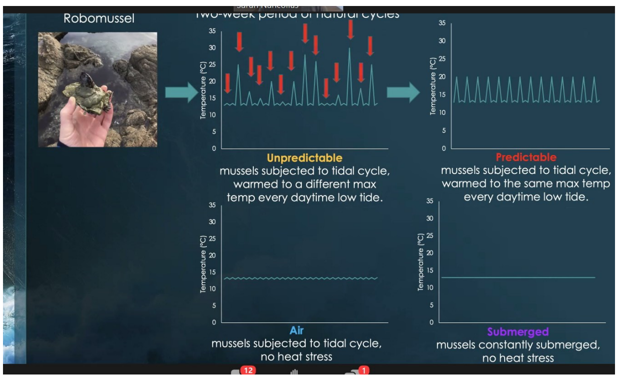

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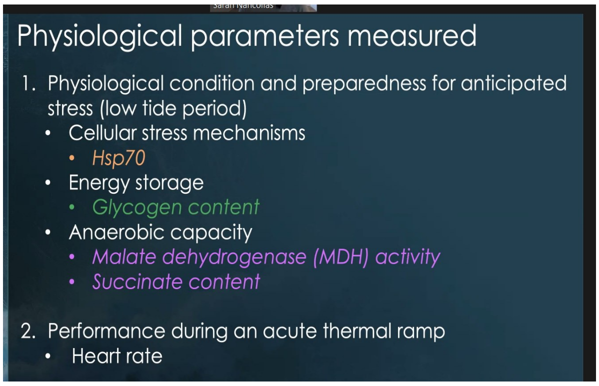

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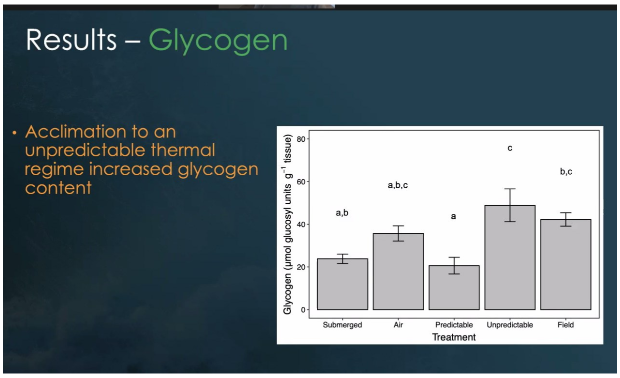

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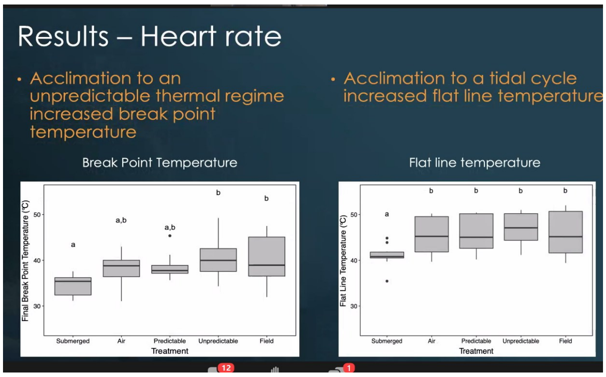

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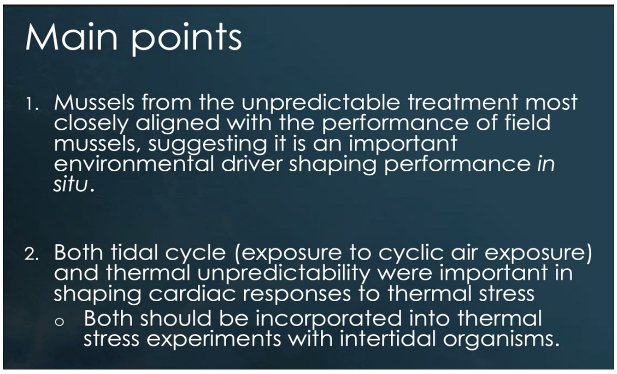

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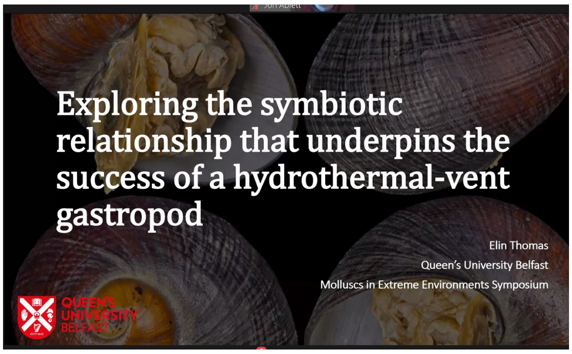

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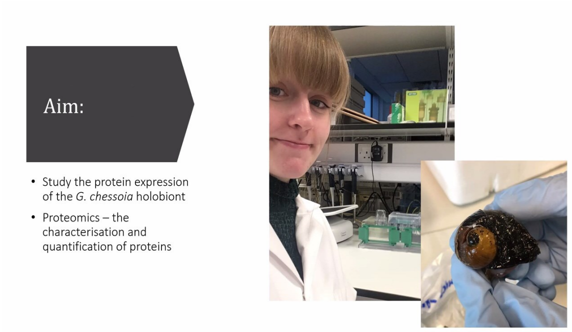

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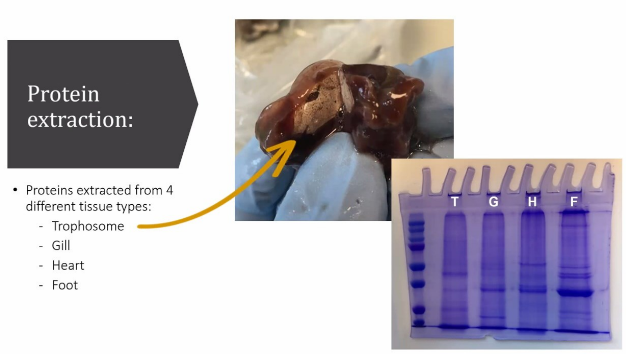

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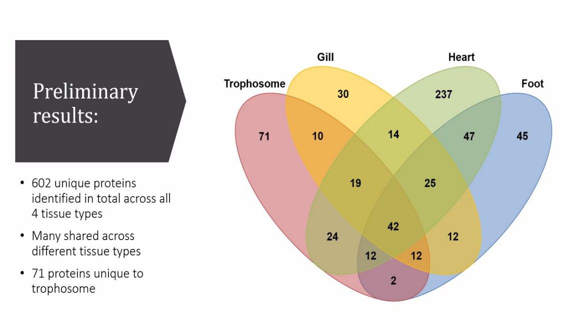

