# Antenna

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Royal Entomological Society

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Submissions are made by email to antenna@royensoc.co.uk and reviewed by *Antenna's* editorial team. There are no page charges for publication in *Antenna*, where we encourage use of full colour figures and photographs to accompany text. Standard articles are normally 1,000–3,000 words in length and submitted with four to eight images (file should be original size of image taken and not reduced in size nor cropped heavily).

**Cover Picture:** 'Damselflies Mating'. Photo: Peter Sabol. (Front cover: White-legged Damselfly, *Platycnemis pennipes* (left); Azure Damselfly, *Coenagrion puella*; Back cover: Azure Damselfly, *C. puella*).

# Editorial

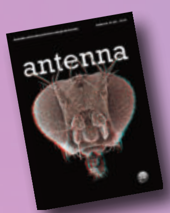
This year's ENTO meeting attracted the most delegates ever, with the research presentations, networking and, yes, fashion, receiving rave reviews from in-person attendees, as evidenced by the write-ups on pages 200 onwards. Neither has the Society been resting on its laurels elsewhere, with two excellent evening meetings (free to members, of course) on the latest developments in insect science, reported on by Kimberly Gauci and Richard Harrington. Possibly the most striking research, though, is that described by Stuart Reynolds in his Research Spotlight, indicating the evolutionary significance of apyrene sperm – that is, cells lacking a nucleus, and therefore DNA - to Lepidopteran reproduction. Who knew?!

Of course, it's good to balance all this groundbreaking stuff with some history, as we can never fully understand where we're going without reflecting on where we've been. Having volunteered at a wildlife veterinary hospital for many years, the article on page 187, on the history of scabies, captured my interest. The subspecies of sarcoptic mite responsible for scabies in foxes is not the same as that associated with serious infections in humans, but I know a few veterinarians who have experienced the joys of catching the fox variety! A quite different historical perspective is offered by Ian Hodkinson, on page 192, who describes a well-known entomological 'watering hole' in the southern part of Lakeland.

Chelsea isn't the only flower show, and Barbara Tigar describes worthy efforts to engage the public with insect science at a flower show in the northwest of England. A broader attempt to engage with the public is Biolinks, described under the Grants section of the journal.

Rob Jacobson provides a useful review of integrated pest management 'at the coal face'. Being Welsh, the Honorary Fellow interview also caught my interest, as Peter Smithers' victim this time is Hefin Jones (to the uninitiated, his first name is pronounced 'Hevin', by the way!) who emerged from the wilds of west Wales to become a professional entomologist of some renown. There could be hope for some of us yet!

Dafydd Lewis




## Antenna
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# Letter from the President

Wow - what an amazing Ento23 meeting at the University of Exeter in Cornwall in September! A fabulous location, great weather and an amazing opportunity to network with insect scientists. I hope many of you were able to attend either in person or online. It was the largest Ento meeting the Society has held, and it was great to see so many people. I'd like to thank the Exeter organisers – Ben Raymond, Ben Longdon and Jason Chapman – as well as all the RES staff for organising such a great event. Also, many thanks to all the speakers and people who offered posters and talks. At our AGM it was lovely to welcome our new trustees, Jane Stout (as president-elect) and Walter Leal, and to thank our outgoing trustees, John Baird and Helen Roy (past-president) – thank you so much for everything you have done for the Society. I'd also like to thank the Ento23 plenary speakers – Jaap de Roode, Elli Leadbeater and Vanessa Kellermann – and don't forget you can listen to their talks on YouTube if you missed the talks live, and you would like to hear more about 'Migration, microbes and medication in the Monarch butterfly'; or 'Adaptation in a warming world: Insights from *Drosophila* and bees'; or 'Does (collective) cognition produce efficiently foraging bees?' If you are keen for more exciting insect science, don't forget our online evening talks – check the RES website for more details of all our events. Ento23 was a great opportunity to offer workshops and networking events, and we will be looking to improve on these in future to make sure there is something for everyone. I'm sure Ento24 will be even better!

As we approach the midpoint in the Society's 2022–25 Strategy to 'enrich the world with insect science', it's an interesting time to reflect on progress as well as what more there is to do. Our Strategy was built on consultation with our membership and we will continue to consult as we make progress on our strategic aims. Check our web pages for more information on the Strategy. One upcoming major change is the planned move of our current headquarters from Mansion House in St Albans, UK. Many of you will remember the previous move in 2007 from 41 Queen's Gate in central London, where the Society had been based since 1920, to Mansion House. It is now time to move again, to ensure the Society continues to provide the best support for our Members and Fellows, and to support the strategic aims of the Society in future. We have surveyed the membership and will use this information to better understand what you value in a headquarters, as we decide where our new 'home' will be. Exciting times ahead!

As the Society continues to grow its membership – we now have more than 2,000 members - it is important to consider the benefits of being a Member or Fellow of the RES. When I joined the Society, I valued the opportunities to network and really appreciated the support provided for early-career researchers. I also enjoyed hard copies of *Ecological Entomology* turning up in my pigeonhole at work, although the publishing world has changed a lot since this pre-digital last-century experience! Of course, publishing is still core to the Society's activities and income from publishing, including our excellent journals, underpins most of our Society's activities. As publishing continues to evolve, and there is an ever-increasing number of journals and publishers to choose from, the RES is keen to build a strong community of support around our journals, as the go-to place for publishing. Please continue to support our journals, either as an author, reviewer, editor or reader – they are a vital part of our Society.

**Jane Hill OBE**
President
Royal Entomological Society



RESEARCH SPOTLIGHT

# No Nucleus: The puzzling infertile sperm of Lepidoptera

Suddenly, insect chromosomes became big news

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**Insect sperm cells that lack chromosomes**

At the turn of the twentieth century, insect chromosomes gained a centre-stage position in the biological science spotlight when Columbia University graduate student William Sutton's landmark cytogenetic study of spermatogenesis in the Plains Lubber Grasshopper (*Brachystola magna*) provided proof of the essential role of chromosomes in heredity (Sutton, 1902; 1903). Suddenly, insect chromosomes became big news.

But within the year, another discovery concerning insect sperm was made that was to prove a long-running embarrassment to geneticists. In 1903, the German cytologist Friedrich Meves demonstrated that in some animals, especially moths and butterflies, many sperm cells don't possess a nucleus and therefore have no chromosomes at all (Meves, 1903). Looking specifically at the Buff Tip moth *Phalera* (=*Pygaera*) *bucephala* (family Notodontidae) (Fig. 1), Meves described these sperm cells as 'apyrene', contrasting them with the 'eupyrene' sperm of the same species that have a normal nucleus (the word 'pyrena' refers to the 'stone' of a fruit, such as a peach). His paper clearly showed that in apyrene sperm the chromosomes fail to segregate properly during meiosis; subsequently, the resulting nuclear debris is ejected from the elongating spermatid.

In the early 1900s, the very existence of anucleate sperm cells could not easily be reconciled with the brand-new chromosomal theory of inheritance. On the face of it, a sperm cell without a nucleus was nonsensical! If there is one cell type in an animal's body that has a single, obvious function, then it must surely be the spermatozoon; even in 1903 everyone knew that sperm cells exist solely to transfer male genetic material to the next generation, yet without chromosomes they can have no genes to transfer! How could evolution by natural selection result in sperm without nuclei?

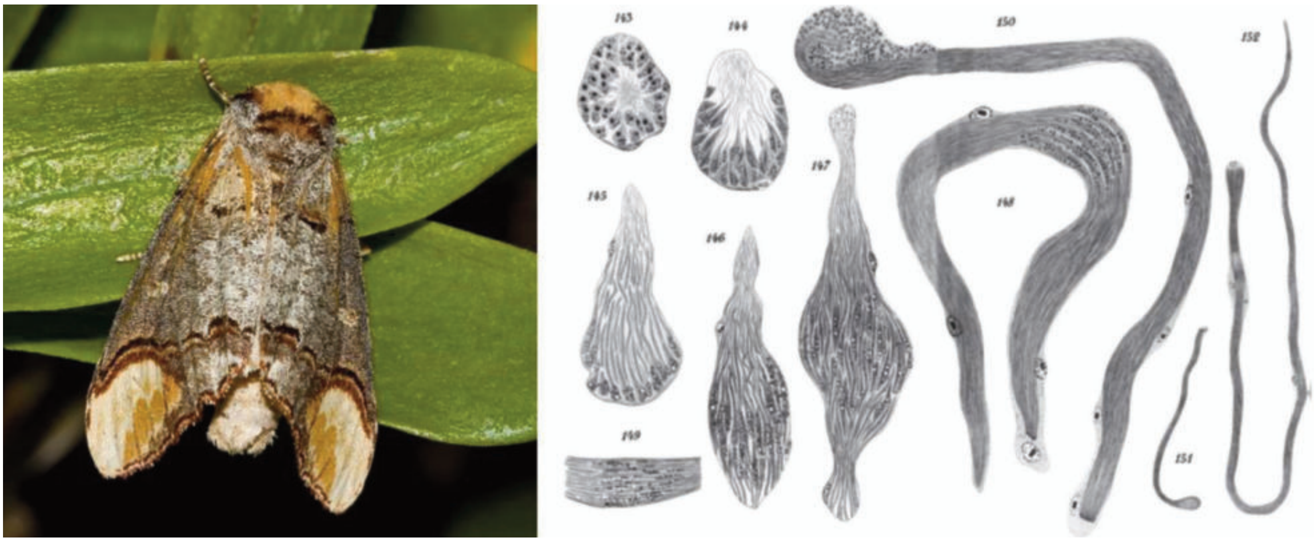

**Figure 1.** (Left) The Buff Tip moth (*Phalera* (=*Pygaera*) *bucephala*) (Notodontidae). Photo by Olei, CC BY-SA 3.0. (Right) Plate VII from Meves (1903) showing intratesticular development of apyrene spermatozoa (143–151) and the progress of enucleation during development of apyrene sperm. In (147) and (148), the micronuclei move down the apyrene bundle towards the tail, and in (150) are shown being ejected from the cells at the tail end of the cyst. Legend adapted from Friedländer *et al*. (2005).

In the first decade of the twentieth century, biologists were just getting to grips with the idea that genes were located on chromosomes, and they just didn't want to know about apparent exceptions to the rule. Thus, the fact that most lepidopteran sperm do not possess any chromosomes at all was largely ignored for almost 70 years. Where recognition of the existence of apyrene sperm couldn't be avoided, it was simply asserted that they were degenerating cells resulting from developmental mistakes (*e.g.*, Gatenby, 1917).

Only after 70 years did interest in apyrene sperm begin to pick up again with a new investigation by Friedländer *et al*. (1972), at the Hebrew University, Jerusalem, Israel. Using modern microscopical techniques, he looked carefully at what actually happens during sperm maturation and transfer in the domestic silkmoth, *Bombyx mori*. It was clear that apyrenes do not simply 'degenerate' and (apart from not having either a nucleus or an acrosome) in many respects they resemble ordinary sperm (although they are shorter). (An acrosome is a vacuolar structure present in the sperm head that is otherwise highly conserved through evolution). Apyrene sperm are not the result of a developmental accident – in Lepidoptera the destruction of the nucleus occurs regularly in all the spermatocytes in a certain type of testicular cyst and at a specific developmental stage. After ejecting their nucleus, apyrene spermatozoa don't die, but are released from the testis and are stored and ejaculated alongside their eupyrene siblings (Fig. 2) (Friedländer *et al*., 2005; Seth *et al*., 2023). Once activated by an enzyme secreted by the accessory glands during copulation, apyrenes are in fact even more vigorously motile than their eupyrene siblings (Nagaoka *et al.,* 2012).

Even today, many insect scientists are unaware of this strange situation, perhaps because most standard general entomology textbooks fail to mention apyrene sperm at all! Of those I have sampled, only the otherwise excellent *The Insects: Structure and Function* (Chapman *et al.,* 2013)


**Figure 2.** (Left) *Spodoptera litura* (Noctuidae), male. Photo: Birgit E. Rhode, CC BY 4.0. (Right) Squash preparation of eupyrene and apyrene sperm from the sperm storage organ (the duplex) of the male reproductive tract of *S. litura*. Apyrene spermatozoa (Ap) have already disaggregated and are seen as tangled individual, thin profiles; bundles of eupyrene sperm (Eu) are seen as fewer, thicker profiles, each representing 256 eupyrene sperm cells derived from a single testicular cyst. From Seth *et al.* (2002).


**Figure 3**. *Pachysphinx modesta* (Sphingidae) male. This species is the current record-holder for the highest proportion of anucleate sperm; 98.7% of sperm in the male sperm storage organ are apyrene. Photo: Didier Descouens, CC BY-SA 4.0

acknowledges apyrene sperm, and even then devotes only two lines to apyrenes without considering what their function might be.

## Prevalence and evolution of apyrene sperm

In fact, a surprisingly large fraction of lepidopteran sperm are of the apyrene kind. In a recent study of 17 moths and butterflies from 14 families by Shepherd *et al.* (2021a), it was found that in 80% of species more than half of their sperm are anucleate. The record is currently held by the Poplar Sphinx moth, *Pachysphinx modesta* (Fig. 3) in which an amazing 98.7% of sperm are apyrene. In general, there is a steep increase in the proportion of apyrene sperm with increasing insect size, but even very small moths produce at least some apyrene sperm.

Among butterflies and moths, sperm heteromorphy is not only extreme in character but is also practically universal (Friedländer, 1983). The only known exceptions are members of the genus *Micropterix* in the most primitive and atypical lepidopteran family, Micropterigidae, where at least two species, *M. calthella* (Fig. 4) and *M. aruncella* produce no apyrene sperm at all (Sonnenschein *et al.*, 1990). From this we may assert with confidence that this kind of spermatogenesis probably first arose 190–200 Mya, not long after the evolutionary origin of the order (Mitter *et al.,* 2017), and that since that time no lepidopteran has reverted to having only one kind of sperm. This leaves us with a lot to explain. Such an apparently expensive trait must surely confer a strong selective advantage. But why would any insect produce less than two sperm cells in 100 that can actually undertake fertilisation?

## Both eupyrene and apyrene sperm are essential

It was almost a century after the publication of Meves' 1903 paper, that Ken Sahara, at Hokkaido University Japan, proved that both eupyrene and apyrene sperm are required for the successful fertilisation of lepidopteran eggs (Sahara *et al.*, 2002). To do this, he teased apart the functional roles of eupyrene and apyrene sperm of *B. mori* using two different experimental treatments (Fig. 5). Mild heat shock (33°C, 24h) of larvae at the time of spinning prevents the resulting male moths producing any apyrene sperm, the shock being given at exactly the stage of development when spermatocytes destined to form apyrene sperm are undergoing meiosis; eupyrene spermatocytes are unaffected because the shock occurs after the completion of their own meiotic reduction division. Even though their eupyrene spermatozoa are unaffected, the resulting male insects are completely sterile. This result alone shows that apyrene sperm are necessary for fertility.

Going one better than this, Sahara *et al.* (2002) also showed that polyploid male moths (produced by cold-shocking eggs at the time of early embryogenesis) are unable to make eupyrene sperm. This result occurs because later in life the cold-shocked sperm cells eliminate their own perfectly good nuclei during spermiogenesis in just the same way that normally occurs only in developing apyrene sperm. Unsurprisingly, without eupyrene sperm the resulting adult males are completely infertile. Remarkably, however, when

**Figure 4**. *Micropterix calathella* (Micropterigidae), one of only two lepidopterans known not to produce anucleate sperm. Photo: Wouter Bosgra, CC BY-3.0

normal female moths were doubly-mated to males of these two different kinds, one with only apyrene sperm and the other with only eupyrenes, fertility was restored to almost the same level as was seen with a single mating to a control male. A similar result was obtained when artificial insemination with mixtures of cryopreserved semen from the two kinds of experimental male insect was used instead of double-mating (Sahara *et al.,* 2003). These findings confirm that neither mating behaviour, nor the spermatophore in which sperm are deposited, play a part in the result of the double-mating experiments, and that the simultaneous presence in the female of the two types of spermatozoa is both necessary and sufficient to secure fertilisation.

Additional proof of the absolute requirement for apyrene sperm has recently been obtained using gene editing techniques to disrupt genes that are separately essential for the normal formation of one or other type of sperm. In *Bombyx,* the gene *poly(A)-specific ribonuclease-like domain-containing 1* (*pnldc1*) is required for the formation of normal eupyrene sperm. When this gene was disrupted using the CRISPR/Cas9 gene editing technique, only abnormal eupyrene sperm could be seen in the testis and a much-reduced

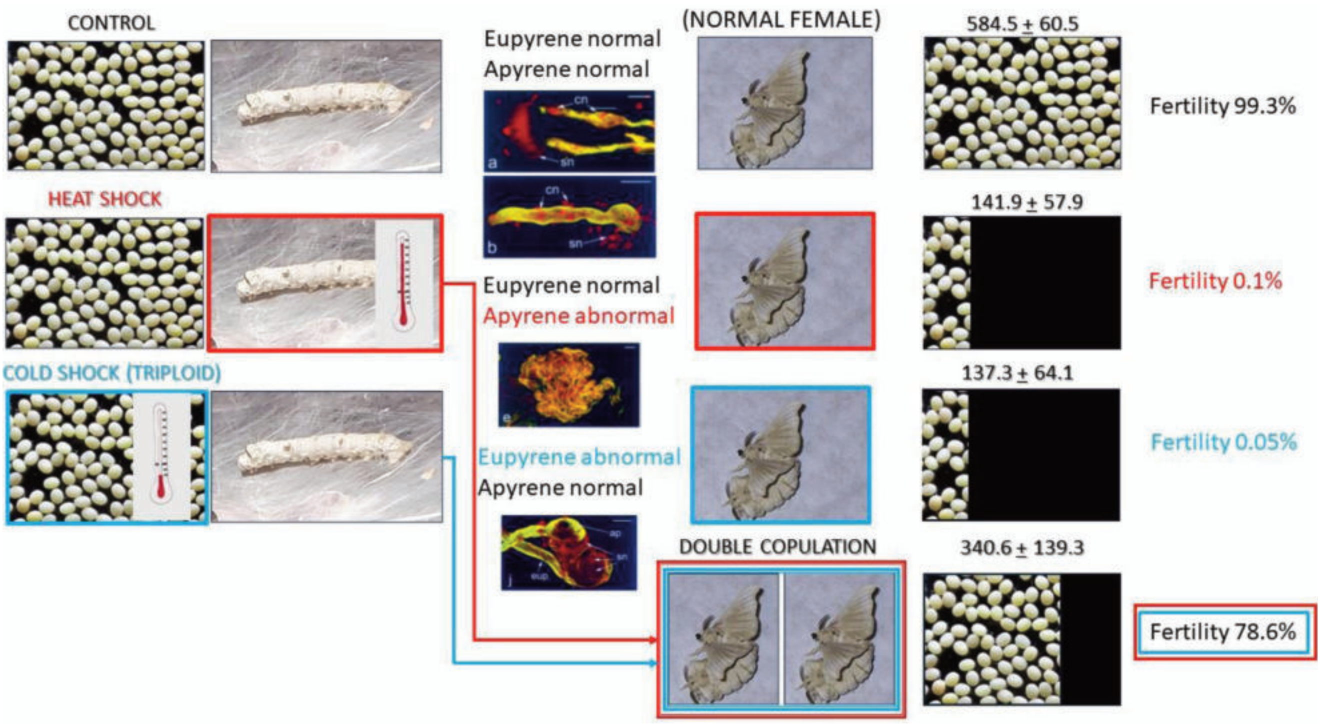


**Figure 5.** Graphic summary of the heat and cold shock experiment that proved that apyrene sperm are required for fertilisation in *Bombyx mori.* Experimental design and data taken from Sahara *et al.* (2002). Heat shock (33°C) administered to spinning male larvae causes abnormal development only in spermatocytes destined to produce apyrene sperm (outlined in red). Cold shock (-10°C) administered to male eggs results in the development of a triploid male. This causes abnormal development only in spermatocytes destined to produce eupyrene sperm (outlined in blue). In each case, when the resulting adult males are mated to normal females, the number of eggs laid is reduced by 75% compared to control males, and fertility is close to zero. But when a normal female is double-mated first to a heat-shocked male and then to a cold-shocked male, the number of eggs laid is restored to about 60% of control, and fertility to about 80%.
Photos: new-laid silkworm eggs: puremysore.wordpress.com; spinning larva: iNaturalist.org, CC BY-NC; mating silkmoths: Oakenking at Wikipedia, CC BY-SA 2.5; images of sperm bundles reproduced with permission from Sahara *et al.* (2002).

number of eupyrene sperm, all abnormal in appearance, was found in the ejaculate. By contrast, normal, motile apyrene sperm were present as usual. Without the *pnldc1* gene these male insects were completely sterile (Chen *et al.*, 2020). On the other hand, when a different gene, *sex-lethal* (*sxl*), was disrupted, normal eupyrene spermatogenesis occurred, but those apyrene sperm that were formed in the testis were abnormal, and no apyrene sperm at all appeared in the ejaculate (Sakai *et al.,* 2019; Chen *et al.,* 2020). As expected from the experiments of Sahara *et al.* more than a decade earlier, the fertility of a female that had not received apyrene sperm could be fully restored by an immediate second mating with a male that lacked eupyrene sperm, but which transferred apyrenes normally (in the case of the study by Sakai *et al.,* the latter was a polyploid male, while in the case of Chen *et al.* it was a gene edited male lacking the *pnldc1* gene).

Taken together, these elegant experiments definitively show that normal eupyrene sperm alone are not enough for fertility, and that despite the absence of a nucleus in apyrene sperm, the presence of apyrenes is required to allow eupyrene sperm to fertilise eggs. This means that the genes underlying the formation of apyrene sperm must be subject to selection, even though they cannot themselves pass on those genes. We must conclude that apyrene sperm contribute to fitness by 'helping' their sibling eupyrene sperm to fertilise eggs.

One might comment that this 'helping' role of apyrene sperm is not extraordinary; it is in principle no different from the way in which all of the non-reproductive (somatic) cells of a multicellular organism's body promote the transmission of their own genes to the next generation through inclusive fitness (Queller *et al.,* 2009). But importantly, we must acknowledge that unlike the somatic cells of the body, apyrene spermatozoa are, like their eupyrene siblings, the progeny of germ-line stem cells, and production of apyrenes is therefore directly at the expense of forming the same number of eupyrene sperm. This means that in producing apyrenes, the insect is taking a decision to sacrifice some of its fertile gametes in favour of infertile 'helpers'. Astonishingly, this implies that the allocation of a unit of resource to the formation of an apyrene sperm cell actually contributes as much to fitness as for a single eupyrene sperm.

