© 2017. Published by The Company of Biologists Ltd | Journal of Experimental Biology (2017) 220, 1163-1165

INSIDE JEB

Web stickiness optimised to humidity

An *Araneus marmoreus* female as her retreat is being opened. Photo credit: Brent Opell.

Blundering into a sticky spider's web is unpleasant enough, even when you are large and can tear free. But for smaller creatures, impacting a web is a death sentence. Brent Opell and colleagues from Virginia Tech, USA, explain that the stickiness of a web depends on the stretchiness of the adhesive globules that are dotted along the spiral thread. 'When an insect flies into an orb web, its legs, wings and body present different textures to the web's sticky threads and the insect's struggle to escape generates forces whose magnitude and direction change rapidly', says Opell. Previous lab-based experiments had shown that the stickiness of web glue could be optimised to the humidity of the spider's natural environment, as the stretchiness and adhesion of the droplets changes as the humidity alters. But what could this natural variation mean in practice for snared insects; could variations in local humidity affect the survival chances of a thrashing fly?

Having recorded that the humidity in forests inhabited by marbled orb-weaver spiders (*Araneus marmoreus*) ranged from 67% to 76%, Opell and his colleagues then collected portions from spider webs in the same locations to test the effects of different humidities on the sticky adhesive droplets. Back in the lab, Opell and Mary Hendricks kept the sticky threads at 20–90% humidity and found that the adhesive became stretchier and contacted a larger area on the surface of trapped victims as the humidity increased to 72%, before declining as the air became moister. And when they compared the strength of the adhesive attachment, it was greatest at 72% humidity. The spiders' webs seemed to be optimised to hold fast at the humidity found in their home territory.

But what would this mean in practice for insects fighting to free themselves from peril? Stabilising intact web portions at 37%, 55% and 72% humidity before gently placing an anaesthetised fly across the sticky threads and filming its bid for freedom, undergraduate students Katrina Buccella, Meaghan Godwin and Malik Rivas recorded that all of the flies escaped in periods ranging from 3.3 to 34.7 s. However, the flies that were detained on the web at 72% humidity had the toughest time escaping and were trapped for 11 s more than the flies that encountered the drier webs.

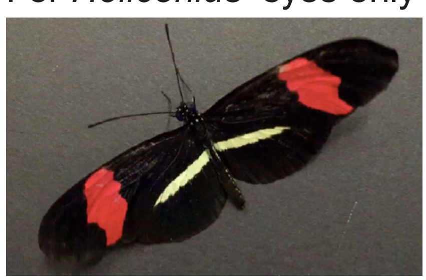
So, humidity clearly affects the length of time it takes for a trapped insect to break free of its bonds and Opell says, 'This difference … is ecologically significant as the short time after an insect strikes a web, and before a spider commences wrapping it, is the insect's only opportunity to escape'. Opell also points out that these observations agree with other studies, which have shown that evolution has fine-tuned the stickiness of spider webs to the humidity of the environment by changing the compounds that attract water to the sticky glue droplets, allowing webs to hold on hardest to hapless victims at the spider's home humidity.

10.1242/jeb.159186

Opell, B. D., Buccella, K. E., Godwin, M. K., Rivas, M. X. and Hendricks, M. L. (2017). Humidity-mediated changes in an orb spider's glycoprotein adhesive impact prey retention time. *J. Exp. Biol.* **220**, 1313-1321.

Kathryn Knight

For *Heliconius*' eyes only



Red postman *Heliconius erato* butterfly in white light. Photo credit: Susan Finkbeiner.

Some colours are the visual equivalent of a scream; from 'Eat me', to 'Don't eat me', to 'Come hither', plants and animals constantly flaunt their talents or warn each other off with pageants of colour. Adriana Briscoe from the University of California, Irvine, USA, explains that other animals sometimes take advantage of the deterrent effect of warning signals and imitate the bright markings to avoid the unwanted attentions of predators. One family that takes advantage of this form of mimicry are the *Eueides* butterflies that mimic the distinctive yellow bars found on the wings of their toxic distant *Heliconius* butterfly relatives. However, when Briscoe analysed the yellow pigment in *Eueides* butterfly wings and other members of the extended family, she found that it was different from the 3-hydroxy-DL-kynurenine (3-OHK) pigment that Keith Brown had found in *Heliconius* wings, even though the warning markings were extraordinarily similar to our eyes. Why had the butterflies adopted different pigments when both produced a bright yellow warning hue?

Knowing that many animals see a broader palette of colours than are visible to us, Briscoe wondered whether the warning bar on the wings of red postman butterflies – *Heliconius erato petiverana*, which are members of the *Heliconius* family – is visible under UV light and was impressed when she discovered that it is. As *Heliconius* butterflies have an additional light receptor that is sensitive to violet shades, she realised that their 3-OHK-pigmented bar would appear completely different from the yellow shade that we see on *Eueides*' wings; 'this "UV-yellow" is a butterfly form of human purple, which is a mixture of red and blue light', explains Briscoe. Could the 3-OHK marking be sending coded messages for the eyes of *Heliconius* butterflies only?

Printing out thousands of paper butterflies with the red postman's distinctive red and black pattern, Susan Finkbeiner added yellow Manila paper covered with a UV filter to produce the correct shade of yellow without the UV component, while

Journal of Experimental Biology

Journal of Experimental Biology (2017) 220, 1163-1165

she reproduced the true red postman yellow shade with synthetic 3-OHK. In addition, some of the models were painted with yellow UV-reflective paint while others were covered with a UV filter. Then, she tested the attractiveness of the paper imposters to red postman butterflies and hungry birds. Analysing the butterflies' responses, Finkbeiner, Briscoe and Daniel Osorio were impressed that the red postman butterflies always preferred the fake butterflies with 3-OHK UV in their yellow bands; and when they monitored the butterflies for longer periods, the insects made amorous advances to the 3-OHK models, while they were not seduced by the plain yellow paint substitutes. However, when Finkbeiner posed all four paper models in the forest to find out whether predatory birds had a preference for one pigment over the other, the birds found all of the models equally delectable. In addition, Briscoe made the exciting discovery that the 3-OHK pigment was fluorescent, producing a faint green glow: 'We thought that the fluorescence might be contributing to the colour signal the butterflies were responding to', says Briscoe. However, when Dmitry Fishman calculated the strength of the fluorescent message, the fluorescence was too faint to be seen when the butterflies are active in daylight.

Briscoe suspects that toxic *Heliconius* butterflies adopted the novel UV-reflective 3-OHK pigment, in preference to the yellow pigment used by *Eueides* and other members of their extended family, to avoid confusion. 'They [*Heliconius*] have two problems to solve: avoiding predators like birds and finding appropriate mates', says Briscoe. She suggests that *Heliconius* butterflies evolved 3-OHK because it resembles the ancestral yellow sufficiently for birds to learn to give butterflies with yellow warning bars a wide berth, while allowing members of the *Heliconius* family to distinguish their own species from distant relatives when seeking a mate.

10.1242/jeb.159178

Finkbeiner, S. D., Fishman, D. A., Osorio, D. and Briscoe, A. D. (2017). Ultraviolet and yellow reflectance but not fluorescence is important for visual discrimination of conspecifics by *Heliconius erato*. *J. Exp. Biol.* **220**, 1267-1276.

Kathryn Knight

Chilly white-browed babblers huddle to avoid torpor

A white-browed babbler, foraging. Photo credit: Tegan Douglas.

Australia is a continent blessed with animals that operate at a slow pace; from koalas that spend up to 20 h a day sleeping, to antechinus marsupials that drop their body temperature and resort to torpor in the aftermath of an inferno, many of the continent's smaller animals have opted for a sedate lifestyle to eke out meagre resources. But how do birds cope when nutritious insect populations dwindle as the temperature falls? Do they resort to torpor to conserve energy or have they evolved alternative survival strategies that help pull them through lean periods? Intrigued by the possibility that birds may allow their body temperature to drop to conserve energy (i.e. become torpid) during winter, Tegan Douglas and Christine Cooper from Curtin University, Australia, and Phil Withers from the University of Western Australia fitted white-browed babblers (*Pomatostomus superciliosus*) with minute temperature loggers to record their body temperature over the course of consecutive winters.

