PULSE

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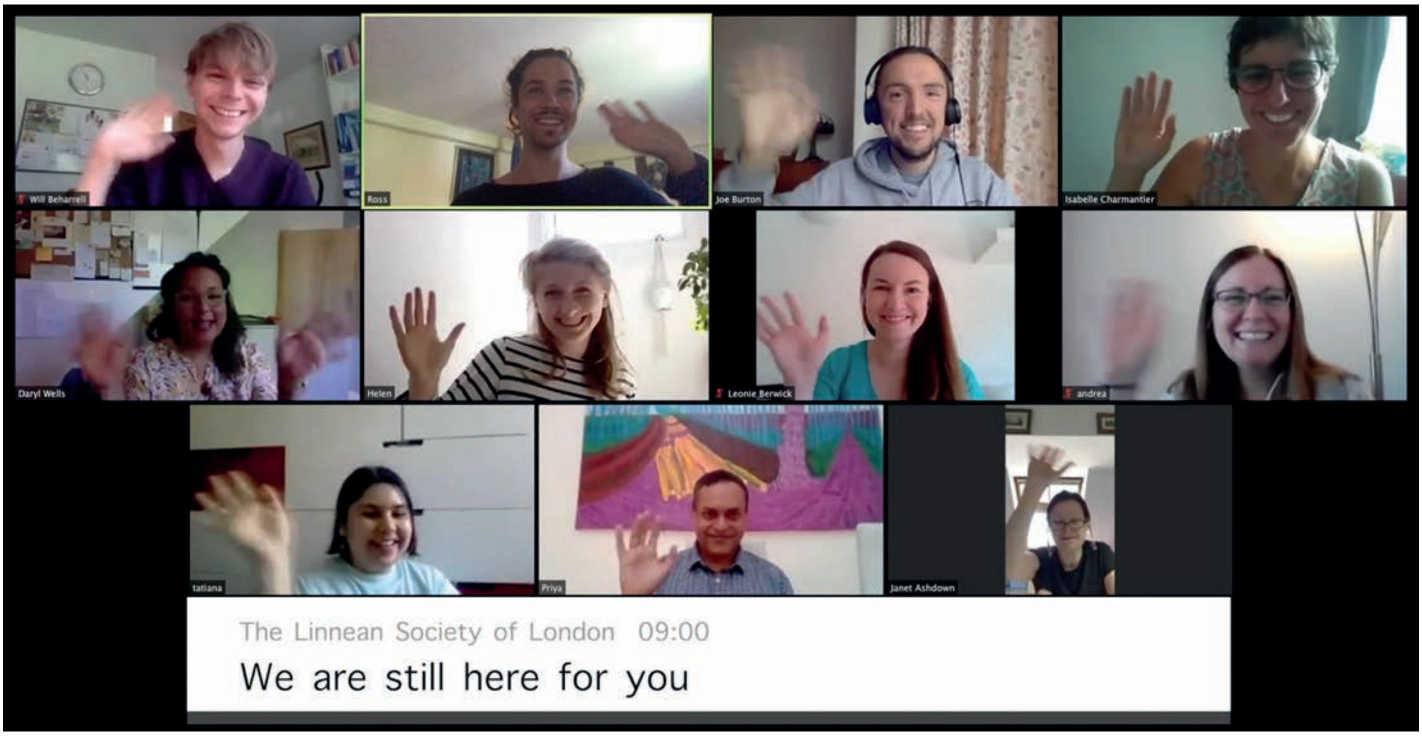
NEWS FROM THE LINNEAN SOCIETY OF LONDON – A FORUM FOR NATURAL HISTORY

The Linnean Society is here for you



The COVID-19 pandemic has forced us all into a new perspective, as we recognise the terrible hardship, sacrifices and loss of life all round us. While many have been able to reconnect with nature locally during this time, conversely an inevitable economic slump may mean less funding available for biodiversity research and conservation programmes in the future. This is something to address in forthcoming issues of *PuLSe*, so please get in touch if there are articles you would like to contribute, or issues you think should be raised. The recent events in the US, UK and around the world which have shone a spotlight on racial discrimination will also be a major point of focus for the Society going forward; providing a clear and sustainable plan outlining what the Society can do to support racial equality in science will deservedly take time.

The pandemic has made the Society re-think our operations, and in doing so we have become far more connected to the Fellowship, albeit virtually, as we met the demand for the first ever virtual AGM and Anniversary Meeting at the end of May. To vote in our Council election, Fellows had to log into our Fellows' Area, which many had not done previously. We hope that our members will now have discovered Fellows near them, Fellows with common interests, and overseas Fellows they can connect with.

We were pleased that so many Fellows from so many countries were able to join us on 22 May, and we are very appreciative of the enthusiastic feedback that we've received. While we can't wait to get back to our amazing rooms and collections in Burlington House (BH), we realise that there is an appetite for Fellows who cannot join us physically to be able to participate in real time. So, the Linnean Society will be striving to present much more live-streamed and interactive content online, be this our regular evening and lunchtime lectures, skills workshops or other educational output. Interactive virtual will be the new normal.

Of course, when our staff will be able to return to BH is still being discussed, and we don't know when our audiences will feel comfortable returning either. The staff teams of all the learned societies around BH Courtyard are busy discussing how we will ensure a safe environment for both working and visiting. In the interim, the staff are working hard to bring you more virtual content, so please do check out our many videos on YouTube and podcasts on Soundcloud, as well as all the blogs and resources on our website – you can find convenient links to everything here: www.linnean.org/athome.

We know life has been tough in many ways, and we are overwhelmingly grateful to all those who have been able to pay their annual contributions. It goes without saying that we hugely appreciate the support the Fellowship has given the Society. We thank you all and look forward to a fulfilling future together, growing the Fellowship and working towards our vision of *a world where nature is understood, valued and protected.*

Keep safe everyone!

Dr Elizabeth Rollinson, Executive Secretary
elizabeth@linnean.org

ADVENTUROUS FELLOWS: PART ONE
DEEP SEA OBSERVATIONS ON THE *CHALLENGER* EXPEDITION

By Glenn Benson, Curator of Artefacts

It struck me as strangely poignant that during the COVID-19 lockdown, while we are all required to stay in our own homes as much as possible, I was due to give a talk at the Linnean Society about some of its many 'Adventurous Fellows' and their extensive travels.

The limits imposed in the UK on how far you may travel to shop and to exercise has been a challenge for many of us, but it has also encouraged us to explore our local environment, perhaps more than we normally would. With more time on our hands, many of us have become aware of the natural history that is around us. Though aimed at children, *Linnaeus at Home* (our free-to-download activity book: https://www.linnean.org/learning/linnaeus-at-home) has inspirational ideas for all ages in order to explore, record and learn about life on earth, and on our door step.

One of the greatest, arguably *the* greatest, adventure ever undertaken by any Fellow of the Society was by Sir Charles Wyville Thomson (1830–82), who led the civilian scientific team on board the HMS *Challenger*, on what was to become known as the *Challenger* Expedition (1872–76).

'Thick as a family bible'

One of the many questions the expedition set out to answer was 'how deep is the ocean'? Or, as I like to think of it, 'how low can you go on Earth'? Thomson wrote:

The objects of the Expedition have been fully and faithfully carried out. We always kept in view that to explore the conditions of the deep sea was the primary object of our mission, and throughout the voyage we took every possible opportunity of making a deep-sea observation.