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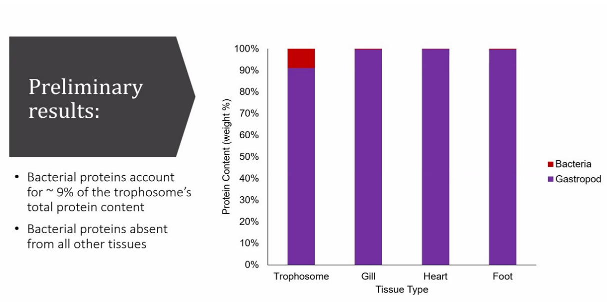

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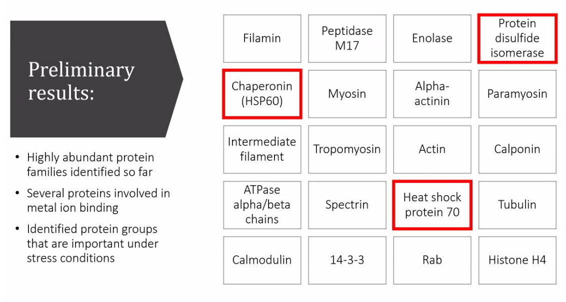

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Obituaries

Brian Morton
1942 - 2021

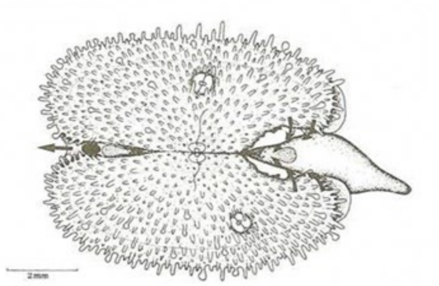
Brian Morton, malacologist, marine biologist and marine conservationist died on March 28 2021 at Littlehampton, England. 28th March, 2021.

The contribution that Brian made to our knowledge of the anatomy and ecology of bivalves was profound. Over his career he investigated bivalves from a huge spectrum of families, employing meticulous dissection coupled with serial thin sections. Throughout he was notable for use of ink drawings of shells, gross anatomy and microscopic structures seen in thin section with only rare use of photographic images. These studies followed and developed from the tradition of functional morphology established by Sir Maurice Yonge in previous decades.

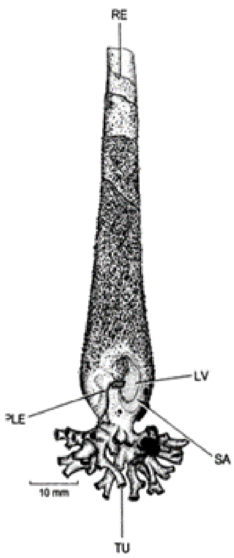
His bivalve investigations began with his PhD (1968) study of the biology of the invasive *Dreissena polymorpha* in a west London reservoir (his PhD supervisor Richard Purchon was, in turn, a former student of Yonge). Interest in dreissenid bivalves later came back into prominence following invasion of *Dreissena* into the American Great Lakes, the spread of *Mytilopsis* around the world and the discovery of a cave-living *Congeria* in Croatia; Brian was involved in all these studies. Similarly, earlier research into *Corbicula fluminea* in Hong Kong became globally relevant with the spread into numerous freshwater systems. Together with Joseph Britton, Brian published the definitive practical guide to the study of *Corbicula*.

Brian was always fascinated by bivalves at the extremes of morphology or ecology. This led to his studies of the anatomy and ecology of coral-boring bivalves in the families Lithophaginae and Gastrochaenidae and also mangrove mud-living bivalves such as *Geloina* and *Laternula*. A long-term interest was in the anatomy and commensal associations of galeommatoidean bivalves with burrowing invertebrates, such as sipunculans, echiuroids and crustaceans.

Another focus was the Anomalodesmata, for a while recognised as a distinct sub-class of Bivalvia although molecular results now confirm the group is part of the radiation of heterodont bivalves. They exhibit a range of life styles but the clade of Cuspidariidae, Verticordiidae and Poromyidae lack normal gills and have adopted a predatory, carnivorous diet, feeding suctorialy on small crustaceans. Over the years, Brian described the anatomy and possible food capture mechanisms of a range of these unusual bivalves (most recently with Fabrizio Machado) that live mainly in deeper water. The most bizarre anomalodesmatan bivalves belong in the superfamily Clavagelloidea most notably the tubular 'watering pot' shells *Brechites*, *Nipponoclava* and *Verpa* with the flared, perforated anterior ends resembling the rose on garden watering cans while the true shells are embedded into the wall of the tube. Brian investigated their anatomy and hypothesized about the mode of tube formation. Other clavagelloideans include forms that excavate crypts in limestone and coral and have short funnel shape tubes. Brian rarely found these genera alive but his persistent search of museum collections and rare finds resulted in evolutionary scenarios and a proposed separation into two distinct families Clavagellidae and Penicillidae. These studies culminating in a recent comprehensive review (with F. Machado) of their origin, relationships and evolution.



***Galeomma taki* (from Morton, 1973)**



***Stirpulina ramosa* (from Morton 2007)**

Brian had a long-term interest in the eyes of bivalves, beginning with the siphonal eyes of *Laternula* and continued with descriptions of the structure and distribution of various types of pallial and cephalic eyes in a wide range of species. Major review papers discussed their evolution and phylogenetic distribution.

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The ecological importance of Mytilidae in rocky shore communities of Hong Kong led Brian with many students to long term studies of all aspects of the biology of intertidal mussels particularly *Perna*, *Mytilisepta*, *Septifer* and *Brachidontes*.. Most recently, collaborative molecular studies of Mytilidae have clarified disputed relationships of some species.

Following his BSc and PhD at Chelsea College, University of London, Brian worked briefly on shipworms at the Hayling Island Laboratory of University of Portsmouth before moving to the Zoology Department at Hong Kong University in 1971 where he stayed until retirement. It is fair to say that in 1971 HKU was a backwater of marine biology but by the time of Brian's retirement and led by his efforts it had been transformed into a powerful and influential centre in Asia. Along with the many students that were trained and went on to prominent positions in marine biology or environmental agencies in Hong Kong or abroad, his most notable achievement was the construction and opening in 1990 of the Swire Institute of Marine Sciences at Cape d'Aguilar where he was Director for 13 years. The laboratory has acted as a major focus for marine research ever since.

