Royal Entomological Society

Volume 48(3) | 2024

Antenna

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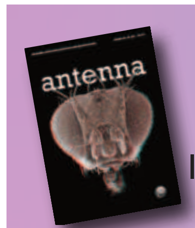

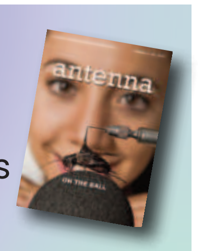

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Cover Picture: *Episyrphus balteatus* - Hoverfly homing in by Zach Haynes.

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Editorial

There is something of a conservation theme running through this issue of *Antenna*. V.P. Uniyal and Vandana Mehrwar relate how they were able to engage their university campus in India in a collaborative pollinator project, focusing on the often-overlooked solitary bees. Conservation of a different kind is recounted in the article on the earliest entomology books held in the Old Library at Cambridge, and Rose Pearson reviews some of the RES's own collection of books.

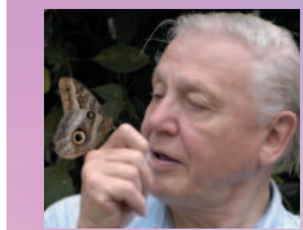
We have two letters from our President in this issue. Our outgoing President, Jane Hill OBE, has contributed much to the success of the Society during her tenure, and our incoming President is Professor Jane Stott, whose account of her work in insect conservation in Ireland is of great interest. This is an area in which the RES as a society has played a significant role, for example having established Invertebrate Link (Joint Committee for Conservation of British Invertebrates: please see https://www.royensoc.co.uk/invertebrate-link/ for details).

Stuart Reynolds contributes another excellent article in the 'Research Spotlight' series, this time on the longstanding (as in, millions of years') war between moths and bats. Peter Smithers' Honorary Fellow Interview victim is Rebecca Kilner, a Professor of Evolutionary Biology at Cambridge and a Director of the Cambridge Museum of Natural History. Rebecca delivered both the Verrall and Young Verrall lectures this year and is no stranger to being interviewed, having recently been the subject of the BBC Radio programme *The Life Scientific*. Peter has conducted more Honorary Fellow interviews than some of us have had hot mealworm dinners, and we are very grateful to him for his substantial and enduring contributions to *Antenna*. While this is Peter's final interview in the series there remain Hon. Fellows on the loose, so this is a good time to remind readers that we would now welcome someone to take over the baton.

The Society's outreach activities include providing awards to deserving entomologists, including scholarships to promising MSc students. The stories of this year's recipients (one of whom only heard of entomology relatively recently!) are revealed on pages 144 and 145, and make interesting reading. Meanwhile, Diptera, Hymenoptera, Lepidoptera and Odonata, as well as riverflies, silverfish and long-dead lacewings, are among the winning entries in the 2023 RES annual photography competition; they can be seen on pages 146 to 155. To borrow a contemporary idiom, people who enjoyed these images may also enjoy those depicted on the website https://www.insectweek.org/art-and-photography, where previous years' winning entries, going back to 2016, may be found.

Dafydd Lewis

Author Guidelines



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Antenna

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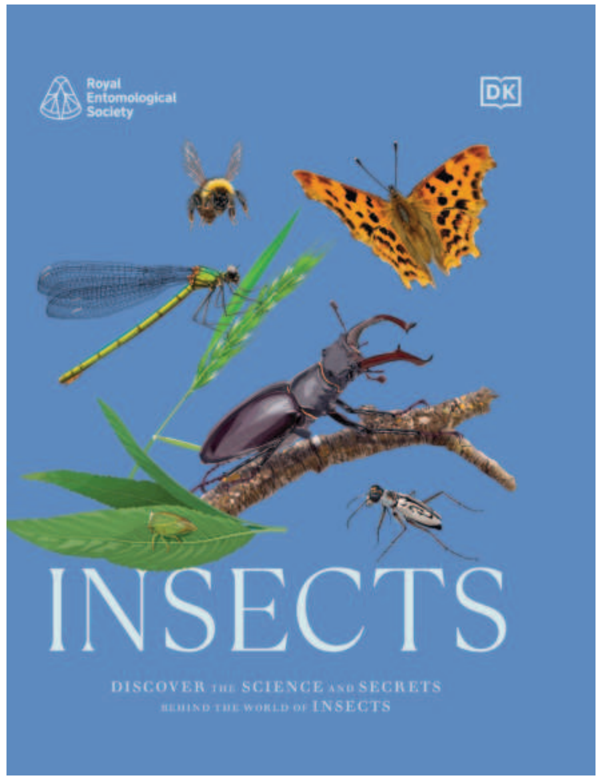
Letter from the outgoing President

It's been a great honour to be the RES President over the past two years. Time has flown by! I'm proud to have supported the Society in making such excellent progress in addressing its strategic aims. There is more to be done of course, but it's great to have been involved with a Society that is forward-looking and ambitious.

I have seen the Society go from strength to strength, increasing our membership (we now have more members than we have ever had), increasing the number of papers we publish in our journals, and arranging more great ways for members to network and talk about insect science. It's been a privilege to work with the RES staff team – you are fabulous! Many members may not be aware of what a great team they are, working hard to make the Society, and everything we do, better for everyone. And of course, a huge thank you to all our members who volunteer for the Society, and who lie at the heart of our successful Society and its activities. If you are not doing so already, I encourage you to get more involved with the Society – there are lots of ways of doing this - have a look at the Society's webpages to find out more.



Thank you to everyone who contributed to the book.

If I had to choose, the 'Presidential' highlights for me over the past two years have been the RHS Chelsea Flower Show (what an amazing opportunity to talk with people about the wonders of insects, and bringing insects into our gardens), visiting Daneway Banks (a joint RES event with the Botanical Society of the British Isles, on a glorious sunny June day when the Large Blues were flying), and working with Helen Roy (Past President), Allan Watt (trustee) and Emilie Aimé (Director of Publishing) to produce the book on 'Insects' with DK publishers. I think DK were surprised when we said we would go out to our members for content – and what an amazing response from members! Thank you to the 90 members who got involved and shared your amazing knowledge and enthusiasm for insects - I hope you are all proud of what we have achieved.

I was fortunate to learn from the wise advice and leadership experience of the previous President, Prof. Helen Roy, and it's now a privilege to hand over to Prof. Jane Stout, knowing that the Society is in safe hands (and for the first time we have a President based outside the UK). There are huge concerns about insect declines, especially declines of pollinators, and tackling this important issue is a key part of Jane's research, helping to improve environmental policy and practice. Good luck Jane, and I hope you enjoy being President as much as I have!

Jane Hill OBE
President
Royal Entomological Society

Letter from the incoming President

It's a real pleasure to be writing this as RES President. I am extremely honoured to be in this position, and very fortunate to be following in the footsteps of our wonderful outgoing President, Jane Hill, from whom I am already learning an enormous amount. I am grateful for all the work that Jane has put in as RES President, and that the RES has instigated a system of keeping the Past President on speed dial, as I try and learn the ropes.

It has been wonderful getting to know the RES staff and trustees over the past year – there is a fantastic team spirit, great optimism and genuine commitment from everyone I have met. I look forward to working with all of them, and all of you, the members, over the coming years. It's been great to watch from the sidelines as the 'Insects' book has been finalised, and I was thrilled to be able to contribute, along with so many of you.

I have been a Fellow of the RES since hosting the 2015 Annual Meeting in Trinity College Dublin, Ireland. It was a real pleasure to host Ento15, and I'm excited to be able to build on that experience now. I note that I am the first non-UK-based President and hope that I can bring a more international perspective to the Society's work too.

Although I started my entomological career in England, doing my PhD at the University of Southampton with Dave Goulson, on bee foraging ecology, I have been based in Ireland since 2001. I have continued to work on bees – on their ecology and conservation, as well as the benefits they bring to human society, its health and economy. I have been able to go beyond bees to insects more broadly, and the value of biodiversity and its restoration in general.

I co-founded the All-Ireland Pollinator Plan with Una FitzPatrick, who won the RES Award for Insect Conservation in 2022, and it has been wonderful to watch the Pollinator Plan, and people's fondness and fascination for pollinators, grow beyond all expectations. Every Local Authority on the island of Ireland has now signed up to the Plan, agreeing to manage public land in a pollinator-friendly way. In addition, several hundred businesses are taking actions for pollinators, along with countless community groups, sports clubs, schools and other organisations. Of course, actions that benefit pollinators often benefit other insects too, which given the biodiversity and climate crises we are currently experiencing has never been more important. I also co-founded Natural Capital Ireland, a not-for-profit organisation that promotes the value of nature, and works to support greater understanding of our dependencies and impacts on nature.

In my current role in Trinity, I am Vice President for Biodiversity and Climate Action, and lead the development and implementation of our Sustainability Strategy. One of the learnings has been the importance of partnership and effective communication. No-one has all the answers, but by taking an evidence-based approach, educating ourselves and others to increase understanding, sharing challenges and learnings, working together, and investing strategically in resources, we can make progress. These things align very closely with the strategic priorities of the RES, and I look forward to working on the next iteration of the RES's Strategy.

So, a massive thank you to Jane Hill for everything, and I look forward to my term as RES President, and to kicking it off by seeing many of you at Ento24 in Liverpool!

Prof. Jane Stout
RES President Elect

RESEARCH SPOTLIGHT

The noisy, deceptive ultrasonic world of moths and bats

Bats are a menace to night-flying moths

This Research Spotlight focuses on how moths defend themselves from predatory bats, not only by avoiding flying when bats are active, but adopting stealth body coverings, 'listening in' to bat calls, and even actively interfering with the predator's echolocation system. Astonishingly, some moths even send threatening messages to the predators using the bats' own ultrasonic hearing channel. Müllerian mimicry explains why many of these moths not only look alike but sound alike too. Fascinatingly, some moth species dishonestly parasitise the same communication system by emitting fake warning calls through Batesian mimicry. Welcome to the complicated and noisy adversarial world of bats and moths!

Stuart Reynolds
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Bats and moths

If you were a moth, you would be worried about bats, most of which are predators of nocturnal flying insects, many being moth specialists; more than 70% of insects consumed by the bat *Miniopterus schreibersii* are lepidopterans, with noctuid moths the most frequently consumed prey (Aihartza *et al.*, 2023). Individual bats can eat as much as 85% of their own body mass in insects every day (Kurta *et al.*, 1989). At peak hunting times, individual hawking bats may attack a moth as frequently as once every 4–5 s, with a success rate of 30–40% (Kalko, 1995). All of this shows that bats are a menace to night-flying moths.

Bats hunt in the dark; living in a sensory world that is dominated by hearing, they orient their flight, detect obstacles, and most importantly locate their insect prey by repeatedly emitting pulses ('clicks') of loud (~125 dB) ultrasonic sounds from their larynx, detecting reflected soundwaves using ears tuned to the frequencies of their own calls (Jones *et al.*, 2007). Ultrasonic echolocation for navigation and predation has proved a remarkably successful predatory strategy. It was probably already in use by the first bats, which appeared around 64 MY ago (Thiagavel *et al.*, 2018; Hand *et al.*, 2023); since then, bats have

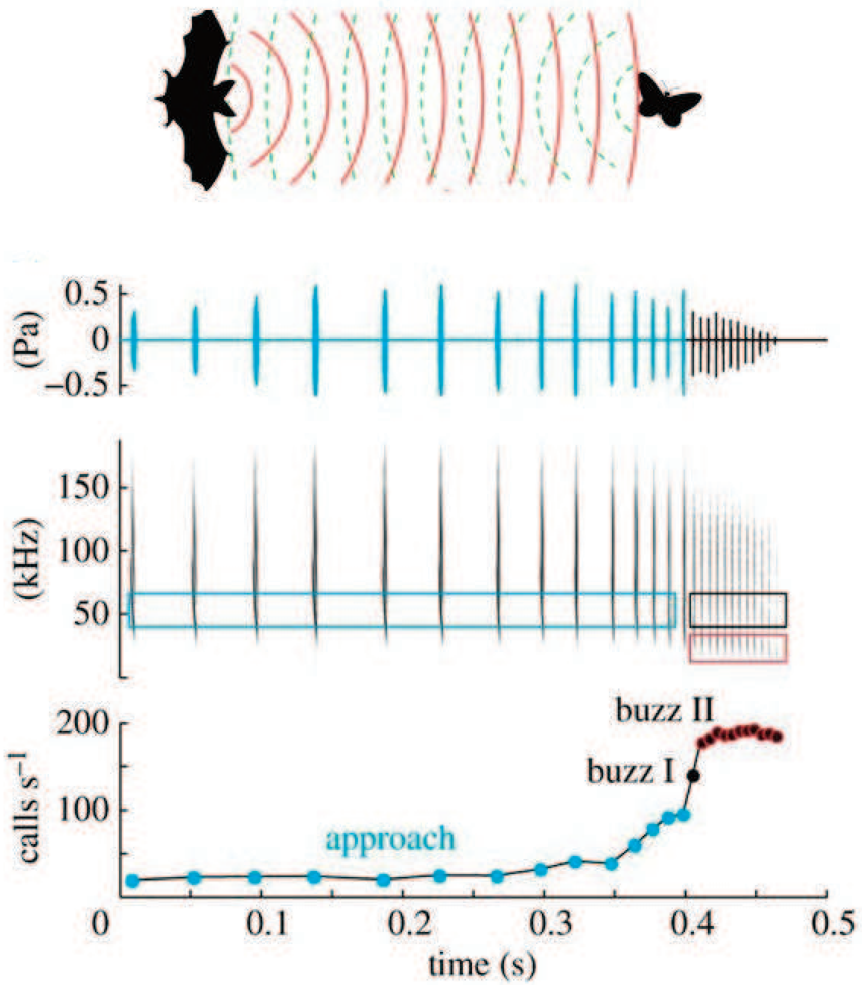

Fig. 1. Echolocation calls as a bat approaches and prepares to seize a moth. From top, cartoon of echolocation principle (red, bat-emitted calls; green, reflected sound from target); sound pressure oscillogram of emitted call; frequency distribution spectrogram; pulse frequency. Data for *Myotis daubentonii* from Ratcliffe *et al.* (2013), reproduced with permission.

proliferated so greatly that there are now more than 1,400 species, representing about 20% of all mammals (Hao *et al.*, 2023).

Key features of bat echolocation calls are illustrated in Fig. 1. A notable feature in almost all bats is the gradual increase in the calling frequency during the pursuit of a flying insect, culminating in a terminal 'buzz' during the final approach, when the frequency of ultrasonic pulses rises sharply to 100–200 calls s^{-1} (Ratcliffe *et al.*, 2013). This enables an observer with ultrasonic hearing to follow the progress and possible success of a bat's pursuit of a moth. Such observers include not only scientists, but also other bats, and (as we shall see) the moths themselves.

Defensive strategies: time of flight

The majority (~80%) of moths are nocturnal; the remaining ~20% of species have evolved to fly in the day, mitigating the nighttime predation pressure exerted by bats. Phylogenetic analysis indicates that although the earliest lepidopterans were probably diurnal, there was an early (250 MY bp) transition to nocturnality in the ancestor of all heteroneuran families (the vast majority of today's Lepidoptera). This switch was successful because it took place when there were no echolocating bats and enabled avoidance of daytime predators (lizards or dinosaurs, presumably – too early for birds), but with the advent of echolocating bats, nighttime risk increased sharply. Since then, more than 40 separate reversions to daytime activity have occurred, probably to allow moths to escape bats (Kawahara *et al.*, 2017). The best-known diurnal Lepidoptera are of course butterflies (Papilionoidea), but many other moths fly during the day. Even so, life in the light is not completely safe. Specialist avian predators of flying insects include swallows and martins (Hirundinidae), swifts (Apodidae), and Old World and New World flycatchers (respectively Muscicapidae and Tyrannidae), not to mention aerial predatory insects such as dragonflies (Odonata), robber flies (Asilidae), and hornets (Vespinae).

Acoustic invisibility

Since most moths remained active only at night, new strategies to avoid bats must have been needed by night-flying moths. One partial solution was to become less visible to bat echolocation calls by absorbing incoming ultrasonic sound, effectively reducing the distance from which moths can be 'seen'. This soundproofing relies on a unique asset of lepidoptera, the overlapping array of scales that covers the body and wings.

Lepidopteran scales have long been known to provide thermal insulation (Grodnitsky *et al.*, 1991) as well as visual camouflage or conspicuous display (Mouchet *et al.*, 2018); moreover, the easy detachability of scales makes moths slippery and hard to catch (Eisner *et al.*, 1964). We now know that moth scales also constitute a 'stealth' coating of soundproofing metamaterial, which strongly absorbs incident sound energy (average 67%) over a wide range (20–160 kHz) of ultrasonic frequencies (Neil *et al.*, 2020a). The ultrathin moth scales are

The moths that are most at risk of being predated by bats are also those best equipped to hear the calls of their enemies

individually tuned (Shen *et al.*, 2018) and broadband sound absorption is achieved by using a wide variety of scale architectures. Thoracic scales are more diverse in size and shape than wing scales and soak up ultrasound even more efficiently (Neil *et al.*, 2020b), directing attention away from the moth's vulnerable thorax and abdomen, towards the wings. Scale-mediated anti-bat soundproofing is more strongly absorbent in larger moths, which would otherwise be more easily detected by bat sonar (Simon *et al.*, 2023).

