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Inside JEB

JUMPING SPIDERS IDENTIFY VICTIMS BY THEIR ANTENNAE


Robert Jackson

Evarcha culicivora jumping spiders are picky eaters by any standards. Explaining that the arachnid's environment is swamped with insects, Ximena Nelson from the University of Canterbury, New Zealand, says, 'You can see from the diet when you find them in the field that there is a high number of mosquitoes in what they eat'. And when Robert Jackson investigated their diet further, he found that the spiders were even more selective. The delicacy that *E. culicivora* prize above all others is female blood-fed *Anopheles* mosquitoes, which puzzled Nelson. How could these picky spiders pick out blood-engorged *Anopheles* mosquitoes from the swarms of similarly sized insects infesting the area? Nelson and Jackson decided to do some jumping spider psychology to find out how the arachnids pick out blood-fed female *Anopheles* mosquitoes from the crowd (p. 2255).

According to Nelson, identifying *Anopheles* mosquitoes is quite straightforward, especially for *E. culicivora*. 'The bodies of *Anopheles* mosquitoes rest on a 45 deg angle from the substrate but most others rest parallel', she explains. But what other distinguishing features could the famished spiders use when selecting their preferred female snacks? 'Obviously, blood-fed females have an engorged red abdomen and the other difference that comes to mind between males and females is the antennae', says Nelson. Explaining that male *Anopheles* have luxuriant fluffy antennae, while the female's are less elaborate, Nelson decided to see which mosquito features *E. culicivora* fixate on.

Collecting male and female *Anopheles* and *Culex* mosquitoes at the International Centre for Insect Physiology and Ecology in Kenya, Nelson, Godfrey Sune and other helpers painstakingly constructed hybrid mosquitoes. Combining the head and thorax of one insect with the abdomen of another, the team was able to produce Frankenstein mosquitoes with blood-engorged female abdomens and male antennae, slender male abdomens and female antennae, and every other combination in between. Then, they mounted the hybrid mosquitoes in their correct postures and tested the spiders' preferences.

'The great thing about jumping spiders is they're very decisive', recalls Nelson, who could clearly see that the spiders preferred intact blood-engorged females over everything else, even females engorged with transparent sugar solution. And, when Nelson offered the spiders the choice between a Frankenstein female (made from the head and thorax of one female fused to the blood-engorged abdomen of a second female) and a hybrid constructed from a male head-and-thorax and a blood-engorged female abdomen, the spiders usually selected the hybrid with the female antennae, even though both hybrids were packed with blood. Also, when she tempted the spiders with animated simulations of blood-engorged mosquitoes with either male or female antennae, the spiders consistently pounced on the simulated female.

The spiders weren't just picking out *Anopheles* mosquitoes with abdomens full of blood; they were able to identify the mosquitoes by their antennae. 'The thing that really amazed me is that I couldn't actually see the difference when I was looking at the screen', recalls Nelson. Even when she got down to the spider's level, the mosquitoes were too small for Nelson to discern the insects' minute antennae.

Having found that picky *E. culicivora* can identify the tastiest mosquitoes by their antennae, Nelson is curious to find out how they process this visual information: whether they assess all of the mosquito's characteristics simultaneously or systematically tick features off a check list before deciding to attack. Nelson also adds that she is baffled by how the spider's tiny brain processes all of the sensory information that they must handle when making their decision.

10.1242/jeb.075218

Nelson, X. J. and Jackson, R. R. (2012). The discerning predator: decision rules underlying prey classification by a mosquito-eating jumping spider. *J. Exp. Biol.* **215**, 2255-2261.

Kathryn Knight

THE LOCUST TAKE ON DISCONTINUOUS VENTILATION

Insects have to manage a delicate balancing act while breathing. According to John Terblanche and his colleagues Berlize Groenewald and Steven Chown from Stellenbosch University, South Africa, and Stefan Hetz from Humboldt University at Berlin, Germany, insects have to supply sufficient oxygen to meet their metabolic demands while managing carbon dioxide waste removal. And they do all that without drying out the delicate fluid-filled tracheoles that transport oxygen directly to their cells. Explaining that insects tackle the problem using a variety of tactics, the team adds, 'The most controversial of the proposed adaptations is the use of discontinuous gas exchange cycles'.

During discontinuous gas exchange, insects minimise the amount of time that the respiratory system is open to the atmosphere. They only take in air to supply oxygen during the second phase of the cycle (known as the flutter phase) and release carbon dioxide during the final phase (the open phase) when they finally open the spiracles that initially sealed the respiratory network at the start of the cycle (the closed phase). Yet, how and why insects evolved this complex respiratory mechanism is unclear. Explaining that there are several competing theories, ranging from protection from oxidative damage to prevention of dehydration, Terblanche, Groenewald, Hetz and Chown decided to find out more about how desert locusts use this particular form of respiration (p. 2301).

'Desert locusts are big and easy to instrument', says Terblanche, who explains that this is a particular advantage when taking pressure measurements inside the insect's tracheal system. 'It is extremely challenging to insert tiny tubes into the locust's spiracles', he adds. Having travelled to join Hetz in Germany, Groenewald measured the carbon dioxide release patterns, the pressure in the tracheal system and the thorax movements of 12 resting locusts as they performed discontinuous gas exchange.

Analysing the insect's movements, the team noticed that the insects pump the thorax in two ways: telescoping the thorax along its length and compressing the top and bottom. Also, instead of pumping during the open phase – when other insects pump to expel carbon dioxide – the locusts were pumping during the closed phase. The team suspects that instead of expelling gases from the body, the insects pump the thorax to increase the pressure in the tracheal system, reducing the evaporation of water into the air to reduce the insect's water losses during the open phase of the cycle. Alternatively, the pumping action could improve gas exchange between the tracheoles and the tissues that they supply with oxygen.

Turning their attention to the pressure and CO_2 recordings, the team was surprised to see that the locusts were releasing CO_2 during the closed phase, despite the pressure dropping in the trachea. Explaining that no other discontinuously ventilating insects release CO_2 during the closed phase – when they usually consume the oxygen held in the trachea while storing the resulting CO_2 in their body fluids – Terblanche says, 'This suggests considerable complexity; perhaps constriction of spiracles in one part of the body while not in another part of the tracheal system, or possible cuticular CO_2 leakage'.

Having shown that discontinuous ventilation varies widely amongst individual locusts and that they probably use this mode of ventilation to avoid dehydration and supplement gas exchange while at rest, the team is continuing to investigate the evolution and mechanism of this intriguing ventilation pattern.

10.1242/jeb.075234

Groenewald, B., Hetz, S. K., Chown, S. L. and Terblanche, J. S. (2012). Respiratory dynamics of discontinuous gas exchange in the tracheal system of the desert locust, *Schistocerca gregaria*. *J. Exp. Biol.* **215**, 2301-2307.

Kathryn Knight

HOW BUMBLEBEES COPE WITH SHADE AND CHANGE

Guided by scent and vision, foraging bumblebees are on a single-minded mission to collect nectar. However, Sarah Arnold and Lars Chittka from Queen Mary University of London, UK, explain that distinguishing the colours of succulent blooms can be challenging when the transition from broad daylight to leafy shade can dramatically alter a flower's hue. 'Fortunately bees have colour constancy. They can correctly recognise colours even if the illumination changes', explains Arnold, although she adds, 'but there were hints that this wasn't completely perfect and under some lighting conditions they make more mistakes than under others'. Curious to find out how foraging bumblebees cope with shady conditions, the duo decided to test the insect's abilities to distinguish similarly coloured flowers in clear and shady circumstances (p. 2173).

Using a flight arena where they could control the lighting conditions, the duo installed a well-stocked nectar feeder and trained bees that had never seen a flower to visit it. Once they were sure that a bee was a keen forager, they introduced sweet-tasting purple simulated flowers and bitter-flavoured mauve 'flowers' for the bee to explore, hoping that the bees would learn to visit the sweet purple flowers. 'We knew the bees could tell the two colours apart, but it was a reasonably difficult task', says Arnold. Then, after 100 training sessions under simulated daylight, Arnold removed the simulated flowers' flavours, tested how well the bees recognised the purple flowers and was pleased to see that they were able to successfully pick them out 86% of the time. However, when she mimicked the effect of leaf shade – by filtering the daylight through green filters and tracing paper – the bumblebees found the discrimination task much trickier. They took longer to learn to distinguish between the colours and struggled to pick out the purple ones, only successfully identifying them on 75% of their visits. The bees found it more difficult to distinguish colours under leaf shade than daylight.

Next, Arnold tested how the bees behaved when they had a choice of lighting conditions to forage under. Simulating the patchy shade encountered in a wood – by filtering the light illuminating two of the arena's quadrants with the green simulated-leaf filters while leaving the other two quadrants exposed to full light – Arnold monitored the foraging bees' preferences. However, instead of preferring to forage under the daylight quadrants where their colour discrimination was best, the bees' preference was determined by their life experience. If they had previously foraged under daylight, they initially explored the quadrants that were illuminated by daylight, whereas bees that had been pre-trained under simulated leaf shade had no preference, and were equally happy foraging under daylight or shade. Arnold also recalled that when she first introduced bees into the leaf-shaded arena at the start of training, they seemed fazed, while the bees that were introduced to the arena under daylight took to the new setting much better.