Brian collecting 1986 Marine Biological Workshop, Hong Kong

Soon after arriving in Hong Kong Brian realised that on these diverse shores there was a severe taxonomic impediment that hampered research. In order to address this problem, he organised a series of residential malacological and marine biological workshops and invited experts in various animal groups from around the world to visit Hong Kong and conduct field-based research at a youth centre near Tolo Channel in the New Territories. The workshops increased in size and became logistically complex with organised shore work, vehicles, boats, dive groups, trawling and dredging coupled with improvised laboratories. These workshops were amazingly effective with the results published in a series of voluminous proceedings from 1979 –1989. Some of the locations, habitats and their biota documented by the early workshops

have now disappeared or impacted by increasing urbanisation and the publications stand as a valuable data archive. Many participants returned regularly to Hong Kong to continue research. Later, three smaller-scale workshops were based at the Cape d'Aguilar laboratory.

A milestone in marine ecology of Hong Kong was the book 'The Seashore Ecology of Hong Kong' (1983) written by Brian and co-author John Morton (from New Zealand and no relation). All the major habitats were described and the constituent flora and fauna illustrated largely by composite line drawings. Better than dry academic research papers this book proved to be major stimulus to education and public awareness of the marine habitats of Hong Kong. Other books on seashore ecology written and illustrated in similar style followed featuring the Azores and Gulf of Mexico. A lifelong connection to the Azores with repeated research visits began in 1965 with an undergraduate expedition from Chelsea College. There Brian first met and became friends with Antonio Frias Martins (then a trainee priest) who later became a zoologist and they collaborated on the book 'Coastal ecology of the Azores' (1998). Another book 'Shore ecology of the Gulf of Mexico' (1989) resulted from a long-term research collaboration and friendship with Joseph Britton then of Texas Christian University.

In the 1970s the marine environment of Hong Kong was severely impacted by pollution and habitat destruction from increasing urbanisation. Soon after arriving Brian became a passionate, vociferous and outspoken advocate for the formation of marine reserves and controls of the marine disposal of industrial and domestic effluent. Change came slowly but in the end persistence paid off with the establishment of a series of marine parks and reserves including the corals at the Hoi Ha Marine Park and the Cape d'Aguilar reserve. The first and major success was the World Heritage site of the Mai Po wetlands administered by the World Wildlife Fund.

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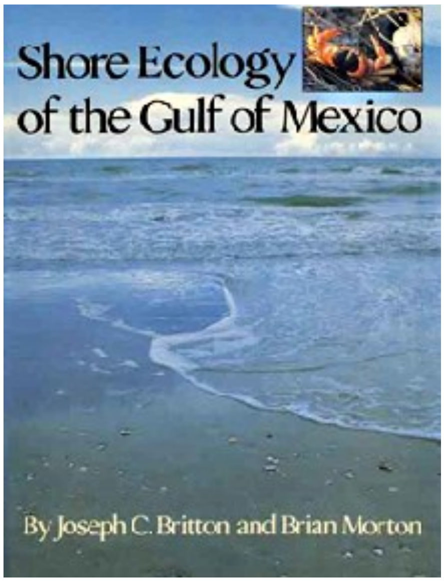
By any standards his research output in terms of publications was enormous and sustained by prodigous drive and determination throughout all his career. In retirement in 2003 and back at Littlehampton the stream of papers, books and articles continued and he was still completing papers in the last weeks of his life. For all the many achievements his constant need to keep proving himself or outdoing perceived competitors either within his own institute or more broadly was at times challenging for friends and colleagues. Although often scathing in criticism of the work of others he could be belligerent when his own work was challenged. Some of us remember Friday evening consumption of alarming quantities of beer in the Senior Common Room at Hong Kong University which brought out both the best and worst in a generous, talented and complex man.

Brian received many awards for his conservation work including election to the Global 500 by UNEP, investiture as Knight of the Golden Ark, Netherland (1997), Order of the British Empire (1999) and the Duke of Edinburgh Conservation Gold Medal (2004). He was a long-term supporter of the Malacological Society and elected as Honorary Life Member.

John Taylor (with input from Emily Glover and Liz Harper)



In English pub 2015
Published by Mackie

IN MEMORIAM

John B. ("Jack") Burch
1929 - 2021

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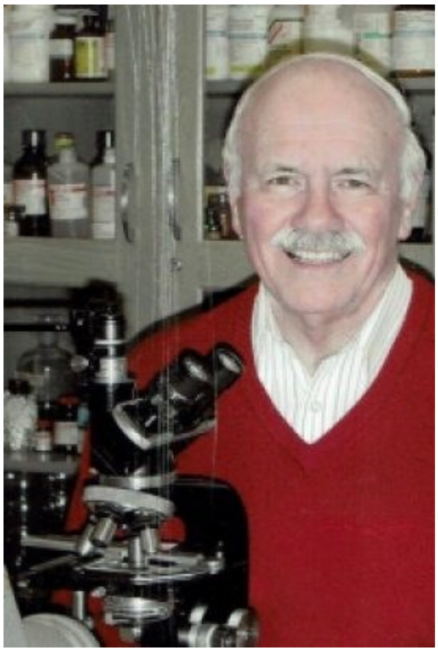

I am deeply saddened to inform you that our esteemed colleague John B. ("Jack") Burch died yesterday at the age of 92 after a long illness. He had been very well taken care of by his family and passed away peacefully in their company in Littleton, Colorado. His devoted partner of 69 years, Peggy Burch (pegburch@umich.edu), informed me that a family memorial or Celebration of Life may be held at a later date (we are still in the middle of a pandemic) and that, in lieu of flowers, donations in his memory be made to The John B. Burch Malacology Fund, or to a charity of your choice.

Jack had an extraordinary, long-lived, and highly influential career in science serving as Professor and Curator of Molluscs at the University of Michigan since 1962 (*Emeritus* since 2001). See below an outline of some of the highlights, and his *Curriculum Vitae* for details.

Honors & Awards

Honorary Life Memberships: American Malacological Society (2009), Malacological Society of Korea (1994), Malacological Society of the Philippines, (1994).
Lifetime Achievement Award: The Freshwater Mollusc Conservation Society (1999).
Special Recognition Award: The Science Society of Thailand (1995).