Ultrasonic sound absorption by scales is now known to be widespread in night-flying species right across the Lepidoptera (Simon *et al.*, 2023), but interestingly, the wing scales of butterflies (not under selection pressure from bats) are much less efficient absorbers of sound than those of nocturnal moths (Neil *et al.*, 2020a).

The ears of bats

A defensive strategy against bats used by many moths is to monitor the bats' own echolocation system. Almost 150 years ago, White (1877) speculated that some moths had anatomical structures that looked like ears, whose function was to detect bats. Early attempts to confirm this (e.g., Turner *et al.*, 1914) were frustrated by the fact that moths do not readily react to sound frequencies audible to humans. The key to progress was the realisation by Griffin *et al.* (1941) that bat clicks utilise short pulses in which almost all the acoustic energy is ultrasonic, i.e., they use sound frequencies higher than those that can be heard by humans (Fig. 1). Fifteen years later, Haskell *et al.* (1956) discovered that some moths have specialised ears (tympanal organs) that detect ultrasonic sound. They have a very simple structure with a small number of sensory neurons (derived from ordinary stretch receptors) embedded in a tightly stretched membrane over an air-filled cavity (Neil *et al.*, 2021); the range of frequencies of sound that stimulate these sense organs is similar to that used by echolocating bats (Fig. 2).

Today, we know that all the most diverse families of

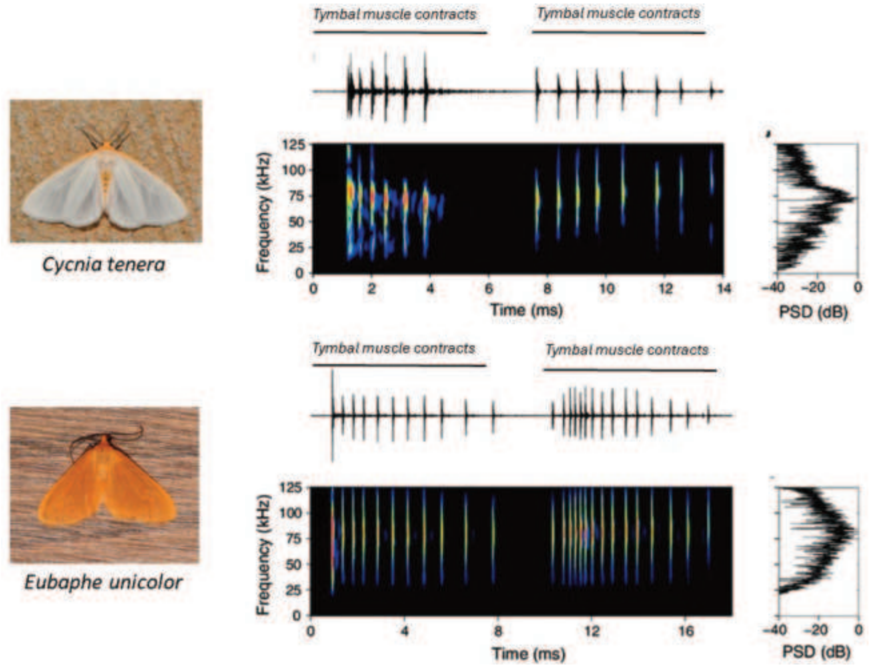

Fig. 2. Moth defensive sounds. *Top*, the Dogbane Tiger, *Cycnia tenera* (Arctiinae) emits aposematic clicks that convey an honest warning signal of its distastefuness. Below, the Orange Beggar, *Eubaphe unicolor* (Geometridae) produces a similar pattern of clicks that are Batesian mimics of those of *C. tenera* and other chemically defended arctiids, thus sending a dishonest warning signal. For each species, the figure shows (middle top) sound intensity oscillogram of the on- and off-phases of the tymbal sounds; (middle below) spectral composition; (right) power spectral density. Images: *C. tenera* by Andy Reago & Chrissy McClarren, CC BY 2.0; *E. unicolor* by Laura Gaudette, CC BY-SA 4.0.

Fig. 3. The Lucerne Moth, *Nomophila nearctica* (Crambidae). Image by Eugene Zelenko. CC BY-SA 4.0.

macromoths are able to hear. Moths equipped with ultrasonic ears have been shown to take evasive action (e.g., to fly erratically, or cease flying altogether) when they hear the predator's ultrasonic clicks. A nice example is the Lucerne Moth, *Nomophila nearctica* (Crambidae) (Fig. 3), which detects and avoids the calls of a hawking bat long before it is close enough to be targeted (Nakano *et al.*, 2018).

Being able to hear a bat echolocation call makes it possible for a moth to react evasively to bat calls, either by getting out of the way, or if not already airborne, staying on the ground (Nakano, 2015b). Both males and females of *Pseudaletia unipuncta* (Noctuidae) and *Ostrinia nubilalis* (Pyralidae) terminate mate-seeking behaviour when alerted to bat ultrasound (Acharya *et al.*, 1998).

Multiple independent origins of

ARTICLE

Fig. 4. *Melese laodamia* (Arctiinae), image by Stephen Easley, CC BY-NC.

lepidopteran tympanal ears are suggested by their various different locations on moth bodies. DNA-based phylogeny of Lepidoptera (Kawahara *et al.*, 2019) confirms this, indicating that ultrasonic ears have evolved on at least 9 separate occasions, all in the most derived clades. Surprisingly, however, Lepidopteran ears apparently first arose 77.6-91.6 MY ago, a period at least tens of millions of years before the first echolocating bats. This indicates that the immediate prompt for the evolution of moth ears was not (as previously assumed) selection pressure from bat predation, but to satisfy some other need, possibly avoiding non-bat animal predators (perhaps birds), or intraspecific sexual communication, which may have involved ultrasonic signals (see below). Clearly, however, once ultrasonic ears had been invented, they would have been strongly selected by bat predation.

Naturally, evolution has ensured that those moths most at risk from bats are also the best equipped to hear the calls of their enemies. Segura-Trujillo *et al.* (2024) used DNA methods to survey moths caught by 17 species of bat in Mexico; they note that the families of moths most often eaten by bats all possess ultrasonic ears. That bats eat mostly eared moths is not because they are more vulnerable (as we shall see, they are actually less at risk), but simply because these are the species that fly in the dark. Moths without ears are not only less diverse, but they are also more diurnal, presumably being excluded from the nighttime environment by the threat from bats.

Passive defensive sounds of moths

Many moths go beyond mere avoidance and reply to the predators' calls by emitting their own ultrasonic signals. That some arctiid moths emit audible clicks when disturbed was first noticed by Carpenter (1938), the sound being produced by paired abdominal air-filled cavities underlying a region of thin surface cuticle, subsequently termed 'tymbal organs' by Hinton (1955). It was then discovered by Blest *et al.* (1963) that in the Central American arctiid, *Melese laodamia* (Fig. 4), the clicks produced by the moth's tymbal organ are bursts of 1-20 sound pulses of substantial ultrasonic content, with most energy content being at 30-90 kHz. Although the best studied examples are tiger moths (Arctiinae), the production of ultrasonic calls by night-flying lepidopterans is widespread across the order. Moths from other families, e.g., Geometridae (Corcoran *et al.*, 2014a) and Sphingidae (Barber *et al.*, 2013) also have tymbal organs and use them to make similar sounds with a proven defensive role, and it has recently been estimated that as many as 20% of Macroheterocera (higher moths) emit ultrasonic sounds (Barber *et al.*, 2022); this would represent more than 30,000 species of moth.

What is the function of these bat-evoked clicks? Many insects produce defensive sounds in the presence of predators (Low *et al.*, 2021). The evoked noises (not necessarily ultrasonic) are startling to the predator and may potentially cause it to miss its target. They are effective as anti-predator devices simply because they are unexpected, loud and distracting. The visual equivalent of such sounds is usually called a 'startle display' or deimatic behaviour (Drinkwater *et al.*, 2022), in which a previously concealed bright colour is suddenly revealed on disturbance; such displays occur in many phasmids, mantids and grasshoppers, as well as notably in lepidopterans such as eyed hawk-moths that display brightly coloured areas of their cuticle (Umbers *et al.*, 2015a).

It is an attractive idea to suppose that the ultrasonic defensive sounds of moths may have first evolved as deimatic deterrents to predation by bats. Surprised by the sudden noise, we may suppose that the startled bat would be distracted and allow the insect to escape. But Corcoran *et al.* (2014) were sceptical that startle is ever a primary defensive mechanism against bats. They reported that startle responses are observed when first introducing arctiid moths to bats during experimental training regimes, but the predators learn quickly not to be fooled in this way. Only 1-3 trials are required for the bats to habituate to recorded clicks (Bates *et al.*, 1990) and a single trial is enough when the ultrasonic clicks come from a real moth (Barber *et al.*, 2007).

But I think that we should not abandon the idea that the first-evolved moth defences against bats may originally have been deimatic in nature; trained bat experiments of the type just described may not be a realistic model of natural bat behaviour. The missing feature is the presence of other bats. In real life, hawking bats are almost always within hearing range of others, not necessarily conspecifics, and competition for prey may be fierce. In the dark, the best evidence that an insect is nearby is the accelerating pulse train of another bat as it closes in on its intended prey. Bats are known to listen actively to the calls of their rivals, competing to be first to seize the hapless insect (Lewanzik, *et al.*, 2019). Under these more challenging conditions, the evoked moth ultrasonic calls may be more distracting than when only one bat is present at a time. Nevertheless, however the first bat-evoked ultrasonic clicks of moths arose, it is certain that early in their evolution they acquired additional features that enabled them to outwit questing bats.

Aggressively defensive sounds

Another effective way for moths to ward off bat attacks is actively to interfere with the predator's echolocation system, by flooding the bat's auditory input of reflected ultrasonic sounds with the moth's own defensive calls. Because the bat's echolocation system relies on the estimation of distance from target by measuring the duration of the gap between the time at which a sound pulse is emitted and the time of its return as a reflected echo, the moth can 'jam' the system by emitting a loud sound of the right frequency to be heard by the bat during this brief 'empty' return phase (generally 1-2 ms) in-between the repeated pulses of the bat's echolocation calls. The theoretical possibility of 'jamming' interference of this kind was first postulated by Fullard *et al.* (1979) and was only much later shown to actually occur in Grote's tiger moth, *Bertholdia trigona* (Arctiinae) (Fig. 5), whose defensive clicks are effective in jamming the echolocation system of the Big Brown Bat, *Eptesicus fuscus* (Corcoran *et al.*, 2009). Because of the need to measure the return echo time, the echolocation calls of most bats are made up mostly of periods of silence that are briefly interrupted by pulses of ultrasonic noise, even during the accelerating final 'buzz' [i.e., these calls have a 'light duty cycle' (LDC), in which <20% of the signal's cycle is occupied by ultrasound]. Unlike the pursuing bat, however, the insect has no need to leave empty sound space, and some moths have evolved to produce 'high duty cycle' (HDC, >20%) calls, in which ultrasonic pulses are both longer and separated by relatively little 'empty' time. Moth calls of this type are very frequently made only as the bat approaches closely and are accompanied by evasive action.

In another study (Fernández *et al.*, 2022), recorded *B. trigona* defensive calls were experimentally altered by progressively increasing the length of ultrasonic pulses to leave shorter gaps, thus increasing the duty cycle from 0% to 100%. When these synthetic clicks were played back to bats during a tethered capture protocol, the ability of the bats to catch moths declined steadily as

Fig. 5. Grote's Bertholdia, *Bertholdia trigona* (Arctiinae). Image by Christian Schwartz, CC BY-NC.

the % duty cycle increased; there appeared to be no threshold value for jamming. Interestingly, as pulse width increased, the duration of the terminal buzz also increased, as though the bats were finding it more difficult to determine the location of the moth.

The jamming story as told so far is almost certainly more complicated than this. Some bats, like horseshoe bats, *Rhinolophus* spp., always use HDC echolocating pulses in which the pulses are longer, with shorter intervening gaps, than are used by LDC bat species. The reason for this is not known, but it looks as though an HDC echolocation system is harder for the moth to evade or interfere with, and two species of crambid moth, *Conogethes punctiferalis* and *Ostrinia furnacalis*, showed lower hearing thresholds for detecting bat sounds when the pulse duration of ultrasonic pulses was longer, meaning that they would be able to detect the presence of these bats when they are farther away.

At first sight, we might speculate that all moth anti-bat calls ought to use HDC rather than LDC clicks, but in fact most moth anti-bat calls are of the LDC type. This isn't because HDC anti-bat calls are more expensive to make; their cost is insignificant (Corcoran *et al.*, 2014b). It may be that to use HDC calls would make the moths more detectable at a distance; it may also decrease the moth's ability to monitor the signals of the bat itself. This could be disadvantageous, especially when there are other bats nearby. Moreover, it may not be necessary for chemically-defended moths to use HDC signals; a highly distasteful arctiid (*Creatonotos transiens*), which uses only LDC ultrasonic signals, is still able to deter HDC-using horseshoe bats, presumably because it is recognised as being distasteful (Hu *et al.*, 2023).

Moth ultrasonic clicks and sex

A complication to this story is that some moths emit ultrasonic sound for the additional purpose of sexual signalling. Male moths from several families use very low amplitude ultrasonic 'whispers' to communicate with females at very close range (in the order of 1 cm), perhaps because this reduces the risk of the call being eavesdropped by a bat (Nakano *et al.*, 2009;

Fig. 6. Spindle Ermine moth, *Yponomeuta plumbella* (Yponomeutidae). Image: Hectonichus. CC BY-SA.

Takanashi *et al.*, 2010). Ermine moths, *Yponomeuta* spp. (Fig. 6) are examples of this (Mendoza Nava, *et al.*, 2024). Ultrasonic communication of this kind is produced not by tymbal organs, but by flexing specially modified areas of wing cuticle. These quiet ultrasonic sexual signals may occur much more widely than has so far been realised (Nakano *et al.* 2015b). To be useful, ultrasonic sounds have to be heard, and so perhaps these amorous 'whispers' may explain why moth ultrasonic ears evolved in the first place.

Some loud ultrasonic anti-bat sounds produced by tymbal organs in night flying macromoths also appear to have sexual significance. The HDC clicks produced by *B. trigona* males are required for successful mating, females of this species preferring to mate with males producing calls with higher duty cycles (Fernandez *et al.*, 2020). This appears to be an example of sexual selection of a costly heritable trait (ultrasonic sound production). Noisy male moths are telling choosy females that they can produce high quality bat-deterrent signals, indicating their desirability as reproductive partners. This raises the question of whether the ultrasonic acoustic signals of moths might in some cases be subject to a trade-off between mating competitiveness and the ability to deter bats.

The aposematic warning sounds of tiger moths

The most intensively investigated acoustic defences of moths against bats are those that are produced when the moth takes the offensive, conveying to a potential predator the message "Don't eat me, or you'll be sorry". Signals like this can be described as 'warning sounds' and are the acoustic analogue of the more familiar 'warning colours' (Caro *et al.*, 2019); both are advertisements which serve to inform potential predators that the intended victim is protected by distasteful or toxic chemicals, such that any attempt to attack and eat the prey species is likely to prove an unpleasant, probably costly experience. The original idea of warning coloration, first announced in a private letter to Charles Darwin and then published anonymously, was that of Alfred Russel Wallace (1867). Warning sounds and colours are both now recognised as examples of the general class of 'aposematic signals' (Poulton, 1890), which have been studied intensively by both empirical and theoretical evolutionary ecologists (see Ruxton *et al.,* 2018). Although moths from other families also employ acoustic warning signals, aposematic sound production is particularly well-developed among tiger moths (Arctiinae) (ter Hofstede *et al.*, 2016). Many tiger moth larvae feed on toxic plants and accumulate toxic pyrrolizidine alkaloids, cardenolides and some other minor chemicals from their food. Additionally, several biogenic amines including histamine and acetylcholine are synthesised *de novo* (Weller *et al.*, 1999). As is so often the case, these chemicals are highly aversive to many animals, and as they are retained by the insect during larval, pupal and adult stages, all stages are distasteful to predators.

Potential predators are notified of the insect's nasty taste by means of aposematic warning signals. Many arctiids are protected in this way both as larvae, which are often both extremely hairy and also brightly coloured, and as adults, which are frequently conspicuously patterned and coloured. An example is the Ornate Bella Moth, *Utetheisa ornatrix* (Fig. 7). Sometimes adult warning colours are readily observed both when the moth is active and at rest, but in this species (and others) the conspicuous aposematic body colour is concealed under the wings and revealed only when the wings are spread in a deimatic display.

Because bats are not visual predators, the distastefulness of arctiid adults must be communicated to the nocturnal predator in some other way. Examples of tiger moths that emit aposematic warning sounds include the Banded Tussock, *Halysidota tessellaris* (despite its name, an arctiid) and the Isabella Tiger Moth, *Pyrrharctia isabella*. That their ultrasonic clicks protect these moths was shown by Dunning *et al.* (1965), who replayed recorded moth sounds while offering a tasty insect (a *Tenebrio* mealworm) to captive bats, which

Don't eat me or you'll be sorry

were deterred by the sounds from capturing and eating the reward. By way of a control, replaying bat clicks (or playing no sound at all) had no such deterrent effect.

These results strongly suggest that the deterrent effect of arctiid anti-bat clicks is due to aposematic communication, but don't prove it (a deimatic response, for example, is not ruled out). However, forty years later, using a different arctiid, the Milkweed Tussock Moth, *Euchaetes egle*, Hristov *et al.* (2005) used diet manipulation (i.e., not feeding on poisonous milkweed) to produce moths that were not chemically defended, as well as simple surgery to remove the tymbal organs so that no ultrasonic clicks could be produced. Naïve Big Brown Bats, *Eptesicus fuscus,* were trained to take palatable non-clicking

Fig. 7. Ornate Bella Moth, *Utetheisa ornatrix* (Arctiinae), image by Laura Gordette, CC BY-SA 4.0.

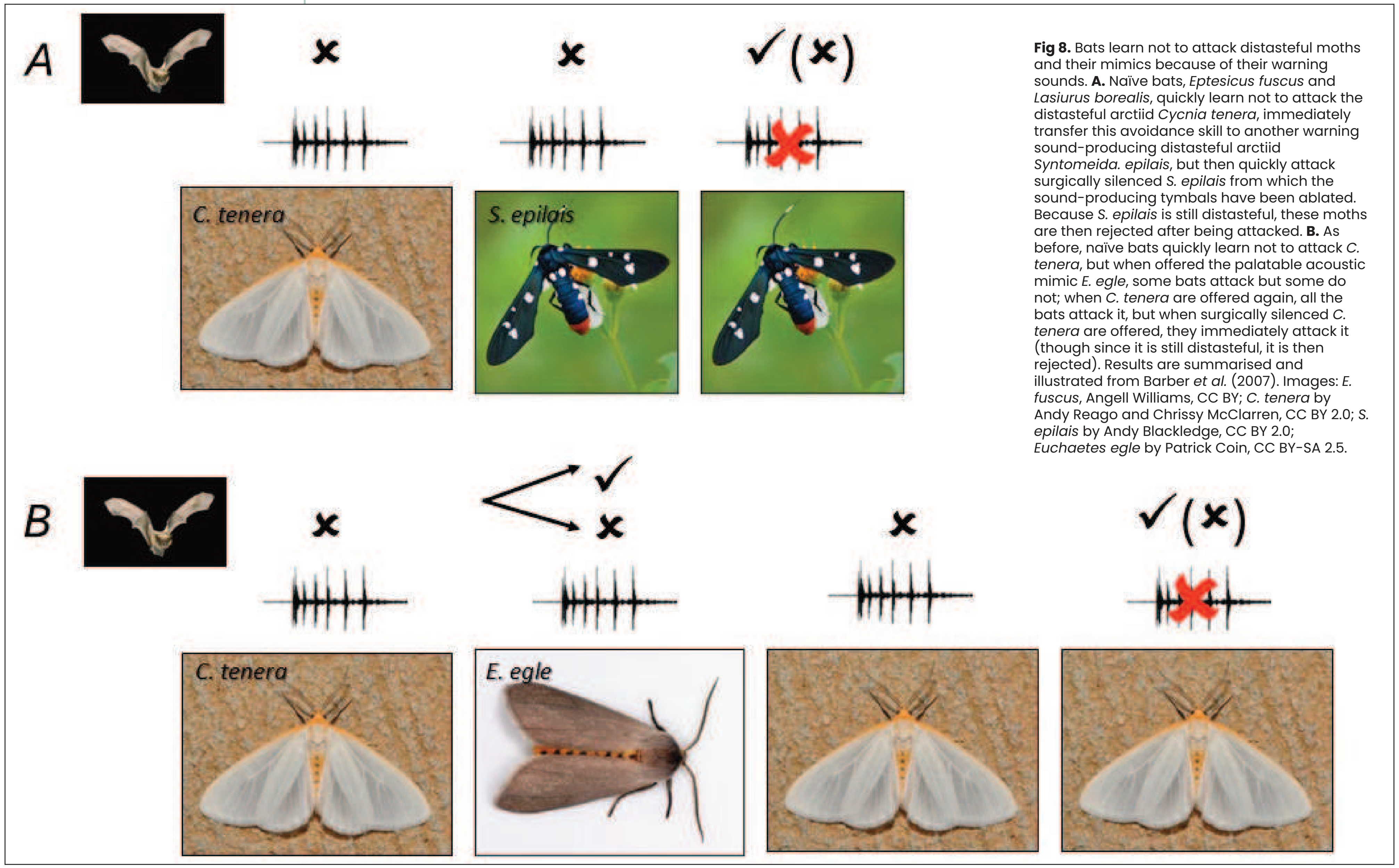

Fig 8. Bats learn not to attack distasteful moths and their mimics because of their warning sounds. **A.** Naïve bats, *Eptesicus fuscus* and *Lasiurus borealis*, quickly learn not to attack the distasteful arctiid *Cycnia tenera*, immediately transfer this avoidance skill to another warning sound-producing distasteful arctiid *Syntomeida. epilais*, but then quickly attack surgically silenced *S. epilais* from which the sound-producing tymbals have been ablated. Because *S. epilais* is still distasteful, these moths are then rejected after being attacked. **B.** As before, naïve bats quickly learn not to attack *C. tenera*, but when offered the palatable acoustic mimic *E. egle*, some bats attack but some do not; when *C. tenera* are offered again, all the bats attack it, but when surgically silenced *C. tenera* are offered, they immediately attack it (though since it is still distasteful, it is then rejected). Results are summarised and illustrated from Barber *et al.* (2007). Images: *E. fuscus*, Angell Williams, CC BY; *C. tenera* by Andy Reago and Chrissy McClarren, CC BY 2.0; *S. epilais* by Andy Blackledge, CC BY 2.0; *Euchaetes egle* by Patrick Coin, CC BY-SA 2.5.

moths on the wing, and then offered experimental *E. egle* moths. The bats learned in only one or two trials to avoid intact *E. egle* moths but were unable to learn to avoid either distasteful moths that did not click, or those that clicked but did not contain unpalatable chemicals, thus establishing the link between distastefulness and warning sounds. *E. egle* produces HDC clicks capable of interfering with bat echolocation signals, so that it was theoretically possible that at least some of the deterrent effect of moth clicking could have been due to jamming. The fact that in the first day's trials, the bats initially captured and then rejected control moths (i.e., those that were chemically protected and also retained normal sound production) suggests that any jamming effect of this species is either ineffective or perhaps has a lesser effect secondary to that of aposematic signalling.

It's all very well doing experiments on tethered moths, but do these ultrasonic defences work as well when both the bat and the moth are free to fly without restraint? Dowdy *et al.* (2016) used multiple infra-red cameras to reconstruct the flight trajectories of moths and bats in 3-D space. As expected, they found that moth ultrasonic calls were protective; two ultrasonically signalling moths, *Pygarctia roseicapitis* (Arctiini) and *Cisthene martini* (Lithosiini), were captured significantly less often by bats if they were able to produce ultrasonic clicks, as compared with those that had been surgically prevented from doing so. The bats actively avoided the moths that emitted defensive clicks. Interestingly, the calling strategies of the two moths in response to the approach of bats were different. *P. roseicapitatis,* which is less toxic, responded earlier to bat calls, and frequently paired its clicks with evasive 'diving' behaviour. By contrast, the more distasteful species, *C. martini* was more 'nonchalant', responding with clicks to bats later in the bat's pursuit sequence, and using evasion in fewer interactions.

Warning sounds and warning colours

Most moth species producing aposematic sounds are also conspicuously coloured in both sexes as adults. Why do these moths go to the trouble of advertising their distastefulness using two different communication channels at the same time? It may be that the two different signalling modalities each have their own particular benefits. Most obviously, their benefits might be partitioned between day and night, since visual warning signals are useful in the day and are directed against predators that use vision to recognise prey, while ultrasonic aposematic sounds are only useful in deterring those predators that can hear them. Even in moths that only fly during the day, warning colours may still be useful to an immobile moth in deterring non-bat predators that seek out cryptic insect prey.

Acoustic warning signals have some advantages over other sensory modalities. These include the advantage to the prey of being audible over long distances, allowing long-range deterrence and avoiding the possible cost of being tasted and rejected. By the same token, the predator avoids the opportunity cost of wasting time on close inspection of prey. Additionally, warning sounds are transient, and thus can be directed at potential predators only when necessary (i.e., when the prey species is threatened); this reduces both the risk associated with producing the warning sound of inadvertently attracting the attention of predators not already present, and also the energetic cost of making the sound.

Mimicry: honest and dishonest warning sounds

Right from the start, much of the interest from evolutionary theorists in the topic of aposematic communication has concerned the existence of species which appear to mimic the morphological appearance of others, a topic first explored by H.W. Bates (1861) who recognised that models for mimicry are almost always actually distasteful to a wide range of predators, while those mimicking them are impostors, species that benefit from reduced predation, even though they are actually perfectly edible. This is what we call 'Batesian mimicry', in which the mimic species gains a selective free ride, not merely benefitting from a reduced rate of mortality on account of its dishonestly displayed warning coloration, but also gaining fitness through its avoidance of the expense of manufacturing or sequestering the advertised (but non-existent) toxic defences.

It was quickly recognised that the benefit to the mimic of such coloration is dependent on how quickly and completely predators learn to avoid both the model and the mimic through encounters with the distasteful species; under this condition, the persistence of mimicry in the wild must depend on the relative rarity of impostor mimics compared to the frequency with which the truly distasteful models are encountered. For an extended

Are tiger moth warning sounds honest?

review of these ideas, see Ruxton *et al.* (2018).

It is thus very satisfactory to find that just like warning colours, warning sounds appear to be highly susceptible to mimicry. An excellent example is the Orange Beggar, *Eubaphe unicolor* (Geometridae) (Corcoran *et al.*, 2014) (Fig. 8). The ultrasonic calls of this insect are very like those of arctiids, and since this moth is not chemically protected, this appears to be a case of acoustic Batesian mimicry. Appropriately, this geometrid moth even looks like an arctiid, to the extent that it was initially mistakenly identified as such by Corcoran *et al.* (2010), so that it is a visual Batesian mimic too. Because the sound-producing tymbal organ in this moth is located in the prothorax, rather than in the abdomen as in arctiids, there's no doubt at all that this moth's aposematic sounds are not homologous with those of its arctiid mimetic model.

In general, warning colours show a pronounced tendency to converge on a small number of models through both Batesian and Müllerian mimicry (Pinheiro, 2011). Is the same true of warning sounds? In principle, this is a difficult question to answer. When we say that one aposematic colour pattern is 'similar' to another, we are performing a sophisticated visual analysis using our own very complex system of colour and pattern recognition. It would be presumptuous of us humans to suppose that an animal predator would see the colour in the same way. But in the case of the ultrasonic warning sounds of moths, we can't hear them at all. Two methods are available to tackle this problem. First, we can make recordings of large numbers of sound-emitting moths and use Artificial Intelligence (AI) to assign the calls into groups. Barber *et al.* (2022) did this for a community of 33 moth species from Ecuador; they found that the sounds could be regarded as 5 different groups, which they presumed to be Müllerian and Batesian mimicry rings.

Second, and to me even more convincingly, we can ask the bats what they think about them. Barber *et al.* (2007) trained hand-reared naïve bats using a two-part training regime in which each bat was first offered a distasteful arctiine moth, *Cycnia tenera*, which it rapidly learned to avoid. It was then offered a second unpalatable species of arctiine, the Polka Dot moth, *Syntomeida epilais*, a species that has a completely different appearance, but which utilises the same food plants and accumulates the same unpalatable chemicals as *C. tenera.* The bats immediately extended their learned avoidance behaviour from *C. tenera* to include *S. epilais* (Fig. 8A). That this was entirely explained by the ultrasonic signals emitted by these two species was shown by then offering to the same trained bats, individual *S. epilais* moths that had been surgically silenced by interfering with their tymbal organs. These moths were quickly attacked, but because they were distasteful, were then dropped. Both moths emit similar ultrasonic warning sounds and the researchers concluded that the rapid transfer of bat avoidance behaviour was due to acoustic Müllerian mimicry. But the experiment also shows that, to be maintained, such mimicry needs to be supported by the underlying chemical defences.

Barber *et al.* (2007) used the same experimental set-up to look at the transfer of learned bat avoidance behaviour from the same distasteful model species, *C. tenera*, to a different arctiid, *Euchaetes egle,* which had been fed under a regime that rendered it non-toxic and palatable. The two species both produce warning sounds, which to humans look similar on the computer screen. As in the previous experiment, when naïve bats were initially trained on *C. tenera*, they rapidly learned not to attack it. When then offered the palatable but ultrasonically similar *E. egle*, some bats quickly learned to attack and eat it, but some did not. This implies that the warning sounds of the two moths are sufficiently similar to be confused by at least some bats. When *E. egle* was again replaced in the training regime by the distasteful *C. tenera*, all the bats quickly returned to avoiding it. Finally, when they were offered surgically silenced *C. tenera* moths, all the bats immediately returned to attacking it, even though it was distasteful and so could not be eaten (Fig. 8B). This shows that *C. tenera*'s ultrasonic warning signal can be the subject of Batesian mimicry by a 'similar' fake warning signal that is in fact empty of meaning.

Fascinatingly, tiger moth aposematic sounds can be mimicked by insects that aren't even moths. Gough *et al.* (2024) have shown that seven species of tiger beetles (Cicindelidae) that fly at night respond to playback of bat sonar calls by producing their own ultrasonic warning sounds, with multiple parameters of the calls being highly similar to those of arctiids. These beetles were readily eaten by bats in handheld feeding trials, but it isn't yet known whether the sounds would protect them from being taken in flight. By contrast, 12 cicindelid species that fly only in the day did not produce warning signals. Tiger beetles, of course, don't have moth-like tymbal organs, and produce ultrasonic clicks using their wings.

Costly aposematic signals

Evolutionary theorists have devoted much attention to aposematism, asking under what conditions warning signals can be considered to represent 'honest' signalling (Summers *et al.*, 2015). It is conventional wisdom that, under most conditions, the best indicator of a signaller's honesty is that the signal is intrinsically costly to its own fitness (Johnstone, 1995). Are tiger moth warning sounds costly, and to what extent do bats rely upon them? Again, we find that the best thing to do is to ask the bats. Although the metabolic cost of actually producing clicks seems to be negligible (Corcoran *et al.*, 2014b), arctiid warning signals are clearly costly to fitness in the sense that they inevitably make the prey more apparent to the predator. Despite emitting warning signals, tiger moths are quite likely be attacked by naïve bats that have yet to learn what the warning signal means (Barber *et al.*, 2007). Even though the manhandled insect is subsequently dropped, there is considerable chance of harm to the moth. When Ratcliffe *et al.* (2005) experimentally prevented *C. tenera* moths from issuing warning sounds, so that they were captured but then dropped by bats, 25% of the moths were seriously damaged.

These considerations don't enable us to predict the actual cost of signalling in a real field population of intact ultrasonically active moths, but the probability of harm must surely be greater than zero. According to evolutionary signalling theory, then, bats have good reason to think that the moths are being honest when they warn the bat that it may be sorry if it eats them. But the same experiments by Barber *et al.* (2007) also show that bats learn quite quickly when a palatable moth is pretending to be distasteful. This appears to mean that bats *mostly* trust the warning signals of night-flying moths, but every now and then they check, just to be sure.

Acknowledgements

Thanks to the RES Librarian Rose Pearson for (as always) being super-helpful in tracking down obscure nineteenth century papers in foreign languages, and to John Ratcliffe (University of Toronto, Canada) and Aaron Corcoran (University of Colorado, USA) for sending PDF copies of their papers. I especially thank Jim Costa (Western Carolina University, USA) for discussions about the origin of the warning coloration idea.