### What is the function of apyrene sperm?

There are plenty of plausible hypotheses about how apyrene sperm might contribute to fitness, mostly relating either to competition between the sperm of different males, or to sexual conflict between males and females (Sheppard *et al.,* 2021b; Swallow *et al.*, 2002). It's important to note that it's likely that only some of these fitness-promoting traits will be used by the spermatozoa of any one lepidopteran species. Moreover, the selective forces 200 Mya that drove the peculiar lepidopteran evolutionary innovation of anucleate sperm are probably unknowable; all we can do is to investigate their role in a selection of living moths and butterflies.

The best evidence we have of present-day apyrene function comes from the gene editing study on *B. mori* (Chen *et al.*, 2020) to which I referred above. Following the engineered knockout of the gene *sex-lethal* (*sxl*), normal eupyrene sperm are present in the male tract but apyrene sperm are absent; as a result, ejaculated eupyrene sperm are present in the female's bursa copulatrix (the female structure that receives sperm from the male) but fail to migrate to the female's sperm-storage organ, the spermatheca. Thus, in this species, 'help' given by apyrene sperm evidently takes the form of assisting eupyrenes to move within the female reproductive tract. Currently, we still don't know the exact nature of this boost to eupyrene motility. One possibility is that apyrene sperm cooperate to generate bulk flow of semen in the female tract (more on this below).

### Sperm–sperm competition and sperm motility

Other hypothetical forms of 'help', however, are not excluded by the above result. Most alternative proposals relating to the apyrene contribution to fitness are based on the idea that in multiply-mated females, spermatozoa from different males compete to fertilise eggs, thus imposing sexual selection on genetic traits expressed in the sperm cells themselves (Parker, 1970). Extending this idea, and using a term of doubtful taste, Silberglied *et al.* (1984) described apyrene sperm as 'eunuchs', implying that their function is to guard the mated female's eggs against the approach of eupyrene sperm derived from other males. In other words, apyrenes 'help' eupyrene sperm present within their own ejaculate to compete with eupyrene sperm from other males.

Specifically, Silberglied *et al.* (1984) suggested that apyrene spermatozoa could play a sacrificial 'kamikaze' role in which they would physically or chemically antagonise the eupyrene sperm of other males; this subsequently became a popular hypothesis to explain reproductive behaviour in both animals and people (Baker *et al.,* 1988), although the idea has not subsequently received much empirical support (Moore *et al.,* 1999). In any case, it isn't clear how sperm from one male could sabotage those from other males without collateral self-harm. In fact, such direct antagonism is not required for sperm competition, and the evidence is that where competition does occur, it is mostly mediated by the female simply dumping surplus sperm from previous matings (Snook *et al.,* 2004). It may therefore be beneficial for the male to use apyrene sperm to provoke the ejection of stored sperm from previous matings. Simple numerical 'crowding' competition between sperm is seen to occur in many animals with polygamous mating systems; put simply, in such cases it is the male that transfers more sperm which gains a proportionately greater success in securing paternity, although other variables may lead to more complex dependence of male fitness on ejaculatory effort (Parker *et al.,* 2010; Parker, 2020).

The other side of the coin, however, is that because (due to meiosis) the individual haploid sperm produced by a single male are not genetically identical,

**Figure 6.** The Chinese Windmill (*Byasa alcinous*) (Papilionidae), male. Despite being almost exclusively monandrous, males of the species produce a high percentage of apyrene sperm, strongly implying that apyreny has functions other than post-coital sperm competition. Photo: Alpsdake, CC BY-SA 3.0

genetically based competition will occur between sperm within the same ejaculate to secure fertilisation (Sutter *et al.,* 2020). Such internecine strife is likely to be detrimental to the diploid male that produces the sperm since effective competition with other males to secure fertilisation might well require cooperation between his own sperm (*e.g.*, collaborative swimming – see below). In this view, the lack of a nucleus in apyrene sperm may be seen as a parentally-enforced adaptation to avoid within-ejaculate competition between spermatozoa. Since apyreny occurs to the greatest extent in Lepidoptera, this implies that within-ejaculate sperm cooperation may also be notably prevalent in this order of insects. A further possible benefit of using a large number of less costly apyrene sperm to fuel the transport of a smaller number of eupyrene sperm might be to reduce the cost of surveillance to ensure that the latter (the actual gametes used for fertilisation) are of uniformly high genetic quality.

## Apyrene sperm and sexual conflict

It has been pointed out (Edward *et al.,* 2015) that direct competition between sperm may inflict collateral damage on the female, so that male-male conflict may in some circumstances lead also to male-female conflict (*i.e.*, the reproductive interests of the male and the female do not coincide). The most generally observed response to sperm competition is for males to ejaculate more sperm at each mating (Simmons *et al.*, 2012). The presence of more sperm, and perhaps also of additional associated accessory gland proteins (Wigby *et al.*, 2020), might be directly damaging to the female. Prolonged mating, needed to transfer more sperm, might also do physical harm to females. Damage might be indirect; for example, greater numbers of sperm might be accompanied by higher concentrations in the female reproductive tract of damaging reactive oxygen species (ROS) (Ribou *et al.,* 2012). Selection to minimise such damage might result in females attempting to reduce the density of sperm within their sperm storage organ (spermatheca). They could do this by directly shedding sperm in excess of immediate requirements; there is evidence that this occurs in Lepidoptera (Etman *et al.*, 1979).

An alternative evolutionary response of females to sperm-inflicted damage would be to impose energetic or structural barriers to movement of sperm within the seminal duct (this connects the bursa copulatrix, in which the spermatophore is deposited, to the spermatheca); such barriers would include making the female duct longer and narrower. This might then lead to increased investment by males in less costly, infertile 'helper' sperm that assist the movement of fertile eupyrene sperm within the seminal duct by vigorously swimming to generate bulk fluid flow within the duct's lumen. This might involve flagellar cooperativity and collective motion of multiple sperm (Simons *et al.*, 2021).

Although direct sperm-sperm competition (whether accompanied by male-female sexual conflict or not) may have been important to the original evolution of apyreny, there is little evidence that it maintains the production of apyrene sperm in extant Lepidoptera. Although apyrene sperm are relatively more numerous in polyandrous species (Shepherd *et al.*, 2021a), males of some notably monandrous species such as the swallowtail butterfly *Byasa alcinous* (Papilionidae) (Fig. 6), in which there is normally no competition at all between the sperm of different males, nevertheless produce many more apyrene than eupyrene sperm (Konagaya *et al.,* 2016). This might simply be due to the well-known rapid evolution of male-reproductive-related traits (Meiklejohn *et al.*, 2003), which might allow the persistence of the regulatory genes that produce apyrene sperm even after the selective basis for their original selection has been lost. Alternatively, it is possible that the presence of numerous apyrene sperm is evolutionarily 'addictive'. Once within-male cooperativity of sperm swimming effort has become established as a result of inter-male sperm competition, the eupyrene sperm themselves might evolve to be dependent on the presence of 'helper' apyrenes. Under these circumstances, the continued presence of sperm competition might no longer be needed to maintain the requirement for apyrenes.

## Effects on female remating

An entirely different sort of sexual conflict is that in which the interest of the female is to hedge her reproductive bets by mating with multiple males of differing genotypes, thereby producing offspring adapted to an uncertain future environment (Yasui *et al.*, 2016). By contrast, the male's interest is to maximise his own share of paternity in each individual female's reproductive output. A male therefore attempts to monopolise access to the female's eggs by influencing her ability to remate once the transfer of his own sperm has been completed. This can be achieved in a number of ways but is most simply done by filling to repletion the female's sperm storage organ, the spermatheca, with infertile but inexpensive *faux* gametes (*i.e.*, apyrene sperm). The assumption is that the female's choice to remate or not is dependent on her ability to monitor the state of fullness of her spermatheca.

There is good evidence to support this idea from the polyandrous Green-veined White butterfly (*Pieris napi*) (Fig. 7) (Cook *et al.*, 1999; Wedell *et al.*, 2009). Female butterflies of this species that remate are those whose spermatheca contain only small numbers of apyrene sperm, whereas those that do not remate are those whose spermatheca contains relatively more apyrene sperm. Seen from the point of view of the male, the main function of apyrene sperm would thus be to reduce the probability of female remating, and thus to boost his own fertility, even if this is at the expense of the female's fitness. In this evolutionary scenario, apyrene sperm in the ejaculate are a 'cheap filler' that attempts to deceive the female about the true number of fertile sperm stored in her spermatheca. In a system like this, in which the male seems to be 'in control', the presence in the ejaculate of non-fertile apyrene sperm might drive evolution of the mating system towards monogamy (Hosken *et al.*, 2008).

But sexual conflict theory also predicts that females may respond by developing ways to distinguish between apyrenes and eupyrenes, allowing surplus apyrenes to be preferentially discarded and thus sidestepping male control of remating. This may lead to an arms race in which the extent of male deception (*i.e.*, the apyrene:eupyrene ratio) escalates, especially if the cost of making apyrene sperm is low. The very high percentages of apyrene sperm seen in many lepidopterans seem to offer some support for this idea.

Sexual conflict does not however point exclusively towards the evolutionary amelioration of direct sperm competition between males. Hosken *et al.* (2009) have pointed out that although male-female conflict can in some circumstances act to promote a shift away from polygamy to monogamy, it can also act in the opposite direction, promoting polygamy at the expense of monogamy. In the case of Lepidoptera this might be the outcome where apyrene sperm are utilised by the female as a recyclable resource to enhance her own fertility.

## Proteins of eupyrene and apyrene sperm

Proteomic analysis provides clues about the differential functions of eupyrene and apyrene sperm in Lepidoptera. This has been facilitated by the development

**Figure 7**. The Green-veined White, *Pieris napi* (Pieridae), male, ventral view. In this insect it has been shown that the transfer of apyrene sperm by the male mediates inhibition of female remating. Photo by Didier Descouens, CC BY-SA 4.0

**Figure 8**. The Monarch butterfly (*Danaus plexippus*) (Nymphalidae), female. This species is highly polyandrous. Photo: © Derek Ramsey, used with permission.

(Karr *et al.,* 2015) of a simple experimental technique to separate apyrene and eupyrene sperm. Whittington *et al.* (2019) separately analysed the proteins expressed in the two sperm types in two lepidopterans, the Monarch butterfly (*Danaus plexippus*) (Fig. 8), and the Tobacco Hornworm moth (*Manduca sexta*) (Fig. 9). Although they were able to identify only about 700 sperm proteins in each case (almost certainly an underestimate of the actual total) we may for the present regard their findings as representative of the entire sperm-associated set. As expected, many proteins related to motility are present in both types of lepidopteran spermatozoa. But the eupyrene proteome is both more extensive (*i.e.*, more proteins) and more complex (*i.e.*, a wider range of predicted functions) than that in apyrene sperm, and only about half of eupyrene sperm proteins are also found in apyrene sperm. Apyrene sperm have no nucleus and therefore lack proteins with specifically nuclear locations; further, they do not undertake protein synthesis from newly transcribed mRNA. This is reflected in fewer proteins involved in nuclear structure and protein synthesis. Additionally, apyrene sperm lack an acrosome, and this is reflected in a paucity of proteins associated with vacuolar components. Apyrene sperm are also poor in proteins associated with extracellular matrix proteins compared with eupyrene sperm, which are encased in a glycoprotein sheath that is not removed until semen has been transferred to the female. All this implies an extensive functional streamlining during evolution of an eupyrene 'ancestor' present at the root of Lepidoptera. Presumably this absence of expressed proteins reduces the cost of producing those sperm that are useful only in a 'helper' capacity, but we may also speculate that it could be positively advantageous for the apyrene sperm *not* to display certain proteins found in eupyrene sperm, perhaps because they are the targets of inhibitory proteins expressed in the female tract as anti-sperm reagents during sexual conflict.

Importantly, reflecting the specialised function of apyrene sperm, a subset of proteins (61 in *D. plexippus* and 146 in *M. sexta*) is expressed only in apyrene cells (Karr *et al.,* 2015; Whittington *et al.,* 2019). Proteins enriched in apyrene sperm include those related to cytoskeletal processes involved in extruding the apyrene spermatocyte's nucleus during

**Figure 9**. The Tobacco Hornworm moth (*Manduca sexta*) (Sphingidae), male dorsal view. Females of this species normally mate only once in the wild. Photo: Didier Descouens, CC BY-SA 4.0

spermiogenesis. It is particularly interesting that several proteins associated with nervous system and neuron development are upregulated in apyrene sperm. Whittington *et al.* (2019) speculate that this may reflect the possibility that apyrene sperm may "deliver neuro-endocrine active proteins that modulate female post-mating responses", reminding us that such behavioural interference is one of the few proposed apyrene 'helper functions' that is supported by experimental evidence.

Proteomics and genomics have been combined to compare the extent of DNA sequence variation in the genes that encode sperm-related proteins within wild populations of *M. sexta* and *D. plexippus* (Mongue *et al.,* 2019), allowing estimation of the rates of adaptive and non-adaptive evolutionary sequence changes. The incidence of non-synonymous nucleotide substitutions in genes encoding proteins found in eupyrene sperm was significantly greater than the 'background' rate in the rest of the genome of the highly polyandrous species *D. plexippus*, but this was not the case for proteins found only in apyrene sperm. Interestingly, in *M. sexta*, which generally mates only once, there was no difference in the rate of sperm-protein gene evolution in either sperm type compared with the genomic background. These findings are in accord with the supposition that direct competition between eupyrene sperm probably occurs in *D. plexippus* but apparently does not occur in *M. sexta*. The authors suggest that the results also "cast doubt on" the hypothesis that the adaptive function of apyrene sperm is concerned with post-coital sperm competition.

Even if apyrene sperm are not involved in present-day sperm competition in either of these moths, it remains possible that such competition occurred in the past in these species and continues to occur in other Lepidoptera. Moreover, sperm are not the only components of semen, and the study of Mongue *et al.* (2019) did not consider sequence changes in genes encoding seminal fluid proteins produced by accessory glands, which are known to influence sperm function and which may bind to the surface of spermatozoa (Wigby *et al.,* 2020). Finally, we cannot rule out the possibility that apyreny evolved as the result of direct sperm competition between males in the remote past when dichotomous spermatogenesis first arose in this order of insects, when the adaptive fitness landscape may have been very different.

## Afterword

After more than 120 years of research, we still don't fully understand the reproductive role(s) played by the apyrene sperm of Lepidoptera. But at least we can now acknowledge that there is a problem to understand! While it is likely that a single adaptive benefit of apyreny accounted for its initial evolution in a long-dead lepidopteran ancestor, it is probably now futile to look for a single fitness-conferring apyrene-related trait that operates in all its descendants. Unlike the insect scientists of the first decades of the twentieth century, however, we can now understand in general terms the evolutionary processes that led to lepidopteran anucleate spermatogenesis. Apyrene spermatogenesis is now seen as of considerable interest as a model for the effects of sexual conflict on evolutionary adaptation.

## Acknowledgements

I salute the memory of the late Michael Friedländer (1930–2011), who introduced me (and many others) to the puzzling apyrene sperm of Lepidoptera. I thank Tracy Chapman, Tim Karr, Rakesh Seth and Nina Wedell for discussion and advice, but stress that I am solely responsible for any remaining mistakes.

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# Invertebrate Workmates

Figure 1a. A recently planted 'organic' sweet pepper crop.

The agricultural press often gives the impression that integrated pest management (IPM) is a novel concept – perhaps an aspiration rather than a reality. However, British tomato, pepper, cucumber and aubergine growers have been implementing whole IPM programmes for over five decades. I am proud to have worked as a consultant at the interface between academia and those innovative growers for over 40 years. I believe that this industry provides an excellent example of how applied entomology can contribute real benefits to the world of commercial food production.

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So, what exactly is IPM? Definitions vary – at one extreme the term seems to be used as a synonym for biological pest control while at the opposite end of the spectrum it may describe a spray programme which simply makes a small reduction in the total number of broad-spectrum insecticides applied to a crop. Our industry's approach to IPM falls somewhere between those two definitions, embracing multiple and varied techniques to eliminate the use of broad-spectrum insecticides.

Our industry's range of protected crops are all grown in a broadly similar manner (*e.g.*, Figure 1). They are usually planted at the beginning of the calendar year in high-quality glasshouses with computer-controlled environments and then harvested continuously until the autumn. A small proportion are grown all-year-round using supplementary lights, powered by electricity generated on site, when natural light is limiting. All the crops follow the same IPM philosophy, although each crop / site requires an individually designed programme.

The environment created to grow these crops provides ideal conditions for over 20 species of herbivorous insects and mites including whiteflies, aphids, mealybugs, heteropteran bugs, thrips, caterpillars, leaf miners, spider mites, eriophyid mites and tarsonemid mites. The numbers and combination of pest species vary between sites and crops, but it is not uncommon for growers to be simultaneously combating over eight different species. While the pests differ taxonomically, they share common traits which allow them to thrive in this growing environment; *i.e.*, they are largely polyphagous and breed continuously with high fecundity and short generation times. This results in rapid population growth which can lead to serious plant damage. Unless successfully constrained, any one of the species is capable of destroying the crop (*e.g.*, Figure 2).

Figure 1b. A tomato crop in full production.

Each pest species is typically controlled by a combination of primary and secondary measures. The primary controls are usually predatory or parasitic invertebrates – our indispensable workmates which provide season-long suppression of the pests. Cultural methods, semiochemicals and physical controls are used to assist the primary control measures by slowing down pest development while the biological agents become established. Compatible plant protection products (PPPs) may be used as a 'second line-of-defence' (SLoD) to redress the pest / natural enemy equilibrium when environmental conditions favour the herbivores. The key to success in any IPM programme is to understand how to use these components in combination to maintain pest populations below economic damage thresholds.

In the late 1980s, a few forward-thinking tomato growers started to introduce Buff-tailed Bumblebees (*Bombus terrestris*) to pollinate their crops (Figure 3). The advantages, in

Figure 2. Organic tomato plants destroyed by Obscure Mealy Bugs (*Pseudococcus viburni*).


Figure 3. A *Bombus terrestris audax* colony in a tomato crop

Figure 4. Monitoring numbers of pests and natural enemies to aid decision making in a tomato crop.

terms of reduced labour and improved fruit set, were so great that within a few years every long-season tomato grower in the UK had adopted the technique. Biological pollination is now vital to the economic viability of UK tomato production and, as a consequence, all pest control techniques must be compatible with the bumblebees.

First and foremost, our industry's IPM programmes are knowledge-based and depend on a thorough understanding of the four-way interactions between the plants, herbivores, natural enemies and environmental conditions. It is important to appreciate that every action taken when managing an IPM programme can affect some other component, thereby solving one problem but creating another. Day to day decisions must be based on regular crop monitoring to provide current information about the size of the populations of all the pests and beneficial species present (Figure 4). This is a highly skilled and time-consuming task which adds significant cost to an already expensive pest control strategy. However, it is essential to the success of the overall programme.

There are now many biological products in the growers' armoury, including entomopathogenic nematodes, fungi and other micro-organisms, as well as the parasitoids and predators. Physical controls include the use of screens, traps and barriers, while cultural methods make use of tolerant cultivars, good hygiene practice and manipulation of the environment within parameters that are acceptable for optimal plant growth.

The use of parasitoids and predators has traditionally been reactive. The pests are detected as early as possible by crop monitoring and the appropriate biocontrol agents are then ordered from the supplier and released into the crop (Figure 5). This allows the pest to gain a head start and it takes some time for the natural enemy to catch up before causing the pest population to crash. Some crop damage in the interim is therefore inevitable. The most common reason for failure of the primary biocontrol is that the pest population is allowed to cross the economic damage threshold before it crashes. It is essential that practitioners recognise where and when this is about to happen and

Figure 5. Checking the quality of biological control material before release into a tomato crop.

employ a timely SLoD treatment to avoid the impending catastrophe.

Traditionally, SLoD treatments were target-specific chemicals which caused more harm to the pest population than to the natural enemies; *e.g.,* buprofezin against Glasshouse Whitefly (*Trialeurodes vapariorum*) and fenbutatin oxide against Two-spotted Spider Mite (*Tetranychus urticae*). Such PPPs often had an impact on only one of the pest's life cycle stages, but this would be sufficient to assist the primary biocontrol in keeping damage below the economic threshold. There should be no doubt that minimal employment of IPM-compatible PPPs according to this strategy has been a major factor in the success of whole IPM programmes in protected edible crop production. However, our industry is dynamic and, over the last decade, practitioners have been seeking even more sustainable SLoDs with controls based on entomopathogenic fungi (*e.g., Beauveria bassiana*) (Figure 6) and nematodes (*e.g., Steinernema feltiae*) (Figure 7) becoming increasingly common.

Another means of preventing the pests crossing economic damage thresholds is to release the natural enemies prophylactically, so that they are already present in the crop when the pest arrives. In this case, there is no delay before the natural enemies are released and they begin to have an impact much earlier in the pests' population growth. Several different approaches have been developed to enable natural enemies to

Figure 6. Tarnished Plant Bug (*Lygus rugulipennis*) killed by the entomopathogenic fungus, *Beauveria bassiana*.

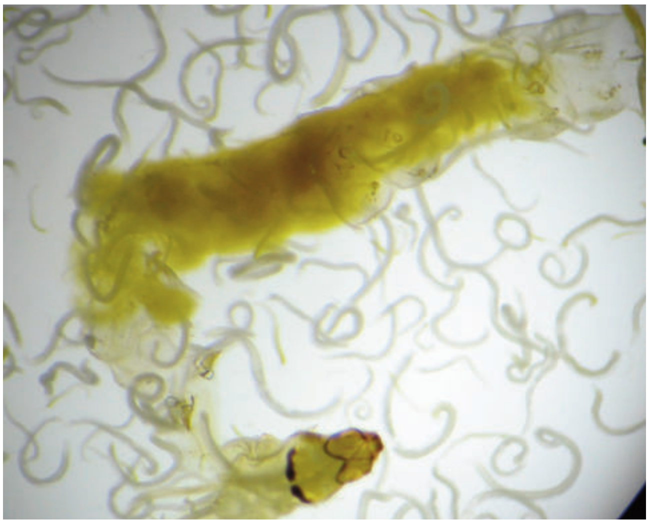

Figure 7. Entomopathogenic nematodes (*Steinernema feltiae*) emerging from a *Tuta absoluta* larva.

Figure 8. Encapsulated brine shrimp eggs (left) supplied as alternative food for *Macrolophus pygmaeus* (right).

become established in crops in the absence of the target pests.

In its simplest form, prophylactic control can be achieved by frequent inundative releases of the biocontrol agents. Sadly, this approach considers the natural enemies to be expendable and it is inevitable that many will be released prematurely and therefore wasted. From a commercial standpoint, frequent inundative release is only practicable where the product is relatively inexpensive; *e.g.*, use of the parasitic wasp, *Encarsia formosa*, against Glasshouse Whitefly.