Research Interests

Jack had broad interests in the biology of non-marine Mollusca, especially freshwater snails, and he made numerous significant contributions to their global study. Early in his career, a major focus was the application of karyological, serological, and tissue culture techniques to characterize the roles of intermediate snail hosts in the epidemiology of human schistosome parasites. This involved extensive field work throughout the tropics and lab work in Ann Arbor (below, left). One of his major immuno-cytological discoveries was the presence of cryptic diploid and polyploid (tetra/hexa/octoploid) lineages in populations of the important intermediate host *Bulinus truncates/tropicus* complex, that were differentially susceptible to infection by human schistosome parasites. This seminal work led to years of research (supported by NIH, NSF, and the World Health Organization) and international outreach, the latter involving numerous workshops on medical malacology as well as the training of scientists from a large diversity of countries.

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In addition to his medical malacology research, Jack made many important basic science contributions to our fundamental knowledge of non-marine molluscan diversity in his >180 publications. He was also distinguished by his prodigious outreach and service to malacology as a discipline. One aspect of this was his exquisite guides to North American freshwater molluscs (*Freshwater Unionacean Clams of North America, Freshwater Sphaeriacean Clams of North America, North American freshwater snails*) and land snails (*Land Snails of The University of Michigan Biological Station Area, Identification of Eastern North American Land Snails, How to Know Eastern Land Snails*). Another was his astonishing record of founding four new malacological journals, one of which, *Malacologia* (currently the top-ranked Zoological journal by citation metrics), endures. The other three are now either transformed into a new entity (*Walkerana*, now *Freshwater Mollusc Biology and Conservation*), or, after decades of production (*Malacological Review*, *Journal of Medical and Applied Malacology*), retired.

To paraphrase Shakespeare (*Othello*), Jack has "*done the state* (of Malacology) *some service, and they know't.* "
He will be missed.

Jack Burch in the 1960s

Diarmaid Ó Foighil
Museum of Zoology & Department of Ecology & Evolutionary Biology
The University of Michigan.

Editor's note -In an email conversation with Diarmaid about Jack Burch, I told him that in my younger days, I'd met Jack at conferences a few times and found him to be a gentlemanly, kind person. Diarmaid replied " Your interaction with Jack was highly characteristic. He was a warm and supportive personality who wore his scientific pre-eminence lightly and was invariably encouraging to younger scientists - that was also my experience. "

Arie W. Janssen

With great sadness we inform you that Arie W. Janssen, nestor of fossil and recent malacological research in the Netherlands, passed away in the night of 6th August 2021. He reached the age of 84 years and during the last few months suffered from a rapidly deteriorating physical condition; nonetheless until just a few days before his death he kept on working on pending publications with zeal and a bright mind as ever.

Arie was a self-taught researcher and had a long career as malacologist and palaeontologist that started at the Rotterdam Museum of Natural History in the mid nineteen sixties. From 1969 onwards he continued at the Rijksmuseum van Geologie en Mineralogie (the National Museum of Geology and Mineralogy) that is nowadays part of Naturalis Biodiversity Center in Leiden. As curator of the fossil mollusc collections he ensured major enlargements through fieldwork and through donations from the networks Arie had been building. The collections at the department of fossil mollusca rank among the top ones of their kind in the world. Arie's extensive field work and research during the first part of his career was focused on Tertiary and Quaternary molluscs mainly from the North Sea Basin, but also from other parts of Europe.

The front of Arie's funeral card, depicting a pteropod of the genus *Edithinella.* Arie described and named it after his wife Edith.It also shows his favourite definition of pteropoda, which he used in most of his messages and emails combined with his signature.

Since the mid nineteen eighties, Arie increasingly concentrated his research on fossil planktic gastropods (mostly pteropods and heteropods). He promoted and implemented the stratigraphic use of these groups of fossil molluscs, as they proved to be very useful to enable long-distance correlations and the establishment of stratigraphic ages of geological units. He developed into a specialist of worldwide renown in this field and personally contributed to what is today the world's largest planktic molluscan collection (fossil + recent), housed in Naturalis. Nowadays planktic gastropods are important indicators for the state of our oceans and their increasing acidity. Arie's research is being continued by the Naturalis Plankton Group under the leadership of Katja Peijnenburg.

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In Memoriam

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Arie was one of the co-founders of the WTKG, the Dutch Work Group of Tertiary and Quaternary Geology, a team of professional and above all non-professional enthusiasts. He built a widespread network that delivered important results in scientific 'grassroots' research of fossil molluscs, but also on local stratigraphy. Besides encouraging the members with his thorough knowledge and ability to enthuse people, Arie was also for many years the editor of the WTKG's scientific publications, that appeared from 1964 first under the name *Mededelingen* (Contributions) and from 2002 onwards under the name *Cainozoic Research*.

Arie leaves behind an enormous œuvre of more than 300 publications, smaller papers but also a considerable number of voluminous books. A highlight for the knowledge of Dutch Miocene molluscs was his 450-pages book with a 82-plates atlas on the fossil fauna of the Miste beds (near Winterswijk, The Netherlands) that appeared in 1984. But not only fossil molluscs caught his interest; in 1965 he wrote, together with the recently deceased Ed de Vogel, a book on Dutch freshwater molluscs. This early work found its updated continuation in the 1998 standard work *De Nederlandse Zoetwatermolluscen*, authored by a consortium of scientists with Arie's participation. But his most important scientific legacy are the many papers with groundbreaking research results on planktic molluscs. After his retirement in 1997, Arie and his wife Edith moved to Malta, where he intensified his research on fossil pteropods. They moved back to The Netherlands in 2013, where Arie continued his research work even up to the last days of his admirable and fruitful life.

His name will live on through no less than 32 eponyms, named in honour of his work by colleague scientists. Besides twenty-three new mollusc and five new fish species, four new mollusc genera bear his name. But above all his name Janssen will remain forever present, connected to no less than 175 molluscan species described by him as new to science, a stunning 115 of which in the Pteropoda and Heteropoda, plus one new family, one new subfamily, twelve new genera and two new subgenera.

He will be greatly missed by colleagues and worldwide co-reseachers. It is a great loss for his friends and to science, and above all to his wife, his son and his daughter and his four grandchildren.