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‘Theatre of Insects’: an exhibition of rare entomology books in the Old Library, Queens’ College, Cambridge

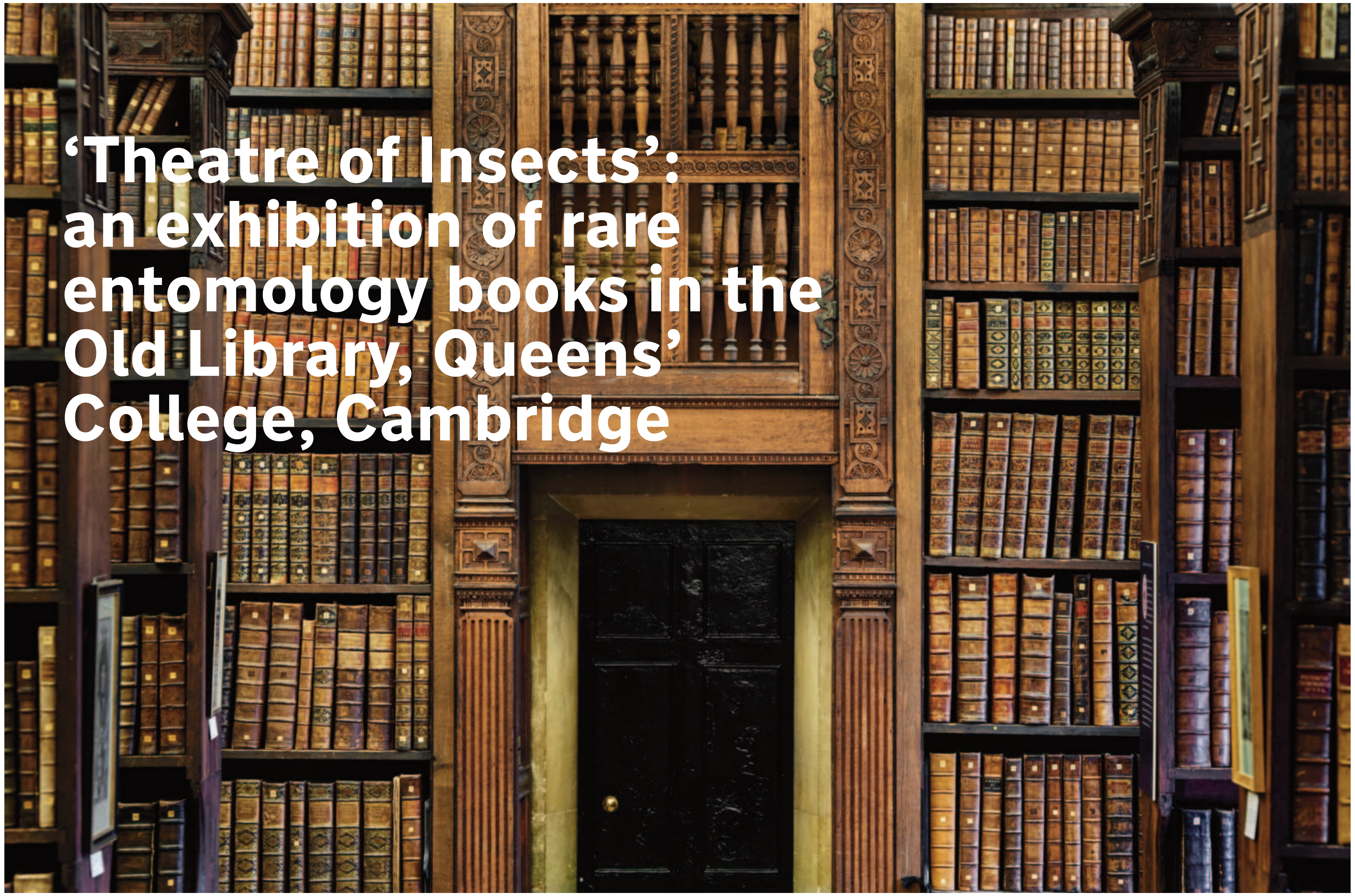

Figure 1. The Old Library in Queens’ College, Cambridge © Sara Rawlinson Photography.

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Amidst the hush of the ancient bookshelves of Queens’ College Old Library, a fear of insects has long been ingrained and pest management has been an important concern across the centuries. Established in 1448, it is the oldest college library at the University of Cambridge in continual use that retains its original location (Fig. 1). The provenance of many items in its collection of 30,000 early printed books includes marks of use by generations of former owners, with notes added in faded ink, inscriptions written on the front page, and idle doodles captured in the margins. Similarly, historic insect infestations have left their own ownership marks, leaving distinctive holes and damage trails across the fragile paper (Fig. 2). Book lice, carpet beetles, furniture beetles, deathwatch beetles and silverfish (Fig. 3) are among the arthropods that can severely damage books.

However, the development of microscopes, pioneered in the seventeenth century by scholars such as Antonie van Leeuwenhoek, Jan Swammerdam, Robert Hooke, and others, allowed natural philosophers to magnify the miniature insect worlds that exist in such profound proximity to human life, publishing books collected by Queens’ scholars that would become the foundations of the field of entomology. The library, therefore, hosts an array of perspectives on the ever-evolving relationship between humanity and insects.

In the summer of 2023, Professors David Sattelle (UCL, UK) and Kazuhiko Matsuda (Kindai University, Japan), approached Queens’ librarians about the possibility of an exhibition of rare books tracing the history of entomology, to accompany an international workshop entitled ‘Control of human disease vectors, pests, and parasites.’ The librarians were happy to facilitate this display, and the exhibition, held in Queens’ medieval library, was shown to over 60 workshop participants, and hosted over 200 visitors and members of the public over a two-week period. Some of its highlights are the subject of this article.

The first ever substantive European book on insects, *Insectorum sive Minimorum* (Fig. 4) was published in 1634, long after the death of the four contributing authors, Thomas Moffett, Edward Wotton, Conrad Gessner and Thomas Penny (a former student at Queens’ College, Cambridge). Most of the drawings in this landmark volume are by Penny, an authority on plants and animals, and the book is a landmark study of the entomological world and boasts a fascinating array of woodcut engravings of specimens, such as the Swallowtail butterfly (Fig. 5). Another stunningly visual example is the *Historia naturalis de insectis*, part of a six-volume encyclopaedia by John Jonston, a Polish scholar (Fig. 6). It is particularly notable for its splendid illustrations by Matthias Merian Jr., a member of one of Basel’s patrician families. His half-sister, Maria Sibylla Merian, was one of the first female entomologists (see *Antenna* 47(1) 19), and the author of several groundbreaking works on butterflies and silkworms. In 1699, she undertook a pioneering scientific expedition to South America, studying the insects of Suriname.

The exhibition engaged closely with the conference’s study of pests and vectors, showcasing a variety of texts relating to the impact of insects on human development, including an inexpensive instruction manual for aspiring gardeners. It was published by Gervase Markham in 1614, not in scholarly Latin but in English, and therefore accessible to individuals from a variety of backgrounds. In this book, Markham teaches gardeners how to control particular pests, such as greenflies, gnats, and ‘pismyers’, or ants (Fig. 7). Originating in Middle English, ‘pismire’ was the rather crude word for ant, referring to the smell of anthills caused by formic acid. Over 250 years later, another Queens’ graduate, R.J. Tillyard, published *The Insects of Australia and New Zealand* (Fig. 8), and his seminal work also seeks to advise on the biological control of pests, particularly the introduction of *Aphelinus mali*, a tiny North American wasp, into New Zealand’s orchards to control populations of Woolly Apple aphids.

Humans have long been fascinated by the origins of insects, and the prevailing theory for much of human history was that of spontaneous generation, or Aristotelian abiogenesis, the belief that living creatures could arise spontaneously from decaying matter. Marcus Vitruvius Pollio’s *De architectura libri decem* (the sole surviving treatise on architecture from antiquity) acknowledges the belief in spontaneous generation, with advice for the building of libraries. Vitruvius notes that bookworms could emerge due to excessive wind, and so, to thwart their generation, he advises orienting libraries toward the east to harness morning light, while avoiding south or west orientations to prevent offensive weather.

Some early entomologists challenged these ideas, with fascinating consequences for the development of modern science.

Figure 2. Insect damage to a 16th century edition of a treatise by Cornelius Tacitus, entitled *Historia augusta actionum diurnalium* [Histories] (Basel, 1519) [F.1.4].

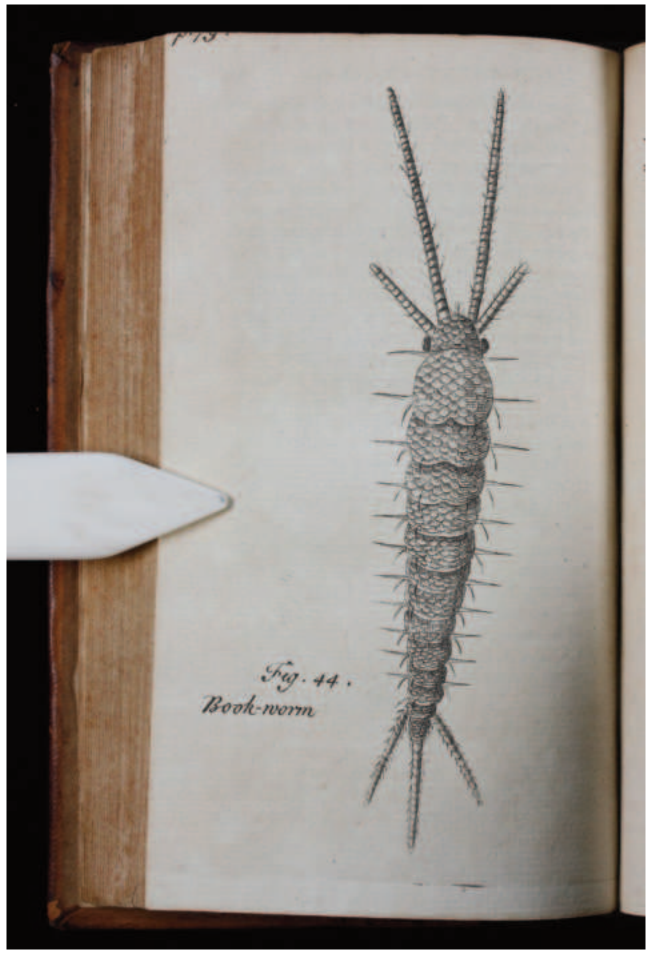

Figure 3. The silverfish, *Lepisma saccharina*, a common source of book damage, is shown in a figure from Thomas Boreman's *A description of a great variety of animals and vegetables* (London, 1736) [G.21.19].

Figure 4. The cover page of the first substantive European book on insects, co-authored by Thomas Moffett, Edward Wotton, Conrad Gessner and Thomas Penny, titled *Insectorum sive Minimorum animalium theatrum* [*Theatre of Insects*] (London, 1634) [F.9.17].

A pocket-sized book, *Experimenta circa generationem insectorum* [Experiments on the generation of insects] (Amsterdam, 1671) [H.17.17] (Fig. 9), written by Francesco Redi and first published in Italy in 1668, was the first to effectively confront this belief He cautiously framed his findings in alignment with theological tradition to avoid conflict with the Catholic Church, and his adage '*omne vivum ex vivo*' ('all life comes from life') echoed biblical passages. Redi's research examined ectoparasites, particularly ticks, including deer and tiger ticks. His treatise meticulously described over 100 species of parasite, and his innovative use of controls in experiments laid the foundations for modern biological research. In one engraving in this volume, Redi demonstrates that flies can lay their eggs in fruit, which hatch and become maggots, but are not generated from the fruit itself.

By revealing the processes of the insect life cycle, it was possible to challenge a variety of superstitions and beliefs, as in Thomas Browne's *Pseudodoxia Epidemica*, first published in 1646, arguably one of the first examples of scientific journalism. In the book, Browne examines the notion of the 'Dead-Watch', a clicking sound like that of a timepiece that was believed to foretell the death of a household member. Browne reveals that the noise is caused by "a little sheath-winged gray

Figure 5. Thomas Penny's illustration of the Swallowtail butterfly *Papilio machaon*. Note that he depicts the adult and larval form together.

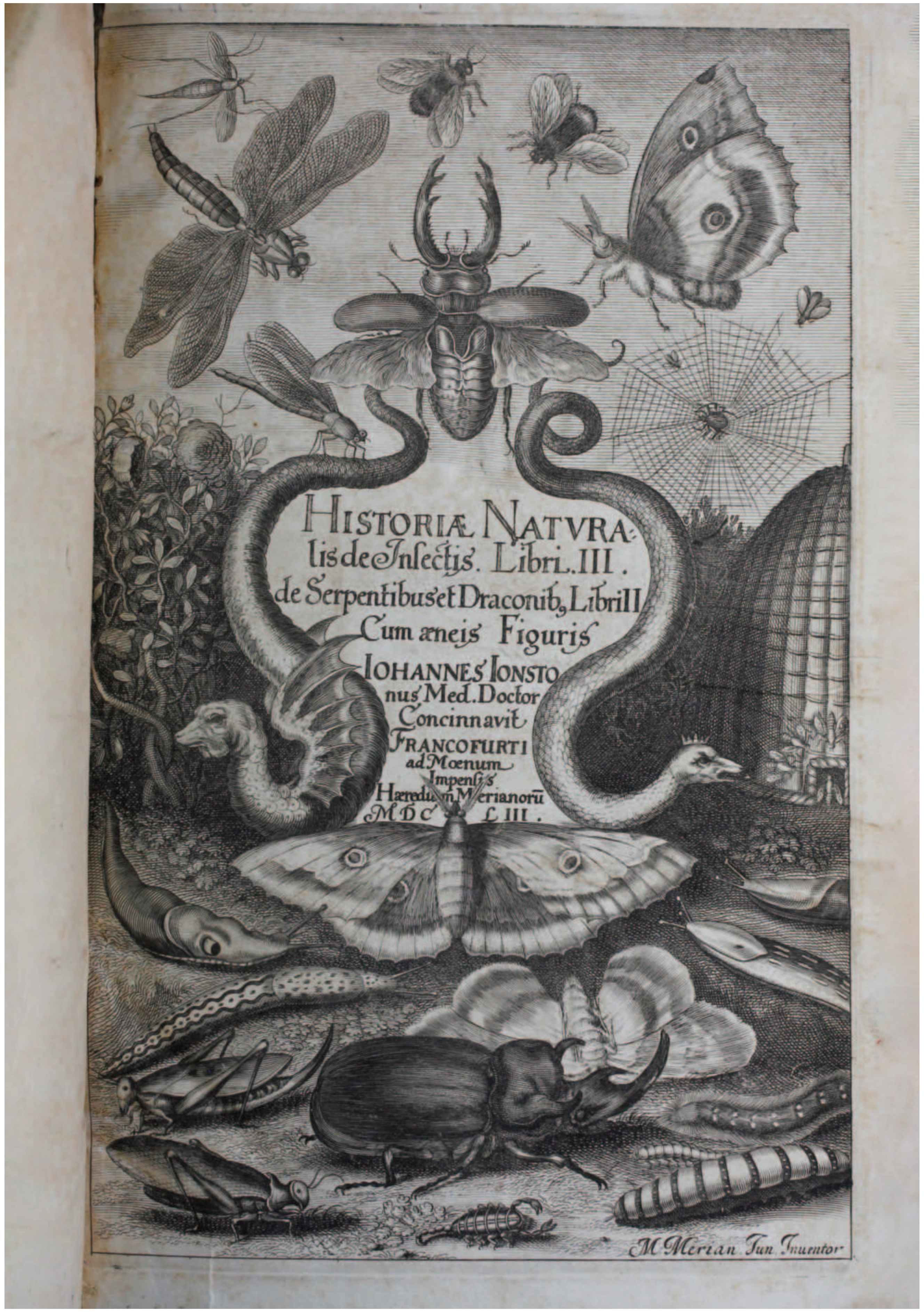

Figure 6. Title page from Joannes Jonstonus, *Historiae naturalis de insectis* [The natural history of insects] (Frankfurt, 1650) [F.9.8]. The remarkable illustrations in this volume are by Thomas Merian, whose half-sister, Maria Sibylla Merian, was the pioneering entomologist and artist whose detailed field-based illustrations of the insects of Suriname did much to establish the concept of metamorphosis in these tropical lepidoptera.

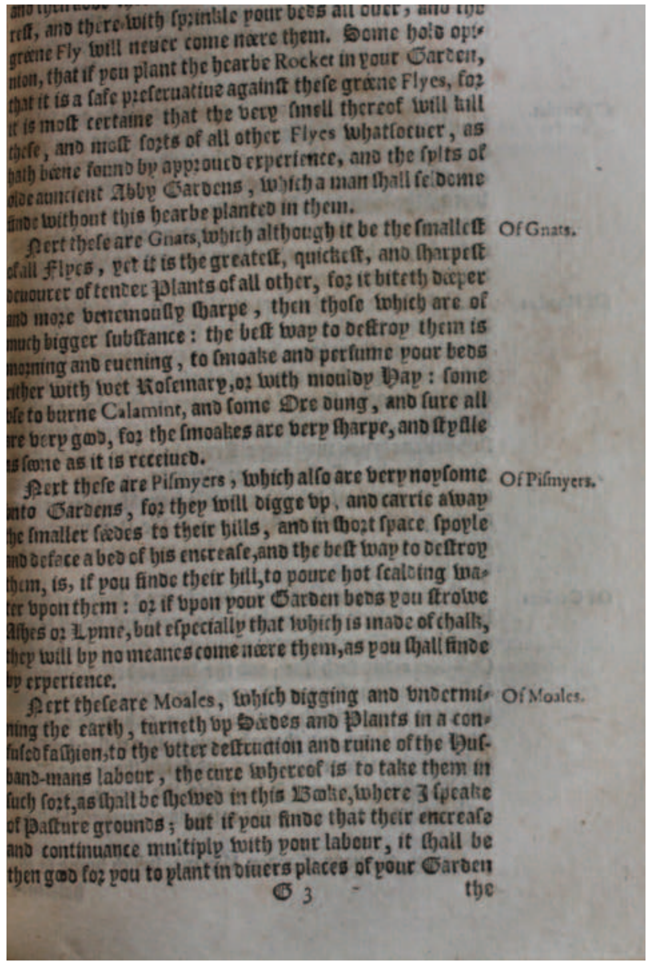
and then with sprinkle your beds all over, and the
rest, and there-with sprinkle your beds all ouer, and the
greene Fly will neuer come neere them. Some hold opi-
nion, that if you plant the hearbe Rocket in your Garden,
that it is a safe preseruatiue against these greene Flyes, for
it is most certaine that the very smell thereof will kill
these, and most sorts of all other Flyes whatsoeuer, as
hath beene found by approued experience, and the spits of
olde auncient Abby Gardens, which a man shall seldome
finde without this hearbe planted in them.
Next these are Gnats, which although it be the smallest Of Gnats.
of all Flyes, yet it is the greatest, quickest, and sharpest
deuourer of tender Plants of all other, for it biteth deeper
and more venemously sharpe, then those which are of
much bigger substance: the best way to destroy them is
morning and euening, to smoake and perfume your beds
either with wet Rosemary, or with mouldy Hay: some
else to burne Calamint, and some Oxe dung, and sure all
are very good, for the smoakes are very sharpe, and stifle
as soone as it is receiued.
Next these are Pismyers, which also are very noysome Of Pismyers.
vnto Gardens, for they will digge vp, and carrie away
the smaller seedes to their hills, and in short space spoyle
and deface a bed of his encrease, and the best way to destroy
them, is, if you finde their hill, to poure hot scalding wa-
ter vpon them: or if vpon your Garden beds you strowe
Ashes or Lyme, but especially that which is made of chalk,
they will by no meanes come neere them, as you shall finde
by experience.
Next theseare Moales, which digging and vndermi- Of Moales.
ning the earth, turneth vp Seedes and Plants in a con-
fused fashion, to the vtter destruction and ruine of the Hus-
band-mans labour, the cure whereof is to take them in
such sort, as shall be shewed in this Booke, where I speake
of Pasture grounds; but if you finde that their encrease
and continuance multiply with your labour, it shall be
then good for you to plant in diuers places of your Garden
G 3 the

Fig. 7 Text from Gervase Markham, *The second booke of the English husbandman* (London, 1614) [M.19.33] dealing with garden pests.

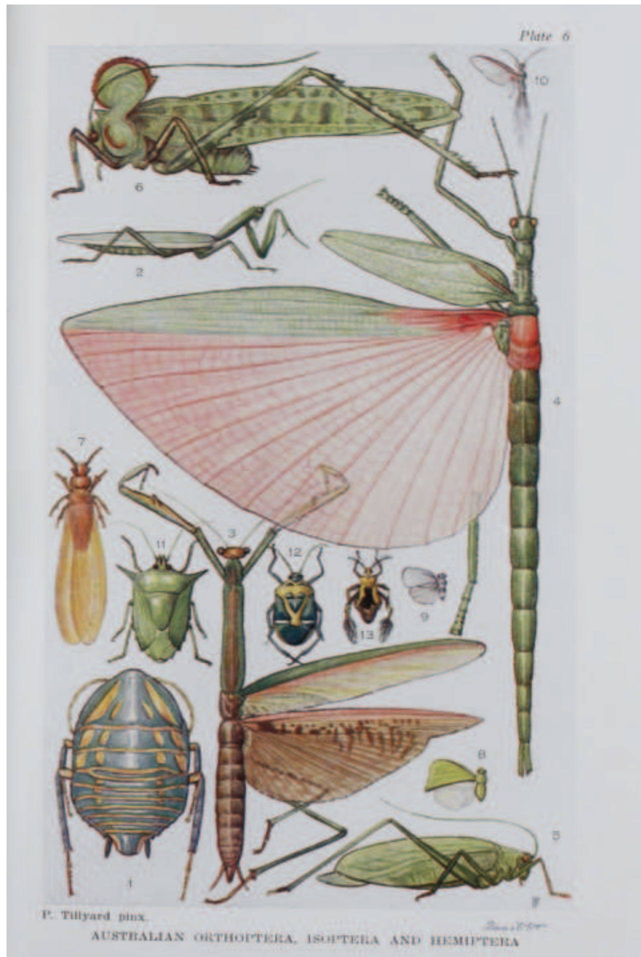

Fig. 8 Plate from R.J. Tillyard, *The insects of Australia and New Zealand* (Sydney, 1926) [Dd.7.44] illustrating examples of Orthoptera, Isoptera and Hemiptera.

insect found often in Wainscot, Benches, and Woodwork", possibly describing *Hylotrupes bajulus*, a type of wood-boring beetle, whose gnawing may have been particularly audible to humans in the hushed atmosphere of a deathbed vigil.

In conclusion, an entomological journey through the rare books at Queens' College Library not only unveils the rich history of insect studies, but also emphasises the profound impact insects have had on human culture, science, and beliefs. Figures 2–8 are from books that formed part of the 'Theatre of Insects' exhibition in Queens' College Library.

Acknowledgements
The authors are indebted to Dr Tim Eggington (Librarian, Queens' College, Cambridge) and Professor Stuart Reynolds (Emeritus Professor of Biology, University of Bath) for their generous help in preparing the paper. The codes in square brackets shown after book titles refer to the book's shelfmark location in the Queens' College Old Library.

Fig 9. Illustrated title page from Francesco Redi's *Experimenta circa generationem insectorum* [Experiments on the generation of insects] (Amsterdam, 1671) [H.17.17], showing a female figure peering down a microscope to look at an insect.

A triumph for pollinator conservation in the Doon Valley, India

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Solitary bees, often overshadowed by their social counterparts, are crucial pollinators, conservation of which can significantly impact ecological health and agricultural productivity. To mark World Bee Day 2024, solitary bee nests were installed at the Graphic Era University campus, underscoring the university's commitment to conservation of biodiversity and the sustenance of pollinators of the Shiwalik landscape in the Doon valley.

Understanding the importance of solitary bees
Solitary bees, unlike honey bees and bumblebees, do not live in colonies. Each female operates

independently, building and provisioning her own nest. Species such as mason bees and leafcutter bees are known to pollinate plants more effectively than honey bees, often visiting more flowers per day. Their role in the ecosystem is paramount, contributing to the pollination of both wild plants and agricultural crops. Despite their efficiency, solitary bees are often neglected in conservation efforts. Habitat loss, pesticide use and climate change have significantly impacted their populations. Recognising their importance and the threats they face, Graphic Era University took a bold step on World Bee Day to install solitary bee nests across its campus.

The solitary bee nest initiative

The initiative began with a collaborative effort from the university's Department of Biotechnology, the Campus Biodiversity Monitoring Team, and enthusiastic students who had heard a series of talks and watched a documentary film. These aimed to educate students and faculty members about the significance of solitary bees and the specific requirements for their nesting habitats. Participants learned that solitary bees prefer nesting in small cavities, which can be provided by specially designed bee boxes or natural materials such as bamboo reeds and drilled wooden blocks.

On World Bee Day, the campus buzzed with activity as students and faculty members gathered to install the bee nests. The installation sites were chosen to ensure they met the habitat preferences of solitary bees. Locations included areas rich in flowering plants, as well as sheltered spots that offer protection from the elements. The boxes, crafted with precision and care, were mounted at various heights to accommodate different species of solitary bee. They were strategically placed near academic buildings, gardens and along walking paths to maximise visibility and engagement from the campus community. This hands-on experience not only fostered a sense of ownership and responsibility among participants but also provided valuable practical knowledge about pollinator conservation.

Educational workshops and community engagement

The installation was accompanied by educational workshops aimed at raising awareness about the importance of solitary bees and how to support their conservation. Students and faculty participated in hands-on sessions where they learned about the different species of solitary bee, their nesting behaviours and the ecological benefits they provide. A procession with informative placards/signage and bee-saving slogans advocating their conservation efforts was led by the monitoring team in the campus vicinity.

Monitoring and maintenance

To ensure the success of the initiative, the university established a monitoring system. Biodiversity students were tasked with regularly inspecting the nests, documenting the species that occupied them, and recording their nesting success. These data will contribute to ongoing research and conservation strategies, providing valuable insights into the solitary bee populations on campus.

Impact on campus and beyond

The solitary bee nest installation is already showing promising results. Initial observations indicate that several bee species have begun to explore and utilise the new nests. The presence of these pollinators is expected to enhance the pollination of campus flora, thereby boosting local biodiversity and supporting the health of the university's green spaces. This project also provides a living laboratory for ongoing research on pollinator behaviour, nesting preferences, and the impact of environmental changes on solitary bee populations. The university plans to expand the project in the coming years by installing more bee boxes and integrating pollinator-friendly practices into campus landscaping. Future initiatives include the creation of wildflower meadows, reducing pesticide use and promoting community involvement in pollinator conservation.

Beyond the immediate ecological benefits, the initiative has fostered a sense of environmental stewardship within the university community. Students and staff have become more engaged with biodiversity issues, taking pride in their role in conservation efforts. This heightened awareness extends beyond the campus, as participants share their knowledge and experiences with the broader community, advocating for solitary bee conservation in their own neighbourhoods.

A beacon of hope for pollinator conservation

Graphic Era University's solitary bee nest installation serves as a model for other institutions and communities. By taking a proactive approach to pollinator conservation, the university has demonstrated that meaningful environmental impact can be achieved through well-planned, collaborative efforts. The initiative highlights the importance of integrating education, community involvement and scientific research in conservation projects.

The solitary bee nest installation on World Bee Day at Graphic Era University stands as a testament to the power of collective action and the importance of preserving our natural world. As solitary bees quietly go about their essential work, the university's initiative ensures that they have a safe haven in which to thrive. This project not only supports the health of local ecosystems but also inspires a new generation of environmental stewards dedicated to protecting our planet's invaluable pollinators.

Insects in the News

April to June 2024

Richard Harrington
with the help of material from
Stuart Reynolds and
Hugh Loxdale

Insect stories in the popular press have been hotting up with the weather. According to the BBC, daylight saving time was first proposed by American postal clerk George Hudson because he needed more daylight time to study insects after work. *The Guardian* reported a study showing that bumblebee nests are overheating to fatal levels because workers are struggling to fan them adequately. They might do better than expected in the rain, though, as *The Telegraph* reported that dormant bumblebees can survive under water for a week. This was discovered when an experiment went wrong and condensation build-up in a fridge dripped into tubes housing sleeping queens. Then again, at the end of our very wet spring, *The Telegraph* reported results from the Bumblebee Conservation Trust's BeeWalk citizen science project saying that the rain delayed queens from setting up colonies as they struggled to forage, leading to lower numbers.

The Daily Telegraph weatherman, Joe Shute, told me something I really should have known. May 20th is UN World Bee Day. This honours the pioneering Slovenian beekeeper and artist, Anton Janša, born on that day in 1734, who was a strong advocate for the importance of pollinators. Why should I have known this? Because May 20th is my birthday. Two days later, the papers ran a story that bees are 'scared to venture out' because of Asian Hornets (*Vespa velutina*), and that DNA evidence shows that the hornets are now breeding in the UK.

Bees were still on *The Telegraph*'s mind on 25th May, when they published a picture of helicopter crews inspecting a hive at the Royal Naval Air Station, Culdrose, where a beekeeping club has been set up. Googling 'helicopter and bee', I discovered that Network Rail's survey helicopters are a make called 'Bumblebee' – and that you can buy it in Lego. Sir Jim Ratcliffe, the petrochemical billionaire and owner of Manchester United, has won a lengthy planning row over a beekeeping facility at his holiday home in Hampshire, according to *The Daily Telegraph*. Another wealthy man who is into bees is David Beckham. Is it a coincidence that the first professional club he played for was Man U? Anyway, Golden Balls has apparently been swapping beekeeping tips with the King and has been given an ambassadorial role with his sustainability charity, The King's Foundation.

His Majesty's new portrait (the red one) by Jonathan Yeo features a Monarch butterfly flapping above the King's right shoulder. The same artist has recently painted a portrait of our Hon. Fellow Sir David Attenborough in a similar style but bluey-green and with no butterflies. I like far less the picture of Nigel Farage at his 60th birthday party wearing a tie with butterflies on it. Mind you, his dad did use to attend the Verrall. Other lepidopteran stories in brief: the National Trust is planting 20,000 Marsh Violets in Shropshire to boost the Small Pearl-bordered Fritillary (*Boloria selene*); the UK Butterfly Monitoring Scheme reports that Small Tortoiseshells (*Aglais urticae*) are at their lowest ebb ever; and scientists in China and America are developing body armour using silk from genetically modified Domestic Silkmoths (*Bombyx mori*). Apparently, the silk bulletproof vest was invented by American George Emory Goodfellow (1855–1910) and was proposed as far back as the late Seventeenth/early Eighteenth Century by Wilhelm Leibnitz, best known as an inventor of calculus.

The Guardian's Environment reporter, Helena Horton, wrote a series of articles on pesticide usage in the UK, saying that although the weight of pesticides used has halved since 1990, their toxicity has 'shot up' and they are being applied to a greater area. Our trustee, Lynn Dicks, told Helena that insects are declining at a rate of about 1% per year but she remained optimistic that we can reduce pesticides in all our farmland. Help is at hand. The same paper's Environment Editor, Damian Carrington, reported on work published in *PNAS* from Wageningen University (The Netherlands) developing a non-toxic, biodegradable glue spray that kills small insects whilst not affecting larger insects such as bees.

Australia has a reputation for animals that bite and sting. According to *The Guardian*, the sting from the bright green caterpillar of the moth *Comana monomorpha* 'feels like the seven rings of hell' and produces 'blood-filled boils and welts'. However, scientists at the University of Queensland have accumulated a venom library and are busy identifying key molecules that interact with ion channels, potentially leading to targeted therapeutics for virtually any human disease where an ion channel is involved.

The Observer reported that a Deathwatch Beetle (*Xestobium rufovillosum*) from the oak timbers of HMS Victory has been used to create the first fully sequenced genome of the species. That's the way to get your research into the papers!

Immediately after I thought I'd completed this piece, I sat down for a coffee and a read of *The Daily Telegraph*, and therein was a huge picture of Luke Chambers' winning photo of two cuckoo bees in last year's Insect Week competition. What a nice way to end. See pages 146 to 155 for more.

Featured Insect

T. sinensis by Luc Viatour, CC BY-SA 3.0.

Chinese Mantis, *Tenodera sinensis*

Scientific name: *Tenodera sinensis* (Saussure, 1871)

Common name: Chinese Mantis

Order: Mantodea

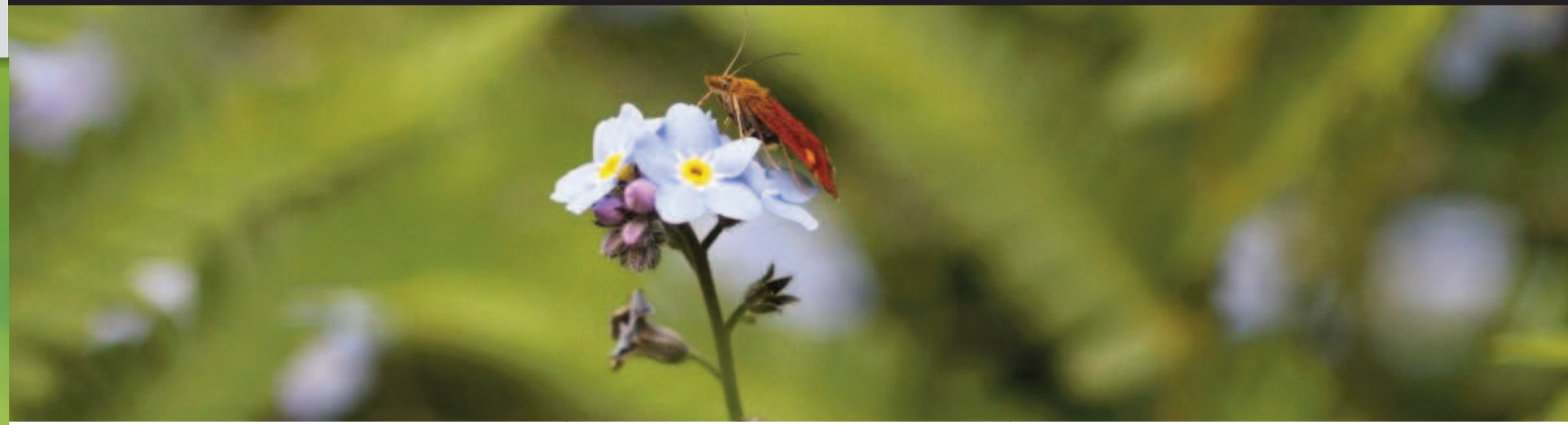
Family: Mantidae

Throughout my career as a neuroethologist and chemical ecologist, I have probed the brains of insects – mainly the giant sphingid moth the Carolina Sphinx, *Manduca sexta*. That lovely creature has been my lab rat for research on the mechanisms and roles of olfaction in insect behaviour. But for my featured insect I choose a praying mantis.

My affection for these insects arose when I was a young boy in suburban Boston, Massachusetts, long before I knew anything about olfaction. I liked to search for insects, spiders, and snakes and to observe their behaviour in a wild field behind my father's business. When I first spotted a mantis, I was smitten. After that chance encounter, I searched for them whenever I was on the prowl in that field, and I read about them, played with them, found their egg masses, and eventually raised them at home. I could recognise two species in my neighbourhood, both of which were introduced into the USA at least 100 years ago: the European Mantis (*Mantis religiosa*) and the Chinese Mantis (*Tenodera sinensis*). Of course, I favoured the latter because they are big! What fascinated me about mantises was their behaviour. When a mantis saw me, it would rise up in its 'ready to strike' posture and fix its predatory gaze on me, turning its head as I moved. The dark pseudopupils in its compound eyes assured me that it was staring directly at me and (I presume) sizing me up as a possible victim of its strike. To the best of my knowledge, mantises are the only known insects that can swivel their heads through 180 degrees and see in 3D! Then when I saw a mantis capture a cricket and make a brisk dinner of the hapless victim, I was amazed by the accuracy and speed of the strike, not to mention the voracious ingestive behaviour of the triumphant predator.

Later, about 15 years after I met my first mantis and when I was a Ph.D. student, I chanced upon a new book in the university library. What caught my attention was an impressive colour image of a praying mantis on the dust cover. That small book was *Nerve Cells and Insect Behavior*, by Kenneth D. Roeder (Harvard University Press, 1963). Having been 'caught' by that mantis, I sat down and read the entire book. With captivating style, Roeder revealed to me what we now call neuroethology – the study of the neural basis of natural animal behaviour – through accounts of his own experiments on mantises and other insects. By the time I returned the book to its shelf, I knew what I wanted to do as a scientist. Then still later, soon after I launched my independent research career, I became acquainted with Ken Roeder – an inspiring and unforgettable scientific hero for me and many others. So, you see, I owe a debt of thanks to praying mantises for stimulating my fascination with insects, seducing me to the field of neuroethology, and introducing me to one of its founders.

John Hildebrand
University of Arizona,
Tucson, Arizona, USA



Mint Moth (*Pyrausta aurata*). Photo: Fabian Harrison.

News from Council

Council meeting
Council met online on 1st May 2024.

CEO's report
The CEO reported on: key performance indicators as we enter the final year of the current Society strategy; references to the Society's written evidence in Parliament's Scientific Innovation and Technology Committee report on Insect decline and UK food security; progress with the relocation of the Chelsea Flower Garden; a range of grant applications in which the Society is involved; development of the Society's conservation strategy; updates on books and journals; and various Society events.

Trustee roles and term lengths
It was agreed that the main role of the Vice Presidents is to be familiar with Society affairs such that VPs could deputise if the President required. The President Elect's main role is to gain an understanding of Society affairs in preparation for becoming President, whilst that of the Past President is to advise the President as requested. Attention was drawn to the potential loss of several trustees in 2025 as a result of synchronised terms, and mitigation options were discussed.

Head Office relocation
The CEO reported that the Working Group had visited three London properties. The brief provided to our agents takes account of comments in the membership survey, and more properties will be viewed over the coming months.

Honorary Fellows' afternoon tea
This was attended by 15 Hon. Fellows, some of whom have since contributed ideas for the new Society strategy. It was agreed that further events to engage Hon. Fellows would be useful.

Policies
The Director of Finance presented a revised reserves policy, for which a priority was to protect the Society against potential financial implications of changes in the publications model. The paper was accepted as a first step in an ongoing process. He also presented an updated risk management policy and risk register, suggesting that four low risks be removed from the register but continue to be monitored by the Senior Leadership Team. The approach to risk management was approved.

Organisational membership
A scheme prepared by the Membership Committee allowing organisations to join the Society was approved. Three levels of membership will be available, with increasing benefits matching increasing subscriptions.

Eleanor Ormerod's grave
Council approved the provision of a small amount of extra funding to that agreed in 2020 to complete the restoration of the grave in St Albans of this pioneering applied entomologist. A new Society award is soon to be launched in her name.

Editor agreements
The implementation of agreements to be signed by Editors-in-Chief of our journals was approved.

Ento25
The move of Ento25 from Aberdeen to Glasgow was approved.

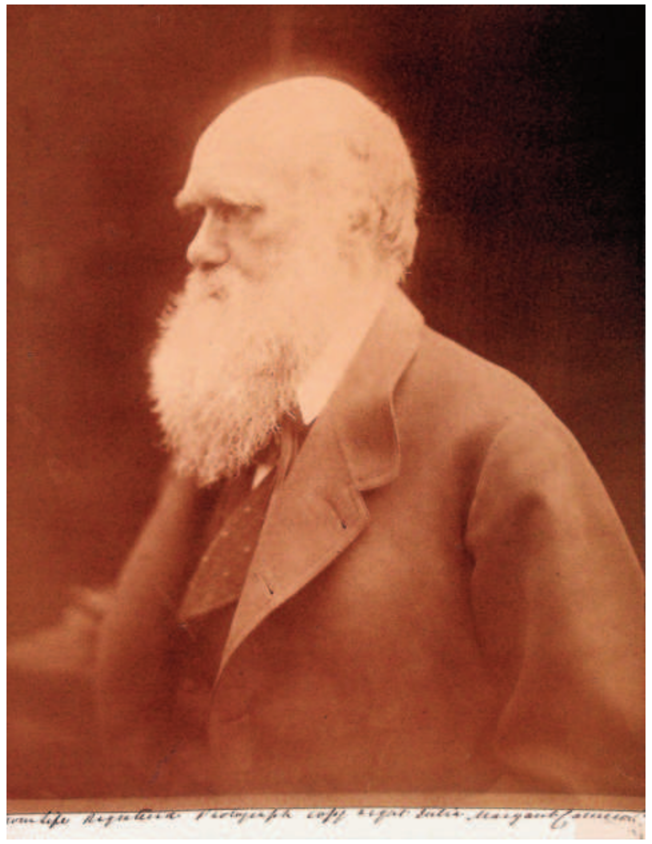
Committee minutes
Minutes of meetings of the following committees were tabled: Finance; Science, Policy & Society; Education & Training; Membership; and Meetings.

Journals and Library

Treasures from the RES Library and Archive

Rose Pearson
RES Librarian and Archivist

The Society has collected portraits of entomologists, professional and amateur, since its founding in 1833, and continues to do so today. The collection includes presidential photos, formal studio portraits and group photos from conferences, as well as entomologists at work in the laboratory and in the field. Here we pick out some of the more unusual images from this unique collection. All the images are available to view onsite at our library in St Albans; e-mail library@royensoc.co.uk or call 01727 899387 to make an appointment. Scans of images can be supplied on request, subject to copyright.



Charles Darwin (1809-1882)

Photo by Julia Margaret Cameron (1815-1879).

This photo is one of a series of four photos of Darwin taken by Cameron on the Isle of Wight in the summer of 1868. The photo was liked by the Darwin family who owned a number of copies, one of which was donated to the RES by Darwin's daughter, Henrietta Litchfield (née Darwin, 1843-1927). Darwin became Vice President of the Society in 1838 and donated insects collected from his voyage on the Beagle to the Society. Taking up photography in 1863, at the age of 48, Cameron was one of the earliest pioneers of the art. As well as portraits of prominent Victorian figures such as Darwin, she is known for her romantic depictions of young women.

John Obidiah Westwood (1805-1893)

Photo by Hill and Saunders of Oxford, 'Photographers to H.R.H. The Prince of Wales'.

Westwood was a founding member of the Royal Entomological Society; he was President from 1852-1853, and in 1883 he became the second person to be conferred the title of Honorary Life President. He authored and illustrated a number of works on natural history, including *The Cabinet of Oriental Entomology* (1848) and several other works on Asian insects. Despite this, he did not travel widely and most of his illustrations were drawn in the UK from specimens collected by others.

Joshua Hudson (1889–1974)

Photographer unknown; photo and biographical details courtesy of Catherine Jones.

Joshua Hudson was an amateur entomologist from Wombwell, South Yorkshire. One of nine siblings, he left school at the age of 12 and worked as a mines inspector for over 50 years, retiring in 1954. He devoted his retirement to studying lepidoptera and built up a large collection of specimens, including the Atlas Moth (*Attacus atlas*) shown here. He published a number of articles on natural history in the South Yorkshire Times and was elected a Fellow of the RES in 1959, at the age of 70.

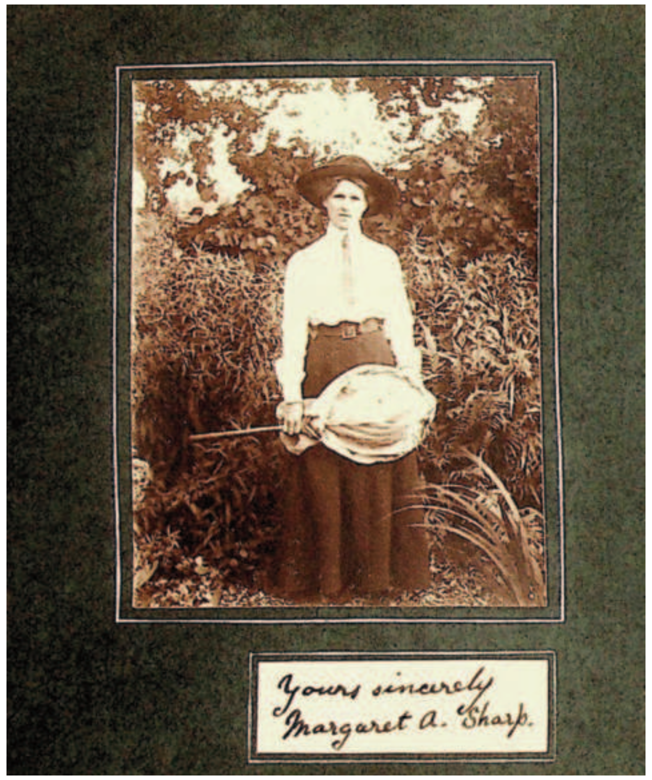
Eleanor Ormerod (1828–1901)

Photo by Elliot and Fry.

Ormerod was a pioneer of agricultural entomology who became a sought-after expert on pest control. In 1878 she became only the third woman to be elected to the Society. Her annual reports 'Notes of Observations of Injurious Insects' ran for 17 years. Virginia Woolf wrote a short story, 'Miss Ormerod', based on her life. This photo was taken at Ormerod's house in St Albans in 1900.

David Sharp (1840-1922)

Photographer unknown.



Margaret Annie Muir

Photographer unknown.

David Sharp, pictured here relaxing in the field in 1909, was a coleopterist who authored over 250 papers on entomology and served as RES President from 1887-1888. His daughter Margaret Annie Muir (née Sharp) worked closely with him in his entomological laboratory, and later married fellow entomologist Frederick Muir. Following his death in 1922 Sharp left his collection of specimens to her.

Meetings

Monthly Online Meetings

Reports by Richard Harrington

Physiological Entomology

8th May 2024

Speakers for the second in this journal-associated series of online meetings were two editors of *Physiological Entomology*, Nick Teets from the University of Kentucky, and Thies Büscher from Kiel University.

Nick's talk was entitled *Entomology in Antarctica: environmental adaptations in the world's southernmost insect*. Antarctica is home to around 100 tick and mite species, 15 springtail species but only two 'true insects', both chironomid midges, *Belgica antarctica* and *Parochlus steinenii*. The former is endemic and the subject of Nick's talk. As mammals and birds associated with Antarctica are aquatic, *B. antarctica*, at 2–6 mm long, is the largest Antarctic terrestrial animal. It is adapted to extreme conditions by having a 2-year life cycle with synchronised emergence to facilitate mating. Adults do not feed and live for only two weeks. They are wingless, as it is usually too windy for flight. The larvae are detritivores and live in the soil. They are tolerant of freezing, desiccation, salinity, freshwater, anoxia and heat. Nick and his team have conducted comparative physiological, genomics and population genetics studies on *B. antarctica* and *Eretmoptera murphyi*, a midge that has invaded Antarctica's Signy Island and threatens the stability of the ecosystem. The idea is to investigate factors that determine survival and range of the midges to assess whether *E. murphyi* could potentially overlap with *B. antarctica* and what the outcome might be.

As winters get warmer, cold injury is reduced and metabolic rate increases. In overwintering simulations in incubators at −1°C, -3°C and −5°C, one of Nick's team, Jack Devlin, found that there was higher mortality of *B. antarctica* in warmer conditions, possibly due to metabolic costs.

Jack has also investigated microplastics as potential stressors to *B. antarctica* larvae. In experimental toxicological studies involving seven microplastic concentrations from 0 to 2,000 mg/kg, short-term exposure was found to be non-lethal. The rate of ingestion of microplastics was low relative to other chironomids. Oxygen consumption was unaffected, there was a dose-dependent reduction in lipid stores, and there were no changes in carbohydrates or proteins. In a field study, one larva in 200 was found to have ingested microplastics.

Thies spoke on attachment systems of insects. The Bee Louse, *Braula coeca* (which is actually a fly in the family Braulidae), attaches to the hairy surface of honey bees, where it eats particles around the bee's mouth. It has a 'safety factor' (force per body weight) of 1,130, meaning that it could attach 1,130 times its weight, essential for clinging on in the face of various forces such as wind drag. This is possible through highly modified claws. The record safety factor, 4,500, belongs to the Antarctic Seal Louse, *Echinophthirius horridus*, a marine insect which has to cope with hypoxia, high pressure and other challenges to remaining attached to its host. Its tibial claw locks into a soft cuticular pad-like structure at the base of the tibia and secures the louse to a seal hair.

There has been convergent evolution in attachment mechanisms, with diverse insects and other animals showing similar systems. Thies has studied in detail the mechanisms in stick insects and leaf insects (Phasmatodea). There are two main mechanisms. Hairy attachment pads comprise flexible setae that deform and increase the contact area. Smooth attachment pads are not setae, but soft deformable bubbles which are covered with different functional patterns. The formation of these patterns can be explained by reaction-diffusion models based on two morphogens and can potentially change due to a single point mutation. Thies showed electron-micrographs of mechanisms in a range of these insects and how they are suited to different surfaces. The design of attachment systems is not related to phylogeny, but to ecology. Surface features such as roughness, chemistry, geometry and contaminating particles determine the evolution of attachment mechanisms. Furthermore, there are differences according to developmental stage and sex, relating to different behaviours associated with plant surfaces inhabited. Thies described this as a huge playground for future research.

After this gripping talk came a lively Q&A session including why midges, rather than other insects, have colonised the Antarctic, how they might have spread between Antarctic islands, which Nick thought might be by rafting on moss, and whether they could survive being eaten in the egg or larval stage and hence be spread by birds. Thies was asked whether non-insect ectoparasites such as mites have similar attachment mechanisms to insect ectoparasites, and said that mites often attach by anchoring in the skin. He was also asked how easy it was to find the Bee Louse, as it is rare in Europe, partly because Varroa Mite control measures also kill the Bee Louse. Thies obtained his Bee Lice from South Africa from hive colonies where such treatment is not used. Finally, there was discussion on the coevolution of plant surfaces and attachment mechanisms of beneficial insects.

Some members may not consider physiology to be 'their thing' but these two talks would have delighted and enlightened anybody with a broad interest in entomology. Don't judge a book by its cover – register for these events and expand your horizons, as 43 people did on this occasion.

Many thanks to the speakers, their co-authors and the RES team.

Belgica antarctica larvae and adults.

Bee Louse, *Braula coeca*.