In some circumstances, generalist predators can survive in the absence of the main target pest by scavenging on other less important prey. Several predatory mites, such as *Amblyseius swirskii* and *Neoseiulus californicus*, come into this category. Other generalist predators can survive by feeding on the plant itself. The predatory bugs, *Orius* spp., and several species of predatory mite, thrive on the copious quantities of pollen released by sweet pepper flowers. Another predatory bug, *Macrolophus pygmaeus*, can survive by feeding on tomato plant foliage, though its fecundity is much reduced on this vegetarian diet. *Macrolophus* spp. must be managed very carefully as they can cause economic damage themselves later in the season, after they have devoured all the available invertebrate prey.

Several techniques have been developed which provide natural enemies with alternative sources of food until the pests arrive. These techniques tend to be labour-intensive, and therefore costly, but several examples have been very successful.

Eggs of the Mediterranean Flour Moth (*Ephestia kuehniella*) or brine shrimp (*Artemia* spp.) have been used to enhance fecundity and therefore population growth of the generalist predator, *M. pygmaeus*, in tomato crops when numbers of the pest species are limiting (Figure 8).

Open-rearing units (ORUs) have been used in pepper crops to maintain populations of various species of aphid parasitoids ahead of the arrival of the pests (Figure 9). The ORUs are based on cereal plants infested with cereal aphids which are common hosts for the parasitoids but not a threat to the crop. As the season progresses, care must be taken to ensure that the ORUs do not become rearing units for hyperparasitoids, which would be counterproductive.

Culture packs containing cereal-based food for stored product mites, which in turn provide food for the predatory mites *Neoseiulus (Amblyseius) cucumeris*, are widely used in cucumber, pepper and aubergine crops (Figure 10). The cultures remain active for 6–8 weeks during which time predators gradually emerge to feed on various species of thrips, such as Western Flower Thrips (*Frankliniella occidentalis*).

Control programmes based on biological control agents are

Figure 9. Culture packs are used to rear *Neoseiulus (Amblyseius) cucumeris* within crops.

generally more expensive than those based on broad-spectrum insecticides, although they do have other less tangible benefits to the environment, crop workers and consumers. The cost of biocontrol products has always constrained the numbers that could be released at the beginning of the season. However, after the pest population has been controlled, there are usually vast numbers of natural enemies remaining in the crop which rapidly disperse in an uncontrolled manner. In recent years, several methods have been developed for collecting these beneficials for redistribution in areas of need. For example, the parasitoid, *Diglyphus isaea*, attacks Tomato Leaf Miner (*Liriomyza bryoniae*) larvae within the leaf, and the immature wasps develop alongside their hosts. Many immature *D. isaea* are present within the leaf material when the pest population crashes. These leaves are collected in large boxes and moved to an area of need (Figure 11). As the wasps mature, they are attracted to the light and emerge from a mesh covered 'window' in the top of the box. The mesh allows the passage of adult *D. isaea* but retains any of the larger adult leaf miners which may still be present. Apart from the obvious financial benefits, this practice is beginning to change the whole approach to reactive biocontrol. Growers can greatly increase the numbers of natural enemies released in the early stages of pest infestation in the knowledge that they can recover the costs later in the season.

Figure 10. An open-rearing unit used to enhance establishment of aphid parasitoids in a pepper crop.

During the past five decades, there have been many new challenges as non-indigenous pests have arrived and existing pests have changed their status. Each problem has required innovative solutions, and the IPM programmes have constantly evolved to adapt to the ever-changing circumstances. Our experience has allowed us to take a theoretical approach to the design of new IPM programmes, which has enabled their rapid implementation in commercial crops. For example, the South American Tomato Moth (*Tuta absoluta*), which has leaf- and fruit-mining caterpillars, arrived in the UK in 2009 and rapidly became the most important pest of our commercially-grown tomatoes. At the time, there were no IPM-compatible *T. absoluta* control measures available to UK tomato growers and this new pest threatened the continued use of biocontrol and biological pollination. However, a completely new IPM strategy was quickly designed, developed and adopted by the whole industry. Within this programme, decisions are based on crop monitoring using pheromone-baited traps in the early season followed by counting active mines as the season progresses. The primary biological control agent is *M. pygmaeus* which can probe into the leaf and feed on the moth larvae within the mines. Ideally, the predators are released before the pest is found and their establishment is enhanced with supplementary food during the first few weeks. Meanwhile, the pest's population growth is slowed using sticky barriers to intercept larvae that drop to the floor to pupate, and a pheromone-based mating-disruption system. The latter has been so successful at some sites that it has eradicated the pest.

We do remain aware of the pest's potential to circumvent this control measure by reproducing parthenogenetically (Grant *et al.*, 2021). Initially, spinosad, which is derived from a naturally occurring soil-borne fungus, was applied through the irrigation system as a SLoD treatment. The systemic application separated it from the bees and natural enemies operating on the surface of the plants, so that the treatment had minimal effect on biological pollination or the other components of the whole IPM programme. After a few years, the pest became resistant to spinosad at some sites and it was substituted with the target-specific PPPs, chlorantraniliprole or cyantraniliprole. Other options for SLoD treatments are the entomopathogenic bacterium, *Bacillus thuringiensis,* and the nematode, *S. feltiae*.

**Reference**

Grant, C. *et al.* (2021) *Pest Management Science* **77**, 3445–3449.

Figure 11. A chamber for redistributing *Diglyphus isaea* parasitoids after a *Liriomyza bryoniae* population has been controlled.

# Scratching the Surface: Connecting the Sarcoptic Mite and scabies

## Introduction

'And Elisha sent a messenger unto him, saying, Go and wash in Jordan seven times, and thy flesh shall come again to thee, and thou shalt be clean.'
King James Bible (Kings 5:13)

Scabies is a highly infectious skin condition caused by infestation with the parasitic mite *Sarcoptes scabiei* var. *humanis* (Reviewed: Chosidow, 2006). These mites are transmitted between people through close physical contact. Once mated, the tiny female mites burrow into the cutaneous skin layer to lay eggs. This causes some initial irritation, but more severe symptoms develop weeks later; characteristic rashes form over the groin, under the arms and across the breast (Chosidow, 2006). Sufferers can hardly fail to notice the condition; the itchiness is said to drive those suffering scabies to distraction. Thus, the common name; 'the itch'.

Scabies is a *cause célèbre* amongst epidemiologists; it is considered the first human disease whose underlying cause was correctly identified. It was also the first condition shown to be caused by parasitic infestation. However, it took many centuries for this to be accepted. Mites are barely visible, and difficult to isolate. Additionally, symptoms develop some time following infestation, easily creating confusion.

Scabies is considered the first human disease whose underlying cause was correctly identified

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Commonly known as the Scabies or Sarcoptic Mite, there is considered to be a single species, *Sarcoptes scabiei* (Arlian and Morgan, 2017). However, there are numerous varieties, each being host-species specific. Many mammals harbour these parasites, including our pets. They cause sarcoptic 'mange'; affected animals often lose considerable fur. Animal varieties are unable to become established on us, causing only mild irritation. Scabies mites are classed as Acariformes, belonging to the family Sarcoptidae (Arlian and Morgan, 2017). There are three subfamilies and 16 genera.

## Ancient Times

Humankind has suffered from scabies for thousands of years. The evolutionary jump from animal to human parasite probably occurred in pre-history. What could have been sarcoptic mites were observed in Ancient China and India (Ng, 2002). Documentary evidence of scabies has been found in Ancient Egypt; diagrams depict symptoms suggestive of infestation (Friedman, 1947).

Scabies may have been mentioned in the bible. The opening quote is from Kings 5 of the King James version and refers to treatment; the river Jordan is sulphur-rich and may have eased itching. Leprosy is mentioned in Leviticus, but the description more closely aligns with scabies (Currier *et al.,* 2011). In Classical Greece, Aristotle (384-322 BC) may have described the mites, calling them 'lice of the flesh' (Beeson, 1927). He described lice that would escape from pimples if pricked, suggestive of *S. scabiei* (Roncalli, 1987). These he called 'Acarus', meaning 'little and atom like' (Ng, 2002). The Roman Greek Physician Galen (129-200 AD) also probably described scabies. The name scabies comes from the Greek scientist Celsus (25–50 AD); 'scabere' is Latin 'to scratch' (Friedman, 1947).

## The Middle Ages: Scabies as a humoral disease

Medical thinking in the Middle Ages was dominated by Galen's 'humoral' causes of disease (Mount, 2015). The delicate balance in body fluids was obviously being upset by scabies. Bad humours wished to escape, causing itching. Laxatives were used to restore the balance (Mount, 2015).

Despite their small size, mites may have been observed during this period. The Moorish physician, Avenzoar, (1094–1162) (Latinised Arabic name: Ibn Zuhr) called them 'Syrones' and described removing a mite from the skin (Friedman, 1947). However, he made no connection with scabies. German physician Saint Hildegard (1098–1179) described possible treatments in her book '*Physika*'.

'And one who has scabies on his head should take the flowers and leaves of calendula, squeeze them out their juice and a little water and fine whole wheat or rye flour, prepare paste. He should put it all over his head, covered by a cloth cap, until it grows warm........'

Hildegard called the disease 'snebelza' and prescribed Galen's humoral causes. The Arab physician Avicenna (980–1037) (Latinised Arabic name: Ibn Sīnā) also described symptoms and attributed them to 'corrupt blood' (Atarzadeh, 2016).

## Bonomo and the letter to Redi: Connecting mite and disease

Progress in understanding was made in the 17th century with the development of the microscope.

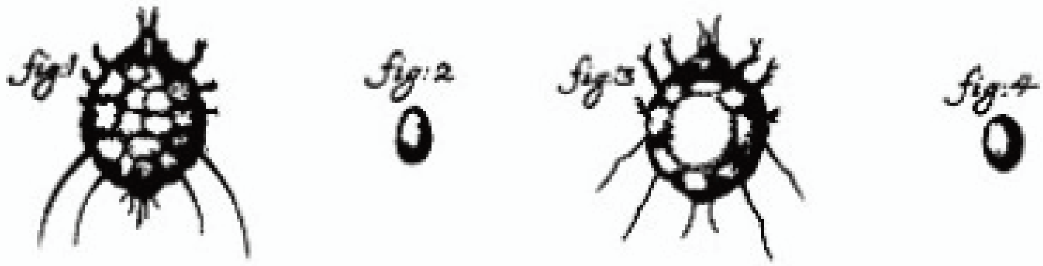
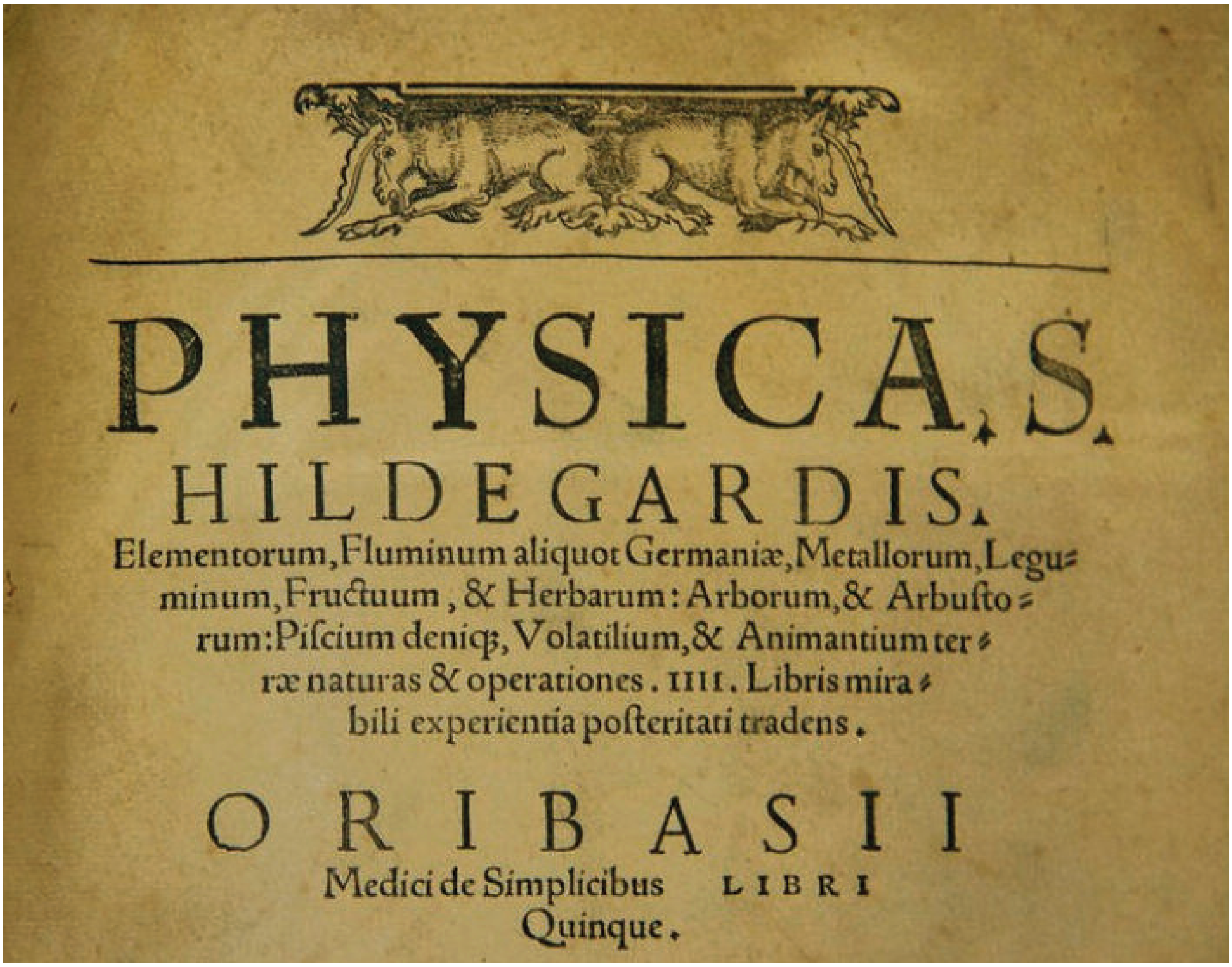



Figure 1: Bonomo's drawing in his letter to Redi.



PHYSICA S. HILDEGARDIS.

Elementorum, Fluminum aliquot Germaniæ, Metallorum, Leguminum, Fructuum, & Herbarum: Arborum, & Arbustorum: Piscium deniq;, Volatilium, & Animantium terræ naturas & operationes. IIII. Libris mirabili experientia posteritati tradens.

ORIBASII

Medici de Simplicibus LIBRI Quinque.

Figure 2: Saint Hildegard's book 'Physika'.

The Englishman Thomas Moffett (1553–1604), famous for '*Theatrum insectorum*', accurately described the mite (Moffett *et al.*, 1634). August Hauptman provided the first microscopic drawings in 1657. However, Italian scientist Giovanni Cosimo Bonomo (1663–1696) (often also referred to as Gio or Giovan) is credited with connecting mite and disease, and showing it was parasitic (Montesu *et al.*, 1991). Bonomo was a naval doctor in Livorno. His profession meant he inevitably encountered many suffering with scabies. Those working on ships were particularly prone to infestation because frequent port visits allowed regular female liaisons. With the help of medic Diacinto Cestoni (1637–1718), Bonomo made microscopic observations.

These findings appear in a now famous letter to Francisco Redi (1626–1689), a noted Italian scientist of the time. He is most well-known for discovering that flies develop from eggs, instead of generating spontaneously as was the prevailing consensus. The letter to Redi describes finding mites and eggs in those with scabies. He provided startlingly accurate diagrams of the mites themselves. These are drawn with six legs, indicative of the larval stage of the parasite. Bonomo found that mites could survive several hours away from the host, something not proved again until the 20th century.

"I repeated the search in several itchy persons, of different age, complexion and sex, and at different seasons of the year, and in all found the same animals; and that in most of the watery pustules."
(Translation: Ramos-e-Silva, 1998)

Bonomo also made the connection with scabies:

> "And though by reason of their minuteness, and colour the same with the skin, it is hard to discern these creatures upon the surface of the body, nevertheless I have sometimes seen them upon the joints of the fingers in the little furrows of the cuticula, where with their sharp head they first begin to enter, and by this gnawing and working in with their body, they cause a most troublesome itching".
> (Translation: Ramos-e-Silva, 1998)

Redi published the findings by Bonomo in his book *Observations about the 'pellicelli'* (Redi, 1687). However, the world was not ready to discard the humoral theories underlying disease; Bonomo had implied disease could be contagious. The Pope's Chief Physician Giovanni Maria Lancisi (1654–1720) was highly critical, and using Biblical Scriptures as evidence, silenced Bonomo. Others, such as the English physician Richard Mead (1673–1754) were firm advocates, writing in his support (Mead, 1703).

### The French Connection

Debate continued as to whether scabies was a humoral disease or caused by mites (Ng, 2002). Scabies can be confusing; many things cause rashes and itching, thus often those with itchiness had no mites. Even if due to scabies, rashes did not necessarily occur where mites were. Sometimes those infected had no rashes; in others, rashes developed only weeks later.

Linnaeus gave the mite the Latin epithet *Acarus humanus subcutaneous* in 1768. This was revised by De Geer in 1778 to *Acarus scabiei*. De Geer produced pictures of the Scabies Mite and the similar-looking Cheese Mite (Thyresson, 1994). The current genus name *Sarcoptes* is derived from Greek; meaning 'of the flesh' and 'to cut' and was given by French zoologist Pierre André Latreille (1762–1833) in 1803.

Further progress was made in France by Jean-Chrysanthe Galès (1783–1854) who isolated mites and infected himself, thus showing how transmission could occur. The French for scabies, 'la gale', is not dissimilar to his own name. Simon François Renucci had seen peasants removing mites from burrows using a needle on his native Corsica, and propagated the technique. He also developed a diagnostic method, the 'burrow ink test', using ink to highlight burrows.


Figure 3: Advertising product for killing mites. Drawing, 1920's. The Wellcome Collection.

### A skin, not a systemic, disease

The next steps were taken by Austrian dermatologist Ferdinand Von Hebra (1816–1880). He injected himself with mites, placing them on the skin under his hands, recording the development of a localised rash, then a more generalised one, thus showing scabies was a localised skin disease, not a systemic internal condition (von Hebra, 1856). Von Hebra also realised that a form of crusted leprosy was instead a form of severe scabies where a large number of mites cause crusted skin.

### The Twentieth Century

By the Twentieth Century, the connection between parasite and disease was clear. However, confusion regarding transmission continued. A particularly common belief was that parasites can be transmitted on toilet seats (Friedman, 1947). The Encyclopaedia for Healthful Living (Rodale, 1973) said:

> "They can be "caught" from toilet seats, public towels, on doorknobs or umbrella handles, sleeping in a bed recently occupied by a carrier, *etc*."

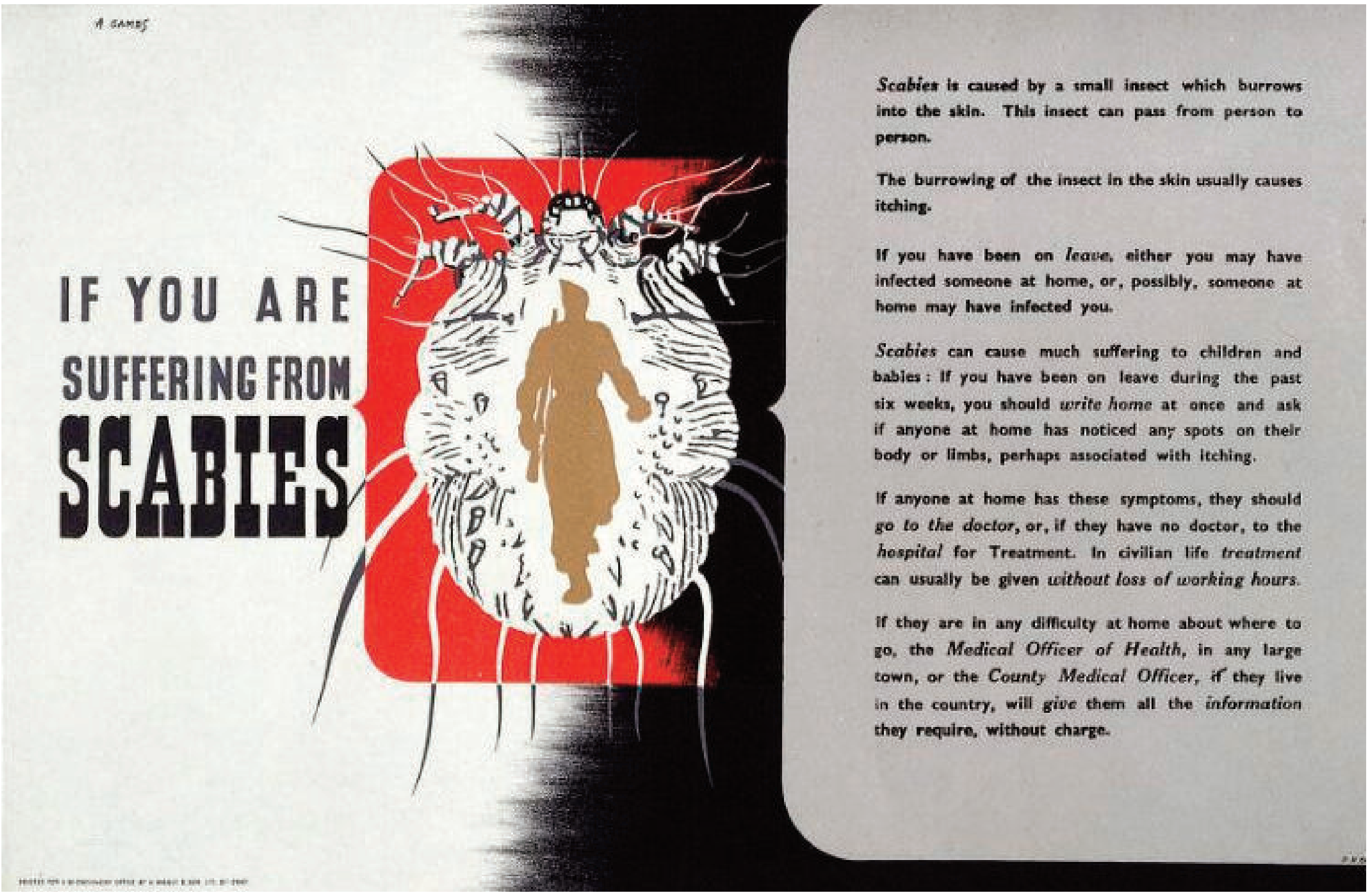



Figure 4: The Scabies Mite as a danger to soldiers. Colour lithograph after A. Games, 1942. The Wellcome Collection.