Jaap van der Voort (close friend and independent reseacher, Ostercappeln, Germany),
with contributions from
Frank Wesselingh, Ronald Pouwer and Katja Peijnenburg (Naturalis Biodiversity Center, Leiden, The Netherlands)

LIST OF TAXA DESCRIBED
BY ARIE W. JANSSEN (INCLUDING with CO-AUTHORS) SORTED BY YEAR OF PUBLICATION, AND SHOWING THE TAXONOMY USED IN THE ORIGINAL PUBLICATION, IRRESPECTIVE OF POSSIBLE LATER EMENDATIONS. Newly described (sub)genera or (sub)families are shown in *CAPITALS*.

Solariella (Solariella) formosa Janssen, 1967
Skenea minuta Janssen, 1967
Daronia (?Cyclostremella) punctata Janssen, 1967
Circulus quadricarinatus Janssen, 1967
Cingula (Ceratia) regiorivi Janssen, 1967
Cingula (Chevallieria) pseudoproxima Janssen, 1967
PSEUDALVANIA gen.nov. Janssen, 1967
Pseudalvania dingdensis Janssen, 1967
Teinostoma (Solariorbis) hosiusi Janssen, 1967
Teinostoma (?Solariorbis) partimstriatum Janssen, 1967
Gegania miocenica Janssen, 1967
Cerithiopsis (Cerithiopsis) vogeli Janssen, 1967
Cerithiopsis (Cerithiopsis) vandermarki Janssen, 1967
Cerithiopsis (Cerithiopsis) andersoni Janssen, 1967
Cirsotrema (Opaliopsis) turbonillaeforme Janssen, 1967
Cirsotrema (?Opaliopsis) koeneni Janssen, 1967
Circulus praecedens gliberti Janssen, 1967
Putilla gottscheana westfalica Janssen, 1967
Aclis (Stilbe) neglecta Janssen, 1969
Polinices (Euspira) staringi Janssen, 1969
Phalium (Semicassis) bicoronatum belgicum Janssen, 1969
Idasola lignicola Janssen, 1969
Axinulus germanicus Janssen, 1969
Alvania (Actonia) basisulcata Janssen, 1969
Amaea (Undiscala) marialuisae Janssen, 1969
Turriscala (s.l.) straeleni germanica Janssen, 1969
Euspira edithae Janssen, 1969
Hinia (Tritonella) twistringensis Janssen, 1969
Cancellaria (Merica) contorta gelriana Janssen, 1969
Narona (Aneurystoma) canaliculata Janssen, 1969

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Microdrillia teretiaeformis Janssen, 1969
Aphanitoma ronaldi Janssen, 1969
Aphanitoma fransi Janssen, 1969
Conus (Chelyconus) altenai Janssen, 1969
Eulimella (Eulimella) lutaria Janssen, 1969
Ebala (Ebala) vandervlerki Janssen, 1969
Spiratella kautskyi Janssen, 1969
Astarte (Isocrassina) omalii scaldensis Janssen, 1974
Tridonta (Tridonta) domburgensis Janssen, 1974
Gyraulus (Gyraulus) acuticarinatus vleminckxae Janssen, 1980
Nystia (Nystia) glibertheinzeli Janssen, 1980
Pododesmus (Monia) anitae Janse & Janssen, 1983
Skenea schuermanni Janse & Janssen, 1983
Rissoella (Jeffreysiana) hesselinki Janse & Janssen, 1983
Hinia (Hinia) cimbrica (Ravn, 1907) *voorthuyseni* Janse & Janssen, 1983
Babylonella stemerdinki Janse & Janssen, 1983
Daphnella defectiva Janse & Janssen, 1983
MISTEIA gen.nov. Janssen, 1984
Trigonostoma (Misteia) mistense Janssen, 1984
Trigonostoma barnardi Janssen, 1984
Trigonostoma lindeni Janssen, 1984
Trigonostoma pouwi Janssen, 1984
Trigonostoma geslini josephinae Janssen, 1984
Sveltia gliberti Janssen, 1984
GLIBERTTURRICULA gen.nov. Cadée & Janssen, 1985
Glibertturricula vervoeneni Cadée & Janssen, 1985
Spirulirostra baetensi Janssen & Müller, 1985
CAPEDOPECTEN gen.nov. Dijkstra & Janssen, 1988*Clio gailae* Goedert & Janssen, 2020
VAGINELLINAE subfam.nov. Janssen 2020
Capedopecten anellus Dijkstra & Janssen, 1988
Limacina ingridae Janssen, 1989
Limacina irisae Janssen, 1989
Limacina jessyae Janssen, 1989
Limacina mariae Janssen, 1989
Linacina wilhelminae Janssen, 1989
'Creseis' berthae Janssen, 1989
Clio blinkae Janssen, 1989
Clio irenae Janssen, 1989
Clio jacobae Janssen, 1989
Clio pauli Janssen, 1989
SPOELIA gen.nov. Janssen, 1990
Spoelia torquayensis Janssen, 1990
Limacina curryi Janssen, 1990
Limacina lunata Janssen, 1990
Limacina tatei Janssen, 1990
Vaginella victoriae Janssen, 1990
Vaginella sannicola Janssen, 1990
Clio nielseni Janssen, 1990
Vaginella tricuspidata Zorn & Janssen. 1993
FREDENIA gen.nov. Cadée & Janssen, 1994
Streptodytion impiger Cadée & Janssen, 1994
Streptodyction schnetleri Cadée & Janssen, 1994*.*
Streptodyction twistringensis Cadée & Janssen, 1994
Streptolathyrus masculinus Cadée & Janssen, 1994
Streptolathyrus regularis Cadée & Janssen, 1994
Fusus dhondtae (nom.nov.) Cadée & Janssen, 1994
Gamopleura melitensis Rehfeld & Janssen, 1995
Cuvierina jagti Janssen, 1995
Ireneia marqueti Janssen, 1995
Ireneia nieulandei Janssen, 1995
Clio giulioi Janssen, 1995
DIACROLINIA gen.nov. Janssen, 1995
? Diacrolinia elioi Janssen, 1995
EDITHlNELLA gen.nov. Janssen, 1995
SPHAEROCINIDAE fam.nov. Janssen & Maxwell, 1995