London's Royal Society acquired the *Challenger* from the Royal Navy, removing her guns and making her fit for purpose by incorporating new laboratories and increasing the number of cabins. Between leaving Sheerness on 7 December 1872 and arriving at Spithead on 24 May 1876, the *Challenger* Expedition covered some 68,890 nautical-miles (127,580 km) measuring the depths of the oceans, and in the process, discovering and describing over 4,000 new species.

Between 1886–95, around 100 scientists were involved in examining the findings and discoveries that were made. A series of reports on the expedition were written, and these ultimately filled 50 volumes that were each said to be as 'thick as a family bible'. Overseeing their production fell, in the main, to (Sir) John Murray (1841–1914). The reports' authors were not paid, though they were each given a copy of their published report and expenses. Murray spear-headed, and

ABOVE:
Sir Charles Wyville Thomson, stipple engraving by C. H. Jeens, 1876. © Wellcome Collection.

BELOW:
Challenger Medal awarded to Percy Sladen FLS, held in the Society's collections. © The Linnean Society of London.

funded, the creation of a medal awarded to those who had contributed to the expedition and the subsequent work on its findings. The medals were designed by William S. Black (an Edinburgh artist active in 1881–97), and William Birnie Rhind, (1853–1933) an Edinburgh sculptor. They were cast, possibly in Paris, for the company James Crichton & Co., of 47 George Street, Edinburgh, Scotland. The Linnean Society holds one of the 120 bronze medals that were awarded from the Challenger Expedition offices in Queen Street, Edinburgh, between August 1895 and February 1897.

This medal was presented to marine biologist Walter Percy Sladen FLS (1849–1900), for his work on the *Asteroidea* (Starfish) found during the expedition, a task that took him nearly a decade to complete. Sladen was Zoological Secretary (1875–85) and Vice President of the Society. (The Linnean Society administers the Percy Sladen Memorial Fund, making grants to support field work in the earth and life sciences: www.linnean.org/psmf.)

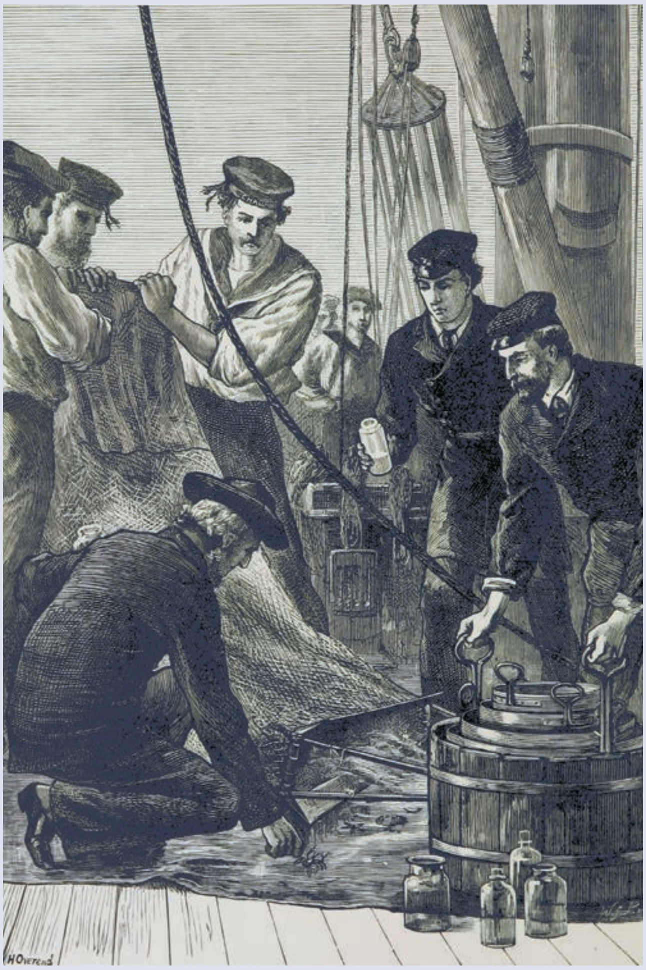
So, just how low can you go on Earth?

The answer is to the bottom of the 'Challenger Deep'—an oceanic trench named in the expedition's honour, forming part of the Mariana (or Marianas) Trench in the western Pacific Ocean. In 1875, the scientists aboard the *Challenger* measured the depth of the deepest part of the trench to be 4,475 fathoms (8,184 m) deep. Modern-day measurements have put the depth at just over 10,900 m.

Was it the greatest adventure of any Fellow so far? If the facts already detailed are not sufficient to support my claim, I submit this as further evidence…

Two of the greatest technological explorations of modern times were named after the expedition: NASA's ill-fated Space Shuttle *Challenger*, and the Apollo 17 lunar landing module (LM *Challenger*), the latter perhaps one of the greatest achievements of human kind.

'Challenger Medals' continue to be issued biennially by the Challenger Society for Marine Science. The modern-day medal is awarded to a UK marine scientist or person who has made a single major or sustained contribution to the development of marine science, or whose innovation has opened up new perspectives.



LEFT:
The crew of the *Challenger* examines a haul as it is pulled on board.