Systematic Entomology

12th June 2024

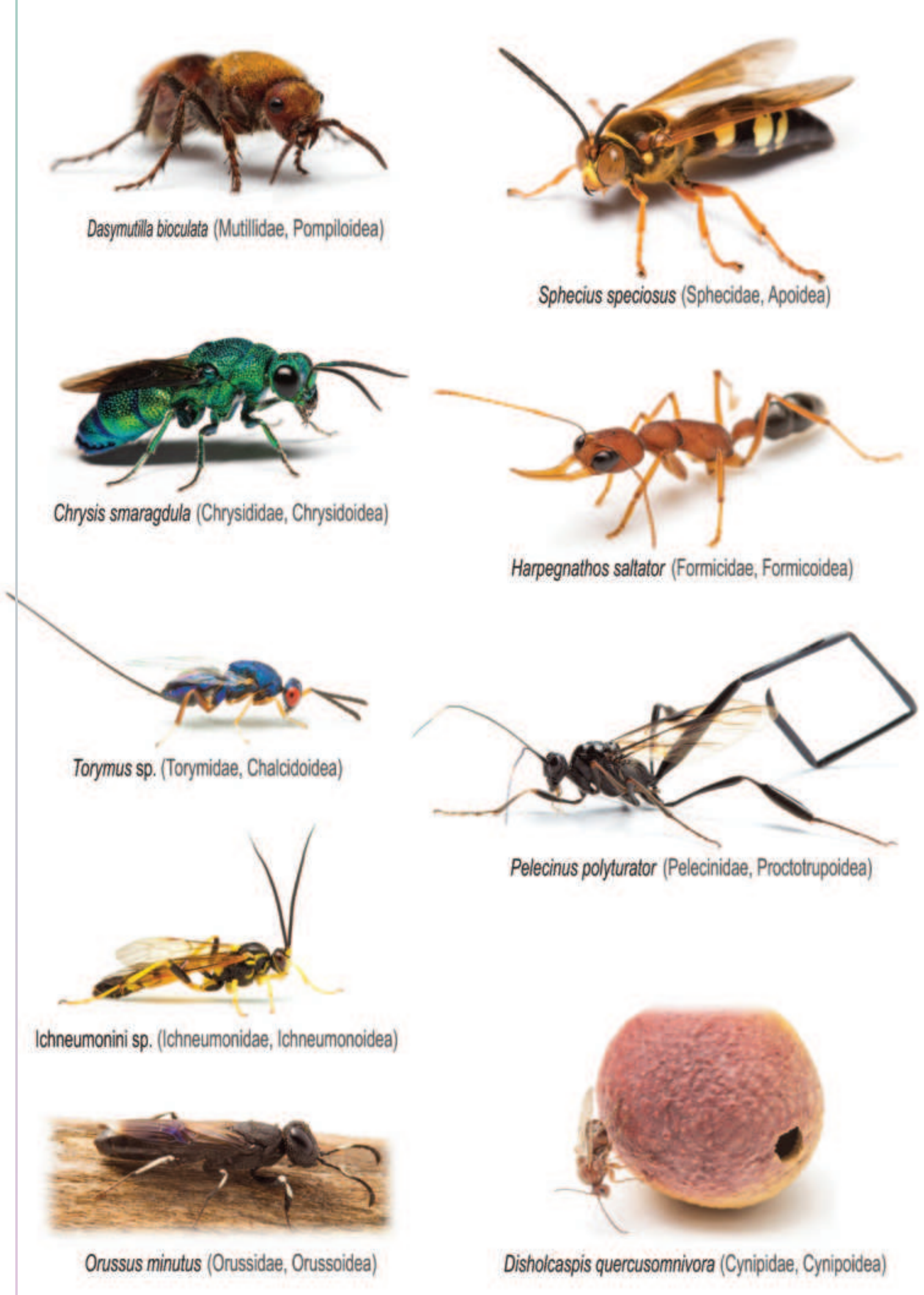
Our journal *Systematic Entomology* took centre stage for the June lecture, with Bonnie Blaimer, one of the four Editors-in-Chief, in the chair. She introduced Tamara Spasojevic from The Natural History Museum, Vienna, and Miles Zhang from the University of Edinburgh, who previewed their forthcoming invited review paper: *Evolving Perspectives in Hymenoptera Systematics*, co-authored with Silas Bossert from Washington State University.

The last comprehensive review of Hymenoptera systematics was published in 2007. Miles pointed out that, since then, we have fully entered the age of phylogenomics. The new review looks at integrating various morphological and molecular methodologies in determining phylogeny, building on a 2023 paper by Bonnie looking at the role of key morphological and behavioural innovations in the diversification of Hymenoptera. Twenty-nine extant superfamilies (up from 22) comprising 143 families (up from 90) were identified, one third of which were in the superfamily Chalcidoidea. The Xyelidae (a family of sawflies) was proposed as the oldest hymenopteran family, followed by other sawflies. Miles gave updates on new families identified. Dark taxa (DNA sequences not identified to species level) are a complication which Miles thinks can best be resolved through mega-barcoding (which allows for the simultaneous identification of many taxa within the same sample) and global collaboration.

Tamara explained how timelines for hymenopteran evolution are investigated using molecular methods. The molecular clock hypothesis assumes that genetic distances between taxa correlate with time, but not necessarily in a linear manner. Thus, so-called 'relaxed clock models' are used. Node-dating approaches (requiring age constraints to be applied to the internal nodes of the evolutionary tree) and tip-dating approaches (placing fossils directly on the phylogeny to provide time information for the analysis) are used. The crown-group Hymenoptera is estimated by molecular clocks to date back 280 M years to the Permian, although no fossils have been found that are less than 40 M years younger. Tamara reviewed dating studies on a range of taxa (Symphyta, Proctotrupomorpha, Evaniomorpha, Ichneumonoidea, Aculeata). Molecular clocks often estimate the age to be significantly older than the oldest fossils, which is unsurprising bearing in mind the scarcity of fossils in many taxa. Many lineages await focused dating analysis. Tamara suggested that more consistent age estimates need an increased effort in studying fossils, records from the southern hemisphere being much more depauperate than from the northern hemisphere, and a concentration on underrepresented families. Advances in the methodologies for studying fossils are helping (*e.g.*, CT-scanning) and new morphological features are being used.

The presentation generated a lively Q&A session. The speakers and editor were asked whether *Systematic Entomology* would accept papers using solely molecular data to describe new taxa, to which the answer was no, the journal requires a full description. In response to the question of what early-career researchers should focus on, Tamara suggested underrepresented groups and integrative approaches. Miles suggested focusing on what interests you most and collaborating to generate novel research. One questioner pointed out that black and yellow stripes occur widely among taxa and asked whether this was likely to be repeated evolution or a very conserved feature, the former being thought to be the case.

The paper is probably out by the time you are reading this, so do take a look at this important piece of work. Many thanks to the authors and to the RES team.



Specimen photos included in the *Systematic Entomology* paper (Silas Bossert).

Climate Change and Medical & Veterinary Special Interest Groups Meeting: The Impact of Extreme Events

Queen Mary University London
25th April 2024

Convened by Scott Hayward (University of Birmingham), Marion England (The Pirbright Institute) and Arran Folly (Animal and Plant Health Agency, APHA)

Report by Jane Phillips

Commensurate with the importance of understanding the impacts of extreme events on insects and the diseases they transmit, there was a brilliant turnout online and in-person, with delegates including seasoned academics in the field to early-career entomologists and students. The SIG event opened with a keynote online talk from Prof David Renault, University of Rennes. David spoke of the impact of climate change on native and non-native insects, including insect reproduction, physiology such as thermal fluctuation, and insect pest sensitivity to xenobiotics such as pesticides.

A selection of engaging speakers followed, covering a range of topics, including the impact of extreme heat on disease vectors. For example, Hester Weaving (University of Bristol) spoke on the efficacy of critical thermal limits to assess the capacity of different Tsetse fly species to cope with extreme heat, as well as impacts on female fertility. The data gathered will inform distribution predictions and population viability. Hester's presentation impressed the audience and was adjudged the best student talk on the day. The topic of responses to extreme heat was extended later in the day, with the 2nd keynote presentation provided by Sinead English (University of Bristol) covering a comprehensive meta-analysis of published data on insect thermal limits.

Mirjam Schilling and Nick Johnson (APHA) continued the disease vector theme, separately presenting their findings on mosquito-borne viruses. Mirjam explored the impact of climate change-induced diapause delay in mosquitos on the increased risk of mosquito-borne diseases reaching the UK, such as West Nile Virus in equids. They also reviewed the detection of Usutu virus in 2020, this being the first mosquito-borne viral zoonosis in the UK.

The final keynote presentation was delivered by Roger Morris (British Hoverfly Recording Scheme), who reflected on landmark heatwaves and drought throughout the 20th century and their notable impact on hover fly abundance. One key appeal from Roger was a new generation of recorders to come forward and collect data. "We can't rely on opportunistic data," said Roger. Targeted long-term studies are needed, Roger emphasised, encouraging a new generation of taxonomic entomologists and enthusiasts to learn the skills.

The impact of climate change is of course not isolated to disease vectors, and there are other insects that either benefit or suffer from weather extremes. Aaron Bhambra (University of Birmingham) shared his PhD research on the range expansion of the Noble Jewel Wasp (*Hedychrum nobile*). A relatively new species to England, its dispersal across the landscape and foraging behaviour are hindered by wet and windy weather, while drought facilitates its movement and increases suitable nesting sites, thus having the potential to benefit population numbers over time.

Sean Rands (University of Bristol) has been simulating heavy rainfall to study its impact on bumblebee movement, in turn impacting pollination, and noted the challenges of simulating rain in a way that is biologically realistic. Liam Crowley (University of Oxford) used a long-term experimental rainfall experiment at Wytham Woods to investigate the effect of drought and irrigation on plant-pollinator visitation networks, and emerging adult arthropods in a calcareous grassland ecosystem.

Many more fascinating presentations were given, too many to cover in this short report.

There was also a brilliant display of posters, including one by Sofia Samoylova (Bristol University) who described the use of viviparous cockroaches to study the impact of elevated temperature on adverse pregnancy outcomes; the cockroaches were used as model insects, alongside human data analysis.

Colin Johnston (UK Health Security Agency) presented an update on the invasive mosquito surveillance project operating at 58 entry point sites, such as ovitraps at ports and airports, resulting in the detection of the first Asian Tiger Mosquito (*Aedes albopictus*) eggs in the UK. This species is a vector of diseases such as Zika, dengue fever, and chikungunya.

The winner of the student poster award was Emily Wenban-Smith (University of Cambridge) who displayed her findings on the correlation between historical extreme heatwave events and butterfly wing morphology traits, such as length and depth. Understanding these morphological responses historically will enable better preparation to mitigate the impact of extreme weather on butterfly populations.

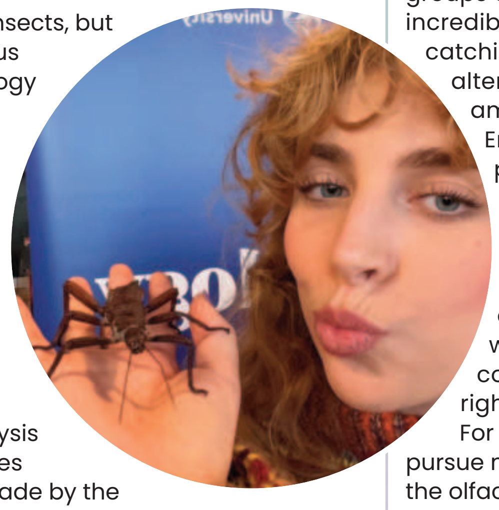
This event clearly highlighted the impact of climate change on both beneficial insects and vectors of disease, as well as the real world application (impact) of entomological research. It brought together groundbreaking new research, while also offering a sober reminder of the challenges facing insect species and the spread of disease vectors.

RES Scholars 2024

The Royal Entomological Society supports three Master's student scholarships every year, following a rigorous application process. This year's winners introduce themselves and explain what the award means to them.

Simon Ward (RES), Ella Curry, Sharna Broadhurst and Bethany Wright.

Sharna Broadhurst



I haven't always loved insects, but when my tutors taught us about forensic entomology during my BSc Forensic Science at UCLAN, I was astonished that these little creatures could reveal so much about the circumstances surrounding a person's death. For my dissertation, I combined my interest in forensic entomology and bloodstain pattern analysis to analyse the differences between fly artefacts made by the blow fly *Protophormia terranovae* when they spread blood around a crime scene with perpendicular blood spatter. While rearing my flies, I felt elated just standing and watching them in their different life stages. I decided that there was no other option than to study an MSc in entomology. This was solidified when visiting the Forensic Anthropology Research Facility in Texas (the body farm) and seeing the diverse array of insects making themselves at home in a vessel that used to be someone else's home.

Since coming to Harper Adams, I have realised how important insects are for the world. They make up 90% of the Earth's animals and deserve recognition. Being part of a generation taught from a young age about climate change and told that the job is ours to heal a world we didn't wound is difficult. However, knowing that I am studying possibly one of the most important groups of animals and trying to find solutions is incredibly important. I have particularly enjoyed catching and identifying insects and learning about alternatives to pesticides using natural enemies. I am incredibly thankful to the Royal Entomological Society for facilitating this by providing me with a scholarship, which has allowed me to dedicate more time to achieving this goal. I have always been a victim of impostor syndrome, but being awarded the scholarship, the support from the amazing staff at Harper Adams and the wonderful friends I have met have given me confidence and assured me that I made the right decision.

For my master's research project, I have decided to pursue my interest in forensic entomology and utilise the olfactory learning of *Bombus terrestris* to detect rat cadavers using the proboscis extension reflex (PER) assay. Hopefully, you are envisioning little sniffer bees in yellow high-vis jackets with 'POLICE' printed in big letters on the back. Bees, wasps and moths have been used to detect explosives and have even been taught to play football. My idea is that if they are capable of learning to associate a specific odour profile with decaying matter of human or animal origin, we could attach a tracker to them to locate the remains for use in forensic cases or mass disasters.

I am still deciding what career path I want to take, but I will be travelling around Europe and Australia for a year to gain some world experience and learn what is important. I am incredibly excited about what's to come and advise you to follow your passions, and that it's never too late to start caring about insects!

Bethany Wright

Having grown up loving wildlife and being outdoors, it is embarrassing to admit I had not heard of entomology until 2022. Even after completing (and thoroughly enjoying) my BSc in Environmental Science at Aberystwyth University, I did not know what sort of career I wanted. However, during three months of volunteering at Beinn Eighe NNR in the Highlands, I met a group of entomologists working for the Darwin Tree of Life Project. Their insect interests were visible for everyone to see: from their wash bags and jewellery to their conversations and competitions to list all the insect Orders at dinner. The passion they had for their work and the bizarre knowledge it gave them was utterly intriguing and everything I was looking for as a career. So, while completing an online entomology diploma later that year, I applied to study MSc Entomology at Harper Adams.

The RES MSc Entomology Scholarship has given me the financial ability to not only do MSc Entomology at Harper Adams, but also to have the financial freedom to do the course full-time without working in other industries. This freedom was particularly important to me as it has meant I can fully focus on my studies and take every opportunity to go into the field, attend events, gain experiences, and make contacts. Learning to drive will be the icing on the cake, as there are so many wonderful locations where I can now realistically dream of doing fieldwork.

My main priority after graduating is gaining professional fieldwork and research experience in ecological entomology. I have always enjoyed the physicality of fieldwork, and I am very excited to start balancing the physical and mental aspects. The identification process really appeals to me as I love anatomy, particularly now that Harper has given me an understanding of invertebrate evolution and adaptation. I am happy to learn and work with any insect group, but Odonata have a special place in my heart, causing me to always be watching the skies and searching for exuviae around small bodies of water. I am particularly interested in Britain's temperate rainforests, and I am working to understand better how invertebrates might be used to indicate these mystical and understudied habitats. Preserving and expanding these historical rainforests is crucial, so I also hope to get involved in habitat conservation. A few years down the line, I would love to do an entomology PhD, but first I look forward to getting some work experience to build my knowledge and confidence as an entomologist.

Ella Curry

I have adored all things arthropod from a young age – I held my first tarantula at age three, dressed as a spider for costume day at preschool, and since I could walk could be found grubbing about in the garden or forest with woodlice, snails, beetles, and everything in between. Before the age of ten I had ant farms, worm farms, caterpillars and Australian spiny stick insects, and my avid reading of 'bug books' meant I supplied endless 'bug facts' to willing listeners. My entomological interests evolved during my time at Cambridge University, where I took part in moth and arthropod biodiversity surveying and volunteered at the Cambridge University Museum of Zoology – despite my first degree being in English! I then worked for several amazing months at Dr Beynon's Bug Farm in Wales (and couldn't resist adopting 50 adorable *Lucihormetica verrucosa* cockroaches when I left) and my mind was made up – I had to study entomology.

My main research area is the rapidly developing field of insect sentience and welfare, so I'm very excited (and hopeful) to see how knowledge progresses there. I'm also looking forward to further improving my identification and taxonomy skills, particularly for beetles and moths – I'd love to know more about the individual species of my favourite families! My other particular interest is burying beetles – they're so fascinating and wonderful that I could never learn enough about them. However, I find anything insect-related fascinating, and want to learn as much as possible!

I am so grateful for the financial aid provided by the scholarship, which has greatly eased my transition into a new field of study with its accompanying equipment-related expenses. However, perhaps the greatest value for me has been the confidence and self-belief the scholarship has instilled: as a woman in STEM who last studied science at GCSE, having the RES provide such a significant vote of confidence in my abilities and potential has really helped me to courageously pursue my passions – and I will continue to do so.

I'm very interested in research – I'm considering a PhD in either insect sentience or burying beetles. However, I'd equally love to undertake conservation work or be part of positive industry change. As long as it aligns with my values and interests, I'd be happy doing anything insect-related! Unifying writing and entomology would also be wonderful – after winning a competition with my short story about insects in space (astroentomology!), I recognised the power of creative writing to educate and enthuse. Finally, working in television is a secret dream of mine – I was thrilled to recently consult on the David Attenborough documentary currently being produced, and television would be an amazing way to teach and inspire. But my greatest aspiration is simply to continue to be excited about entomology and all it entails.

2023 Photography Competition

The winning images in the Royal Entomological Society's Photography Competition 2023 were announced during Insect Week 2024. The annual competition showcases the very best amateur insect photography and attracts entries from around the world from keen photographers of all ages, helping to bring the often-overlooked miniature world of insects into sharp focus.