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Philine aquila van der Linden & Janssen, 1996
Edithinella curva Janssen, 1998
Diacrolinia larandaensis Janssen, 1999
STRIOLIMACINA nom.nov. Janssen, 1999
Clio lucai Janssen, 2000
Clio (Balantium) collina Janssen & Zorn, 2001
Brocchinia gerdae Janssen & Petit, 2003
CURRYLIMACINA (gen.nov.) Janssen, 2003
Heliconoides vanderweideni Janssen, 2004
Bowdenatheca miocenica Janssen, 2004
Clio (s.lat.) ghawdexensis Janssen, 2004
Edithinella bonaviai Janssen, 2004
BELLARDICLIO subg.nov. Janssen, 2004
Cavolinia landaui Janssen, 2004
Cavolinia vendryesiana f. *Pliomediterranea* Janssen, 2004
Cuvierina (Cuvierina) pacifica Janssen, 2005
URCEOLARIA subg.nov. Janssen, 2005
Cuvierina (Urceolaria) cancapae Janssen, 2005
Cuvierina (Urceolaria) curryi Janssen, 2005
Ireneia gracilis Janssen, 2005
JOHNJAGTIA gen.nov. Janssen, 2005
Vaginella basitrunctata Janssen, 2005
Edithinella doliarius Janssen, 2006
Urceolarica nom.nov. Janssen, 2006 (for *Urceolaria* Janssen, 2005)
Atlanta lingayanensis Janssen, 2007,
Atlanta richteri Janssen, 2007,
Atlanta seapyi Janssen, 2007,
Heliconoides sondaari Janssen, 2007,
Striolimacina andaensis Janssen, 2007,
Hyalocylis marginata Janssen, 2007,
Cavolinia baniensis Janssen, 2007,
Cavolinia perparvula Janssen, 2007,
Cavolinia shibatai Janssen, 2007,
Diacavolinia pristina Janssen, 2007,
Diacria italica Grecchi, 1982 f. *fissicostata* Janssen, 2007
Diacria microstriata Janssen, 2007,
Diacria paeninsula Janssen, 2007,
Diacria philippinensis Janssen, 2007
Sphaerocina convolvula Janssen, 2007
Heliconoides lillebaeltensis Janssen, Schnetler & Heilmann-Clausen, 2007
Heliconoides linneensis Janssen, 2008
HAMECONIA gen.nov. Janssen, 2008
Hameconia edmundi Janssen, 2008
Heliconoides daguini Cahuzac & Janssen, 2010,
Heliconoides merlei Cahuzac & Janssen, 2010,
Heliconoides pyrenaica Cahuzac & Janssen, 2010
Limacina? *vegrandis* Cahuzac & Janssen, 2010
Creseis antoni Cahuzac & Janssen, 2010
Vaginella gaasensis Cahuzac & Janssen, 2010
Clio lozoueti Cahuzac & Janssen, 2010
Clio vasconiensis Cahuzac & Janssen, 2010
Diacrolinia cluzaudi Cahuzac & Janssen, 2010,
Creseis roesti Cahuzac & Janssen, 2010
Heliconoides mermuysi Cahuzac & Janssen, 2010
Creseis tugurii Cahuzac & Janssen, 2010
Peracle charlotteae Janssen & Little, 2010
Limacina erasmiana Janssen, 2010
Limacina guersi Janssen, 2010
Gamopleura maxwelli Grebneff, Janssen & Lee, 2011
Limacina asiatica Janssen, King & Steurbaut, 2011
Limacina dzheroiensis Janssen, King & Steurbaut, 2011
Clio (Clio) pyramidata Linne, 1767 f. *tyrrhenica* A.W. Janssen, 2012
Protatlanta kbiraensis Janssen, 2012
Carinaria maempeli Janssen, 2012
Heliconoides wardijaensis Janssen, 2012
Limacina ernstkittli Janssen, 2012
Creseis curta Janssen, 2012

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Styliola schembriorum Janssen, 2012
Johnjagtia baharensis Janssen, 2012
Clio merijni Janssen, 2012
Clio vilis Janssen, 2012
Cavolinia gatti Janssen, 2012
Cavolinia microbesitas Janssen, 2012
Diacrolinia pumilionis Janssen, 2012
Gamopleura pilula Janssen, 2012
Peracle amberae Janssen, 2012
Peracle grebneffi Janssen, 2012
Clione? ignotus Janssen, 2012
Clione? imdinaensis Janssen, 2012
Clione? phosphoritus Janssen, 2012
Clione? tripartitus Janssen, 2012
Clione? tumidulus Janssen, 2012
Heliconoides vonhachti Janssen, 2012
Tibiella watupuruensis Janssen, Renema & Wesselingh, 2013
Altaspiratella tavianii Janssen, Jagt, Yazdi, Bahrami & Sadri, 2013
Limacina aryanaensis Janssen, Jagt, Yazdi, Bahrami & Sadri, 2013
Limacina perforata Janssen, Jagt, Yazdi, Bahrami & Sadri, 2013
Limacina yazdii Janssen, Jagt, Yazdi, Bahrami & Sadri, 2013
Texacuvierina hodgkinsoni Janssen, Jagt, Yazdi, Bahrami & Sadri, 2013
ZHGENTIANA gen.nov. A.W.Janssen, R.Janssen & van der Voort, 2015
Cuvierina tsudai Burridge, Janssen & Peijnenburg, 2016
Limacina novacaesarea Janssen & Sessa, 2016
Limacina tanzaniaensis Janssen, 2017
Heliconoides nikkieae Janssen, 2017
Limacina timi Janssen, 2017
Limacina parvabrazensis Garvie & Janssen, 2020
Limacina pseudopygmaea Garvie & Janssen, 2020

Adhesive defence mucus secretions in the red triangle slug (*Triboniophorus graeffei*) can incapacitate adult frogs

Gastropods secrete mucus for a variety of purposes, including locomotion, reproduction, adhesion to surfaces, and lubrication. A less commonly known function of mucus secretion in this group involves its use as a defence against predation. Among the terrestrial slugs, mucus that serves this particular purpose has been studied for only a handful of species under laboratory conditions, where it is thought to be produced for self-fouling or to make individuals difficult to consume. However, the mechanisms of how these defensive secretions operate and their effectiveness in deterring predation in the natural world have not be described in much detail. Adhesive mucus secretions in the red triangle slug (*Triboniophorus graeffei*) may be an adaptation against predation. Field observations of a large redeyed green tree frog (*Litoria chloris*) trapped in the mucus secretions of a nearby *T. graeffei* revealed that this mucus serves to incapacitate predators rather than just simply as an overall deterrence. Mechanical stimulation of *T. graeffei* under laboratory conditions revealed that adhesive secretions were produced from discrete sections of the dorsal surface when disturbed, leading to the production of a highly sticky and elastic mucus that was unlike the thin and slippery mucus used during locomotion. The adhesiveness of the defensive secretions was strengthened and reactivated when in contact with water. This appears to not only be the first description of defensive mucus production in this slug species but one of the first natural observations of the use of adhesive defence secretions to incapacitate a predator. The biomechanical properties of this mucus and its ability to maintain and strengthen its hold under wet conditions make it potentially useful in the development of new adhesive materials.