However, after two cold seasons it was clear that the small birds did not resort to lowering their body temperature to conserve energy, maintaining a toasty body temperature around 40.3°C, even when the temperature outside the nest fell below freezing. So, how did the birds maintain their body warmth under the difficult winter conditions?

Measuring the metabolic rate of white-browed babblers in the lab, the trio discovered that it was 64% lower than expected for similarly sized birds (46.5 g) and they also lost water at a slower rate, both characteristics that should make the birds ideal torpor candidates. However, Cooper and her colleagues suspect that the secret behind the birds' high body temperature is their communal lifestyle as they huddle together, which allows them to conserve 35–45% of the energy consumed by individuals. And when the team measured the impact of the birds' almost enclosed stick nests on their metabolic budget, they realised that the structures halved the animals' energy losses.

'These substantial energy savings, together with their [the birds'] intrinsically low BMR would play an important role in babblers balancing their daily energy budget and presumably negate any requirement for torpor in their energetically challenging environment', says Cooper. The trio concludes that many of Australia's small birds may resort to similar strategies to avoid using torpor to keep their energy budgets balanced when food is scarce and conditions are harsh.

10.1242/jeb.159202

Douglas, T. K., Cooper, C. E. and Withers, P. C. (2017). Avian torpor or alternative thermoregulatory strategies for overwintering? *J. Exp. Biol.* **220**, 1341-1349.

Kathryn Knight

Journal of Experimental Biology (2017) 220, 1163-1165

Stay-at-home zebra finches use magnetic compasses too

No self-respecting 15th or 16th century explorer would leave home without one: magnetic compasses guided the great explorers as they voyaged into uncharted territory, and migrating birds are no different. Guided by two internal magnetic compasses – one that measures the angle of the magnetic field at the Earth's surface and a second which provides positional information – migrating species embark on voyages that can cover thousands of kilometres. But many less-adventurous species, such as chickens and zebra finches, are also equipped with a magnetic sense, which can help them to locate objects in their environment. Atticus Pinzon-Rodriguez and Rachel Muheim from Lund University, Sweden, were curious to understand more about the zebra finches' sense of direction. Knowing that cryptochrome molecules in the retinas of magnetosensitive creatures are sensitive to specific wavelengths of light and are believed to produce a visual representation of the magnetic field, the duo tested the birds' ability to locate a millet seed reward in a maze under different coloured light at high and low intensity as as the surrounding magnetic field was altered to find out whether cryptochromes also contribute to a zebra finch's sense of direction.

Recording the birds' ability to return to the position of a pile of seed in a cross-shaped maze when the magnetic field had been aligned along one arm of the maze under green light (521 nm), the team was pleased to see that the finches successfully negotiated the maze. And when the duo retested the zebra finches in electromagnetic radio-wave smog – which is known to jam cryptochromes – the birds' compass sense failed and they searched the maze randomly. The birds were clearly using cryptochromes to detect magnetic fields.

However, when they tested the birds' navigational skills under blue light (461 nm), the birds were completely disorientated. Explaining that the magnetic compasses of many migratory species function perfectly in this shade of blue, Pinzon-Rodriguez and Muheim suggest that the difference could stem from the animals' lifestyles. Many animals migrate at night by blue star light while zebra finches are active during the day, when other light wavelengths could disrupt the cryptochrome mechanism that guides nocturnal species. So, long-range migrants and stay-at-home species all seem to use light-dependent magnetic compasses, whether they are circumnavigating the Earth or hopping about in search of seeds.

10.1242/jeb.159152

Pinzon-Rodriguez, A. and Muheim, R. (2017). Zebra finches have a light-dependent magnetic compass similar to migratory birds. *J. Exp. Biol.* **220**, 1202-1209.

Kathryn Knight
kathryn.knight@biologists.com