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INSIDE JEB

Ground spiders overwhelm victims with supersticky silk

A ground spider subduing a larger wolf spider. Photo credit: Arno Grabolle.

Most spiders are content to sit and wait for unsuspecting victims to blunder into their silken traps, but webs are only ever as good as the structures that secure them to the surfaces that support them. 'This [attachment] is done with a special type of silk, called piriform', says Jonas Wolff, from Macquarie University, Australia, adding that most spiders only produce this silk when they need to securely anchor a structural thread. However, when Wolff and Milan Řezáč, from the Czech University of Life Sciences, realised that the piriform silk-producing glands of ground spiders (Gnaphosidae) were different from those of other species – they had fewer and the glands were significantly larger than those of web-spinning spiders – the colleagues were intrigued. 'Why should a lineage of spider deviate from a pattern that is so widespread and hence a long-term success story?', wondered Wolff. That, coupled with the ground spiders' novel hunting strategy – they actively ambush prey, snaring them with piriform silk, and even pick fights with insects and arachnids that are larger than themselves – led Wolff, Řezáč and Stanislav Gorb, from the University of Kiel, Germany, to find out more about the ground spider's extraordinary silk and the glands that produce it.

However, ground spiders are not very common in northern Germany. It was only while collecting animals in the Southern Alps that Wolff stumbled across *Drassodex heeri* concealed beneath stones. Returning to Kiel, Wolff pitted the predators against giant house spiders (*Eratigena atrica*), lace webbed spiders (*Amaurobius fenestralis*) and silver-sided sector spiders (*Zygiella x-notata*) while filming the encounters from beneath. 'The attacks can be very quick; it can be hard to distinguish what is going on', says Wolff, who slowed the movies down to see *Drassodex* attach silk to the floor of the enclosure before running quickly around its prey, producing a trail of sticky thread that dried quickly, ensnaring the victim's legs until it was neatly trussed up.

But how did the *Drassodex* piriform silk differ from the silk produced by web spinners? This time, Wolff staged the spider ambushes on a sheet of plastic from which he could cautiously collect the silk. Although isolating individual strands was extremely difficult, Wolff eventually collected 17 straight specimens and measured the silk's strength. Comparing the piriform silk with other silks produced by web-spinning spiders, he realised that *Drassodex* piriform silk combines the toughness of dragline silk with the remarkable stretchiness of spiral capture threads from webs. Also, the glue coating the thread is extraordinarily deformable and tough, withstanding shear stresses that are more than 750 times the stresses that artificial glues can endure.

After the silk's material properties had been defined, Tomáš Krejči and Řezáč investigated the silk-producing glands and saw that the spigots through which piriform silk is expelled are much larger than those of other species; probably to eject a thick layer of glue at high speed in order to overwhelm victims that may lash out and injure them. The team also realised that the enlarged spigots might become clogged by dried silk components, until they noticed that the spinnerets have a unique anti-clogging mechanism. They remain closed until just before they deploy the silk, when the fluid pressure in the arachnid's body rises and the spigot pops open.

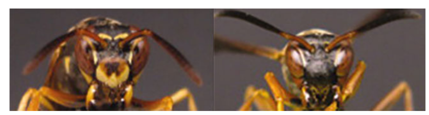
Wolff adds that *Drassodex* spiders are unable to spin the densely packed piriform silk disks used by web-spinning spiders to anchor their webs because of their enlarged piriform silk glands, so they are unable to anchor structural threads. 'This is a textbook example of a trade-off, where a highly efficient prey capture mechanism has evolved at the cost of reduced thread attachment, which is a basic function in all spiders', he concludes.

10.1242/jeb.163493

Wolff, J. O., Řezáč, M., Krejčí, T. and Gorb, S. N. (2017). Hunting with sticky tape: functional shift in silk glands of araneophagous ground spiders (Gnaphosidae). *J. Exp. Biol.* **220**, 2250-2259.

Kathryn Knight

Paper wasps really recognise each other's faces



The face of each *Polistes fuscatus* paper wasp is unique. Photo credit: Elizabeth Tibbetts.

Sculpting delicate nests from chewed-up wood pulp, *Polistes fuscatus* paper wasps are master architects. But the social insects have another skill that makes them appear even more similar to humans: they are capable of face recognition. In fact, the females that found new colonies learn to recognise their nestmates' faces faster than they learn to distinguish other visual patterns. 'Very few animals are known to have the special ability to recognize each other's faces', says Ali Berens, from the Georgia Institute of Technology, USA, adding that the skill 'likely evolved to reduce costly competitive interactions among nest-founding queens'. However, other paper wasp species, such as *Polistes metricus*, are less choosey and never learn to recognise each other visually; they simply learn to recognise patterns. Realising that the difference in the wasps' facial recognition abilities presented the ideal opportunity to begin dissecting the essential components of wasp face recognition, Berens and her colleagues Elizabeth Tibbetts, from the University of Michigan, and Amy Toth, from Iowa State University, USA, decided to

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discover which genes are essential for wasp face recognition.