Gould, J., Valdez, J.W. & Upton, R.
email: jose.valdez@bios.au.dk

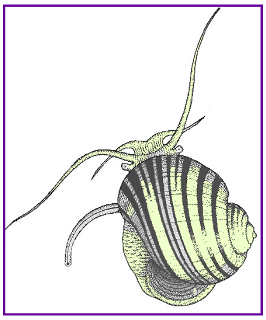
bioRxiv preprint doi: https://doi.org/10.1101/544775

Forthcoming meetings

The Malacological Society of London

HTTP://WWW.MALACSOC.ORG.UK

The Molluscan Forum



Thursday 18th November 2021
0945h – 1630h (to be confirmed)

CALL FOR REGISTRATIONS AND PAPERS
DEADLINE 16 OCTOBER 2021

This informal, annual, and successful meeting is designed to bring together people starting their research on molluscs, to give them the opportunity to present and discuss their work and to compare notes on methods and problems. The deadline for registrations and talk applications is

Attendance to the Molluscan Forum is open to all, but preference is given to **research students, post-post-doctoral researchers, undergraduate students starting molluscan projects, and amateurs** engaged in substantial projects that have not yet been published. Any topic related to molluscs is acceptable: palaeontological, physiological, behavioural, ecological, systematic, morphological, cellular, or molecular.

Short talks (~15 mins) or quick fire talks (3 slides, 5 mins, in lieu of posters) may be offered. They need not be polished accounts of completed work; descriptions of new methods, work in progress, and appeals for assistance with unsolved problems are equally acceptable.

THERE IS NO REGISTRATION FEE.

Enquiries and registrations to:
Phil Hollyman, Fisheries Ecologist, British Antarctic Survey (phyman@bas.ac.uk)

Non-presenters: please let us know you will be coming so that we can estimate numbers.

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FORTHCOMING MEETINGS

The Malacological Society of London

Molluscan Forum, Thursday 18th November 2021
9:45 am – 4.30 pm

REGISTRATION FORM

Return before 1st October 2021, by email to:

Phil Hollyman, Fisheries Ecologist, British Antarctic Survey (phyman@bas.ac.uk)

Name………………………………………………………………………

Address……………………………………………………………………

…………………………………………………………………………

Tel. No……………………………………………………………………

Email………………………………………………………………………

Status: Research Student / Undergraduate / Post-doctoral researcher / amateur (delete as appropriate)

'Other' (please state) ………………………..

Short talks (~15 min) or posters may be offered.
Instead of posters, we will have 5 minute (3 slide maximum) quick-fire powerpoint presentations,

I wish to give a talk / quick-fire talk (delete as appropriate) entitled:

…………………………………………………………………………………………………

…………………………………………………………………………………………………..

Please attach, as a Microsoft Word attachment, an abstract of not more than 350 words, TOGETHER WITH TWO .JPG IMAGES IN SUPPORT OF THE ABSTRACT. Abstracts and images of accepted contributions will be published in the Society's on-line bulletin which is called *The Malacologist. The Malacologist* has an ISSN number and is published and archived on the website of the MSL.

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FORTHCOMING MEETINGS

Abstract submission

Abstracts submitted for the Molluscan Forum should be sent as Microsoft Word files.

Please use the following format:

Title (12pt, left justified)
<blank line>
Authors (10 pt, left justified, presenting author underlined; use superscript numbers to indicate institutional affiliation)
<blank line>
Institutions (10pt, left justified; in this order: Number (superscript), Department, Institution, City, Country)
Presenting Author email
<blank line>
Abstract (11pt, no indentation, left justified, 350 words maximum)

EXAMPLE ABSTRACT

The geographic scale of speciation in *Stramonita* (Neogastropoda: Muricidae)

Martine Claremont[1,2], Suzanne T. Williams[1], Timothy G. Barraclough[2], and David G. Reid[1]

[1]Deptartment of Zoology, Natural History Museum, London, UK
[2]Department of Biology, Imperial College London, Berkshire, UK
Email: m.claremont@nhm.ac.uk

Stramonita is a relatively small, well-defined genus of muricid marine gastropods limited to the tropical Eastern Pacific and the Atlantic. The type species, *S. haemastoma*, is known to have teleplanic larvae and is estimated to remain in the water column for several weeks. *Stramonita haemastoma* shows regional variation, and this has led to the recognition of five geographical subspecies: *S. h. haemastoma*, from the Mediterranean and Eastern Atlantic to Brazil, *S. h. floridiana*, on the east coast of Florida and in the Eastern Caribbean, *S. h. caniculata* on the west coast of Florida and the Gulf of Mexico, *S. h. rustica* in the Western Caribbean and *S. h. biserialis* in the Eastern Pacific. The protoconch has been shown to be similar across the *S. haemastoma* complex, implying that all subspecies have equally long lived larvae. Within these subspecies, cryptic variation is suspected. For example, *S. h. biserialis* is suggested to be differentiated North/South on a small scale. In the presence of teleplanic larvae, speciation on such a small scale seems paradoxical. Various explanations for this paradox are possible. Actual (or realized) dispersal of *Stramonita* species may be more limited than presently believed, leading to allopatric differentiation. Alternatively, morphological differentiation may not be a reliable indicator of genetic differentiation, and *S. haemastoma* (*sensu lato*) might indeed prove to be a single taxon. It is also possible that ecological speciation could result in geographical speciation on a small scale in the presence of wide dispersal. My results suggest that five species of *Stramonita* are present in the Caribbean, at least three of which occur sympatrically. Gene flow is maintained between Caribbean and Mediterranean populations in at least one species, while no genetic differentiation was found along the Eastern Pacific coast. The implications of these results are discussed.

NOTE THAT ABSTRACTS ARE PUBLISHED IN *THE MALACOLOGIST* WHICH IS THE BULLETIN OF THE SOCIETY AND HAS AN ISSN NUMBER.

BEFORE THE FORUM, PLEASE EMAIL TO THE EDITOR OF *THE MALACOLOGIST* (Email address below) TWO IMAGES TO ACCOMPANY YOUR ABSTRACT. TRY TO MAKE THESE IMAGES ONES THAT YOU WOULD NOT USE IN AN EVENTUAL FULL PAPER.