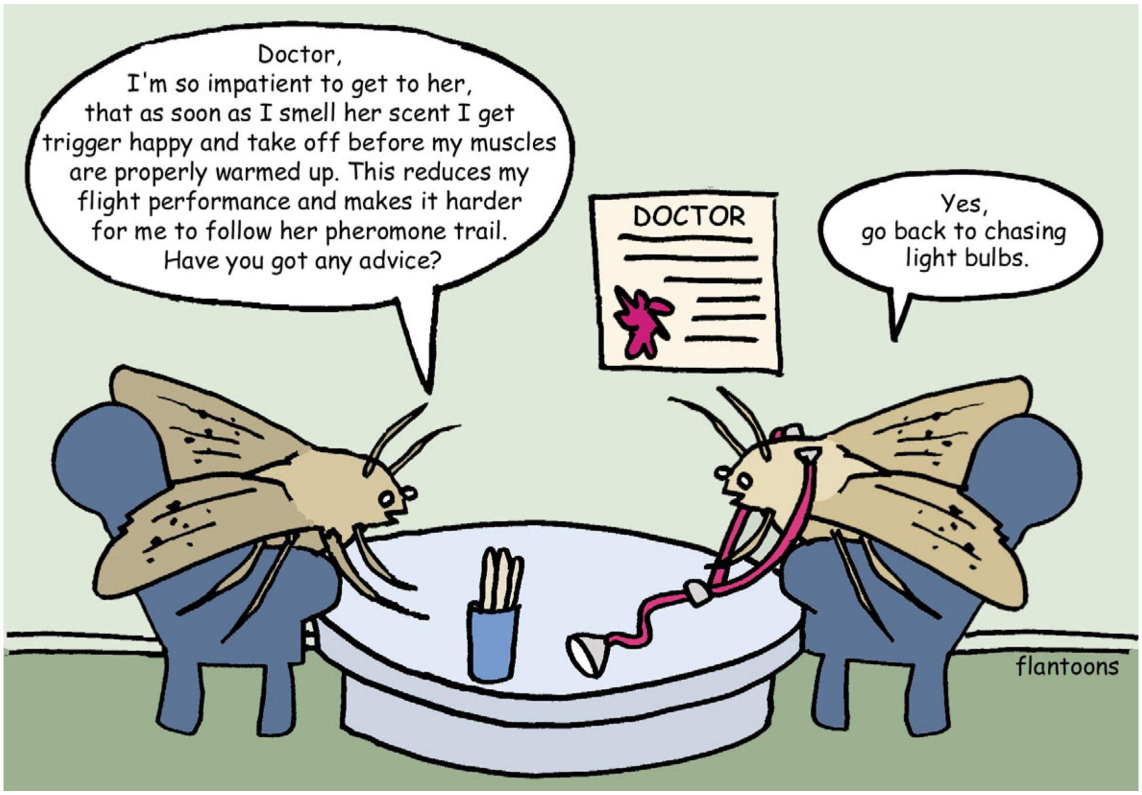
The duo realised that in addition to finding colours more difficult to distinguish under leaf shade, the insects did not like change. However, the novelty-averse bees eventually got over their misgivings and began foraging equally under broad daylight and shade. Arnold also adds that the bees that had previously encountered both daylight and leaf shade were more at ease under patchy lighting, contentedly foraging under both. So, bumblebees don't like change and prefer foraging in light environments with which they are familiar. However, they have the ability to adapt rapidly, allowing them to move on to new environments when flowers no longer provide fertile foraging grounds.

10.1242/jeb.075200

Arnold, S. E. J. and Chittka, L. (2012). Illumination preference, illumination constancy and colour discrimination by bumblebees in an environment with patchy light. *J. Exp. Biol.* **215**, 2173-2180.

Kathryn Knight

MALE MOTHS TRADE-OFF SPEED FOR PERFORMANCE



As soon as moth suitors pick up a whiff of female pheromone, the race is on. Only the fittest and first off the mark will have a chance of winning the girl and passing on his genes to the next generation. But, before keen males can take to the wing, they must warm their flight muscles to a specific temperature by shivering to ensure their optimal flight performance. So, what influence do moth females have on the race to win their favours? José Crespo, Franz Goller and Neil Vickers from the University of Utah, USA, wondered whether the female's potent pheromone cocktail might influence the male's pre-flight warm-up routine (p. 2203).

Placing chilled male moths downwind of an artificial pheromone blend in a wind tunnel, the team measured how long it took for the insects to start shivering, the total amount of time they spent shivering, their thoracic temperature at take off and the rate at which they warmed. Comparing the performances of the pheromone-exposed moths with those of moths that were down wind of other odours (individual pheromone components and other blends), Crespo and his colleagues saw that the pheromone-exposed moths began shivering earlier and took off sooner, even though their thoracic temperature was lower. And, when they measured the maximal vertical force produced by the insects' flight muscles over a range of temperatures (20–48°C), it was clear that the pheromone-stimulated moths' quick get away came at a price. Their muscles produced significantly less force at the lower take off temperature than moths that were slower off the mark and warmed up more, which could significantly compromise their flight performance.

The team says, 'Our results shed light on thermoregulatory behaviour of unrestrained moths associated with the scramble competition for access to females and suggest ecological trade-offs between rapid flight initiation and sub-optimal flight performance'.

10.1242/jeb.075226

Crespo, J. G., Goller, F. and Vickers, N. J. (2012). Pheromone mediated modulation of pre-flight warm-up behavior in male moths. *J. Exp. Biol.* **215**, 2203-2219.

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