Tibbetts and members of her lab collected females of both species from under the eaves of local buildings as the insects founded new colonies and began constructing nests in spring. Back in the lab, they patiently trained some of the insects to recognise simple black-and-white patterns, while others had to learn to identify *P. fuscatus* faces from their distinctive coloured markings. Once the wasps had completed their training and their memories were secure, Tibbetts froze them and shipped the insects to Berens and Toth in Iowa, where the duo analysed the wasps' brain gene expression patterns.

Comparing the gene expression patterns in the brains of the *P. fuscatus* wasps that had learned to recognise simple shapes with those of *P. fuscatus* that had learned to recognise faces, the team was impressed to find differences in 257 genes, including genes that are involved in neuron signalling – such as the serotonin receptor and tachykinin. However, when Berens searched the *P. metricus* gene expression patterns for evidence of the 257 *P. fuscatus* face recognition genes, none cropped up. 'This suggests […] that there is something special about face learning – that it is not just hyper-developed visual learning, but a highly specialized learning response', says Berens.

Having identified the genes that lie at the heart of *P. fuscatus*'s ability to recognise individuals, Toth is now keen to learn more about how these genes function in facial recognition. 'We want to experimentally manipulate some of the genes that we uncovered in this study and then see whether we can make wasps forget each other or, conversely, enhance their memories of one another', says Toth. However, it is less clear how much we will be able to learn from wasps about our own remarkable ability to distinguish between faces. 'As wasp facial recognition evolved independently from human facial recognition, the same genes will not necessarily underpin this behavioural phenotype. However, it is not out of the realm of possibility that some of the genes might be shared', Berens concludes.

10.1242/jeb.163477

Berens, A. J., Tibbetts, E. A. and Toth, A. L. (2017). Cognitive specialization for learning faces is associated with shifts in the brain transcriptome of a social wasp. *J. Exp. Biol.* **220**, 2149-2153.

Kathryn Knight

Jack Chinook's sperm beat hooknose's to the ultimate reward

A Chinook salmon. Photo credit: Vojtěch Kašpar.

Life is beset with competition, from the sprint for victory to a tasty morsel to stylish preening to attract mates, but one of the most fundamental contests must occur in the microscopic realm where fish sperm battle to penetrate an egg first. 'Males often exhibit different tactics to increase their reproductive success', says Ian Butts, from Auburn University, USA. Some male fish pass themselves off as females to outsmart rivals guarding harems, while others try sneaking behind opponents' backs. Small Chinook salmon males – known as 'jacks', which return to the river of their birth a year or two before older and more aggressive hooknose males – invest more energy in their sperm and gonads in a bid to outcompete their larger counterparts. Might the young males' increased investment also be reflected in their sperm's athleticism? In addition, ovarian fluid released when female Chinook salmon expel their eggs alters the viscosity, pH and salt concentration of the water into which the males' sperm is released. Working together as part of Trevor Pitcher's long-term study of Chinook spawning based at the University of Windsor, Canada, Butts, Galina Prokopchuk and Vojtěch Kašpar caught male and female fish from the Credit River in Canada to compare the performance of jack and hooknose male sperm in water and dilute ovarian fluid.

Analysing the tail beat patterns and calculating the speed at which the sperm could swim, their efficiency and the power required to propel the sperm through the water, it was clear that the jack sperm outperformed the sperm of the more robust older fish. The length of the wriggling wave that passes along each beating sperm tail was longer in the jack sperm than the hooknose, and Jacky Cosson calculated that the jack sperm beat their tails faster to propel them through the water at 161 $\mu m\ s^{-1}$, while the hooknose sperm only reached 155 $\mu m\ s^{-1}$. In addition, the jack sperm swam more efficiently in dilute ovarian fluid, with the hooknose sperm using 45% more energy. It was also apparent that the fluid released with the females' eggs impacted the performance of both males' sperm, slowing the beat of the sperm's tail while increasing the sweep from side to side. 'Each female creates a unique spawning environment by simultaneously expelling ovarian fluid along with an egg batch', says Butts.

So although it might look at first glance as if the reproductive odds are stacked against smaller younger jack salmon males, they have a stealthy card up their sleeves in the form of their super-competitive sperm, which outperform the sperm of apparently more superior hooknose males. The team also suggests that 'sperm biomechanics may be driving divergence in competitive reproductive success between alternative reproductive tactics'.