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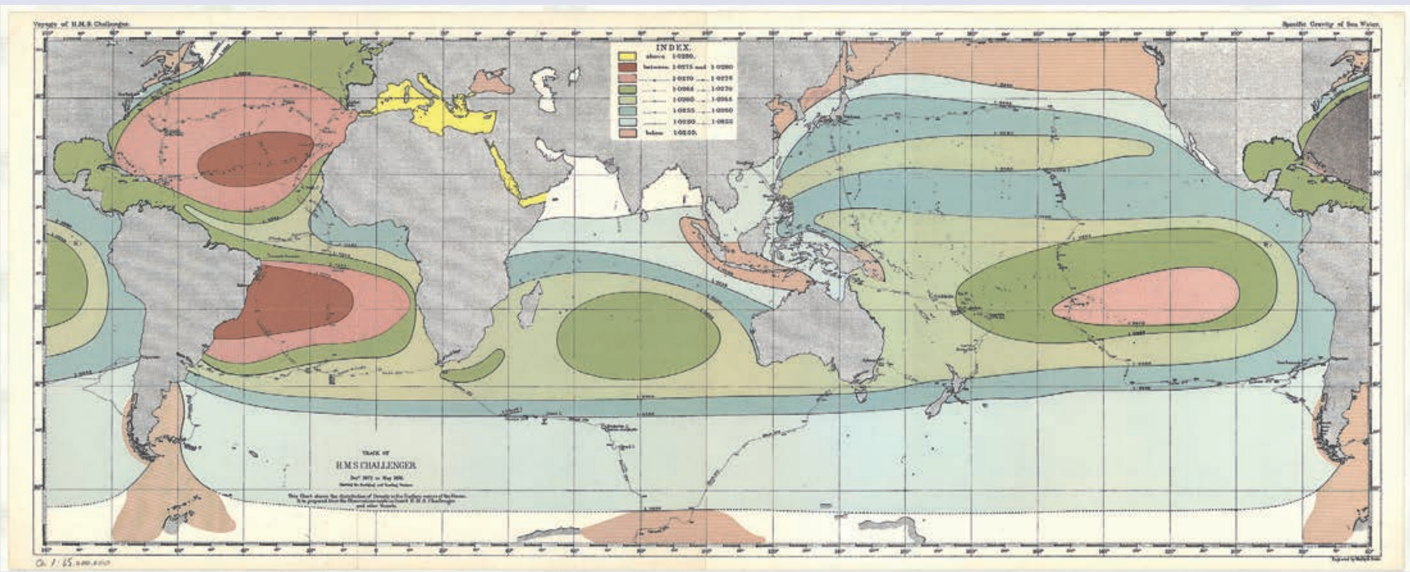
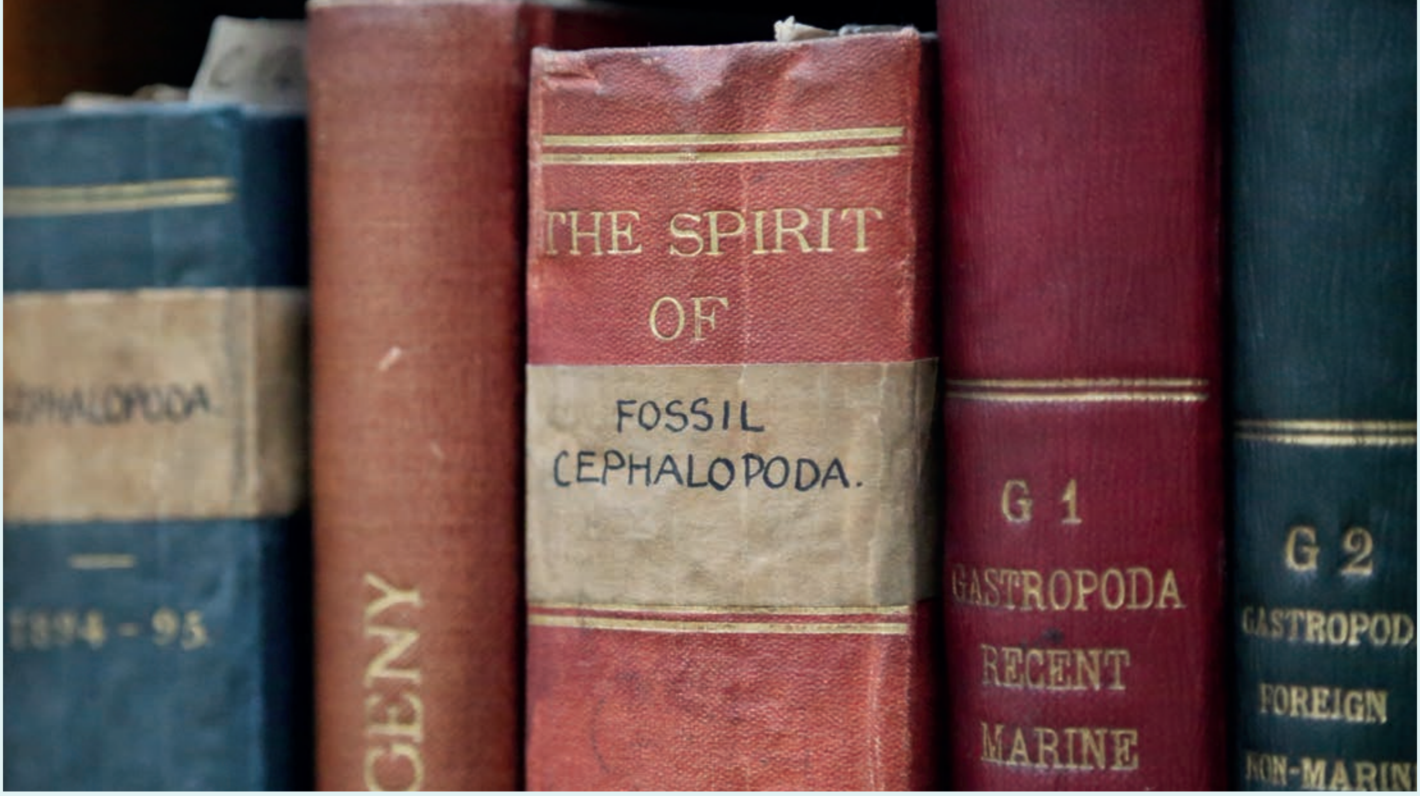


BELOW:
Map displaying the HMS *Challenger's* tracking and measurement of ocean surface density.



OPUSCULA UNBOUND:
ORGANISING OUR 'LITTLE WORKS'

ABOVE:
Some *opuscula* volumes on our shelves have been bound using repurposed covers of religious publications.
© The Linnean Society of London

RIGHT:
Many volumes bound *opuscula* of differing sizes together, making them less stable.
© The Linnean Society of London

BELOW:
A paper on kangaroo beetles found in one of the *opuscula*.
© The Linnean Society of London

On the Piccadilly side of the Linnean Society's library lies a collection of bound offprints, covering a plethora of topics studied in 19th-century natural history, from the tea tree plant, to kangaroo beetles, to termite mounds in Africa. Given to the Society by its Fellows (including Founder James Edward Smith [1759–1828] and botanist Nathaniel Wallich [1786–1854]) and other scientists, the idea was to make sure their scientific papers were readily available for use by their contemporaries. These offprints, known as *opuscula* (meaning 'little works'), were bound together, often thematically, but in the Society's collection those of 'B. B. Woodward' look a little different from the rest. Bernard Barham Woodward (1853–1930), a malacologist and Librarian at London's Natural History Museum, bound his *opuscula* in the repurposed covers of biblical tracts like *Jubilee of the Church, Church Work*, and *Mission Life*. Some even contain notes from the author, or letters about the paper between peers.

However, there are some pitfalls to these bound volumes. In some cases they have been inappropriately bound, with some being overly bulky. Others bind *opuscula* of differing page sizes together; often they can be difficult to open flat and can become dirt traps—inevitably of detriment to the item.

Over the past ten years there has been the occasional flood in the building, and the bound *opuscula* have suffered water damage as a result. Yet, this has offered the opportunity to rethink the way these items have been kept, and make them more easily accessible for research. Conservator Janet Ashdown has been making her way through the most damaged volumes, dis-binding, cleaning, repairing and making them easier to handle. Keeping them as separate 'pamphlets' with individual protective paper covers, they are kept in the same order (in line with how they were catalogued) and housed in conservation grade boxes; often researchers may only require one paper, and this would allow library staff to retrieve just the item requested. Additionally, the new binding is completely reversible, so, if at any point in the future they need to be stored differently, the opportunity to do so is available.

Janet Ashdown & Leonie Berwick

CROSS-TRAINING AT THE LINN

Engaging with teachers and cross-curricular learning

When I joined the Linnean Society's education team as BioMedia Meltdown (BMM) Manager in January of 2019, I was thrilled to dive into the kind of work that truly embraces an interdisciplinary approach to learning. Over many years as an art educator, I'd become increasingly dedicated to cross-curricular projects that benefit the widest range of learning styles. Developing and delivering art workshops with a biological focus in schools, libraries and community organisations all over London was in many ways my dream job, engaging young people in projects with the ability to awaken previously undiscovered scientific and artistic potential.

However, though BMM has grown its engagement annually, there was no programme in place to work with teachers directly. As a former classroom teacher, I've learned that teachers are a chronically underestimated and underserved group, and I firmly believe that no great learning programme is complete without their active participation. When I heard that A New Direction (https://www.anewdirection.org.uk/) was offering grants to cultural organisations in London to deliver a creative INSET day, I leapt at the chance to address this gap.

If successful in our application, we would be delivering the session during autumn term, which is BioMedia's busiest time of year. With this in mind, I reached out to other learning teams around the Burlington House courtyard, asking if anyone was interested in co-delivering, and I quickly received a positive response from the team at the Geological Society.

Our application was one of five accepted for the 2019–20 Creative INSET programme, and by the summer term planning had begun. Having been on the receiving end of numerous teacher CPD workshops, I was eager to avoid the fatal error of 'Do as I say, not as I do'. I was determined to demonstrate the same types of instruction that I would advocate for young people: active learning with opportunities for making, sharing, and reflection.