Research using volunteers by British entomologist Kenneth Mellanby (1908–1994) during World War Two established that very close physical contact was required for transmission (Mellanby, 1941). Many still associate scabies with loose sexual behaviour. However, many cases occur simply through close physical contact, such as occurs in institutional settings like care homes. Nurses, due to their frequent contact with patients, are a group at risk.

### Scabies today

Today in the 'developed West' scabies is considered merely a nuisance and is easily treated (Romani *et al.,* 2015). However, it remains a serious problem in many developing countries. High levels of prevalence occur particularly in low-to-middle-income countries (Romani *et al.,* 2015). Scabies is now classified as a Neglected Tropical Disease with an International Alliance for Scabies Control being established in 2012 (IACS, 2023).

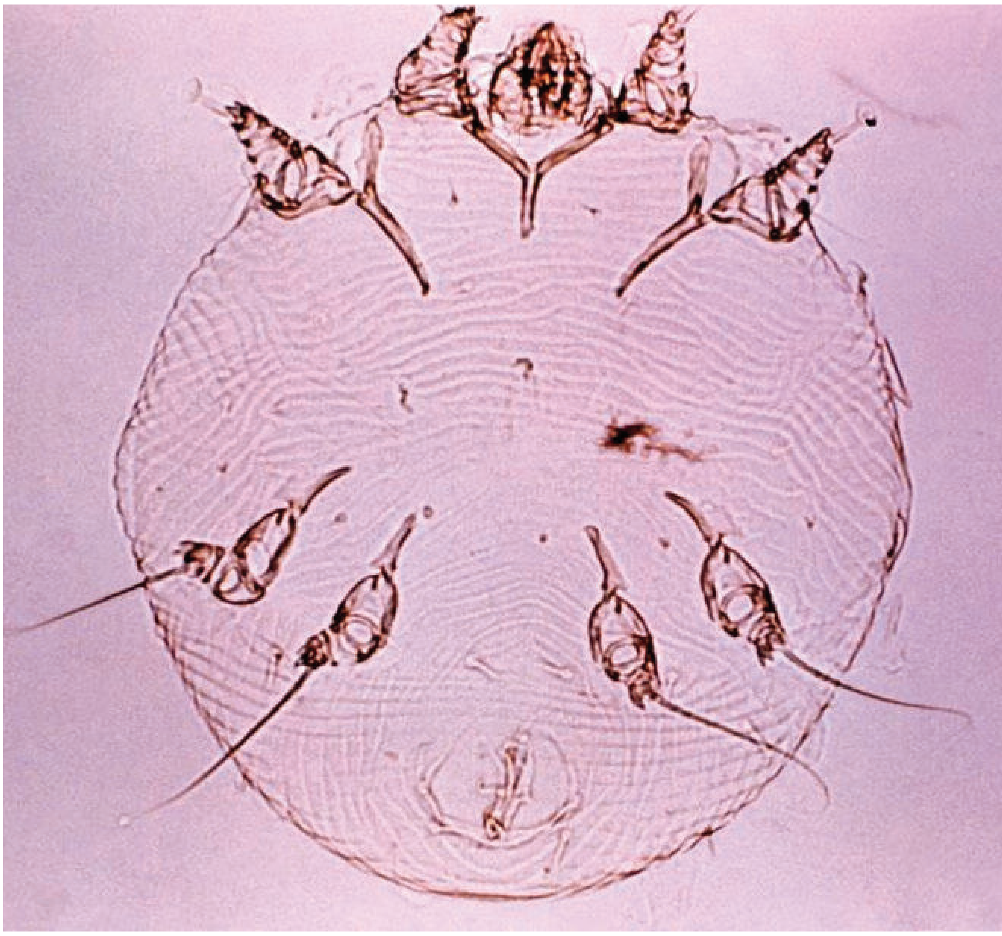


Figure 5: Mounted Human Itch Mite. CDC/ Donated by the World Health Organization, Geneva, Switzerland.

## A timeline of major discoveries relating to scabies ('the itch')

| Development | Principal Discoverers | Date |
|---|---|---|
| Descriptions of scabies | Galen/ CelsusSaint Hildegard 'Physika' | Roman times, c. 200 AD1098–1179 |
| Descriptions of mites | Avenzoar, Thomas Moffett | C. 10th AD1634 |
| Microscopic drawings | August Hauptmann | 1657 |
| Connecting mite and disease | Bonomo: publication by Redi | 1687 |
| Inkblot test | Gale, Renucci | 1835 |
| Localised skin condition | Ferdinand Von Hebra | 1840s |
| Studies into transmission | Mellanby | 1940s |

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Fig. 1. The Derby Arms, Witherslack


# Entomologists' Watering Holes: The Derby Arms at Witherslack

***'… the well known haunt of many entomologists and not half a bad place either.'***

(Soffitt, 1894)

**A favoured haunt of entomologists, particularly lepidopterists**

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The close proximity of the Derby Arms (Fig. 1) to the edge of the south Lakeland mossland, and its location (Westmorland and Furness, GR SD44158295) alongside the woodland and grassland habitats of the carboniferous limestone crags and pavements of Whitbarrow, places the inn in an ideal position from which to access important hotspots of insect biodiversity from its doorstep. Consequently, for over 150 years the inn, built in 1821 on the old turnpike road from Kendal to Ulverston, has been a favoured haunt of entomologists, particularly lepidopterists. The warm welcome it offered to both local and visiting entomologists and other naturalists, including many of our Fellows, has been eulogised in the entomological literature over many decades. What better place to refresh oneself before, during and after a day's collecting! Where else could you have found hanging on the lounge wall in the 1950s a crude painting of moths – carrying the ditty 'Witherslack hath many charms, best of all is the Derby Arms' (Birkett, 1959). Even the flooring of the inn was of interest. The eminent geologist the Revd. Adam Sedgwick, on whose collections the Sedgwick Museum in Oxford was founded, described several invertebrate fossils from the Upper Ludlow flagstone floor (Sedgwick, 1855). This article tells a little of the history of the Derby Arms and the role it has played in entomological activities. The many Fellows of our Society, who reported on their visits to the inn pre-1933, are identified in the text by their year of election [in square brackets], as recorded in our centenary volume (Neave, 1933).

The entomological importance of the Witherslack area, and the attractions of the Derby Arms, were first brought to the attention of others by John B. Hodgkinson [1890], an auctioneer's assistant from Preston, who was a regular visitor, describing the inn as 'my old quarters' (Hodgkinson, 1865; 1870; 1871; 1878; 1896a,b; Birkett, 1959). He must have been a favoured customer, as a visiting entomologist George T. Porritt [1874] from Huddersfield referred to being 'installed in Mr. J.B. Hodgkinson's room, which I found replete with everything necessary for killing and setting specimens, &c.' (Porritt, 1870). A frequent collecting companion of Hodgkinson on his Witherslack visits was his fellow Prestonian John H. Threlfall, son of a cotton manufacturer (Threlfall, 1875; 1876; Birkett 1959). Another regular early visitor, who met Hodgkinson at the Derby Arms and documented his own collecting expeditions, was Joseph Arkle, a teacher from Chester (Arkle, 1886; 1888; 1892; 1893; 1894). Arkle also records meetings there with his friend and fellow amateur entomologist Henry Murray [1909] from Carnforth.

It is beyond the scope of this article to enumerate the many entomological discoveries at Witherslack. The area's species richness is easiest demonstrated by the butterflies (Birkett, 1954). Within a short walking distance of the Derby Arms one still encounters many important UK Biodiversity Action Plan species including High Brown (*Fabriciana adippe*), Dark Green (*Argynnis aglaja*), Pearl-bordered (*Boloria euphrosyne*) and Small Pearl-bordered (*Boloria selene*) Fritillaries, Northern Brown Argus (*Plebeius artaxerxes,* Fig. 2a), Dingy Skipper (*Erynnis tages*), Grayling (*Hipparchia semele*), Wall Brown (*Lasiommata megera*), Duke of Burgundy (*Hamearis lucina*) and Large Heath (*Coenonympha tullia*) as well as a lengthy list of common or locally common species. A longer walk over the River Kent railway viaduct (now prohibited) brought one to the southern outpost of the Scotch Argus (*Erebia aethiops*) on Arnside Knott. However, it was others (Fig. 2 b-d), such as the Witherslack variety of the Silver-studded Blue (*Plebejus argus* var. *masseyi*), Small Blue (*Cupido minimus*) and Wood White (*Leptidea sinapis*), that enhanced the attractions for collectors and drew them to the Derby Arms (Hodgkinson, 1896b; Forsythe, 1902; 1905). These populations, sadly, are long extinct (Birkett, 1954). It is probable that Baron de Worms collected the last Silver-studded Blue specimens from Witherslack in 1936 and 1937 (Eagles, 1949). No Small Blues were taken there after 1924 (Birkett, 1955).

Among other visiting entomologists, including several Fellows, were The Revd Windsor Hambrough of Worthing, Edmund Shuttleworth [1884] of Preston, Benjamin H. Crabtree [1895] of Manchester (a later contributor towards the purchase of our old HQ at Queen's Gate), Russell E. James [1893] of London, Claude H. Forsythe of Lancaster and Charles F. Johnston [1907] of Stockport (Hambrough, 1871; Shuttleworth, 1882; Crabtree 1895; Forsythe, 1902; 1905; James, 1904; Anon, 1917). In the 20th century, one of the most frequent and 'colourful' visitors was the aforementioned Baron Charles George Maurice de Worms [1926], whom I first met at the Verrall Supper while I was still a student (Messenger, 1980). His visits spanned the period 1932–1976 and his captures were meticulously recorded in his collecting diaries (Fig. 3), many of which are now preserved alongside his collection in the National Museum of Scotland, and in the several papers listed below (Bretherton, 1980).

It is surprising how far the Derby Arms' reputation stretched. One might not expect a large potential clientele in places such as Grimsby but the inn still found it worthwhile advertising its special interest holidays to naturalists and entomologists in the pages of provincial papers, including the *Grimsby Daily Telegraph* (Anon., 1949). Russell James, after a recommendation by Charles Johnson, observed of the Derby

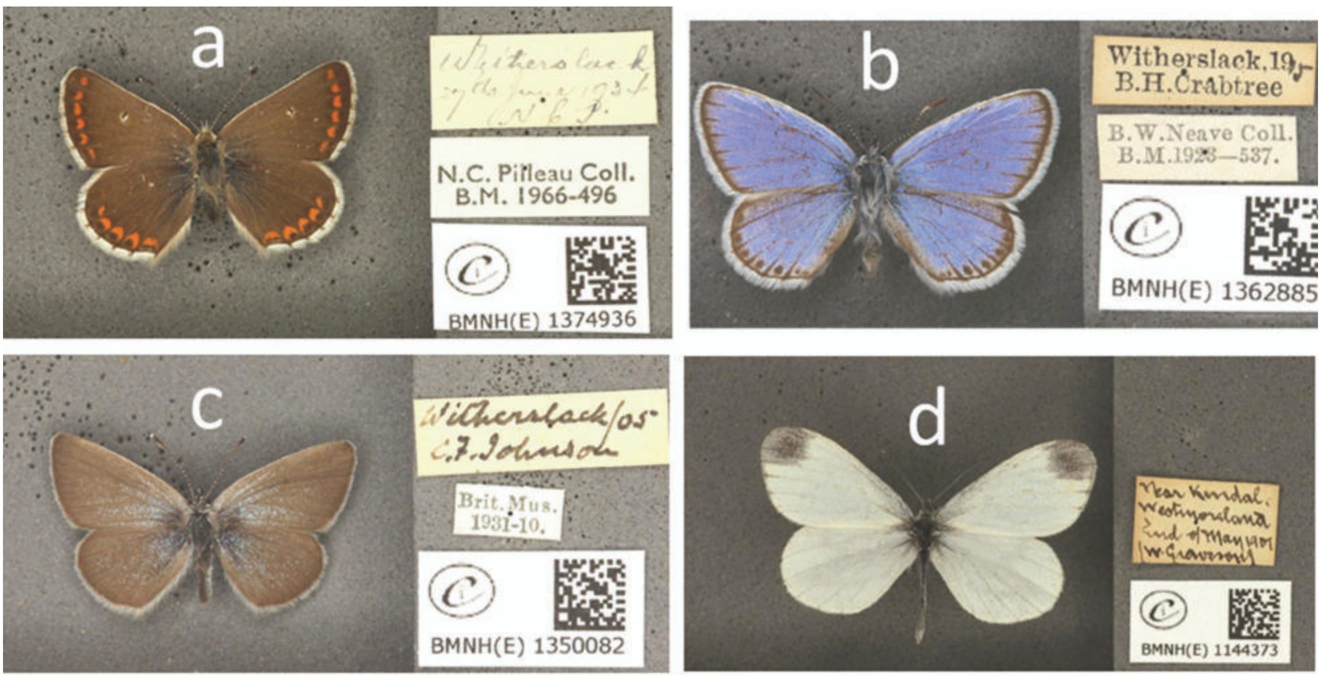


Fig. 2. Witherslack butterflies past and present (Images courtesy of the Trustees of the Natural History Museum, London). a, Northern Brown Argus (*Plebejus artaxerxes*); b, Silver-studded Blue (*Plebejus argus* var. *masseyi*); c, Small Blue (*Cupido minimus*) and d, Wood White (*Leptidea sinapis*).

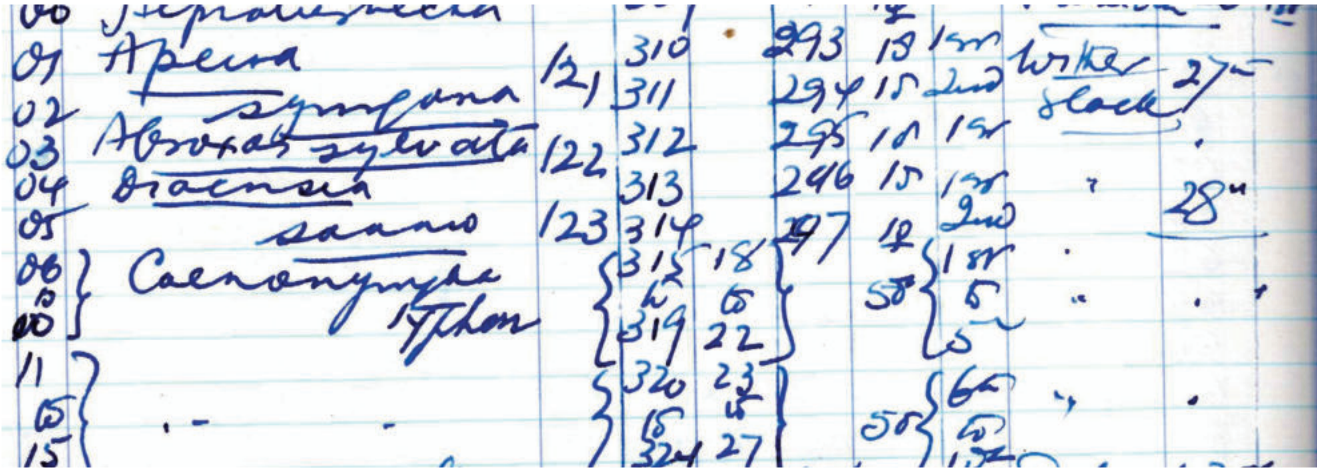

Fig. 3. Example of de Worms' collecting diary for 1961 showing his Witherslack entries for 27–28 July.

Arms in 1904 that 'the accommodation and catering are as such as is rarely found in a country inn, albeit that the tariff is the very moderate one of 5s a day, inclusive of everything. The Lancashire collectors know a good thing when they get it and have hitherto kept it pretty much to themselves' (James, 1904).

The first formal recognition of the entomological importance of the Witherslack area was when Lord Charles Rothschild [1887, and later President 1921–22] included Meathop Moss in his 1915 schedule of sites in Britain 'considered worthy of preservation' and which was adopted by the Society for the Promotion of Nature Reserves as its blueprint for action (Lewis and Cormack, 2015). Subsequently, much of the area around the Derby Arms has been designated as sites of conservation importance. These include the mossland reserves of the Cumbria Wildlife Trust (CWT), namely Foulshaw Moss, Meathop Moss and Nichols Moss, Witherslack. Just along the lane from the inn's back door are the woods and open grassland of Yewbarrow (CWT), and immediately to the northeast lies the varied limestone habitats of Whitbarrow National Nature Reserve, managed by a consortium of CWT, the Lake District National Park and the Woodland Trust on behalf of the Forestry Commission. Within the NNR are two important butterfly reserves, Howe Ridding Wood and the Hervey Memorial Reserve.

The opening of the Ulverston and Lancaster Railway in 1857, with a new station at Grange-over-Sands, had placed Witherslack and the Derby Arms within daily reach of several northern cities. In the early days carriage to and from Grange station to the inn was often provided by an obliging landlord. In 1919, one future Fellow, the well-travelled naturalist and explorer, Joseph Jackson Lister FRS [1927], records being transported with his companion Dr John N. Keynes [1906], Registrar at Cambridge University, from the station by his host, a Mr Jackson, 'a champion north-country wrestler' (Lister, 1919). Occasionally the landlord was even more obliging. Col. Henry G. Rossel was taken to the head of the Langdale valley by his host Mr Tierney, from where he ascended the Langdale Pikes to collect Small Mountain Ringlet butterflies (Rossel, 1961). As cars became more available, visitors to the Derby Arms were often transported from Grange by taxis, as when The Revd George Wheeler [1905, Vice-President 1914] partook of a 'Butterfly Holiday' in 1914 (Wheeler, 1915). The inn later became a favourite staging post for entomologists motoring north to collect in Scotland. Such passing visitors included, among many, Baron de Worms on several occasions between 1939 and 1975, M.J. Leech in 1961, H.E. Chipperfield in 1966 and a party of four led by J.W. Phillips in 1995 (de Worms, 1940;1976; Leech, 1962; Chipperfield, 1967; Phillips *et al*., 1996).

It is clear that the landlords and landladies did much to expedite the collecting efforts of the entomologists but occasionally a new proprietor had to be trained in their ways. Harman (1972) observed sardonically that 'we had quite a task training the new proprietor, Mrs Parry and her staff, to our needs'. Light-trapping for moths and other insects was frequently conducted at the inn and around the adjacent mosses and woodlands (de Worms, 1933; 1940; 1961; 1962; 1964; 1965; 1966a, b, 1972; Chipperfield, 1967). Black Tom's Lane, the locally-named narrow track that runs north from the inn along the ecotone between Nichols Moss, Witherslack to the west and Whitbarrow woodlands to the east became famous as a place to set up such traps (de Worms, 1962; 1964; 1966a; Birkett and Chalmers-Hunt, 1974; Withers, 1976). Named after a stonebreaker at the nearby quarry, it was ideally situated to attract moths from two very different habitats. Sugaring of trees to attract moths was frequently carried out in the Witherslack woods, with Black Tom's Lane often a preferred destination (Hare, 1955; Rossel, 1961). Not everyone, however, was impressed by the lane's suitability. After a particularly fruitless night's sugar-trapping, the one-time Liberal MP for Stockport, Frederic Pennington, thereafter referred to it as 'Tom Fool's Lane' (Hare, 1955).

Insect collecting on the south Lakeland mosses was a hazardous pursuit with several reports of distracted entomologists sinking in the bog and having to be rescued (Anon, 1896). In a tribute to a frequent visitor, the late Colonel Gerald de C. Fraser, Whitely (1957) wrote that 'hunting on the moss was a precarious business as the ground was particularly treacherous and a false step would quickly land one up to the waist in the bog'. Fraser, nevertheless, survived into old age! Sink holes were not the only hazard. Col. Rossel complained that the local haematophagous insect fauna delighted in tasting his recently purchased repellent and that he was saved from their depredations by another entomological guest, Rear-Admiral Arthur D. Torlesse, who 'anointed me with the most effective dope'. (Rossel, 1961).

The Derby Arms often served as a meeting place for gatherings of insect enthusiasts, often for visiting groups or pre-arranged meetings with friends: chance encounters with fellow entomologists, however, were not uncommon. In 1882, for example, John W. Carter of Bradford [1900], led a Whitsuntide outing of the Bradford Naturalists Society to Witherslack, where they dined at the Derby Arms. While awaiting the meal they were shown specimens of the lichen-feeding larvae of the Muslin Footman (*Nudaria mundana*), a local speciality. Carter commented that they had 'breathed the air, pure and free, a most necessary element to we dwellers [and the lichen food!] in the smoke-begrimed town' (Carter, 1882). Almost a century later Birkett and Chalmers-Hunt (1975) described a joint meeting of the Lancashire and Cheshire Entomological Society, the British Entomological and Natural History Society and the Kendal Natural History Society to explore the old localities 'Meathop Moss and Black Tom's Lane, Witherslack' (Birkett and Chalmers-Hunt, 1975). Dr Neville Lawn Birkett, a Society Fellow, was a local GP and amateur entomologist from Kendal who occasionally met up with visitors such as Rossel and de Worms at the Derby Arms. In 1961 and 1963 de Worms stayed at the inn with J. L. Messenger who was later to become his obituarist (de Worms, 1960; 1964; Messenger, 1980).

As well as welcoming visitors from afar, the inn had always been a favoured destination for the more local naturalists. The Lancaster Entomological and Field Naturalists Society in 1896, for example, was able to fit in three visits to the inn on the same day! Arriving in the morning, members partook of a 'refresher' to set them up for a spell of collecting before returning to lunch at the inn. Following a spell of afternoon collecting 'everyone returned in good time' for an early dinner before wending their way back to Lancaster in the evening (Anon, 1896). At a meeting of the short-lived Kendal Entomological Society in 1899 Francis Cragg [1924] of Kendal exhibited a Witherslack specimen of the now nationally scarce Argent and Sable moth (*Melanippe hastata*) 'caught near the Derby Arms' (Moss, 1900).

Thus, for over 150 years the Derby Arms has catered for the needs of entomologists and well-deserves its reputation for local hospitality and easy access to several exciting sites for insect collecting, each with its colourful entomological past.

## Acknowledgements

I thank Rosemary Pearson, our librarian, who kindly sent me copies of several papers not freely available online and Vladimir Blagoderov of National Museums Scotland who sent me scanned Witherslack examples of de Worms' collecting diaries.

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# Featured Insect

Scientific name: *Laphria flava* Linnaeus 1761
Common name: Bumblebee Robberfly
Order: Diptera
Family: Asilidae



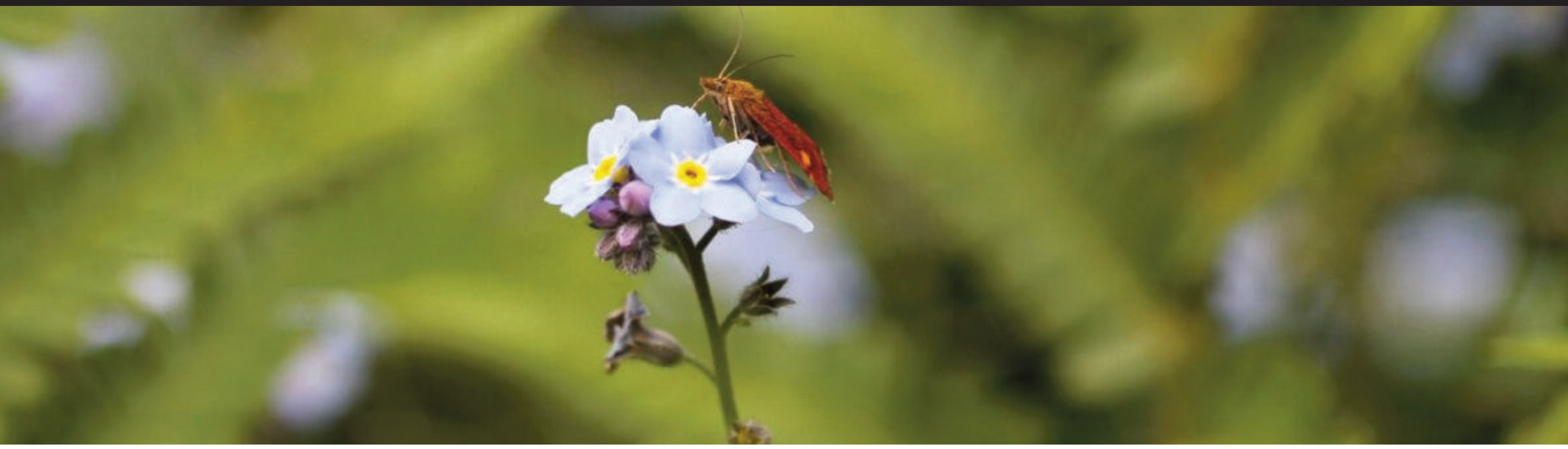
## Bumblebee Robberfly, *Laphria flava*

Being asked to pick an insect to feature in *Antenna*, even if you have a favourite order, I imagine is hard for most entomologists – I just can't pick one. So instead, I will go with one of my favourites, and that's because my mind is on fieldwork and this species is one that I actively try to find whilst sampling with the Dipterists Forum – the most wonderful of organisations dedicated to the study, recording and conservation of true flies – up in the Cairngorms National Park in Scotland. It's one of the robberflies (Asilidae) – *Laphria flava* – the Bumblebee Robberfly. And it's a cutie.

In the UK these are found only in the Eastern Highlands of Scotland, and it was back in 2012 that I first saw them in the Cairngorms. I can still recall my excitement at seeing a male perched on a fence, waiting, and watching for prey or a female – which, I will never know. I was able to see the evidence of where their larvae had developed too, for amongst the stumps of the pine trees were the discarded pupal cases projecting out. The larvae don't feed on the decomposing wood, though, but on the saproxylic longhorn beetles (Cerambycidae) that are feasting on the fallen trees.

The larvae may hide away but the adults can be easily seen, if you know what you are looking for. They are very hirsute – a black body covered with orange/yellow hairs very much resembling the patterning of some of their namesakes. Their femora are strongly swollen, especially so on their back legs. And they have a noticeable proboscis with a mystax – a moustache – the former being rigid and hardened to enable it to pierce even the toughest of prey, whilst the latter helps protect the mouthparts from the flailing spiked creature! This species, and all of the other robberflies, are formidable hunters. They have two amazing adaptations to help them. The first is that they are venomous, and this venom needs to be fast-acting as they can take on other highly aggressive species such as spiders and wasps. Studies have found that there are over 300 venom proteins in this family, of which there are fifteen novel venoms organised into 'Asilidin' protein families. Secondly, they have amazing vision – early research suggested that this species could see up to 10 m away – not bad for a creature that is only 2 cm in length. The majority of the individual eye facets (ommatidia) that make up the compound eyes are good at detecting movement, but at the very front there are some enlarged facets which enable higher resolution – they can swivel their heads round to directly face the prey and zero in on it – formidable creatures!

**Erica McAlister Hon.FRES**
Natural History Museum, London



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

# News from Council

**Council Meetings**
Council meetings were held in person and online on 12th July and 4th September. These notes cover both meetings.

**Trustees**
Professor Walter Leal was confirmed as a new trustee and Chair of the Membership Committee. Professor Jane Stout was confirmed as a new trustee and President Elect. Thanks were given to retiring trustees, Dr John Baird and Professor Helen Roy.

**Move of Headquarters**
Approval was given for a working group to be set up to lead the search for a new HQ and for a Project Manager to be appointed.

**RES Strategy 2025–2028**
A timetable for developing the Society's strategy for 2025–2028 was agreed.

**Annual Report and Accounts**
The 2022/2023 Annual Report was approved, and the President given authority to sign the report and letter of representation written by the auditors.

**Fundraising and Business Development Strategy**
The Society has made good progress in diversifying its income stream and now has a trading company. It was agreed that the Society will register with the Fundraising Regulator to demonstrate to potential donors that the Society complies with the Code of Fundraising Practice. Trustees will be giving training on responsibilities in this regard.

**Code of Conduct and Committee Terms of Reference**
A code of conduct for RES members was approved, as were revised Committee Terms of Reference.

**International Meetings**
The International Congress of Entomology, due to be held in 2032, will be moved to 2033 to coincide with the 200th anniversary of the RES. It was agreed that the Society would submit an expression of interest to host ICE 2033. It was agreed to explore options for joint meetings with other societies but avoiding years that coincide with both the International or European congresses.

**Wigglesworth Award**
Following nomination and voting, Professor May Berenbaum will be offered the Wigglesworth Award and invited to give the Wigglesworth Lecture at ICE 2024.

**Editor Term Lengths**
It was agreed that journal editors can serve for a maximum of three consecutive three-year periods. The Head of Publishing will work with the journal editorial teams to look at this further and develop succession plans for the future.

**Student Representatives**
Ben Hawthorne (Newcastle University) was confirmed as the new Student Rep. Ava Searles has stepped down and was thanked for her service.

**Committee reports**
Reports were received from the Publications, Outreach, Finance, Membership and Science, Policy & Society Committees.

**Other Matters**
There were discussions on: financial performance and data reporting; reserves policy; RES Ambassadors; relocation of the Chelsea Flower Show Garden; Insect Week; the Society's contribution to the Government's call for evidence on insect decline and food security; the Society's work under Natural England's Species Recovery Fund; health and safety issues; the risk register; and future dates and key items for Council meetings.

**Richard Harrington**

# Journals and Library

## Treasures of the RES Library and Archive

**Rose Pearson**
**RES Librarian and Archivist**

In the second of our columns showcasing some of the highlights of the RES Library and Archive collections, we look at *A Natural History of English Insects* by Eleazer Albin; a more than 300-year-old volume of both scientific and artistic significance.

Eleazer Albin (1713–1759) was an artist and painting teacher, before being taught Natural History by the naturalist Joseph Dandridge (1664–1746). He became a keen naturalist, collecting specimens near his home on the outskirts of London. First published in 1720, *A Natural History of English Insects* was the first English entomological book with colour illustrations. Each copy featured 100 individually hand-coloured, copper-plate engravings, each accompanied by a description of the species, its feeding habits and common name. All the insects are pictured on their host plants, and several stages of the life cycle are often included. Around 150 species of Lepidoptera feature, with other insects making only the occasional appearance. 'The Chafer, Oak Web, or May Beetle', today known as *Melolontha melolontha* or the Cockchafer, one of the insects spotted in the RES Garden at Chelsea, is featured on Plate 60.

Hugely time consuming and requiring a high level of skill, it was extremely costly to produce a book of this type. To raise funds, Albin sought sponsorship, and each illustration is accompanied by a dedication to a sponsor. These included the Princess of Wales, Caroline of Ansbach (later, as the wife of George II, Queen), and Hans Sloane, whose extensive collections formed the basis of the British Museum. Several editions were

produced, with the sponsorship of plates varying between editions.

Albin published and illustrated several other works on natural history, including *A Natural History of English Birds* (1731–1738). He trained his daughter, Elizabeth Albin, as an artist and she contributed illustrations to this volume.

The RES also holds Albin's *A Natural History of Spiders and other Curious Insects* and a selection of his original drawings. These and other early entomological works can be viewed in our Library in St Albans. Email library@royensoc.co.uk or call 01727 899387 to make an appointment.



# Meetings

## Ento23

**5th – 7th September 2023**
**University of Exeter, Cornwall**

### Convenors: Jason Chapman, Ben Raymond and Ben Longdon

Delegates at Ento23, 5th - 7th September, University of Exeter's Penryn Campus in Cornwall. Photo: RES.

In early September, the University of Exeter's Penryn Campus in Cornwall welcomed over 200 entomologists for a sold-out Ento23, with an additional 45 delegates joining online.

Ento, the Annual Meeting of the Royal Entomological Society, has been running for 27 years, providing a platform for entomologists across both academia and industry to share their work, meet new contacts and build their careers. Ento23 was the largest Ento meeting so far, and it was great to see the conference reflecting the growing international reach of the Society, with delegates from 30 countries taking part.

Over two and a half days, delegates were immersed in the current themes across insect science, with an excellent programme of plenary and keynote speakers, thematic topics spanning our *Grand Challenges in Entomology*, poster sessions, interactive workshops and a variety of networking opportunities. We also welcomed the following exhibitors, who were able to engage with the community and find more about how they can support those working across insect science: CABI, Entocycle, GT Vision, Open Acoustic Devices, NHBS and Zantiks.

A common theme that emerged from the delegate feedback was how friendly and welcoming the conference was. Outside of the presentations we recognise the importance of extra activities in the programme, such as our Women in Entomology session, LGBTQI+ meet up, journal 'pitch a paper' and various activities for early career entomologists, including the well-loved EntOlympics quiz and conference 'Bug Bingo'. It was also great to see some fantastic Ento fashion on display!

We are delighted to announce that Ento24 will be held at the University of Liverpool from 10th – 12th September, so do save the date in your diaries! We look forward to welcoming returning delegates and new faces for another vibrant and productive meeting in 2024.

**Amy Everard**
*(Events Manager)*

# Ento23

*Ento23 would not have been possible without the hard work and commitment of the local organisers from the University of Exeter. Jason Chapman, Ben Raymond and Ben Longdon. Working within the Centre for Ecology and Conservation (CEC) at the University of Exeter's Penryn Campus, they were responsible for driving the conference programme and have shared their experiences of being involved in Ento23.*

## Convenors' report

*Jason Chapman, Ben Raymond and Ben Longdon (CEC, University of Exeter)*

The Royal Entomological Society meeting of 2023 was particularly long in the planning. Entomologists at the University of Exeter's Cornwall campus were approached in 2018, we assembled an organising committee and in 2019 started inviting plenary speakers and organising sessions and venues. Then there was a pandemic. We were reasonably confident that we could run a good in-person event in 2023 but there were a number of uncertainties that gave us a few nervous moments. Was the entomological community fully ready to meet face to face? Would people want to travel to the far west of England? While initial abstract submission was a little slow, in the end we hosted what has proved to be the biggest Ent Soc meeting ever (as far as records show). We planned optimistically for 180 but when the number of registered delegates reached 200, we had to close to further applicants as we were reaching the maximum capacity of our available venues. The meeting was run as a hybrid conference, and we also had an additional 45 attend online.

Cornwall proved to be a successful venue. The weather was kind, moths were flying into traps while we slept, in the evenings we enjoyed views of sunlight on water as delegates drank well-earned refreshments next to Falmouth Docks or Penryn Harbour. The scientific content also went down well. We selected sessions and plenaries partly based on the interests of the organising committee (Jason Chapman – insect migration; Ben Raymond and Ben Longdon – insect pathology and microbiomes), partly on local session chairs, but we also chose themes relevant to the Grand Challenges set by the Society. The latter included sessions on conservation and insect declines, insect pollinators, biological control, genomics and fundamental science (behavioural ecology). This provided a well-balanced programme ranging from landscape ecology to molecular insect science.


Loretta Mugo (University of Tours & University of Exeter). Photo: RES/Thomas Frost Photography.

There were three fantastic plenary talks (all available to watch at www.royensoc.co.uk/event/ento23/), kicked off by Jaap de Roode from Emory University (Atlanta, USA) on the Tuesday morning. Jaap spoke about his group's amazing work on Monarch Butterflies, first covering the genetics underlying migration before talking about how Monarchs self-medicate to control parasites, before finally linking to how parasites affect migration (and vice versa). On Wednesday Elli Leadbeater from Royal Holloway (University of London, UK) talked about Honeybee cognition, first covering the role of individual learning and memory in foraging before moving on to discuss dance communication as a form of collective decision-making and how this varies across landscape types. The meeting was closed on Thursday by our final plenary speaker, Vanessa Kellermann from La Trobe University (Melbourne, Australia). Vanessa first talked about how heat resistance is important for shaping distributions of fruit fly species but only a few clades of the 100+ Drosophilidae species tested had evolved high heat resistance, as well as looking at the capacity of genetic adaptation or phenotypic plasticity to buffer heat stress. Vanessa finished off by talking about her group's work on native Australian bees, linking thermal limits to environmental variables to understand species distributions and resilience to climate change.

It wasn't all about the scientific programme, there was plenty happening on the social side too! Delegates were provided with ample and tasty lunches and snacks throughout, and for those who liked a tipple, there was good news: the RES President (Prof. Jane Hill) ensured the wine flowed at the President's reception, while the bumper attendance resulted in plentiful wine on each of the tables at the conference dinner at the Greenbank Hotel, which provided beautiful views of Falmouth Harbour. Many delegates also enjoyed good company over local beer and pizza at the Verdant Taproom, a quirky establishment in the unusual setting of an industrial estate, on the evening before the conference opened. One of the most pleasing aspects of the conference for the organisers was the high proportion of students and ECRs among the delegates and speakers, with some of the best presentations coming from this younger demographic. Our local Exeter student helpers are to be congratulated too, especially for getting up early every morning to expertly show the moth trap catches to the keenest entomologists among the attendees. This was a conference that combined scientific edification with enjoyment in equal measure, and it was great catching up with old friends and making new acquaintances while showing off our beautiful campus in glorious Cornish weather!

Ento23

## Plenary profiles

At the centre of the programme, we welcomed three internationally-renowned plenary speakers: Jacobus 'Jaap' de Roode (Emory University, USA), Elli Leadbeater (Royal Holloway, University of London) and Vanessa Kellermann (La Trobe University, Australia). *Antenna* caught up with them to find out more about their work and their experience at Ento23.

### Jacobus 'Jaap' de Roode

**Emory University, USA**
**Plenary title: Migration, microbes and medication in the Monarch Butterfly**

***1) Could you give us a quick introduction? How would you summarise your work and research interest?***
I am excited about studying host-parasite interactions. Having done my PhD research on malaria, I moved my research focus to Monarch butterflies, which are commonly infected with a virulent protozoan parasite. Monarch butterfly caterpillars are specialist feeders on milkweed plants. Milkweeds vary in their concentrations of toxic chemicals called cardenolides. As it turns out, highly toxic milkweeds are medicinal to Monarchs, reducing parasite infection and virulence. Monarchs can take advantage of that by laying eggs on toxic milkweeds when infected. This reduces infection in their offspring, which contract the parasites from their mothers. A great case of 'mother knows best'.

***2) Was this your first time at an Ento meeting, or are you a repeat attendee? How did you find it?***
It was my first time, and I loved it. I found the conference extremely friendly and welcoming. I love conferences that are small in size, as it enables lots of interactions, and allows me to meet new people easily. I would definitely love to attend again.

***3) What do you think the key benefits are of attending these kinds of conferences?***
Being able to share research findings and learn from others is exciting, and making new connections is fun and important. A conference focused on entomology makes it easy for people to find common ground and interact socially. I also love the lack of 'hierarchy' at these conferences, with people chatting, having breakfast or meeting for dinner with anyone, whether undergraduate student or professor.

***4) Do you have a favourite insect, or favourite fun insect fact?***
Oh, that is a difficult one. Many people would assume my favourite insects are Monarch butterflies, but I actually study those because they get sick, not because they are my favourite (don't get me wrong – I do love them, but I still think that the fact that they get sick and can use medication is the coolest part about them). I guess praying mantises? I just love the way they look and their agility and stealth when catching prey. I won't lie – their sex lives are pretty intriguing too.

### Elli Leadbeater

**Royal Holloway, University of London, UK**
**Plenary title: Does (collective) cognition produce efficiently foraging bees?**

***1) Could you give us a quick introduction? How would you summarise your work and research interests?***
I'm a Professor of Ecology and Evolution at Royal Holloway, University of London. My research has two main themes. Firstly, I'm interested in how cognitive abilities such as memory evolve, and I use insects as models to study that. For example, my research group uses social bees to understand how the benefits of investing in learning ability trade off against the potential costs, and hence, what types of environments learning might evolve in. Secondly, I have a strong interest in pollinator conservation and the causes of pollinator decline, and I'm involved in research that seeks to improve current environmental risk assessment practices to better protect insects.

***2) Was this your first time at an Ento meeting, or are you a repeat attendee? How did you find it?***
This was my first time at one of the main meetings, although I remember attending one of the postgraduate events during my PhD, when the RES was based in Central London, and I previously spoke at another postgraduate event. It was a fantastic meeting! Small - so it was possible to talk to lots of people; diverse - so it was possible to learn a lot of new things; and well-organised! I had a great time.

***3) What do you think the key benefits are of attending these kinds of conferences?***
It's a wonderful opportunity to meet new people, and to keep in contact with others. I saw people there I haven't met in years, and heard about their work. It gave me a wonderful idea for a new grant, and introduced me to people who have skills that I don't, but that I might need in the future. Overall, meeting people in person, in an organic way, is really key for generating new research directions.

***4) Do you have a favourite insect, or favourite fun insect fact?***
I have a least favourite insect: the Mexican Honey Wasp, *Brachygastra mellifica.* They stung me way too much and in an incredibly painful way, when I worked on them in Texas. They're one of very few wasps that make honey; but, true to form, they are often poisonous - due to their bad personalities, in my opinion!

Ento23

**Vanessa Kellerman**
**La Trobe University, Australia**
**Plenary title: Adaptation in a warming world: Insights from *Drosophila* and bees**

***1) Could you give us a quick introduction? How would you summarise your work and research interests?***
My research uses model (*Drosophila*) and non-model insects (native bees) to understand how climate and species interactions shape species distributions. I am interested in the capacity of species to respond to novel environments via evolution (both genetic change and phenotypic plasticity) and how this capacity limits/promotes their distributions. My research takes a trait-based approach, focusing on traits that likely underpin adaptation to novel environments, like heat and cold tolerance and fitness traits. Using this trait-based approach, we can also predict which species and environments (*e.g.*, tropical *vs*. temperate) have the greatest climate change risk.

***2) Was this your first time at an Ento meeting, or are you a repeat attendee? How did you find it?***
Coming from Australia, this was my first Ento meeting. I enjoyed the meeting and hearing about the insect research happening in Europe. I met some fabulous researchers and was blown away by the scale of insect research in Europe: the long-term datasets, the vast insect monitoring and biodiversity projects, and the Darwin Tree of Life project.

***3) What do you think the key benefits are of attending these kinds of conferences?***
These conferences are fantastic for hearing about new research, getting new ideas for your own research and meeting new collaborators/friends.

***4) Do you have a favourite insect, or favourite fun insect fact?***
My favourite insect would have to be an allodapine bee (reed bee) in the Exoneura clade. Not only is this bee socially plastic, meaning it will nest solitarily or with other bees, but its nest is commonly parasitised by an inquiline bee that looks identical to its host. How does this host-parasite relationship even evolve?

## The delegate experience

### Meghan Barrett
*(Indiana University – Purdue University Indianapolis)*

This was my first visit to an Ento meeting in person. As an international delegate, coming from Los Angeles, USA, I spent nearly 24 hours travelling from home to hotel - each way. Despite the jet lag, this year's conference had me excited to attend again in 2024.

I chose to come to Ento23 because I'm a new member of the Publications Committee. So, my conference experience kicked off early with the Committee meeting on Monday afternoon. I knew I was in for a good time already when the conversation turned to open science practices and early career support in publishing. I left the meeting with the impression that everyone at the RES is committed to leading the conversation on best practices for 21st century entomology.

The conference itself was smaller than the ESA national meetings I typically attend – but it meant you could really take your time getting to know new people and visiting the sessions/posters without feeling rushed. Similarly, in the workshop I hosted with Bob Fischer and Eleanor Drinkwater, on insect welfare in research and education, we had a relatively small but very engaged group, making for very productive dialogues.

There were many enjoyable social breaks, with *tremendous* vegan food regularly available, and an entomological fashion contest that brought out some stunning attire. I spent some time exploring the cafes in both Penryn and Falmouth and took some quiet, shaded walks through the trees on the University of Exeter's campus.

But of course – we were there to share science! And what great science there was to see. In particular, I loved Ellie Jarvis's poster on *Drosophila* in citizen science (with co-authors Nicholas Priest and Jingbo Liu). The team conducted self-medication studies with the public to see if flies infected with *Aspergillus austwickii* STIs consumed more 2-phenylethanol, 2-PE, which is produced by yeast. Their thoughtfully designed and fun poster highlighted how important it is to engage community members in science, and some of the difficulties of using public participation to get reliable data.

As a bee researcher myself, it is probably no surprise that my standout talks came during the two pollinators sessions. Although there were many fascinating presentations in the sessions – a novel Bluetooth tracking system for tracking bee foraging behaviour (Michael Thomas Smith), an overview of the survey work done by the UK Pollinator Monitoring Scheme in the last six years (Claire Carvell) – I was especially impressed by Jessica Knapp's presentation on interdisciplinary perspectives on pollinators. Her slides were thoughtfully designed and I loved how she highlighted the need to bring ecological, economical, and social science perspectives together if we really want to have a positive impact with our science.

Another shout out goes to Bengisu Subasi, who gave a talk on insect wounding in the wild (using *D. melanogaster* as a case study) in the Infection and Immunity session. It was helpful to be able to follow up on the results by reviewing the preprint online – a great example of open science at work in the RES.

I'm looking forward to next year's Ento already – and thanks so much to all the RES staff for their hard work in organising such a wonderful event.

### Shawan Chowdhury

*(German Centre for Integrative Biodiversity Research)*

I had heard many positive stories about the RES conference; however, I never had the opportunity to attend. This time, when I noticed that the conference was in Falmouth and one of my long-time inspirations and collaborators was a co-organiser, I did not want to miss the chance. Luckily, I got an invitation to give a Keynote presentation on insect migration and conservation. My presentation was in the first session of the conference, right after the plenary talk, so almost everyone attending the conference was there. I was amazed to see so many researchers enthusiastic about insect migration.

In my brief scientific career so far, I have attended several conferences in different parts of the world. In most cases, the conference organisers do not put much effort into arranging the talks, which often leads to parallel sessions of similar talks, or similar talks in different sessions (especially for insects). Even though a few hundred participants attended the RES conference this year, the organisers systematically grouped the talks into specific sessions. As I personally do not like moving from one room to another during the ongoing sessions, this is one point that I really appreciated.

While attending a conference, one thing that fascinates me is getting to know about the work of other researchers. While attending Ento23, I saw many intriguing posters and listened to several wonderful talks. Specifically, I was amazed to see the depth of understanding of several MSc and PhD students. Considering my interests in insect migration and conservation, though, I will certainly be biased in picking some of the talks that I enjoyed the most, and was excited to hear about the insect migration research in the Pyrenees, updates about the PREDICTS database, and insect conservation research in Southeast Asia.

In addition to the session presentations, I attended the social events and enjoyed them very much. The pre-conference mixer was helpful in meeting collaborators in person, getting to know some new faces and making good connections throughout the conference, with the conference dinner good for meeting yet more new people, especially when we were outside of the building where it was a bit quieter (though the food was really good).

Although it was my first participation at the RES, I enjoyed attending all the fascinating talks and meeting so many new people throughout the conference. I look forward to attending the next one!

### Jon Delf

*(University of Liverpool)*

A family trip to Georgia occurring at the same time as Ento19 meant that I missed an annual conference for the first time since attending Ento13 at the University of St Andrews. Unfortunately, the Covid19 pandemic then forced the cancellation of Ento20 and resulted in the movement of Ento21 online. The commendable decision by the RES to hold Ento22 in a hybrid format meant that, although I could not make it to the University of Lincoln in person, I was at least able to be there in 'spirit'.

I decided to drive down to Cornwall for Ento23. Arriving at 6.45pm on the Monday, there was just time to unpack and prepare for the informal mixer at the Verdant Brewery Taproom, where new acquaintances were soon made.

Before departing for the conference, I had checked the NBN Atlas to establish what insects of interest might be found in, and around, the campus. There were very few records of bush crickets from the surrounding area, and none from within the campus grounds. However, Penryn seemed to be a 'hotspot' for *Acanthoxyla inermis* (Unarmed Stick Insect). The records for this naturalised New Zealand species from within the town mainly dated from between the early 1990s and the mid 2000s, but there were no records from within the campus. The bat detector picked up colonies of singing *Conocephalus fuscus* (Long-winged Conehead) in areas of long grass alongside the campus paths (only a handful of records exist in this part of Cornwall, with the nearest being about 5½ km away).

The plenary session on the first full day of the conference consisted of an excellent talk on 'Migration, Microbes and Medication in the Monarch Butterfly' given by Jaap de Roode. After a short break for refreshments, it was back into the main lecture theatre again for a session of seven further talks on the theme of 'Movement and Migration'. Drinks during refreshment breaks, and lunches each day, were served in the main Exhibition Hall where the posters were also on display. The size of this area, together with its adjacency to the two main lecture theatres, allowed mingling and discussion by delegates in reasonable comfort for the full duration of these periods. In the afternoon, I decided to attend the eleven talks within the two Pest, Biological Control and IPM sessions. I surmised that there should be a range of examples of 'whole organism' studies involved, and I wasn't disappointed. The President's Reception, held within the Exhibition Hall, rounded off the formalities for day one.

It was then time to travel by bus to Custom House Quay in Falmouth. While waiting for others from my accommodation block to join me for the walk up to the bus stop, I turned around and was somewhat taken aback to see an adult *A. inermis* resting in a completely exposed position. It was lying upon some bramble, amongst the shrubs, immediately outside the front door of my accommodation block! With this specimen safely incarcerated in a polythene bag and placed upon the shelf in my bedroom, I joined the bus party to partake in a pleasant evening spent at The Front public house on the quayside.

The second day began before breakfast, with a quick visit to the Walled Garden to watch the moth traps

# Ento23


Congratulations to the winning team of the 2023 EntOlympics, 5 Out of 10 Gnats! Photo: RES.

Curious excitement about the many moths from the moth trapping on the campus. Photo: RES.

Loving the variety of Ento-Fashion. Photo: RES.

being emptied. This morning's plenary talk by Elli Leadbetter was entitled, 'Does (collective) Cognition Produce Efficiently Foraging Bees?'. Parts of the talk took me back to my attendance at Ento17 in Newcastle, where I first came across the topic of intelligence testing in bumblebees. Eleven interesting talks within the Pollinators session comprised my programme for the afternoon. The conference dinner that evening was held at the Greenbank Hotel in Falmouth and coaches were on hand to transport us there and back.

The final day of the Conference began with a rush to vacate my room, visit the moth traps, and consume breakfast. The final two parallel sessions were both of interest to me and, with the lecture rooms being adjacent to each other, and the timing of sessions throughout the conference being excellently managed, it might have been possible to switch between the two sessions for different talks. However, I was quite happy to remain seated for the final seven talks on Behavioural and Evolutionary Ecology. Fatigue was beginning to set in and, despite a quick refreshment break, my attention was probably not all that it should have been for the final plenary session by Vanessa Kellermann on 'Adaptation in a Warming World: Insights from *Drosophila* and bees'.

Overall, this year's conference compared very favourably with those that I have attended previously. Opportunities were provided for the exchange of ideas and information, alongside a series of enjoyable activities for social interaction. Subject to there being no clashes next year with family/entomological trips, I will be looking to complete the early bird registration for Ento24.

### Ayman Asiri and Vera Kaunath

*(RES Student Representatives)*

Seventeen million insects are flying over the Pyrenees each year, 568 species of butterfly show evidence of migratory movements and 3% of Odonata species are presumably migratory – the annual Ento23 conference in Falmouth, Cornwall started with the stunning session 'Movement and Migration' and these mind-blowing facts. If not before, then certainly now, the thoughts of the participants had migrated to the many and various talks the conference had to offer.

For us as PhDs in our second year, the conference was an excellent size. The atmosphere was friendly, very stimulating and there were always opportunities to meet new people during the coffee breaks following an inspiring session. You might be having a nice, sleepy chat over your first coffee, and then you find out that just last week you quoted the person next to you in your first paper draft! Somewhat intimidating, but nevertheless it was precisely the conversational atmosphere that Ento conferences manage to cultivate every year that enable such an encounter.

One of our highlights was hearing the ever-inspiring Jane Hill talk about her important role in the establishment of the IPBES report over coffee at the workshop on 'Women in Entomology' (yes, way too much coffee, but we wouldn't want to miss any of the good talks!). We were also thrilled by Jessica Knapp's (Trinity College, Dublin) presentation, which took us on a journey into her diverse research projects and gave us a fascinating insight into the effects of pesticides on the reproduction of bumblebees. Finally, we could not forget Elli Leadbeater's inspiring plenary talk, which covered her work on the mind-blowing dance language of Honeybees.

Wednesday was a very exciting day, too! Not only our first reports on the preliminary results of our PhDs, but also the eagerly awaited Ento-Fashion contest. With a few less nerves, the presentation of the first results went well, and the atmosphere in the room during the presentations was very supportive, with only honestly interested questions. And now, get out your beetle socks and put on your butterfly leggings! We were deeply impressed by the number and variety of people showing off their Ento-Fashion: From lots of great socks (some with the Monarch Butterfly, very fitting to the migration session), self-designed wasp t-shirts and some ornamental moths shirts, and jewellery that showed the beauty of insects, to a *Drosophila*-scientist who even wore an apron with his study insect on it. The judges had a tough choice to make between the tremendous fly apron and the matching butterfly trousers, bag and hat outfit. But then, the butterfly outfit only just managed to outdo the *Drosophila* apron, congrats to Hanna-Isadora Huditz!

The quiz for students, 'EntOlympics', was led by the amazing Liam Crowley on the first evening and was again a success. It is now a tradition as a networking event for students, with questions ranging from taxonomic subtleties to insect superlatives, species identification by pictures and our favourite section on cultural entomology. The many talks were rounded off by morning moth-trapping on the Penryn campus (for those who did find it on time), and Jon Delf even found an Unarmed Stick Insect (*Acanthoxyla inermis*) on an evening stroll.

All in all it was a great conference, and we are already excited about what great things there will be to learn next year and to see many familiar faces again with new progress in their work. An immense thank you to the RES team for the great organisation and also for giving us the freedom to get involved ourselves. Until next time, and be ready for more Ento-Fashion!

### Poppy Lane

*(University of Bristol)*

At only two weeks into my PhD and coming from a background in landscape ecology, Ento23 was my first step into the world of entomology. I was pleased to attend a variety of talks, ranging from migration patterns to pest control, but I was particularly excited by the conservation and declines session. Featuring fascinating talks on global insect population responses to multiple threats, applications of citizen science, and practical approaches to tropical insect research, this session covered several research areas I want to explore during my PhD. I found Eleanor Slade's talk on overcoming taxonomic and capacity limitations in tropical entomology, and Xin Rui Ong's poster on identifying knowledge gaps in Southeast Asian insect conservation to be particularly insightful, as I anticipate facing similar challenges in my PhD project. Through this diverse programme of talks, I have definitely gained a better perspective on current topics in insect research, and how they link together to address global challenges in sustainable development, conservation and scientific progress.

Alongside some fascinating science, I appreciated the opportunities get to know some of the people behind the talks during breaks and social events. One highlight of this was the EntOlympics, which offered networking opportunities with other early career scientists in a less formal setting, while I also learnt some fun insect facts. Overall, Ento23 felt like a great introduction to this research community, and I am excited to continue my PhD journey with the hope of presenting my own work here in the future. In the meantime, I'm already on the lookout for some fun EntoFashion to bring to next year's conference.

## The Workshops

Alongside talks and poster presentations, workshops at Ento23 provided a unique opportunity to network and develop new skills in a more interactive way. This year we offered a range of workshops spanning public engagement, insect welfare, publishing research and the next steps for our Grand Challenges in Entomology.

First thing on the programme for Wednesday was a breakfast workshop focused on the *Grand Challenges in Entomology*. The session looked at the 61 challenges identified in this year's Insect Conservation and Diversity paper authored by the Members and Fellows of the RES (Luke *et al.*, 2023). Despite the early start, participants explored the eleven key themes highlighted in 'Grand Challenges in Entomology: Priorities for Action in the Coming Decades' to generate and discuss ideas about how the RES can most appropriately support the entomological community to tackle the most pressing challenges in global society. Attendees offered practical solutions, especially emphasising the role of the RES in improving access to training, equipment and data, as well as the crucial work that can be expanded to increase the diversity and number of people entering entomological education and careers. The power of societal engagement through multimedia approaches, such as podcasts, and support for collaborative community work were discussed as possible contributions of the RES to addressing the Grand Challenges. The discussions were practical, insightful and relaxed. The workshop underscored the pivotal role of the RES as a society and membership organisation. The ideas generated were recorded and will shape the RES's future publications, conferences, and strategies, reflecting the collaborative spirit of the entomological community. The participants are thanked for their valuable contributions. Please look out for future workshops, meetings and initiatives related to Grand Challenges.

The *How to engage different groups with your research* workshop was coordinated by Fran Sconce (RES), with Seirian Sumner (RES Trustee & UCL) and Derek Green and Sally Luker (Budding Nature CIC). A discussion on the types of audiences, such as different ages, educational backgrounds, and cultural interests, kicked off proceedings, with the speakers then sharing examples of targeting engagement activities to

**Engagement workshop -** Seirian Sumner shared examples of targeted engagement for different audiences in the *How to engage different groups with your research* workshop. Photo: RES/Thomas Frost Photography.

Ento23


**How to get published workshop -** The panel shared their top tips in the *How to get published* workshop. Left to right: Sheena Cotter, Jane Hill, Robert Wilson, Emma Weeks, Adam Vanbergen, and Simon Ward. Photo: RES/Thomas Frost Photography.

particular audiences. The group activity generated new ideas for engagement activities, which were shared with the workshop participants, with ideas including a podcast about cultural entomology and school sessions on self-medicating flies suggested as examples.

Members of the Insect Welfare Research Society (IWRS), *viz.*, entomologist Meghan Barrett (RES; Indiana University-Purdue University Indianapolis), ethicist Bob Fischer (Texas State University) and entomologist Eleanor Drinkwater (Writtle University College; convener of the RES Welfare and Ethics SIG) coordinated the *Community-sourced strategies for improving insect welfare in research and education* workshop. This began with a short presentation on the plausibility of the moral status of insects and their potential welfare, as well as the use of precautionary reasoning in ethical decision-making. Eleanor then shared her work incorporating insect welfare into her pedagogy and research as a case study. Finally, RES members worked in small groups to propose new strategies and resources that could improve insect welfare; these could be employed by individual researchers/teachers, departments, universities, research societies, academic journals, funders, or policymakers. Thanks to the Insect Welfare Research Society for their support of this event.

The *How to get published* workshop began with an introduction to RES publishing and the Society's journals. The panel of Editors-in-Chief gave their top tips, with an interactive discussion led by some great questions from the participants. Following the discussion, RES President, Jane Hill, gave an overview of how the submission and acceptance process worked, again answering questions as they went through. Later in the day there was also a 'Pitch a Paper' event, where anyone could come and informally speak to the editors from the journals to discuss ideas and the potential to publish their future research. This was a great opportunity to get advice and tips, with each journal getting a number of delegates coming to chat.

### References

Luke, S.H. (2023) *Insect Conservation and Diversity* **16**, 173-189.

**Insect welfare workshop -** Ethical decision-making was discussed in the *Community-sourced strategies for improving insect welfare in research and education* workshop. Photo: RES/Thomas Frost Photography.

# International Evening Meeting

## Illuminating Central Europe's Unknown Insect Diversity

**28th June 2023**

### Ralph S. Peters

**Report by Kimberly Gauci**

Ralph S. Peters

Ralph S. Peters, Head of the *GBOL III: Dark Taxa* project and Head of the Hymenoptera Section at the Leibniz Institute for the Analysis of Biodiversity Change (LIB), Museum Koenig Bonn, presented an outstanding online talk about the *German Barcode of Life* (*GBOL*) project. This was the second in a series of meetings organised by the Society's International Representatives.

Dr Peters started by emphasising the importance of knowledge about all the species we have on Earth because of their positive and negative, direct and indirect interactions with humans, and for curiosity-driven and ethical conservation reasons.

The GBOL project, funded by the German Ministry of Education and Research and involving a consortium of natural history museums, universities and research institutes, was established in 2011 and is building a reference library of DNA barcodes for the German fauna, flora and fungi. *GBOL III*, which runs from 2020 to 2024, focuses on the so-called 'dark taxa', *i.e.*, the German fauna that is still largely unknown. There are unknown and under-studied taxa in several taxonomic groups, but *GBOL III* is specifically tackling the Diptera and the parasitoid Hymenoptera, which together comprise about one quarter of the German fauna. With analyses still ongoing, a four-digit number of species was discovered through this project, some of which were either new to Germany or even new to science. As well as expanding the barcode reference libraries, *GBOL III* is increasing knowledge of the selected taxonomic groups and training a much-needed new generation of taxonomists.

Dr Peters ended his talk by noting the current issue of rapid insect decline. Research in Germany has shown a greater than 75% decline in flying insect biomass in protected areas. More than half of the specimens studied belonged to insects from the 'dark taxa', so it is certain that species are declining and being lost before they have even been discovered, making projects such as *GBOL III* all the more urgent.

Please visit www.bolgermany.de for updates and information about the project.

Many thanks to Dr Peters for his engaging talk, and to the RES team for their assistance throughout the preparations for this event.

Photo: O. Niehuis & R.S. Peters.

# Monthly Evening Meeting

## Microbial Symbionts as Sources of Evolutionary Innovations in Beetles

4th October 2023

**Martin Kaltenpoth**
**Max Planck Institute for Chemical Ecology, Jena, Germany**

**Report by Richard Harrington**

Martin Kaltenpoth. Photo: Anna Schroll.

There can be no doubt that herbivory has proven a very successful strategy for insects, with roughly half of all species having adopted it. In nutritional terms, though, it presents challenges. The lower nitrogen:carbon ratio compared to an animal diet means that amino acids and vitamins are scarcer. Polymers in cell walls are hard to digest. Toxic defences have to be overcome and antagonists fought off. In many herbivorous insects, some of these issues are overcome with the help of symbiotic microbes, and Martin described examples from the Coleoptera.

The family Chrysomelidae is super-diverse, with 50,000 species in 13 sub-families. The Cassidinae (tortoise beetles) have pectinase-provisioning symbionts harboured in special structures that can be passed from generation to generation extracellularly via the egg. Fitness benefits have been demonstrated by producing aposymbiotic beetles which have reduced survival and produce no offspring. The symbiont (*Stammera capleta*) genome is the smallest known in any organism living outside its host cell, comprising roughly 271,000 base-pairs and just 289 genes. The symbiont cannot produce amino acids or B vitamins but has been shown to produce pectinases which cleave pectin in plant cell walls, aiding access to cell contents. The beetles themselves can produce the necessary cellulases.

Adult reed beetles (Donaciinae) eat leaves but the larvae suck sap from plant roots under water. Symbiotic bacteria, localised in modified Malpighian tubules, can produce eight to ten essential amino acids which help supplement the larval diet, and pectinases to help the adults digest cell walls. A study of the phylogeny of reed beetle symbionts showed that whenever the host switched to Poales, pectinases were lost, as there is very little pectin in Poales. Once lost, it seems as though it is difficult to regain them. Thus, whilst symbionts can help their host beetles expand their host-plant range, those beetles that lose pectinase-producing symbionts are destined to remain on pectin-poor plants.

In some Tenebrionidae (darkling beetles), symbionts have been shown to confer defences against predators. The symbionts (multiple strains of *Burkholderia gladioli*) colonise three unique dorsal organs and have been shown to inhibit fungal growth on eggs of *Lagria* spp. The dominant strain is unculturable. This strain has been shown to produce a bioactive substance, termed lagriamide, that protects against fungi on the egg and larval surfaces. Less common but culturable strains produce a range of antifungal and/or antibacterial secondary metabolities (*e.g.*, sinapigladioside, caryoynencin, gladiofungin, icosalide and lagriene).

Martin demonstrated clearly how novel associations between beetles and microorganisms can help to show how microbes have contributed to the enormous evolutionary success of beetles. A lively discussion followed, during which a downside to symbionts emerged. Glyphosate can interfere with insect-associated microbial communities, rendering the symbionts ineffective. This might be fine in relation to pest species, but clearly presents wider problems in relation to biodiversity.

Many thanks to Martin and to his students and collaborators for a very informative evening.

# Outreach

## The Bug Hub at the Royal Horticultural Society Flower Show: Tatton Park

**19th – 23rd July 2023**

**Barbara Tigar**
**RES Northern England Rep**

An unexpected phone call from the Royal Horticultural Society led to an opportunity to promote insects and entomology to visitors to the Bug Hub, a 10m diameter tepee at the five-day Tatton Park Flower show. This is the largest horticultural event in the North West of England.

I worked with Biosciences colleagues, students, recent University of Central Lancashire graduates and volunteers, to form a dynamic Bug Hub public engagement team. We delivered insect-related activities and engaged visitors in conversations about how to encourage biodiversity in their gardens by providing diverse foodplants and habitats, undisturbed spaces for hidden life stages, and minimising chemical usage.

We ran 'build a bug hotel' and 'insect origami' workshops and offered insect face-painting. We also helped visitors to view live and preserved insects using magnified viewing chambers and a binocular microscope. There was particular interest in a cicada preserved in Perspex with questions about song-production and periodic mass emergence. It was really rewarding to see younger visitors putting considerable effort into building and decorating bug hotels and making and decorating their origami bees and ladybirds with spots and markings.

The Bug Hub was placed in the centre of the school garden exhibit, and was a popular stop with teachers and students looking for activities and resources. Other visitors included parents, grandparents, young people, and other educators such as youth group leaders. We probably met over 500 visitors, with some enthusiastic younger visitors returning several times. Fran Sconce, the Society's Senior Outreach and Learning Officer, provided copies of five garden insect mini guides (insects, butterflies, bees, dragonflies and ladybirds) and insect postcards. These helped us to engage in conversation with visitors. For example, when giving out the insect mini guides and postcards we asked questions like:

> What difference can you see between a Honeybee and a hoverfly?
>
> What advantage could a hoverfly gain from mimicking a Honeybee?
>
> Have you seen any invasive Harlequin Ladybirds?
>
> Have you accessed the outreach resources and activities on the Society's website?
>
> Did you know you can submit insect photos to the Society's website to find out what they are?

One visitor talked enthusiastically about a large caterpillar with big eyes that had reared up when he approached it. He showed me a photo and was pleased to know it was an Elephant Hawk-moth larva that was feeding on Rosebay Willow Herb. He will now be encouraging the moth and its foodplant in his garden.

This may become an annual event, so look out for requests from the Society to take part.

Special thanks to the Bug Hub team: Dr David Wareing, Susan Wareing, Naser Jabori Khormooji, Abi Sterling, Jaskirat Sign Kaur and Dr Alejandro Perdomo Lopez.

Hand-painting an insect design.

Naser focusing the microscope.

Naser with hand-made bug hotels.

Photos: David Wareing (University of Central Lancashire).

# Grant Reports

## BioLinks Boosts Biodiversity Skills with Visual Resources

Olivia Watts and Keiron Derek Brown

From 2018 to 2022, the BioLinks project worked to boost biodiversity skills and expand the UK's data on underappreciated invertebrate species. Funded by the Field Studies Council and the National Lottery Heritage Fund, this project held 490 in-person events, teaching people how to identify invertebrates. BioLinks successfully equipped over 5,000 participants with the knowledge and tools to identify a diverse range of invertebrates, including flies, beetles, bees and earthworms.