10.1242/jeb.163485

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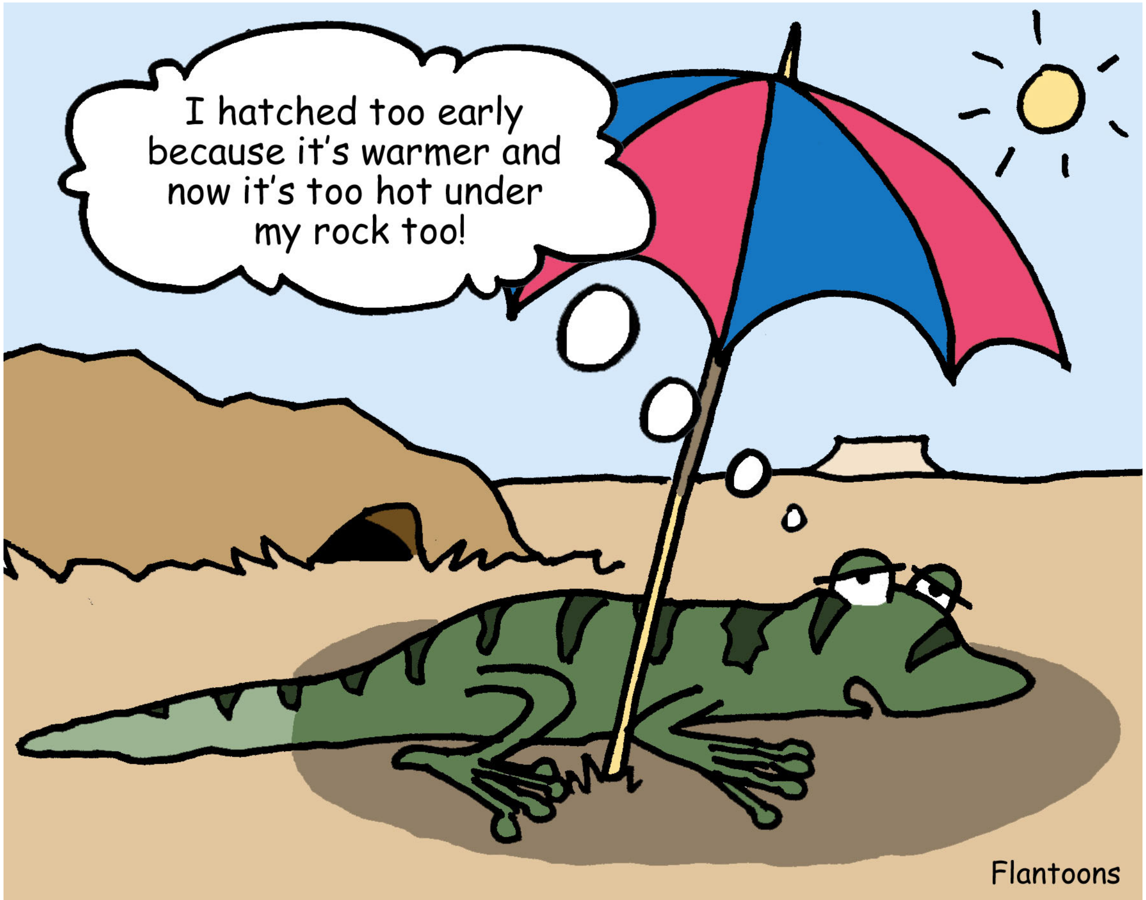
Gecko youngsters more at risk after incubating during a heat wave



The blood of ectothermic animals is far from cold, despite their common name. Fine-tuning their body temperature in shady nooks when overheated and basking in the sun when chilly, ectotherms successfully maintain their optimal body temperature range. But the future may not be so sunny for ectotherms as environmental temperatures continue rising. 'Heat waves have become more common in recent decades and are predicted to increase in frequency in the future', says Jonathan Webb, from the University of Technology, Sydney, Australia. While Webb suggests that adult reptiles will be able to weather whatever the climate can throw at them, he is more concerned for embryos and young hatchlings. 'Developing lizard embryos cannot thermoregulate and may experience thermally stressful temperatures in natural nests during summer', he suggests. Knowing that flies that develop in high temperatures seem to cope better in extreme conditions, Webb and his colleagues, Buddhi Dayananda and Brad Murray, incubated the eggs of tiny velvet geckos (*Amalosia lesueurii*) at high (14–37°C) and moderate (10–33°C) temperatures to find out how heat waves might affect the developing geckos.

Not surprisingly, the eggs that had been incubated at higher temperatures hatched first – 27 days earlier – but their head start didn't give them an advantage when the temperature fluctuated. The trio tested the youngsters' ability to right themselves after being warmed or cooled and then gently turned on their backs, and realised that the geckos that had been incubated in hot nests were more impaired at extreme temperatures than the geckos that had been incubated at lower temperatures. The hot-incubated geckos became incapacitated at temperatures below 6.2°C and above 38.7°C, while the animals that had been incubated at lower temperatures were more robust, only failing to right themselves below 5.7°C and above 40.2°C. And when the team measured the temperatures under the rocks that the youngsters prefer to use for shelter, they could reach a sizzling, and potentially fatal, 50°C. However, crevices in which the hatchlings shelter only reached 33°C.

Webb points out that this will pose a problem for hatchlings that emerge early: 'Shuttling between rocks and shady crevices may expose them to predators, compromising their survival', he says. So gecko embryos that were incubated during a heat wave are less well prepared for scorching temperatures and will likely be more vulnerable to predation.

10.1242/jeb.163469

Dayananda, B., Murray, B. R. and Webb, J. K. (2017). Hotter nests produce hatchling lizards with lower thermal tolerance. *J. Exp. Biol.* **220**, 2159-2165.

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