To maximise these possibilities, we decided to divide our 25 registered teachers into two groups, with half day workshops at the Linnean Society and the Geological Society, delivered twice. We scheduled the event for mid-November, which was soon fully booked. The plan was to introduce basic concepts and techniques for combining art and science in our respective subject areas. The Geological Society decided to explore sedimentary rock and its illustration of geological time; I connected their learning team with Zoë Burt (https://zoeburt.com/), a wonderful teaching artist who helped them flesh out their idea for creating a sedimentary 'book' with each page representing a bedding surface. For the Linnean Society, we decided to introduce two workshops from this year's BMM offerings, and demonstrate how they could be adapted to suit various Key Stage curricula. We examined taxonomy and categorisation through photography and digital collage; we also delved into convergent evolution through techniques of children's book illustration.

We facilitated a guided group discussion of the challenges and rewards of interdisciplinary learning over lunch, allowing teachers to acknowledge their limitations (mainly time and budget) while also investigating paths forward. The grant allowed us to offer generous take-home packs, including ample teaching resources and geological specimens. All in all, the teachers' evaluations of the event were extremely positive, with many planning to create similar INSET opportunities at their own schools, or to implement a combined art/science event or unit for their students.

We were also pleased to have had the chance to deepen our relationship with one of the other courtyard societies. I'm so grateful for the help of the amazing Rose Want and Judi Lakin at the Geological Society, and for the contributions of my colleague Joe Burton. We also thank A New Direction for their generous support.

After hearing of our success, another courtyard society has expressed an interest in partnering for teacher initiatives. Every positive experience builds a stronger foundation for STEAM education in all communities, particularly in those which are under-represented. In the long run, isn't that what we're all about?

Daryl Stenvoll-Wells

ABOVE:
Daryl Stenvoll-Wells led the Society's first INSET day with the Geological Society of London
© A New Direction (Artsmark).

LEFT:
Teacher delegates learn a new way to teach divergent evolution at the Linnean Society.

BELOW:
The Geological Society led workshops on geological time and sedimentary rock.

KEY LAND PLANT INNOVATIONS IN BRYOPHYTES

A CLOSER LOOK AT STOMATA

by Dr Silvia Pressel FLS

ABOVE:
The moss *Bryum radiculosum* with sporophytes. Stomata are present in the basal, darker green, area of the capsule.

BELOW:
The hornwort *Phaeoceros laevis* with developing, horn-like, sporophytes.
All images © Silvia Pressel.

Bryophytes (mosses, liverworts and hornworts) occupy a key evolutionary position, being widely regarded as the closest living relatives of the first plants that colonised land some 500 million years ago (Morris *et al.*, 2018). As such, understanding the structure and biology of bryophytes today can give us unique insights into the origin and early evolution of the land flora. Adorning the sporophytes of both mosses and hornworts, but not liverworts, are tiny stomata which, at least superficially, look the same as those found on the leaves of all other land plants and indeed the surfaces of fossil plants dating back < 400 million years (Edwards *et al.*, 1998). Stomata are part of a suite of major innovations that allowed the first plants, from a freshwater origin, to survive and adapt to life on land. So, what have bryophytes taught us about the origin and evolution of this key innovation, and how do we interpret these lessons given emerging hypotheses placing mosses and liverworts together in the Setaphyta clade—but with the position of hornworts remaining uncertain—and of bryophyte monophyly (Puttick *et al.*, 2018; de Sousa *et al.* 2019; Harris *et al.*, 2020)?

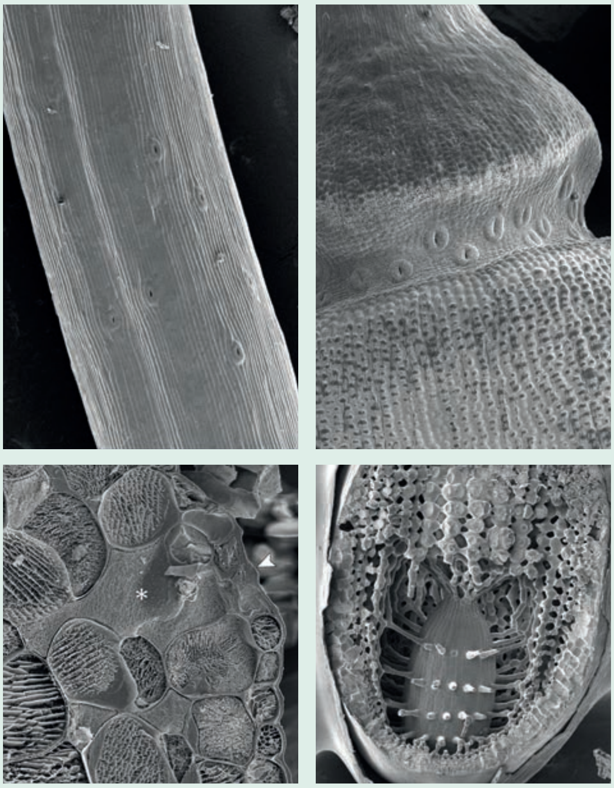
Looks can be deceiving

Stomata are tiny pores bordered by a pair of 'guard' cells in the plant epidermis; they play a major role in the plant responses to the environment by regulating water loss and photosynthetic carbon gain by opening and closing in response to hormonal stimuli and external signals. In addition to opening and closing their stomata, plants can also regulate the number of stomata that develop on their epidermis, the stomatal density, especially in response to changes in atmospheric CO_2 concentrations. While the presence of beautifully preserved stomata on the surfaces of 400 million-year-old fossils gives us clues as to the ancient origin of these structures, a contentious issue which has raged for decades, is whether all stomata, both ancient and modern, not only share the same overall morphology but also the same function. The main assumption here has been that stomata evolved in the ancestor of all land plants and, from their inception, had an active role in regulating gas exchange (e.g. Chater *et al.*, 2017). This assumption also implies that all plants, fossil and living, would exhibit a similar response to changes in atmospheric CO_2 concentrations—by lowering their stomatal density when concentrations are high, and increasing it when CO_2 is in decline (Woodward, 1987).

Understanding this response across land plants, including extinct clades, is not a purely academic pursuit, as stomatal density can be, and has been, used as a proxy for [CO_2] (McElwain, 1998) in the historical and in the geological pasts. This represents a powerful tool for understanding past events and making predictions on how plants may respond to future environmental and anthropogenic changes. Recently, fast-accumulating molecular and phylogenetic data showing orthologs of flowering plant stomatal developmental and functional genes in bryophyte model species, in particular the moss *Physcomitrella patens* (Caine *et al.*, 2016; Chater *et al.*, 2016) and now potentially the hornwort *Anthoceros agrestis* (Chater *et al.*, 2017) have been interpreted as evidence in support of a unitary origin and of fully functioning, actively controlled stomata already present in the common ancestor of land plants. On the other hand, physiological and developmental studies of bryophyte stomata have demonstrated that, in both mosses and hornworts, stomata do not respond to any of the environmental and hormonal stimuli that elicit closure in flowering plants, including desiccation, darkness and the stress hormone abscisic acid (Pressel *et al.*, 2018; Duckett & Pressel, 2018). In bryophytes, there is a single opening event during stomatal development, with stomata remaining open and unresponsive thereafter due to changes in the guard cell walls that render these inelastic (Merced & Renzaglia, 2017) and, in hornworts, the eventual collapse of guard cells, locking stomatal pores in an open position—a phenomenon also observed in some fossil stomata (Renzaglia *et al.*, 2017). These results clearly point to bryophyte stomata as being functionally different from those in flowering plants, with a putative main role in sporophyte desiccation leading to spore dispersal rather than actively controlled gaseous exchange. This, in turn, suggests that acquisition of the key regulatory and physiological mechanisms that govern most modern stomata was not a sudden, ancestral event but rather occurred gradually during land plant evolution, in line with recent findings of passive stomatal regulation in some lycophyte and fern species (e.g. Brodribb & McAdam, 2011, 2017, but see Hõrak *et al.*, 2017). The observation that bryophyte stomata also differ from those of flowering plants in their responsiveness to atmospheric CO_2, with their densities remaining unaffected by changes in [CO_2] simulating current and ancient atmospheres (Field *et al.*, 2015), also raises questions as to how far the stomatal density proxy can be applied across land plants and especially to extinct clades. That members of other ancient groups, such as cycads and some species in the Araucariaceae, have also been shown to be either insensitive to changing [CO_2] or respond only to elevated [CO_2] (Haworth *et al.* 2011a, b) further complicates the widespread use of the stomatal proxy. A better understanding of stomatal development and responses to [CO_2] in key taxa across the phylogenetic tree is now needed; this response can be measured not only in living species grown under elevated [CO_2] but also in historic herbarium collections that extend into pre-industrial times.

The origin of stomata

But what about the origin of stomata? The growing consensus here is that stomata evolved once in the common ancestor of land plants. With latest phylogenetic and phylogenomic evidence pointing to bryophyte monophyly, the emerging evolutionary hypothesis is that the common ancestor of land plants possessed complex, flowering plant-like stomata. These structures were then completely lost in liverworts, whilst the 'simple' stomata of mosses and hornworts, and some early vascular plants, may be explained as the result of reductive evolution, possibly through loss of genes controlling stomatal development and function (Harris *et al.,* 2020). However, this hypothesis does not explain the complete absence of stomata in the extant basal moss clades Takakiales and Andreaeopsida, nor the presence of 'pseudostomata', stomata-like structures but lacking true pores and without subtending intercellular spaces, in *Sphagnum* (Duckett *et al.,* 2009 and literature therein) . Also difficult to marry with the hypothesis of unitary origin are observations that the system of intercellular spaces subtending stomata in bryophytes is initially filled with liquid rather than gas from the onset (Pressel *et al.,* 2014; Duckett & Pressel, 2018), as it is invariably the case in vascular plants. Difference in development between bryophyte and vascular plant intercellular spaces, which are an integral part of the 'stomatal apparatus' may suggest that both intercellular spaces and stomata evolved several times, as it has been shown before for water-conducting cells (Ligrone *et al.,* 2002). Clearly more needs to be learned about the genetic basis of stomatal structure together with finer resolution of the relationships within bryophytes and between bryophytes and vascular plants before this most challenging conundrum of land plant evolution can be resolved (Duckett & Pressel, 2020).



TOP LEFT:
Scanning electron micrograph of stomata adorning the sporophyte of the hornwort *Anthoceros punctatus.*

TOP RIGHT:
Scanning electron micrograph of stomata in the moss *Polytrichum juniperinum.* Differently from hornwort, the distribution and number of stomata vary greatly in mosses.

BOTTOM LEFT:
Transverse section of a hornwort sporophyte showing liquid-filled intercellular spaces (*) subtending a stoma (arrowed)

BOTTOM RIGHT:
Longitudinal section of a moss capsule. As in hornworts, liquid in the intercellular spaces is slowly replaced by gas during sporophyte development.

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PYGMY SEAHORSES

REEF LIFE IN MINIATURE

by Dr Richard Smith FLS

ABOVE:
Denise's pygmy seahorse (*Hippocampus denise*). Southeast Sulawesi, Indonesia.
Images © Richard Smith

BELOW:
South African pygmy seahorse (*H. nalu*). Sodwana Bay, South Africa.

RIGHT:
The newly-discovered Japanese pygmy seahorse (*H. japapigu*). Hachijo-Jima, Japan.

As I peered incredulously at the tiny creature clinging to the gorgonian coral in front of me, the time pressure of being at such great depth beneath the surface began mounting. I was diving off the Indonesian island of Komodo, staring at a windscreen-sized red and purple gorgonian coral having just been pointed to a miniature red and purple fish so small it wouldn't quite stretch across a 50 pence coin. With just a few precious minutes of observation, as a result of being 30 m beneath the surface, I could just about make out the shape of a tiny seahorse before it was time to ascend to the shallows again.

A relatively recent discovery

I first became aware of pygmy seahorses in the late 1990s. At that time, there was just one described species, which had accidentally been discovered by researcher, Georges Bargibant, at the Noumea Museum two decades before. Whilst surfacing from a dive, bearing a specimen of the gorgonian *Muricella* for the museum's collection, he noticed a pair of tiny seahorses hanging on its branches. In 1970 Bargibant's pygmy seahorse was named in his honour as *Hippocampus bargibanti*, measuring just 2.6 cm from the tip of the snout to the tip of the tail. It wasn't until the late 90s that divers occasionally begin to observe them, at which point they were known from just a few scattered locations in southeast Asia, and always at the depth limits of recreational scuba diving.

It's unsurprising that so little was known about these diminutive fishes even after the turn of the millennium; however, the more divers began looking for the small cryptic creatures of coral reefs, the more

they discovered. Several new pygmy species were found, and at the time of beginning my PhD research on the biology and conservation of pygmy seahorses in 2008, a total of three species had been described. In addition to Bargibant's, Denise's pygmy seahorse (*H. denise*) was one of these and also lives on the surface of gorgonian corals. The habitat specificity of Bargibant's and Denise's pygmy seahorses is unique among seahorses, and was likely to have possible influences on their populations and implications for their conservation. This provided some of the initial motivation for my research.

Research on larger seahorses has shown that they are monogamous for at least each brood. Males accept eggs into their brood pouch from their partner and fertilise them upon entry, which therefore prevents any form of cuckoldry through the carrying of eggs fertilised by another male. The male becomes truly pregnant, providing nutrition and a perfect medium for the developing embryos. The pouch is sealed after the clutch has been accepted, as salt water intrusion through pregnancy would damage the eggs. Across the genus *Hippocampus*, to which all seahorses belong, females have been found not to remate for the entire duration of their partner's gestation period. In many cases, the monogamous pair bond is so strong that it endures for at least a season, if not many years. I had observed that gorgonian-associated pygmy seahorses often live in odd numbered groups, eluding to another potentially interesting source of investigation for my research.

Pygmy seahorses differ slightly in morphology from their larger congeners, as adaptations for their extremely small size. They have just one gill opening at the back of the head, rather than two, and they brood their young in a pouch located within the trunk, rather than a large pouch found on the tail. When the males are pregnant, the trunk becomes extremely swollen. I found that the home ranges of the males are much reduced compared to the females. This is likely to be a result of both the female's need to find plentiful food to fuel egg production, and that males find it hard to move around when they're extremely rotund. One of the males had a home range equivalent to three playing cards, whilst one of the females visited an area equivalent to an open magazine.

With so little known about pygmy seahorses, and no research into their ecology aside from their descriptions, there were few places I would have been able to carry out my research. Pygmies at that time had not been successfully kept in captivity, and even now there are many limitations to their husbandry. To accurately study their social and reproductive behaviours I needed almost 24-hour access to a reef rich enough to accommodate them. Thankfully, Wakatobi Dive Resort in southeast Sulawesi, Indonesia were enormously supportive and their House Reef provided everything I could possibly need.

The reef's residents

Carefully descending the stairs, I had a short swim over the reef lagoon to reach the reef crest and drop off. Before long I had reached an *Annella* gorgonian where I knew a group of Denise's pygmy seahorses resided. I had found the group several weeks before, and visited numerous times a day. Using a DSLR camera and macro lens for close-up photography, I had established that the group comprised of three males and a single female. The female had a tiny raised circular pore at the base of the trunk, and the males had slit like openings from where juveniles emerge. The group were helpfully located at a 12 m depth.

Having spent a few weeks observing and recording the group's interactions, I had found that all four slept in the same place every night, and displayed all manner of fascinating behaviours. The three males were surprisingly pugnacious, compared to other seahorses. They would try and strangle each other with their tails; one particularly drawn-out tussle involved all three of the males, with one strangling another, as he himself was being strangled. With all the thrashing about, I was worried that they may draw the attention of an opportunistic predator, such as a small dottyback (Pseudochromidae), but the only drawback appeared to be a sprained tail.

Aside from the sparring males, I also witnessed courtship displays between the males and female. These involved shaking and jerking movements, and the female didn't seem too picky about which of the males these were with. Courtship rituals, such as these, have been shown in other seahorses to aid in the synchronisation of reproductive systems between a mated pair. Females begin to hydrate their eggs around four days before transferring them across to their mate. If the female does this before the male is ready to accept them, they may spoil and possibly damage her reproductive organs or the eggs will go to waste. If too late, the pair may have wasted time when they might have been producing offspring.

Although pygmy seahorses were already firm favourites among divers in southeast Asia, few people could actually see the tiny fish and the perception, after a minute or so of observation, was that they simply sat on their gorgonian homes without exhibiting any particularly interesting behaviours. Revelations of the private lives of the pygmies, told to the resort's dive guides, used my scientific numberings: 1, 2, 3 and 4—this became too much for my friend Wendy who renamed them Tom, Dick, Harry and Josephine, and of course, these names stuck.

As I watched the interactions between the four pygmies in the faint morning light, I saw Tom swim away from the little area where the others resided. I had noticed an escalation in courtship two weeks before, which also coincided with a reduction in the Josephine's girth. I had a hunch that I might just witness something special this morning. Tom coiled up his tail, resembling a Victorian lady pulling up her dress to run, and swam against a fairly stiff current to the edge of the gorgonian. Within seconds, he crunched over and began to expel his offspring. I counted half a dozen dark-coloured fry, just a few millimetres in length, shoot out as little coiled up balls. They quickly unfurled and appeared to be miniature versions of their parents, except in colour.

Immediately after giving birth, Tom swam back to the others. Josephine was eagerly awaiting his return and immediately began to shake to entice him. Tom was looking rather forlorn and still panting from all the exertion. By this time, it was just 15–20 minutes since he had given birth, so I was surprised to see the pair slowly raise up off the gorgonian and intertwine their tails. Over the next 45 seconds, Josephine's trunk shrank in size as her unfertilised eggs moved across into Tom's filling torso. Tom was again pregnant with another of Josephine's broods.

ABOVE:
Pontoh's pygmy seahorse *(Hippocampus pontohi).* Southeast Sulawesi, Indonesia.
Images © Richard Smith

RIGHT:
Large gorgonian coral upon which Denise's pygmy seahorses can be found. Ambon, Indonesia.

Walea Soft Coral Pygmy Seahorse (*H. waleananus*). Togian Islands, Sualwesi, Indonesia.

Denise's pygmy seahorse 'Tom', before giving birth (Left) and after (Right).

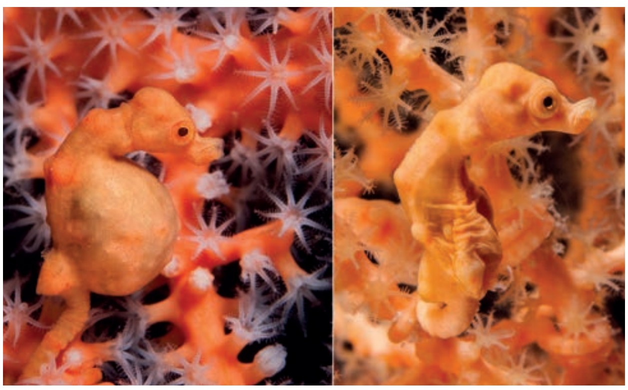
Home is where the heart is

The fry do not remain on the gorgonian with their parents; rather, they are carried away by ocean currents. Their dark colouration provides some camouflage in the open ocean for the several weeks they spend there. After this period, they appear to follow chemical cues in the water and locate a new gorgonian coral. I actually found a baby, just 1.2 cm long and still dark in colour that had just settled onto a gorgonian coral. I returned everyday for the next five days and witnessed the baby change in colour from black to bright pink with dark pink spots. The pink base colour matched the stems of the gorgonian, and the dark spots mimicked the closed polyps.

Whilst conducting population estimates in the area, I had confirmed that Bargibant's pygmy seahorse lives only on *Muricella* gorgonians, making it an extreme habitat specialist. Denise's pygmies on the other hand are also habitat specialists, but much more cosmopolitan in host choice. So far, I have recorded Denise's living on ten different genera of gorgonians. Bargibant's vary in colour slightly to match their host, but Denise's are much more plastic in their ability to blend in colour and texture with their host. Some are smooth whilst others are covered in prominent tubercles, depending on the size of the polyps.

Tom, Dick, Harry and Josephine all differed slightly in size and colour, which allowed me to reliably distinguish between them on the gorgonian. The techniques used for tagging larger seahorses would certainly not work on such a miniature scale. I never saw one of them leave the gorgonian, nor did any other pygmies arrive during the many months of my study.

The biggest surprise was that although Tom was mating with Josephine and giving birth every two weeks, Josephine was also mating every two weeks with Dick. She was mating once a week, but alternating between the two. This is the first time such polyandry has been witnessed in a seahorse. However, the male's clutches of half a dozen fry were about half the size of those produced by the monogamous pairs that I studied.



Burgeoning diversity

In the years since I began my research on pygmy seahorses, there have been a flurry of new discoveries around the Coral Triangle countries of Indonesia, Malaysia, New Guinea, Philippines, Solomon Islands and Timor-Leste. In addition to the two gorgonian-associated pygmy seahorses, the Walea Soft Coral pygmy seahorse (*H. waleananus*) lives with shallow soft corals in only one bay in Indonesia. Further to these habitat specific species, there are several—Pontoh's (*H. pontohi*), Coleman's (*H. colemani*) and Satomi's (*H. satomiae*)—which are much less specific about their habitat choices and can be found living on algae, hydroids or other similar substrates anywhere on the reef. This of course makes them much harder to find, and as a result there has not yet been any focused study into their ecology.

In 2013, a couple of years after completing my PhD research, I presented at the quadrennial Indo-Pacific Fish Conference in Okinawa, Japan. I was ostensibly in Japan for the conference, but for several years I had been keen to go to Japan in search of an elusive pygmy that I'd seen in an image. It was another free-living species, but appeared slightly different. After the conference, I travelled to Hachijo-Jima, 180 miles south of Tokyo, having tracked down some more images coming from the island. Over a few days of diving I found over a dozen of these amazing fish. It wasn't until I met syngnathid taxonomist, Graham Short, through my membership of the IUCN Seahorse, Pipefish and Seadragon Specialist Group, at a conference in Tampa, Florida that I was able to move forward with its description. In 2018, along with colleagues from Japan, USA and Australia, we named the new species as *H. japapigu*. It's amazing that this fish, albeit less than 2 cm long, had remained undescribed just a stone's throw from the world's most populous metropolis.

Despite the initial flurry of new pygmy species, things have begun to slow with new discoveries, so when I got word of an unusual sighting in South Africa my ears pricked up. A pygmy seahorse had never been recorded in the Indian Ocean before. When I was forwarded an image of what the dive instructor who took the shot believed to be a pygmy pipehorse, I was even more surprised to see a pygmy seahorse. Several months after the publication of the Japanese pygmy, I was off to Sodwana Bay in northeast South Africa with Dr Louw Claassens who studies the South African endemic Knysna seahorse (*H. capensis*). With the help of local dive instructor, Savannah Nalu Olivier who took the initial image, we went and found the fish for ourselves. I even found a tiny baby, less than a centimetre long, on a rocky reef at 15 m. The paper describing this new species has recently been published, and the new species named as *H. nalu*. Yet again, the natural world continues to surprise us.

In the almost 20 years since I saw my first pygmy seahorse, we have learnt a lot about these mysterious fishes. In that time, the coral reefs that they depend upon have also changed. Many of the reefs that I used to visit and wonder at the profusion of life, have now become desolate landscapes thanks to multiple bouts of coral bleaching. The greatest danger for Bargibant's and Denise's pygmy seahorses lies in their reliance on specific gorgonian corals for their survival. Although not affected by bleaching, habitat degradation and diseases caused by warming waters are a grave threat. Being so easily overlooked could mean other new species of miniature syngnathids may be lost before we have the opportunity to record them.

Biography

Richard Smith, a British underwater photographer and writer, aspires to promote an appreciation for the ocean's inhabitants and raise awareness of marine conservation issues through his images. A marine biologist by training, Richard's pioneering research on the biology and conservation of pygmy seahorses, led to the first PhD on these enigmatic fishes. Richard organises and leads marine life expeditions where the aim is for participants to get more from their diving and photography by learning about the marine environment. His book, *The World Beneath: The Life and Times of Unknown Sea Creatures and Coral Reefs* will be released in the UK in September: *www.OceanRealmImages.com*
A review of this book will appear in a future issue of *PuLSe*.

ABOVE:
Bargibant's pygmy seahorse (*H. bargibanti*). North Sulawesi, Indonesia.

Denise's pygmy seahorse (*H. denise*). Southeast Sulawesi, Indonesia.

TASMANIAN WILDLIFE DYNAMICS

By Dr John Feltwell FLS

ABOVE:
Watercolour of a Tasmanian tiger by John Lewin (1770–1819), painted c. 1809. Images © John Feltwell, except Lewin watercolour © The Linnean Society of London, and *Transactions* plate courtesy BHL

Pinned up in a wildlife centre in the Australian island state of Tasmania are pages from the Linnean Society's *Transactions* in 1808; it is surprising how far the influence of the Society extends. On 18 April 1807, 213 years ago, Sir Joseph Banks communicated a report from G.P. Harris to the Society on two remarkable mammals: the Tasmanian tiger *Thylacinus cynocephalus,* and the Tasmanian devil *Sarcophilus harrisii,* named after Harris. He had originally classified the two species in the genus *Didelphis* (Harris, 1807). George Prideaux Robert Harris (1775–1810), deputy surveyor in what was then Van Diemen's Land, was not a Fellow of the Society but Banks communicated the paper on his behalf, via the Society's Secretary.

Impressive carnivores

Today, Tasmanian wildlife is still very much about marsupials, and the apex predator is, or perhaps was, the Tasmanian tiger or thylacine. Now likely extinct, this impressive carnivore was a relatively large animal. The specimen Harris measured was *'5 feet 10 inches from tip of nose to end of tail'* with *'16 jet-black transverse stripes',* and a large jaw. The government put a bounty on Tasmanian tigers as they preyed on sheep, and numbers declined until the last one died in Hobart Zoo in 1936—212 years from Western discovery to extinction. (Hobart Zoo itself no longer exists, but there is an excellent review of Tasmanian tigers in Hobart Museum, with images, videos and skeletons on display.) Tasmanian tigers had formerly existed on the Australian mainland but died out before early settlement. However, field workers in Northern Queensland attest to seeing tigers as recently as 2017. Parts of Tasmania are mountainous and without roads (20% of Tasmania has been designated the Tasmanian Wilderness World Heritage Area) so there is always a chance that some tigers might remain, with photographic claims in 1998 (Owen & Pemberton, 2005) and 2006.

Tasmanian devils (*Sarcophilus harrisii*) gain much of the tourist limelight, and are supported by wildlife sanctuaries, having been listed as 'Endangered' on the Threatened Species Protection Act 1995. As with the tiger, a bounty was put on the head of devils, believing that they also took livestock, so their numbers declined into the 20th century. They are efficient scavengers as well as deadly killers. With the demise of the tiger, devils are now the largest carnivorous marsupial in Tasmania and thus, the world (Wilson & Mittermeier, 2015). Unfortunately Devil Facial Tumour Disease (DFTD), a virus which causes a fatal contagious cancer affecting the mouth and face, was first spotted in north-eastern Tasmania in 1996. By 2012 this had caused a near 80% decline in wild populations of Tasmanian devils. According to Dr Elizabeth Murchison FLS, at her talk at the Linnean Society in April 2017, devils can die within months of catching the virus.

It is their blood-curdling sounds as they squabble around food and during mating that has given them such a devilish name. The snarling, that so scared early settlers, sounded much worse at night. Their mating behaviour has facilitated the spread of the disease, as when the female is receptive, she develops a tough band of skin around her neck, which the male bites during copulation. Devils without the disease have been relocated to Maria Island off the east coast of Tasmania where rescue populations are being invigorated. Other populations have been established on the Australian mainland, with a target of an effective population of 500 individuals, as part of the 'Insurance Population Breeding Program'.

Adaptations and further threats

Harris described the contents of the stomach of Tasmanian tiger as containing *'the partly digested remains of a porcupine ant-eater, Myrmecophaga aculeata'* — or, the short-beaked echidna (*Tachyglossus aculeatus setosus*), a monotreme that lays eggs and, like so much Tasmanian wildlife, occurs in Australia as well. Echidnas go out in all weathers, using their long tongue for probing the ground, and are quite at home in snow and sleet. It is not unusual to see echidnas on roadside verges, and on golf courses, where the turf is shorter and ants easier to find. They are similar in size to European hedgehogs, having also developed defensive spines and the ability to roll up when threatened, and are able to bury themselves using their remarkable claws.

An endearing marsupial occasionally seen in wildlife centres is the common wombat, the Tasmanian subspecies being *Vombatus ursinus tasmaniensis*. They occur as roadkill throughout most of Tasmania as they are nocturnal grazers. They dig large tunnels, many metres long, used for decades and large enough for humans to crawl within, as described by James Woodford during research that culminated in his immensely readable *The Secret Life of Wombats* (2013). Just like devils, wombats have backward facing pouches to prevent excavated tunnel soil from entering.

Wombats also have two adaptations against predators: they have amply cushioned backsides so that predators cannot cause much damage, especially when darting into their hole, and more cunningly, they kill intruders in their tunnels by flattening themselves, sliding under the intruder and crushing them against the roof.

The wildlife of Tasmania is influenced by the land usage, now mostly agriculture and forestry, which limits biodiversity. Anthropogenic impact will increase as the current population grows (534,281 in June 2019). Habitats are tempered by fire, a traditional way of managing the land before the European settlers arrived. Regeneration after fire is usually fast but too much regular fire can reduce hillsides to grassland, with occasional isolated trees indicative of the previous habitat. Additionally, most marsupials are nocturnal and therefore susceptible to being struck by vehicles, hence the 55kmh speed limit between dusk and dawn. A 2017 survey by local authorities recorded over a quarter of a million roadkills, of which 3,392 were devils; the overall average being 32 animals killed every hour, or 1 animal for every 3km.