The 2023 overall winner in the '18 and over' category is Yorkshire-based Luke Chambers for his image 'Sleeping cuckoos' that depicts two Black-thighed Cellophane-cuckoo Bees (*Epeolus variegatus*) resting on a blade of grass. Speaking about the image he captured, Luke said: "Something I didn't expect to see when I visited a fairly new location to me, but one of my best encounters to date. Finding any sleeping invertebrate is always brilliant, but two so close together, well that's like winning the photography lottery!"

The 'Under 18' category overall winner is 17-year-old Swedish photographer Gustav Parenmark for his image 'Tranquillity' that shows a Banded Demoiselle damselfly (*Calopteryx splendens*) at rest. Gustav, who is a previous winner in the annual competition, said: "Waking up early is the key to photographing sleeping odonates. This species of damselfly is usually very skittish, but I went out at 4am to capture them inactive, making them easier to photograph."

Ashleigh Whiffin, RES committee member, Entomology Curator at the National Museums Scotland, a keen photographer and one of the competition judges, said: "We've been overwhelmed by the number of entries to the competition this year! It's wonderful to know that so many individuals have engaged with insects in this way, capturing some incredible moments for their world and showcasing the beauty and diversity of insects."

The youngest 2023 winner is multi-award-winning Jamie Smart, aged 8, who was overall runner-up in the '18 and under' category for her image 'Robber fly breakfast' depicting a Slender-footed Robber fly (*Leptarthrus brevirostris*). She has previously scooped awards from World Wildlife Trust, British Wildlife Photography Awards and RSPCA. Talking about the morning she captured the image, she said: "I was up early one morning and decided to have a wander around our wild garden with my camera when I saw this fly on grass. I didn't realise until looking on the computer that he was actually eating another fly!"

The 2024 RES Photography Competition and Art Competition are open for entries until 31 October, with winners' prizes generously donated by OM System. Visit https://www.insectweek.org/art-and-photography for full details.

OUTREACH

Over 18, 1st place, Luke Chambers, UK

Black-thighed Cellophane-cuckoo Bees, *Epeolus variegatus*.

OUTREACH

Over 18, 2nd place, Tim Jonas, UK

Mottled Sedge Caddisfly, *Glyphotaelius pellucidus.*

Having photographed a caddisfly laying her eggs at this location the previous year, I was keen to document the next stage showing eggs and larvae inside the gelatinous mass. I captured images of several egg masses near water, returning a few days later to find they had hatched.

OUTREACH

Under 18, 1st place, Gustav Parenmark, Sweden

Banded Demoiselle damselfly, *Calopteryx splendens*, male.

OUTREACH

Under 18, 2nd place, Jamie Smart, UK

Slender-footed Robber Fly, *Leptarthrus brevirostris.*

Having let our garden grow wild this year, I've enjoyed studying and learning more about all the amazing insects that have been thriving there. Taking macro photos of them allows me to see more of the intricate detail that the naked eye doesn't see.

OUTREACH

Other images received

Specially Commended – Smartphone

Abi Batten, UK

A wasp who joined us for a cream tea
German wasp, *Vespula germanica.*

"Wasp who seemed to enjoy sharing a cream tea with us, favoured raspberry jam over blackcurrant and was very polite. My eight year old son is actively working on his wasp phobia. This was the first wasp he's managed to stay calm around, and we enjoyed photographing it while it was hanging out with us."

Specially Commended – Behaviour

Heath McDonald, UK
Mating Blood-veins
Blood-vein moths, *Timandra comai*.

Blood-vein moths are a member of the moth family Geometridae, they get the name from the distinctive reddish line that runs from wingtip to wingtip. They are usually on the wing in the UK from May to July. The caterpillars feed on Dock and Common Sorrel.

"During one of our early morning visits to a 2 acre patch we are monitoring, we noticed a shape from a distance in the long grass. This mating pair had settled on a blade of grass. At this time of the morning there was no wind and a dew was forming, so I managed to take a few photos."

Specially Commended – Environment

Frank Ashwood, Australia

A pair of silverfish
Silverfish, Lepismatidae.

"These silverfish appeared to be clinging together inside a small, clayey nest structure, and refused to abandon each other when a camera lens pointed in their direction. Some of their brilliant silver scales have rubbed off, which may indicate moulting is about to take place."

"I recently had the opportunity of taking my camera around several farms across Australia. This photograph was taken in Western Australia, in a very dry area of sandy soils. Patience was a real virtue here – it took a lot of test shots to get both silverfish's eyes in focus!"

Specially Commended – Portraits

Neuropteran embedded in Burmese amber.

Enrico Bonino, Belgium
Thorny lacewings, Rachiberothidae.

This incredible specimen belongs to the Neuroptera insect order. It is characterised by two spiny raptorial forelimbs (similar to the mantis) and big eyes. This insect is embedded in ~99 million-year-old amber from the Hukawng Valley, Kackin State, Myanmar.

"Imagine a beautiful day full of amazing creatures. The neuropteran's eyes saw feathered dinosaurs, scaly reptiles, and the first mammals, hiding and running to avoid predators. Unfortunately, during its hunt, it fell on a golden flow of resin. Forever."

HONORARY FELLOW INTERVIEW

Rebecca Kilner

The restless entomologist

I had been planning on talking to Rebecca for some time, so when I realised that she was giving the Verrall Lecture it seemed a perfect opportunity to kill two birds with one stone.

We arranged to meet at the newly initiated Honorary Fellows' Afternoon Tea, to be held at 'Botanica', a short walk from the Natural History Museum. Locating the venue was more difficult than anticipated and I was soon part of a growing group of entomologists who were milling around on the Queen's Gate pavement hunting for our afternoon refreshment. The floral interior of one hotel was a big clue, and we filed in for a very English tea. We were offered a menu of teas, then Rebecca arrived just as tiered platters of sandwiches and cakes were being delivered to our tables.

Max Barclay had organised a quiet room for the interview at the NHM, so having enjoyed afternoon tea we walked to the museum and met Max under the whale. Introductions were made and Max escorted us via a labyrinthine route to a small meeting room. Asking "Are you sure you can find your way back", Max left us to it.

Early life

Was natural history an important part of your childhood?

"No, but I was a curious child. Both my parents had degrees in science – my dad was an engineer before he became a vicar. After I left home, my mother was finally able to become ordained herself, so the church was a gravitational force in our life.

Early in my childhood we moved to a large, very old, rambling rectory that had been magnificent in its heyday but had not been lived in for eighteen months, so it was a little run down. The house was set in three acres of overgrown grounds and my brother and I were given the run of them. So, while natural history was not formally a large part of my childhood it was the backdrop for all our outdoor adventures and exploration.

At school I don't remember any emphasis on natural history. In fact, I found biology quite boring. My mother was a biology teacher and she advised me to stick with it ("it will get better"). I began to find it more interesting as I moved through sixth form, where I enjoyed learning about evolution, and it was when I prepared for the Oxford entrance exam that I really fell in love with biology."

University

"At Oxford, I was in the last year that took the very traditional zoology course, with one phylum a week at its core. I also took courses in animal behaviour and became absolutely hooked when I was taught how to design an experiment that could get me inside an animal's head, to figure out how it saw the world and made decisions. I found this incredible. So, in my third year I began to look for PhD opportunities in animal behaviour. By chance, we had a guest lecture from Tim Clutton-Brock who was at Cambridge, so I applied for a PhD with him. He had just written a book on parental care and offered me a project looking at how mother birds decide which chicks to feed in the nest. It was only when I got to Cambridge that I discovered that Tim had been trying for years to recruit someone to do this project. Everyone else in Tim's group went off to Africa or to remote islands in Scotland for fieldwork. I got to sit in a shed just outside Cambridge and watch captive birds raising their young. But it was perfect for me. It was like being given the keys to a sweetshop by the owner, who then left me alone to enjoy it for three years.

The Department of Zoology was very vibrant, a brilliant place to be a PhD student, and I felt very much at home there. My first desk was an old Belfast sink with a plank balanced on top of it – but the intellectual atmosphere was thrilling. I felt I had found my tribe."

Rebecca's childhood rectory home.

Post Docs and cuckoos

"When I finished my PhD, I had a six-month post-doc with Nick Davies. I learned a huge amount from him in that short time and he has continued to be a guiding influence over my career. Nick and I looked at how the cuckoo corrupts the signalling system between parents and chicks in Reed Warblers. Cuckoo chicks famously evict host young from the nest. To get fed enough food, we showed that the cuckoo chick has to make an excessive begging call to compensate for the disadvantage of displaying only a single gape.

Between 1997 and 2007 I held two research fellowships in succession, each funded by the Royal Society, and continued to work on birds. I spent some time at Cornell University in the USA, extending the cuckoo work to cowbirds. Unlike cuckoos, they grow up alongside host chicks in the nest. We showed that this helps them to solicit more care from host parents. I also went to Australia to study Horsfield's Bronze Cuckoos that parasitise Fairy-wrens, with Naomi Langmore. We showed that Fairy-wren hosts can recognise and reject cuckoo chicks, and we figured out the rules underpinning the decision to reject."

Sexton beetles

"Towards the end of my research fellowships, I was lucky enough to get a lectureship in the Department of Zoology at Cambridge – but it meant my days of travelling each year to Australia were over. As I was wondering what to work on next, I got an email out of the blue from a student asking if they could work on burying beetles in my lab. It might seem like a leap from birds to beetles, but they have in common an interesting family life. By this time, I had spent a lot of time looking at the outcomes of evolution, now I wanted to see some evolution in action. With their shorter generation time, the beetles offered a way to do that, which just wasn't possible with birds. So, the PhD student, Richard Ward, came to Cambridge and set up a small lab for studying burying beetles. He was later joined by Sheena Cotter, and little by little I moved from working on birds to working on beetles. Over the course of about seven years, we experimentally evolved populations of beetles to investigate how social behaviour influences the course of evolution – and saw evolution in action under our noses, with new adaptations emerging, with associated genetic change."

Museum

"Towards the end of this experiment, in 2019, the Directorship of the University Museum of Zoology fell vacant – and I was very privileged to be offered this post, despite my lack of experience in the museum world. It was exactly the kind of new challenge I needed at that point, and I learned something new every day from my amazing new colleagues. The museum had recently re-opened after undergoing substantial refurbishment. My job was to set a new purpose for the museum. Our

Rebecca's sexton beetle cultures.


Rebecca with her baby son.

grand plans were soon thrown off course by Covid, but the museum staff were brilliant. We adapted and coped and have bounced back to higher visitor numbers, more academic staff, and more commercial and research income than ever before.

The Museum of Zoology at Cambridge is like a smaller Russian doll within the larger Russian doll of the Department of Zoology. Now I have moved on to be Head of Department, partly to be able to help the museum even more and partly because I feel it is a way to repay my debts to the department. The department gave me my career. The least I can do now is serve the next generation of zoologists in Cambridge by making sure they feel as intellectually stimulated and welcome as I did when I began my research career."

Life Scientific

"One day I had a phone call from out of the blue: would I like to be interviewed for *The Life Scientific*? This involved the unusual and somewhat indulgent experience of talking to a complete stranger (the producer, Lucy Taylor) for three hours about my life and career. The interview formed the foundation of the program which was beautifully put together and told a story about me that I had not realised before, linking my childhood in the centre of a village community to my current work with different kinds of communities – in the museum and in the department. I do see parallels between churches and museums. They each inspire reverence, and cause people to lower their voice to a whisper. They are places where communities convene around ideas and things that are not part of everyday life. They take people out of their own heads, and their own existences, and connect them to something bigger. I began to think this when I started as Museum Director and it was very noticeable when we reopened after Covid. There was real joy on visitors' faces as they came back into the museum and were taken away from their everyday issues and could connect with other people again, through this shared experience."

Time was short and the Verrall Lecture was calling, so we tentatively wove our way back through the labyrinth of corridors to the cavernous Coleoptera Department, where Max released us back into the hustle and bustle of the main museum. It was then a short walk to the lecture theatre in Imperial College where the Verrall Lecture had been set up and a reception committee was waiting for Rebecca.

Communities have been at the heart of Rebecca's journey from the village and wild garden that nurtured her as a child via the many smaller communities that supported her as a student to the communities that she now oversees and nurtures in return. Always keen to learn, she has moved from one challenge to another, her restless curiosity keeps her moving to seek solutions to ever-larger problems and she ensures that there are always people in the room that can teach her something new. Once a curious child, now an ever-curious adult.

When she talked about her museum work, Rebecca described the natural history collections as the gateway drugs to nature. Long may Rebecca be the dealer who introduces local people to the lure and fascination of museums, and the hard stuff of the natural world itself.

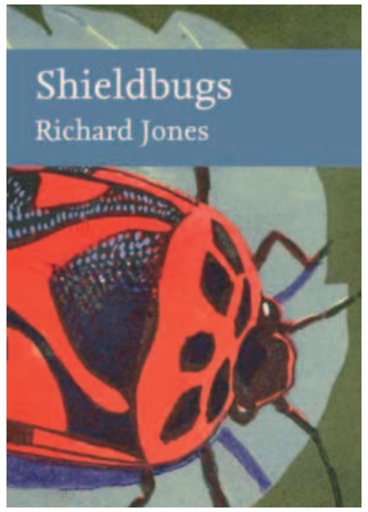
Rebecca's Verrall Lecture on sexton beetles is available on the RES website.

Peter Smithers

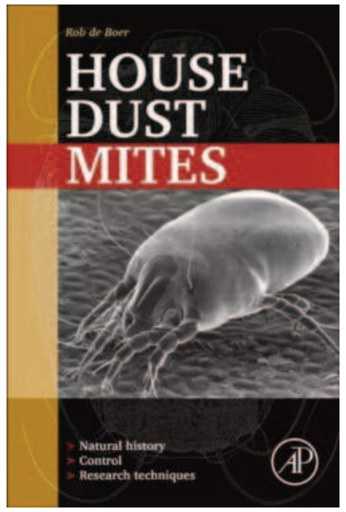
Royal Entomological Society — Antenna Reviews

If you wish to recommend a book for review, please contact: antenna@royensoc.co.uk.

The following reviews have been added to the *Antenna* website:
www.royensoc.co.uk/publications/book-reviews/



Shieldbugs (New Naturalist Series, 147)
Richard Jones
Published by Harper Collins
ISBN 9780008334895
Reviewed by Alex Ramsay



House Dust Mites: Natural history, control and research techniques
Rob de Boer
Published by Academic Press (Elsevier Inc.)
ISBN 9780443191114
Reviewed by Ian Burgess

Small Game Hunter
Peter Smithers
Published by Brambleby Books, 2024
ISBN 9781908241702 (paperback)
Reviewed by Richard Harrington

EVENTS

Details of the meetings programme can be viewed on the Society website (www.royensoc.co.uk/events) and include a registration form, which usually must be completed in advance.

Offers to convene meetings on an entomological topic are very welcome and can be discussed with the Chair of the Meetings Committee (richard@royensoc.co.uk).

October 2024

Wed 9 — 9 October
Online Talk – Ecological Entomology (virtual event)
by the Royal Entomological Society's President Elect, Jane Stout of Trinity College Dublin

Sat 12 — 12 October
New Scientist Live 2024 (external event)

Wed 30 — 30 October
Feeding the Future: Using Insects as Food and Feed (panel debate)

Thu 31 — 31 October
Insects as Food and Feed: Delivering insect proteins in the UK (hybrid event)

November 2024

Wed 6 — 6 November
Orthoptera SIG (hybrid event)

Fri 8 — 8 November
Sustainable Agriculture SIG
Sustainable Agriculture: Innovations in research and practice (hybrid event)

Wed 13 — 13 November
Online Talk – Agricultural and Forest Entomology (virtual event)

December 2024

Wed 11 — 11 December
Online Talk – Medical and Veterinary Entomology (virtual event)

March 2025

Wed 5 — 5 March
Verrall Lecture 2025

Mon 31 — 31 March–1 April
RES Student Forum

June 2025

Mon 23 — 23-29 June
Insect Week 2025

September 2025

Tue 9 — 9–11 September
Ento25

Online Talks

On the second Wednesday of the month, hear talks aligned to our seven journals. Free for members.

9 October: Ecological Entomology
13 November: Agricultural and Forest Entomology
11 December: Medical and Veterinary Entomology

For full details on all RES meetings please visit www.royensoc.co.uk/events

SHAPE TOMORROW'S SCIENCE AT **ENTOMOLOGY 2024!**

Learn the latest in insect science and advance your work at ESA's Annual Meeting, **Entomology 2024**. This event offers a unique platform to present innovative ideas, techniques, and technologies within and beyond entomology while networking with colleagues and sharing your research. Held in Phoenix, AZ, known for its natural wonders and vibrant downtown, the meeting fosters scientific and professional growth. The theme, **"Empowering Tomorrow With Insect Science,"** will explore using AI and modern technology to address global challenges like biodiversity loss, food shortages, and insect-borne diseases.

IMPORTANT DEADLINES

- **SEPT 16** Advance Registration Deadline
- **OCT 11** Housing Reservation Deadline

Visit entsoc.org/entomology2024 or scan to register and be part of the program!

ENTOMOLOGICAL SOCIETY OF AMERICA
SHARING INSECT SCIENCE GLOBALLY