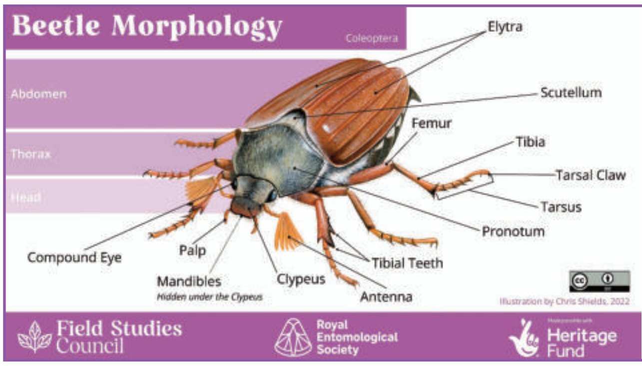
By providing comprehensive training on identification techniques, BioLinks has empowered countless individuals to delve into the fascinating world of invertebrates. Not only did the project enlighten learners, but it also encouraged them to submit biological records based on their newfound expertise. As a result of the in-person courses, an impressive 35,000 invertebrate records have been generated!

To enhance the promotion and dissemination of invertebrate recording, the Royal Entomological Society awarded a Goodman Award Grant to the project. This grant facilitated the creation of accessible insect morphology infographics, contributing significantly to the project's objectives.

**Igniting curiosity: introductory insect infographics**
Insect identification can be an intimidating endeavour for those venturing into the world of entomology for the first time, and the array of terminology may seem rather off-putting. Recognising this challenge, BioLinks took a proactive approach by developing visual resources that gently acquaint learners with the terminology and key features of several common insect groups.

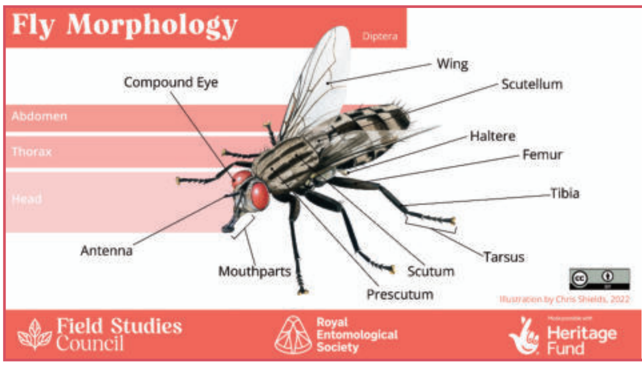
Ten infographics and an educational video have been created, which will help advance the public's understanding of insects. By introducing scientific terminology in a visually engaging manner, these resources act as a stepping stone for individuals who want to use insect identification keys. Furthermore, the BioLinks team has made these valuable resources accessible under a creative commons license, allowing learners to utilise them as indispensable reference materials, while also enabling other organisations to incorporate them into teaching resources.

You can find all the infographics with introductory accompanying text on the Field Studies Council website. BioLinks and the Royal Entomological Society encourage you to use these infographics and information to help educate and inspire others to get involved with invertebrate recording.



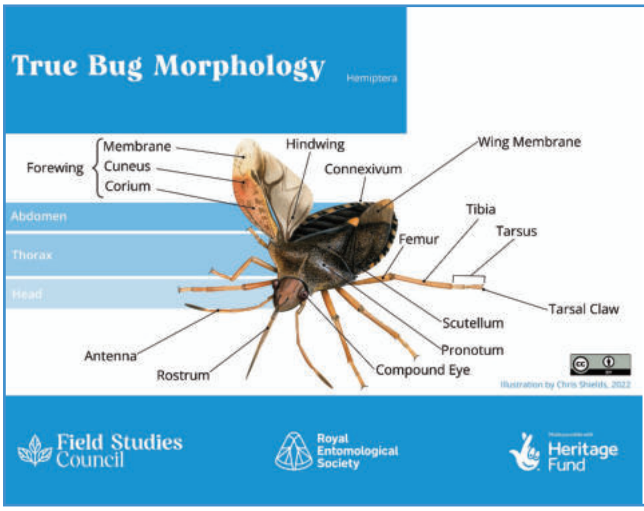

**Beetles (Coleoptera)**
A key feature of beetles is their hardened wing cases known as elytra. Typically, beetles have two pairs of wings; however, their forewings have become hardened. This feature gives beetles their scientific name 'Coleoptera', meaning 'sheath winged'.

Other key features of this group include: membranous hindwings, chewing mouthparts, and usually one pair of compound eyes.




**Flies (Diptera)**
Flies appear to have only a single pair of wings, as the hind wings have evolved into stabilising organs known as 'halteres'. Halteres are small peg-like structures extending from their thorax. They can be tricky to spot in some species, but out in the field, they can be seen on a large species of cranefly.

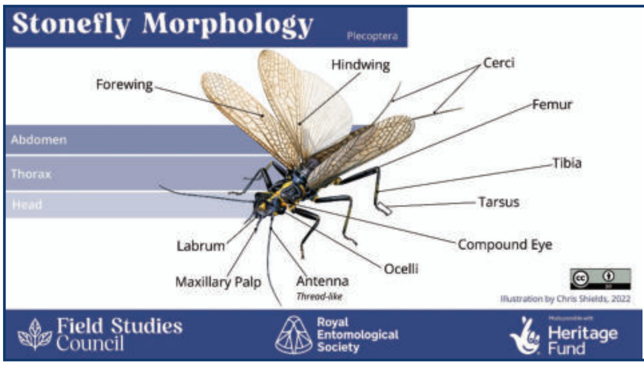
There are other characteristics that make flies stand out, including a large moveable head, very large compound eyes, and sucking or piercing mouthparts.




### True Bugs (Hemiptera)

These small to large insects are found in multiple habitats, and they can vary greatly in shape, size, and colour. The order Hemiptera is broken down into multiple suborders, but this infographic depicts one of the most familiar and commonly encountered suborders (Heteroptera), which includes shield bugs, plant bugs, and forest bugs. But one thing that all Hemiptera have in common is their long feeding tube known as the 'rostrum', which allows them to pierce their food source and extract liquid from within it.

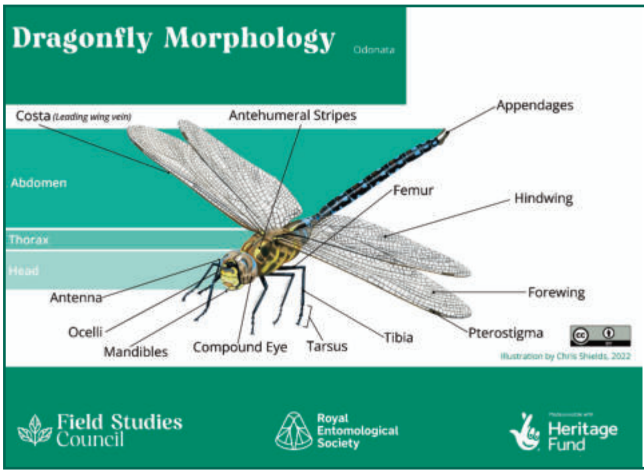
Their wings are also unique, as they do not meet at the midline of the abdomen when at rest. Additionally, the forewings have a partially thickened base, and the rest of the forewing is membranous – it is this feature that gives them their name, 'Hemiptera', which means 'half-wing'.




### Stoneflies (Plecoptera)

Stoneflies are considered one of the most primitive groups of flying insects. The name 'Plecoptera' translates to 'braided wing', which refers to the characteristic shape of the wing cells that result in a ladder-like pattern. Although they have two pairs of wings, they are rather poor fliers. Their wings lie flat against the top of their abdomen when resting.

Other key features include their long thread-like antennae, small beady compound eyes, and a pair of cerci at the end of their abdomen.

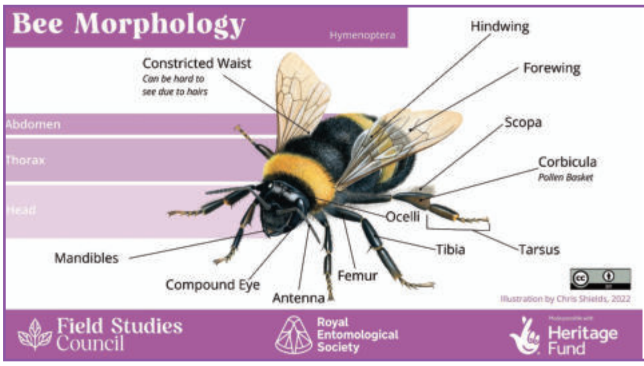



### Dragonflies (Odonana)

The taxonomic group Odonata contains both dragonflies and damselflies. Our infographic depicts a typical dragonfly; however, dragonflies and damselflies possess similar body structures and features.

One of the most noticeable features is their long, thin abdomen. They also have two pairs of long wings, which are all similar in size. On their forewings, they have a 'pterostigma', a dark blotch along the main vein – a feature often used in species identification.

Other key features of the group include their large mobile heads with large compound eyes. This combination of features makes them impressive predators, able to navigate and catch prey at speed.




### Bees (Hymenoptera – this group also contains the wasps, ants, and sawflies)

One key feature of bees is the constricted waist – although this may be hard to see in bumblebees and species covered by dense hairs. Hairs are used to keep the bee warm and collect pollen. Some bees will also have a 'corbicula' on their hind leg (their 'pollen basket'), which is used to collect and transport pollen.

All adult bees have two pairs of wings, with larger forewings and smaller hindwings.

You can view the rest of the infographics and the educational video on the Field Studies Council website, and you can download your own copy to use as reference or to educate and inspire others.

https://www.field-studies-council.org/2023/02/22/insect-morphology/

# ESSA 2023: Travel report

**Zanthé Kotzé**
**Texas A&M University**

Between 11 and 14 July 2023, I was excited to attend the 23rd Congress of the Entomological Society of Southern Africa (ESSA), hosted in Stellenbosch, South Africa, the first in-person ESSA congress since the COVID pandemic. This congress is held every second year and provides both established and budding entomologists from southern Africa an opportunity to network and collaborate. The theme of this year's congress was 'Exploring Insect Biodiversity: Unveiling Hidden Treasures'. Graduate students are encouraged to give oral presentations or poster talks highlighting their research, and seasoned researchers are afforded the opportunity to share their recent work. Attendees were welcomed by Julie Coetzee, ESSA president, and James Pryke, head of the ESSA 2023 organising committee. This year's congress attracted 290 attendees.

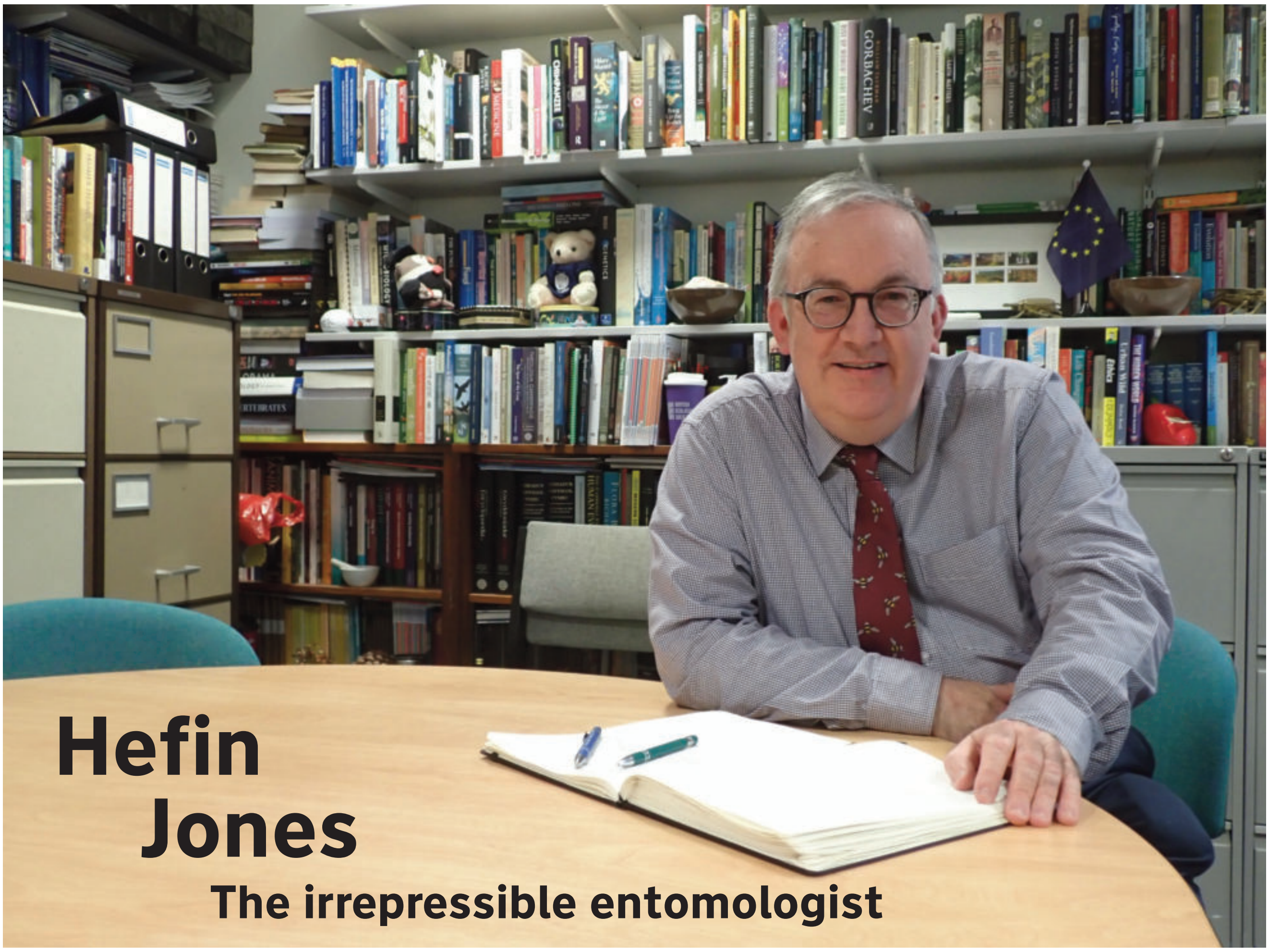
Each day kicked off with a plenary from one of three esteemed speakers: Fleur Ponton (Macquerie University, Australia), Casper Nyamukondiwa (Botswana International University of Science and Technology, Botswana) and Klaus Birkhofer (Justus Liebig University Giessen, Germany). Each of the speakers presented the attendees with fascinating and insightful talks, integrating symbiont-pathogen interactions in insects and mammals, pest management and ecosystem services, and arthropod behaviour and ecology through worldwide collaboration.

I was able to present my work, entitled 'Rewriting the forensic entomology case report: A South African review', highlighting the need for a universal case report format when analysing entomological evidence of forensic significance, in the Medical and Forensic Entomology session. On behalf of the RES, I also presented a workshop entitled 'Publishing a scientific paper', aimed at guiding students through the writing and submission process, as well as explaining the post-submission process on the editorial and reviewer side. This workshop had around 200 attendees, including representatives from Zeiss microscopes and Inqaba Biotech, both of whom provided valuable additions to the workshop.

I would like to thank the ESSA 2023 organising committee and Stellenbosch University for a well-organised and thoroughly enjoyable congress, and the Royal Entomological Society for the financial support for me to attend the congress. I look forward to ESSA 2025!



# HONORARY FELLOW INTERVIEW



# Hefin Jones

## The irrepressible entomologist

Departing the train at Cathays station I dodged the showers on the short walk across the campus to the Bioscience building. I knew I was in the right place when I walked past a metal sculpture of an aphid being attacked by a parasitic wasp (I later learned that it was a memorial to Mark Jervis, who was well known for his work on parasitoid biology / ecology / pest management, but who tragically died in 2014). My train had been on time so I was early for my appointment with Hefin (the rail system can be full of surprises). Hefin's PA made me coffee while I waited for his meeting to conclude (he pointed out later that a PA was one of the perks of being Director of Undergraduate Education!). Having had the call that Hefin was free she escorted me to a lift that estate agents would describe as 'retro and bijou', then on to Hefin's office. Hefin, ebullient as ever, offered a very warm Celtic welcome, and with the caveat that, "I like to talk, so please stop me if I talk too much" he began to outline his life as an entomologist.

### Early Life

"I was brought up in a rural West Wales village where I would spend weekends on my uncle's farm helping to look after the animals, so I was always wandering around the countryside. At school we had a nature table which I often contributed to, and as a class we went on regular nature walks. My parents were very natural history orientated, especially my father who was an amateur botanist, and on our regular Sunday afternoon walks he would talk about all the plants that we encountered. He would teach my sister and I their names – in Welsh, English and Latin!

I was fascinated by 'creepy crawlies' from a very early age, rearing caterpillars that I collected in the garden and watching aphids on dad's beans. My grandfather was a local poet who wrote and contemplated the natural world through his poetry, so nature was a strong thread that ran through my early life. Aged eight I won a natural history competition that had been run by a Welsh TV programme - Telewele. The task was to produce a book of pressed flowers which I thought was wonderful at the time (late 1960s), but the thought of picking and pressing wild flowers horrifies me now.

My primary school was a wonderful experience - we had science every week, where we ran very basic experiments.

After passing my 11+ I attended the local grammar school where the WJEC (Welsh Joint Education Committee) biology curriculum was fantastic. I conducted a project on acid rain for my O Levels and then at A level I conducted a project looking at the biology of soil and the effects of culturing different soil organisms on broad bean plants, which fired up my interest in invertebrates. Our Biology teacher used to take the three of us doing A Level Biology to BAYS (British Association of Young Scientists) events all over South Wales every month. One difficulty I had was that I have always had a deep interest in the arts, particularly literature, but at that time we had to choose arts or science as a route through school, so I went down the science route – but I missed both history and literature."

## University

"I knew by this time that I wanted to be a zoologist so I applied to King's College, London as they also offered several entomological routes in their degree scheme, and I also felt that moving to London would improve my English. As someone who had been brought up in an almost entirely Welsh-speaking community and learnt English as a second language at primary school I had decided that the only way to get rid of the 'chip on my shoulder' about speaking English was to jump in at the deep end! Hence King's, London.

The entomology at King's was taught by Bryan Turner who had a brilliant teaching style that really captured my interest. We had lectures on taxonomy and ecology but also field courses, where we spent the initial part sampling various habitats for insects and the rest of the week identifying the catch and building up my first insect collection.

Student life at King's was a great eye-opener for a simple Welsh country lad - I remember being taken aback by London punk culture, people with safety pins and chains in their ears and noses. We had nothing like this back in Pencader where I was brought up!

King's, because of its founding history (it was set-up as an antidote to 'that godless institute in Gower Street' (UCL)) ran a diploma course for non-theological students. This involved lectures on a Saturday morning and an exam at the end of each year – one of the most fascinating lecture series I recall were those given by Reith Lecturer Ian Kennedy on Medical Ethics. I also became very involved in the antiapartheid movement and spent many nights sitting on the pavement outside South Africa House on Trafalgar Square (little did I know then that I would one day get to meet Nelson Mandela in his Presidential rooms in Parliament in Pretoria while there on an UNA study visit).

At the end of my second year Bryan Turner informed me that King's had a scholarship in memory of the ecologist Ian Healey, for a student to conduct an ecology project over the summer vacation. So I applied and got it! This was working for Bryan, collecting psocids in Epsom Forest, identifying them and carrying out temperature – respiration studies. These data were included in a paper that he was working on and I recall being very excited that I was mentioned in the acknowledgements! This was also the beginning of my interest in communicating science to the public, as I had lots of people approaching me in Epsom asking what I was doing. So, I began to think how best to explain science to non-scientists.

When third year projects came around I decided to work with Bryan on the parasitic wasp *Nasonia vitripennis* that parasitised blowfly pupae. I was looking at the effect that clumping of pupae had on the wasp sex ratio. The project overran term-time so I had to take the pupae home with me in order to observe and count the emerging wasps. I managed to persuade my mother to allow me to keep them in the airing cupboard and gathered the last of my data from there. Bryan and I published the results, which was my first paper."

## PhD

"After graduation I saw an advertisement for a PhD at Imperial College with Mike Hassell, working on the natural enemies of Cabbage Root Fly, so I applied and obtained the position.

I worked on parasitoids that attacked Cabbage Root Fly, looking at the interaction between the fly and the cynipid wasp *Trybliographa rapae* and two species of staphylinid (*Aleochara* spp.) beetle. I conducted small-scale laboratory-based experiments, medium-scale arena experiments in the field, and open experiments under natural (horticultural swede field) conditions.

Silwood was a fantastic place to be a student. Not only academically (the constant visits by international ecologists and entomologists) but also socially: we had Christmas parties, Burns Night suppers and a stunning Summer Ball – with all of us lads in our tuxedos. The bar was very egalitarian; I could drink with my peers one night and senior academics the next. I have no doubt that Silwood made me! "

## Work

"As my PhD came to an end I saw a job advertised at the National Vegetable Research Station at Wellsebourne, near Warwick, working with Stan Finch. I had not written up my thesis at that time but decided I could not miss this opportunity. So I applied and was successful.

The work was to investigate the interactions between the Cabbage Root Fly and brassica caterpillars - Large White, the Garden Pebble Moth, the Cabbage Moth - and various aphids. I spent time looking at the attractiveness to gravid Cabbage Root Flies of cabbages which were grazed by one or more of these other insects. It transpired that those grazed by caterpillars of the Garden Pebble Moths repelled

*Trybliographa rapae.*

Cabbage Root Fly females. We realised that it was the frass that was the repellent, and analysis of the frass revealed that sinapic acid was the agent. This was a metabolite of the sinapoyl glucose found in the brassica leaves. Stan contacted an industrial concern to see if this had any commercial potential. All publication possibilities came to a halt until its viability had been determined. Unfortunately, after what seemed a lifetime, it was deemed unrealistic as the effect was very short lived.

When my three years were up I was talking to Geoff Norton who was based back at Silwood and he told me he was looking for someone to develop a computer-based expert system to offer advice to farmers on Wheat Bulb Fly.

Somewhat hesitantly I took the job, and working with Geoff and the late John Mumford spent my time talking to farmers and colleagues in ADAS, and we developed a prototype expert system that could offer advice to farmers on Wheat Bulb Fly control. I was well-chuffed as we managed to publish this in the *Journal of Economic Entomology* – one of my few applied papers!"

Tephritid fly. Photo: Hefin Jones.

## Silwood Park

"While at Silwood, Mike Hassell and Charles Godfray approached me with a position funded through a NERC grant to look at host parasitoid systems. I jumped at this opportunity – Mike had been a fantastic PhD supervisor, ever supportive but ensuring I developed a degree of independence with my studies (it was Mike who also had encouraged me to join the RES in 1982, my first year as a PhD student!) and Charles had been the entomological post-doc at Silwood while I was there first time around. (It was Charles, as editor of *Antenna*, who got me my first editorial role as Assistant Editor in charge of writing reports on the monthly RES meetings). The position left me jobless for three months. Geoff Norton came to the rescue and found me three months' work at the Pest Infestation Control Laboratory in Slough.

I worked with Mike and Charles for the next five years on the tephritids that attack thistles. Most of the previous work I had done had tended to be laboratory based; these studies were entirely field based. We took over an area of marshy ground at Silwood Park, marking it out in one-metre squares with string and bamboo canes. We mapped all the thistles, every day we would record tephritid and parasitoid presence on these thistles. The thistle heads were harvested at the end of the season and individually placed in a milk carton with a small tube to collect the emerging insects. We had two garden shedfuls of these milk cartons, waiting for insects to emerge from the galls in the thistle heads. These studies were all centered around understanding the interaction between host and parasitoid, and their population dynamics. We also undertook a mark and recapture experiment on both the tephritids and their parasitoids, which was really tricky - we used Southwood's fly marking technique, marking the thorax with tiny dots of different-coloured paints. The results of this study showed how different species of parasitoids foraged in different ways, travelling different distances.

Silwood Park is basically next door to Windsor Great Park. I always used to tell friends that the Royal Family had to bring their carriages through our back garden at Silwood to reach the racecourse in Ascot! I was, however, very frustrated one morning when on arrival at the experimental site I realised that deer from Windsor Great Park had stampeded overnight through the thistle area, pulling out all the canes and string we'd carefully positioned. I was not a happy entomologist!.

As this NERC grant was running out John Lawton, who had not that long before established the Centre for Population Biology at Silwood, asked me if I would be interested in being involved in a climate change experiment in the Ecotron controlled environment facility, as the project leader. This was one of the most exciting opportunities that ever came my way, and I look back on those six years with considerable pride, but also a realisation of what a privilege this was. I had a team of ten colleagues working with me at Silwood - scientists, technicians, an electrician, and a mechanical engineer, plus almost fifty collaborators from some 18 research institutes across Europe. This was an extremely productive period in my career. We also had a continuous flow of visitors, including the infamous Biosphere 2 Team, and considerable international media interest. I was duly baptised 'chef d'Ecotron' by La Monde.

The Ecotron was not everyone's cup-of-tea, and I do recall being surprised, even somewhat hurt, by the criticism thrown at us that we couldn't possibly draw conclusions based on a one metre square plot in a controlled environment facility. John was a great comforter at

Hefin interacting with an undergraduate.

these times – he'd just tell me not to worry and point out that these were the same scientists who had spent their lives working on single plants grown in individual pots in a greenhouse. No, we were not 'true' nature but we were more 'true' nature than single pots!"

## Cardiff

"While I had enjoyed my time at Silwood I was desperate to return home to Wales. So, when the opportunity arose I moved back to Wales, to my current post at Cardiff University. At Silwood I had missed out on interacting with undergraduate students. Both Mike and John had realised that this was important to me and had enabled me to become involved with undergraduate students at Imperial, giving lectures, having personal tutees and marking exams. It became obvious to me that this is what I wanted. Cardiff University has provided me with this, and over the years I have so enjoyed sharing knowledge and developing young minds. There is no greater privilege. I have also had great opportunities to develop research-wise – working with mycologist Lynne Boddy we have explored the interactions between basidiomycetes and soil invertebrates. Lynne is a fun colleague to work with – she and I have worked closely not only on research but on field courses; Lynne's enthusiasm for fungi is infectious – who'd have thought that I'd ever be excited by a mushroom (not the hallucinogenic kind!).

One thing that has worried me greatly over the past decade or so as I spend time with students is the decline in the most basic natural history knowledge and understanding. You can point to a Foxglove, and many will not know its name; I've even been able to convince some students that cuckoo spit is actually cuckoo spit. Yet once the details of the natural world are pointed out to them, they are fascinated. I talk about the Holly Leaf Miner or the complex communities in oak galls and students love it, they are amazed. Until that point they had never stopped to look or even notice. I frequently quote W.H. Davies's poem to them:

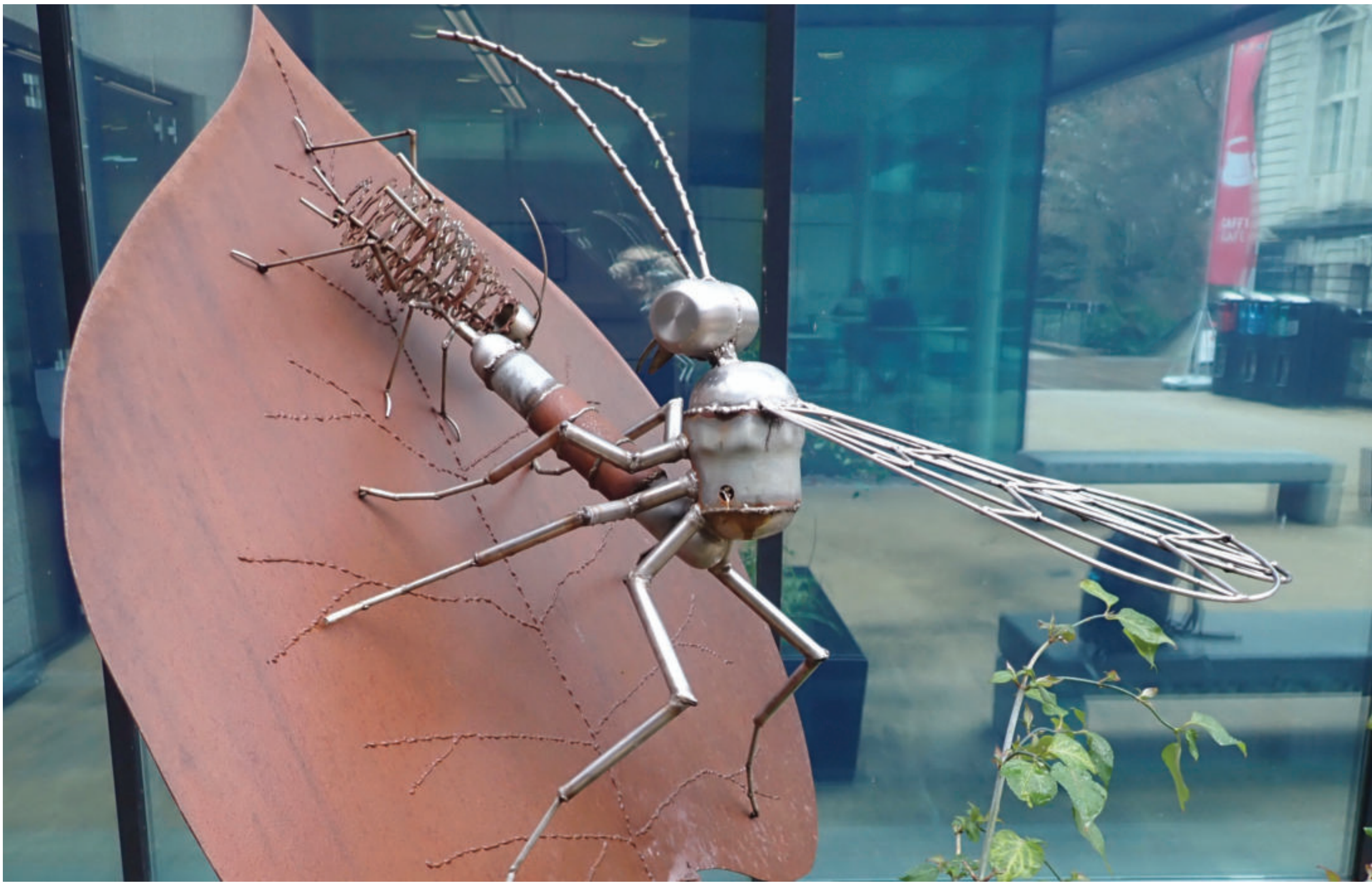
*"What is this life if, full of care,
We have no time to stand
and stare ..."*

## Outreach

"I am passionate about outreach, and we are fortunate to have the Science Education Centre Techniquest here in Cardiff. Through them I have over the years visited many schools and talked about insects. I have to confess, however, more recently due to work pressures I have restricted my visits to Welsh-medium schools, thinking there are plenty of English-speaking entomologists out there but very few who can talk insects in Welsh! I have a very good relationship with a number of schools throughout Wales. In one primary school in Cardiff, after speaking about insects and their lives I leave a task – design a beetle that predates on caterpillars found in the roots of plants, for example. They design and create their models and then I organise for them to come into one of the University's lecture theatres, where each insect model is presented to the class and they vote on the best. Some of the designs are totally ingenious – batteries to provide light spheres for visual ability, drinking straws to suck from root tissue. The kids love it and become very animated!

I also give regular talks to local Rotary and Probus groups where I usually offer an insect pot pourri and talk about insects in literature, poetry, film and theatre. I also give Welsh-medium talks on insects in Welsh poetry, where I use poems' text to delve into various scientific aspects – for example, a poem on the death watch beetle attacking the beams of an old church provides an opportunity to talk of insect courtship behaviour; a sonnet on the peppered moth provides an avenue to discuss evolution and adaptation.

A somewhat morphologically unorthodox beetle but highly evolved creation by four pupils from Ysgol y Mynydd Bach, Cardiff – with battery powered light prey-seeker, robust and protective elytra or digging through soil, and a substantial excretory organ for frass deposition! Photo: Hefin Jones.



'Parasitoid attacking an Aphid' - created by Daren Greenhow, the memorial to Mark Jervis is located outside the Sir Martin Evans Building, Cardiff University. The memorial plaque reads: 'In memory of Dr Mark Anthony Jervis, 1951-2014. Entomologist, scholar, colleague and friend.' Photo: Peter Smithers.

Over the years I've been a regular on Welsh TV and radio science and chat-shows. This aspect of science appeals to me, and I was very humbled when I was awarded the Science Medal by the National Eisteddfod a few years ago for my contribution to promoting the understanding of science through the medium of Welsh. I was also invited into the Gorsedd Bardic Circle of the Eisteddfod for my work in this area.

## RES

I have been a member of the RES for some forty-one years now. As mentioned, my involvement began at Silwood Park, when I was a regular at the monthly meetings in Queen's Gate. I related above how Charles Godfray asked me to write the monthly meetings reports for the house-magazine. For a time, again with Charles's encouragement, I also ran the Parasitoid SIG.  When Charles stepped down as editor of *Antenna*, my colleague and friend, Allan Watt, and I took on the task. This was pre desktop publishing, so we literally had to cut and paste the proof articles to fit the pages. I have been on Council twice, and Vice President twice. I have also been the RES representative at the European Congress of Entomology, and it was a great honour to be made an Honorary Fellow. I have recently ended my term as editor of *Agriculture and Forest Entomology*. The Society has been central to my development, supporting, encouraging and providing incredible networking opportunities. It is a Society of willing volunteers, and it is those volunteers that have given me so many opportunities. As I come to the end of my professional career, I hope the Society never loses sight of that; it is its volunteers, its membership, its editors and communicators, its Special Interest Group leaders and outreach presenters, that make the RES the great society that it is. Without them there would be no RES."

We came to a halt. Hefin's account of his career had been a verbal whitewater ride, a journey filled with excitement, challenge and achievement; from a family and school that imbued in him a love of the natural world to his stellar rise to some of the most important cutting-edge research of recent times. There is no doubt that Hefin loves to talk, he is a born communicator with a passion for the natural world that seeps into everything that he undertakes. This, combined with his meticulous attention to detail, have taken him on a journey from Wales to some of the most exciting frontiers of entomological science, and then back home to Cardiff. But it is always his interactions with people that deliver the most satisfaction. Students, schoolchildren, the local Rotary or natural history society to the media, communicating his work and the wonders of the insect world is what sets him alight. We hope that his passion and infectious enthusiasm will continue to inspire young people and the wider community to a greater appreciation of the natural world for many years to come.

Hefin awarded the Science Medal by the National Eisteddfod, for promoting the understanding of science through the medium of Welsh. He is wearing his robes as a member of Gorsedd y Beirdd – the bardic circle of the Eisteddfod.

**Peter Smithers Hon. FRES**

# Obituary

## Professor Bill Symondson

**15$^{th}$ April 1951 to 17$^{th}$ August 2023**

Bill in a field of barley visiting one of his PhD student's field sites, camera in hand for butterflies.

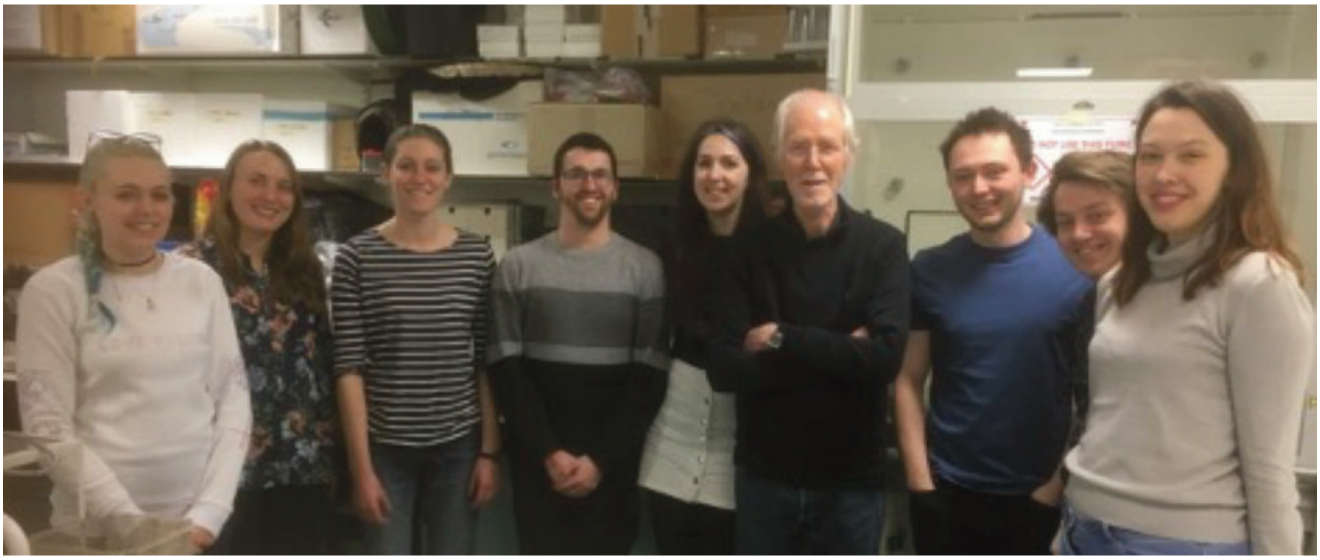
**Introduction**

William (Bill) O. C. Symondson was known to many as an exceptionally passionate entomologist, a dedicated scientist and a warm, compassionate member of the scientific community. Bill is perhaps best known for having pioneered the use of DNA for dietary analyses, but his research accomplishments span conservation biocontrol and trophic ecology, particularly in conservation contexts in his last years. He spent time during his retirement writing an autobiographical account of his childhood spent on a dairy farm in the 1960s, due to be published by Brambleby Books (Oct 24$^{th}$, 2023). Bill will undoubtedly be missed by the entomological community.

**Research highlights**

Bill completed his PhD at Cardiff University in the 1990s, having followed his scientific passion after managing a smallholding in Wales. This kick-started 30 years of exceptional research, first focused on carabid-slug interactions in a conservation biocontrol context, but later expanding into conservation of invertebrates, reptiles, birds and mammals. Alongside co-authoring some prominent reviews on the application of DNA-based methods to dietary analysis, two of Bill's best-known works were published in 2002: one highlighting the potential of DNA for dietary analyses in *Molecular Ecology*, and the other reviewing the role of generalist predators as biocontrol agents in *Annual Review of Entomology*, both of which provided strong foundations for Bill's further research.

Bill's love of slugs extended beyond biocontrol though, evidenced by the Field Studies Council *Slugs of Britain and Ireland* book he co-authored, now the definitive resource for British slug identification. Bill's work included dietary analysis of biocontrol agents, invasive species and species of conservation concern, and spanned insects, arachnids, reptiles, birds and mammals. Bill's research was far from ordinary; he was involved in the discovery of monophagy in a termite-specialist spider, reviewing plant-feeding in spiders and myriad other scientifically significant studies. Bill increasingly collaborated with Durrell Wildlife Conservation Trust in the latter years of his career, assessing the trophic interactions of species of conservation concern like the Turtle Dove, but also taking interest in island food webs, specifically how their invasion by non-native ants and the use of ecological replacements such as giant tortoises



Bill with many of his recent PhD students. Left to right: Lorna Drake, Rosemary Moorhouse-Gann, Jenny Coomes, Ewan Stenhouse, Becca Young, Bill himself, Max Tercel, Jordan Cuff and Sarah Davies.

Bill demonstrating dissection of a wasp larva to extract its guts for molecular analysis.

affected their food webs. The impacts of Bill's work on conservation, management and policy will continue to arise for many years to come.

**Conclusions**

Bill Symondson pioneered molecular dietary analysis, conservation biocontrol and trophic ecology, and he will be greatly missed. Bill's wider natural historical contributions, including discovery of the Ghost Slug *Selenochlamys ysbryda* Rowson & Symondson 2008 and a caterpillar that builds its cocoon from tree resin, are also highly noteworthy. Bill's love of insects was particularly evident from his personal butterfly collection and his enthusiasm for trips to spot new species with colleagues and friends. His passion for the natural world continued unabated; Bill attended meetings with collaborators, contributed to scientific articles, and advised on conservation projects even in his last few months. Bill's legacy continues through his family, the many scientists he inspired, and the exceptional body of research he produced.

Jordan Cuff and Max Tercel

Royal Entomological Society

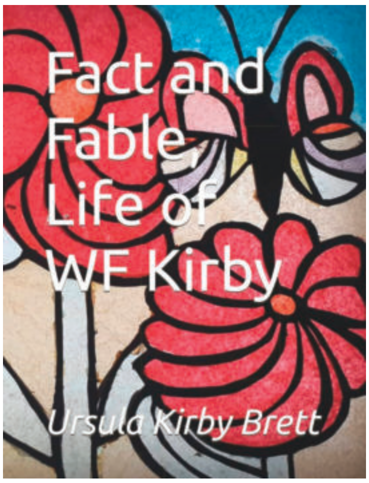
# Antenna Reviews

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/*


**Animals Under Logs and Stones**
**(Naturalists' Handbook 22)**
C. Philip Wheater, Helen J. Read and Charlotte E. Wheater
Published by Pelagic Publishing
ISBN 9781784274177
Reviewed by Richard Jones

The mantra of the field naturalist should be: "see a log – roll it over". I've certainly lived by this credo ever since the day I was big enough to roll over a large flint in my parents' garden and see the handsome Black Rove Beetle, *Ocypus pedater*, go scurrying off into the root thatch. Logs and stones are very important animal habitats, especially for invertebrates. They provide moist shelter in a harsh dry world and each log rolled often reveals its own broad ecosystem. This does mean that the types of creatures likely to be uncovered are hugely varied, and the usual identification guide specialism needs to have much more latitude. Having said that, the usual denizens regularly turn up — mostly beetles, ants, woodlice, centipedes, millipedes, spiders and molluscs. A habitat-based approach has been highly traditional in books about pond-dipping, so it is perhaps surprising that this is the only popular volume based on the cryptosphere, as this semi-subterranean world is sometimes rather grandly titled. The most important ecological aspect of logs and stones is that they form an interface with the soil and leaf litter layer, and their trap/edge-effect element is extremely important when it comes to sampling these expansive and nebulous ecological zones. For the entomologist, rolling over a log is very much opening a window into this hidden secret world. This present book is a massive revamp of the original Naturalist's Handbook first published in 1996 – in those 27 years the slim 90-page booklet has now become a heavy 344-page tome. The majority of the book is given over to identification keys, and these are greatly expanded from the first edition. There must still be some approximation though, it would not be possible to include all the potential ground beetles for example, so larger and commoner species are prioritised. Nevertheless, the finished pragmatic and practical assortment works well. All the usual suspects, and quite a few unusual ones, are here. I think it was an oversight not to include any heteropteran bugs (the shieldbugs *Podops inuncta* and *Thyreocoris scarabaeoides*, and several Lygaeidae ground bugs are frequent) but I've already used the book, to good effect, to identify some springtails, harvestmen and flatworms that I'd otherwise have passed over.




**Fact and Fable, Life of W.F. Kirby**
Ursula Kirby Brett
Published by Amazon Digital Services
ISBN 9798458010207
Reviewed by Richard Jones

For as long as I've had his *Elementary Textbook of Entomology* (1885) on my bookshelves, I've never quite grasped that its author William Forsell Kirby was not the same entomologist as William Kirby, founder member and honorary president for life of this Society. Born in Leicester in 1844, W.F. Kirby came from a completely different stratum of society than his celebrated namesake, and this has left him slightly overshadowed in the history of the science. In his lifetime he worked in several museums, published high-brow monographs and detailed catalogues, numerous scientific papers in the scientific press, and general popular guides. He was also an accomplished linguist, competent in 10 languages, and he translated or edited translations of various literary works. He translated the Finnish epic *Kalevala*, maintaining its trochaic tetrameter and he contributed to Richard Burton's famous ten-volume translation of the *Arabian Nights*. Ursula Kirby Brett, W.F. Kirby's great granddaughter, has taken family oral tradition, private and public documents, and his vast published record to present a wealth of information on this fascinating character. But this is an odd book. Being self-published it lacks the editorial finesse and cohesion imposed by a conventional publishing company. It is presented, rather, as a dossier of documents, anecdotes, quotes, reminiscences and short chapters on various aspects of Kirby's life. As such, it lacks the formal narrative you might expect in a standard biography. Nevertheless, its manifold segments are readable and extremely detailed with copious footnotes, and it comes with full references and bibliography. My biggest gripe is that it does not have an index, a heinous crime in my book, or indeed any book. But I now know all about the 'other' Mr Kirby, and I am grateful for that.

# 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).

**March 2024**

Sat 2 — 2 March
**Young Verrall Lecture 2024**

Wed 6 — 6 March
**Verrall Lecture 2024**

Mon 25 — 25 March – 26 March
**Student Forum 2024**

**April 2024**

Thu 25 — 25 April
**The impact of extreme events (hybrid event)**

**May 2024**

Thu 2 — 2 May
**Forest invertebrates: challenges and solutions (virtual event)**

**June 2024**

Mon 24 — 24 June – 30 June
**Insect Week 2024**

**July 2024**

Wed 3 — 3 July
**AI in entomology (hybrid event)**

**August 2024**

Sun 25 — 25 August – 30 August
**International Congress of Entomology, Kyoto (external event)**

**September 2024**

Tue 10 — 10 September – 11 September
**Ento24**

**For full details on all RES meetings please visit**

**www.royensoc.co.uk/events**