BELOW:
Quolls have a number of colour forms, tan being the most common.

Devil Facial Tumour Disease (DFTD), first spotted in 1996, resulted in an 80% decline in wild Tasmanian devil populations by 2012.

RIGHT:
The echidna, or spiny anteater, is a voracious feeder.

There are three subspecies of wombats, one in Tasmania, the other two on the Australian mainland. It is the largest burrowing herbivore in the world.

BELOW:
The author at Hobarth Falls, Strahan, east Tasmania in a forest of Tasmanian tree ferns (*Dicksonia antartica*).

Changing dynamics

The 'wild west' is different from the coastal grasslands of the east, replete with orchards, vineyards, olive groves, sheep and cattle. On an island where vegetation is influenced by Antarctician and Australian climate (Cameron, 2002), with temperatures varying from 40ºC in Hobart in late March to a snowstorm two days later in Cradle Mountain (1,545 m), wildlife need to have great adaptations.

The dynamics of predator-prey relationships have changed a lot since Harris described the Tasmanian tiger; the apex predator is now the much smaller Tasmanian devil. Another carnivorous marsupial is the Eastern quoll (*Didelphis viverrinus*), which eats insects, skinks, snakes, birds and small mammals, and may be commensal with devils, which rip open carcasses and feed only on the best bits and leave a lot for others. (Wilson & Mittermeier, 2015). In the spotted world of the temperate rainforest, quolls exhibit a variety of camouflage through colour forms, from tan, to black and white, to jet black. Introduced cats and red foxes are the enemy of native species. Whilst there have been falls of 95% of devil populations because of DFTD, recent research has demonstrated that there is a 'trophic cascade' in other animals, with the Eastern quoll declining rapidly, following DFTD where feral cats increased in disease-affected areas (Hollings, 2013 and Hollings *et al,* 2013).

Wallabies in Tasmania have increased in recent years to pest proportions, now requiring culling, some report the wallaby population at about three million, with numbers somewhat controlled by devils and eagles. Devils are mostly scavengers but they also hunt live prey such as possums. They are fast runners covering several miles at night to forage for food. There are certainly plenty of wallabies for devils to eat.

Many of the marsupials exhibit black and white colours, perhaps an adaptation to their nocturnal way of life in the dappled shadows of the temperate rainforest and fern forests (Feltwell, 2016). Yet birds species have also evolved black and white livery, from the Black Currawong (*Strepera fuliginosa*) endemic to Tasmania and the Black Swan (*Cygnus atratus*), through to the black and white Australian Magpie (*Gymnorhina tibicen*), a proud member of the crow family, and the Masked lapwing (*Vanellus miles*), to name just a few.

In the early 19th century, game, which included black swans, was plentiful for officers in the settlement of Hobart: *'Immense flights of black swans frequented the river above Risdon in the breeding season'* (Walker, 1973). Lord Hobart, the Governor, issued an order prohibiting the black swans being molested during the breeding season, a very early measure to protect swan stocks. Happily, the black swan appears to have survived well into this century with a gathering of several hundred seen on the River Tamar in the north of the country.

Hobart was originally settled for its harbour and easy access inland via the River Derwent. In the early settlement years, the Derwent played host to 50 or 60 whales at any one time in the shoal parts of the river (Walker, 1973). The whaling eventually ceased. Now the River Derwent has at least 11 hydroelectric stations and ten power stations, a whole new dynamic impacting on the original balance of nature.

john@wildlifematters.com

ABOVE:
This plate from Harris's paper in the Society's *Transactions* gives a reasonable assessment of the Tasmanian tiger and Tasmanian devil, but the size is wrong: the devil is at least three times smaller than the Tiger.

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BUSINESS AS USUAL

Though we have had to cancel and postpone our events during the COVID-19 pandemic, we are slowly building our programme back up in virtual form. Keep an eye on our website, *PuLSe* and Linnean News for upcoming online events.

Missed a lecture? Follow us on YouTube
www.youtube.com/user/LinneanSociety

Diversity and Distribution in the Solanaceae
Dr Sandy Knapp PLS

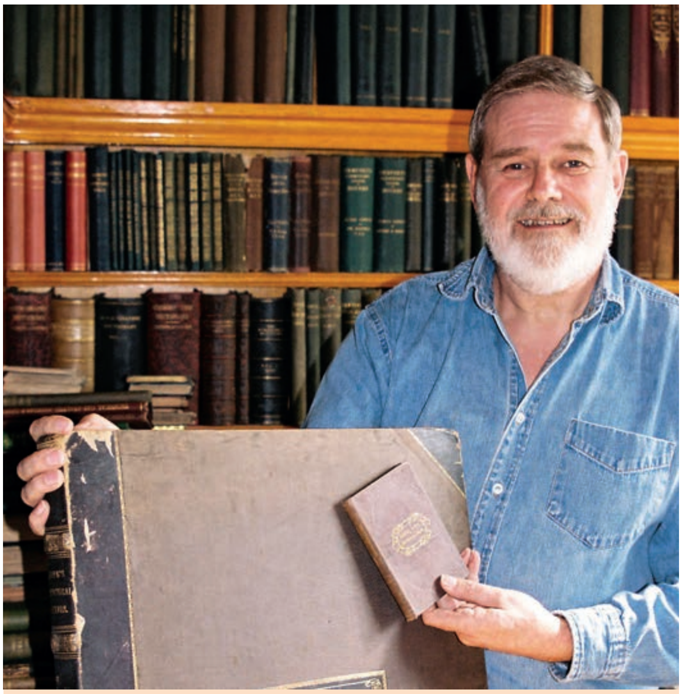
The Lost Art of Nature Printing
Pia Östlund

EXPLORE

PODCAST
The 'Obvious' Truth about Plant Sexuality
Professor Stella Sandford explores whether plant sex was as obvious as Linnaeus suggested
https://soundcloud.com/user-679811756/the-obvious-truth-about-plant-sexuality

BLOG
Collinson's Connections: The Commonplace Book of Peter Collinson
Learn about the 'compendiums of knowledge' of this 18th-century botanist
https://www.linnean.org/news/2020/06/14/collinsons-connections

VIDEO
Tooth and Jaw – Big Cat's Bite
Explore the evolution of the big cat's bite, based on research published in one of our journals
https://www.youtube.com/watch?v=klWSKPL5Qjc



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Celebrating **Professor Raymond Barry Williams FLS**

I am absolutely delighted to bring to your attention the considerable achievements of friend and colleague Ray Williams who has recently been awarded a DSc by Brunel University for his 50 years of 'amateur' unaffiliated private research in Marine Zoology and Historiography of Biosciences. Ray is a leading expert on Anthozoa, principally *Actiniaria*, and has contributed to major advances in knowledge of their biology, taxonomy and systematics.

The external examiner of his momentous work was enthusiastic, declaring Ray's thesis to be '…a more than substantial corpus of published work … many of international or world-class standard'. I was lucky enough to meet Ray, and benefit from his sound advice, more than 40 years ago, when undertaking my PhD project on coccidiosis. Ray was then working at the Wellcome Foundation and was an internationally recognised expert on this protozoal parasite of chickens, indeed he was awarded his 'professional' ScD from the University of Cambridge in veterinary parasitology in 2008. Living locally, I was aware that Ray had bought the aptly named Norfolk House in which to hold the massive aquariums he needed to sustain his anemone cultures and enjoy his retirement! Congratulations to Ray on receiving this prestigious DSc.

Professor David Rollinson FLS

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