EDITOR georges.dussart@canterbury.ac.uk

Malacological Society of London Awards and Grants

The Research Awards Scheme was established to commemorate the Society's Centenary in 1993. Under this scheme, the Society gives awards to support research on molluscs that is likely to lead to publication. The closing date for applications each year is 15th December. Grants are preferentially conferred on students and researchers without regard to nationality or membership of the Society. Preference is also given to discrete research projects that fall within the subject areas covered by the Society's *Journal of Molluscan Studies*. Applications will be assessed by scientific merit, value of the project and for student applicants, the extent to which the research will benefit the applicant's scientific aspirations. The successful applicants will be notified by 31st March and announced at the Annual General Meeting. Awardees are encouraged to publish their work in the *Journal of Molluscan Studies* (full papers) or *The Malacologist* (travel award reports, research award reports, news of ongoing research etc) as appropriate,

Early Career Research grants

Eligibility is restricted to those investigators at the outset of their independent scientific career. Applications must therefore be 1) postgraduate students, 2) within five years of being awarded their PhD (adjustable for career breaks), or 3) independent researchers not having a PhD. Early Career Research Grants will only be awarded to individuals twice, but not within 3 years of receiving a first award

Sir Charles Maurice Yonge Award

There is no application process for Sir Charles Maurice Yonge Awards. These awards are given for the best Travel Award application on bivalves, by a member of the Society to attend an international meeting (not including the Molluscan Forum). Authors of exceptional studies on bivalves in *the Journal of Molluscan Studies* may on occasion also be given this award. The Editor will nominate such papers as he/she sees fit. The award covers the costs requested in a Travel Award, or for open access publication of the paper. Members of the Society will also receive a personal cash prize of £300. Non-members will receive a personal cash prize of £250 plus one year's membership to the Society. If a paper is multi-authored, the award will be made to the corresponding author.

Senior Research Awards

are aimed at established researchers in professional positions, but without regard to nationality. Applicants for Senior Research Awards must be members of the Malacological Society of London. The Society currently awards up to five Senior Research Grants per year, each with a value of up to £1,500, to support research on molluscs that is likely to lead to publication. The maximum amount available should not be considered as a 'target'; rather requests should reflect the research that is proposed. The grants are reviewed by a Reviewers Panel including both Council and non-Council members invited for that purpose.

Travel Grants

Travel Awards are available as bursaries to support attendance at a conference or workshop relevant to malacology. Grants are preferentially conferred on students but researchers without professional positions may also apply. The maximum amount for one of these awards is £500 for Society members and £300 for non-members. Preference will be given to members of the Society. There are two closing dates each year, 30th June for travel starting between 1st September of the current year and 28th February of the following year, and 15th December for travel starting between 1st March and 31st August of the following year.

For further information, guidance notes and to access the application form see here - http://malacsoc.org.uk/awards-and-grants/travel-grants

Annual Award

This Award is made each year for an exceptionally promising initial contribution to the study of molluscs. This is often a thesis or collection of publications. The value of the Award is £500. Candidates need not be a member of the Society but must be nominated by a member. There is no application form: the nominating member should send the material for evaluation with a covering letter or letter of support to the Honorary Awards Secretary. The closing date each year is 1st November. The winner(s) will be notified by 31st March, and announced at the Annual General Meeting.

Applications

Applications for Research Awards and Travel Grants should be sent to the Honorary Awards Secretary, Jonathan Ablett, Division of Invertebrates, Department of Life Sciences, Natural History Museum, London, SW7 5BD For further information, guidance notes and to access the grant application form see http://malacsoc.org.uk/awards-and-grants/research-grants Please note that all applications must be sent by email to MSL_awards@nhm.ac.uk.

Malacological Society of London—Membership notices

Objects

The objects of the Society are to advance education and research for the public benefit by the study of molluscs from both pure and applied aspects. We welcome as members all who are interested in the scientific study of molluscs. There are Ordinary Members, Student Members and Honorary Members. Members are entitled to receive a digital copy of the *Journal of Molluscan Studies* and such circulars as may be issued during their membership. The society's Web Site is at:

http://www.Malacsoc.org.uk

Publications

The Society has a continuous record of publishing important scientific papers on molluscs in the *Proceedings*, which evolved with Volume 42 into the *Journal of Molluscan Studies*. The *Journal* is published in annual volumes consisting of four parts which are available on -line by members and student members. The Society no longer produces paper copies of the Journal.

Members also receive on-line access to *The Malacologist*, which is the bulletin of the Society, issued twice a year, in February and August. *The Malacologist* is published on the website of the Society.

Meetings

In addition to traditional research on molluscan biology, physiological, chemical, molecular techniques are amongst the topics considered for discussion meetings and papers for publication in future volumes of the *Journal*.

Subscriptions

Membership fee structure

Ordinary Members: Journal on-line only £45
Student Members: Journal on-line only £25

Methods of Payment

(1) Sterling cheque to "The Malacological Society of London".

(2) Banker's standing order to: HSBC (Sort code 40-16-08 Account no. 54268210) 63-64 St Andrew's Street, Cambridge C32 3BZ

(3) Overseas members wishing to pay electronically should should use

IBAN GB54MIDL4016084268210

SWIFT/BIC MIDL GB22

(4) Credit card: Overseas members ONLY may pay by credit card: the Society can accept VISA and MasterCard payments only. Please provide the Membership Secretary with your card number and expiry date, card type (VISA or MasterCard.), the name on the card, and the cardholder's address (if this differs from your institutional address). Receipts will only be sent if specifically requested.

Institutional Subscriptions to the Journal

Enquiries should be addressed directly to Oxford University Press, Walton Street, Oxford OX2 6DP, U.K.

Change of Member's Address

Please inform the Membership Secretary of a change of postal or email address

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APPLICATION FOR MEMBERSHIP OF THE MALCOLOGICAL SOCIETY OF LONDON

I wish to apply for (please mark your choice) :-

Ordinary Members: Journal on-line only £45

Student Members: Journal on-line only £25

I enclose a cheque payable to "The Malacological Society of London" for my first annual subscription.

Title . . . . Name . . . .

Department . . . . Institution . . . .

Street . . . . City . . . .

Post /Zip Code . . . . Country . . . . Email . . . .

Malacological Interests . . . .

Signature . . . . Date . . . .

Please send the completed form and cheque to the Membership Secretary: