Inside JEB is a twice monthly feature, which highlights the key developments in the *Journal of Experimental Biology*. Written by science journalists, the short reports give the inside view of the science in JEB.

HANGING ON BY A THREAD


Picture by Brent Opell

Some 225 million years ago, the first spider webs appeared on the scene. The cribellar threads that primitive spiders use to spin their webs are composed of looped fibrils tangled into a mass 'a bit like 3D Velcro' explains Brent Opell, an evolutionary biologist at Virginia Polytechnic Institute and State University. Modern orb-weaving spiders improved on the design of fuzzy cribellar threads; orb-weavers make viscous capture threads by coating their threads with a chemical 'glue', which coalesces into regularly spaced droplets along the thread. Relative to the amount of material invested, viscous threads are 13 times stickier than cribellar threads. Intrigued by the properties that make viscous threads superior to cribellar threads, Opell decided to investigate viscous thread stickiness (p. 553).

Opell explains that when a load (like a juicy insect) hangs from a cribellar thread, most of the force applied to the thread is perpendicular to the load. This means that little of the force is directed inwards along the thread in a way that would allow the middle part of the thread touching the insect to contribute to adhesion. Perhaps a potential advantage of viscous thread, Opell reasoned, is that it enhances the stickiness of the entire length of thread in contact with a load by directing the force inwards along the thread, enabling droplets nearer the centre of the strand to contribute their stickiness. 'We imagined each droplet acting like a cable on a suspension bridge, distributing the force,' Opell says. If this suspension bridge theory is correct, a thread's stickiness should increase as the number of droplets contacting a load increases.

To test this, Opell and Mary Lee Hendricks measured the stickiness of viscous threads touching contact plates ranging from 963 to 2133 μm in width. Having collected some spiders' webs, they pressed the threads against a contact plate that transferred force to a load cell, then pulled the thread back. To measure the thread's stickiness, they recorded the maximum force registered by the load cell before the thread pulled free of the contact plate. Using four different widths of contact plate, Opell and Hendricks showed that a viscous thread's stickiness increases with increasing plate width, since more droplets contacted the wider plates. This was just as they expected to see if a suspension bridge mechanism was operating. But something odd was happening: the droplets were not acting like a perfect suspension bridge. When Opell and Hendricks plotted the increase in the number of droplets contacting a plate against the change in stickiness per droplet, they saw a decrease in the average adhesion per droplet. In a perfect suspension bridge, each droplet should be equally sticky. The fact that average adhesion per droplet decreases suggests that the droplets at either end of a thread contacting a load contribute the most adhesion, while droplets towards the middle of the thread contribute progressively less.

To investigate the limitations of the suspension bridge mechanism, Opell and Hendricks developed a model of the mechanism. They showed that only about six droplets at either end of a contacting thread contribute to thread stickiness, suggesting that there is an upper limit beyond which a longer contact surface does not increase a thread's stickiness. 'This may have consequences for web architecture,' Opell says, as spiders may have to place their threads closer together to compensate for this limitation.

10.1242/jeb.02720

Opell, B. D. and Hendricks, M. L. (2007). Adhesive recruitment by the viscous capture threads of araneoid orb-weaving spiders. *J. Exp. Biol.* **210**, 553-560.

Yfke Hager

HOW MITES COPE WITH LIFE IN THE FREEZER

While a cold and exposed rock face in Antarctica is the last place many animals would choose to live, Antarctic lichen mites, *Halozetes belgicae*, are quite at home. They are often found near gull 'rubbish dumps', or middens, grazing on the lichens encrusting the rocks. How the mites survive this harsh environment interests Tim Hawes and his colleagues at the University of Birmingham and the British Antarctic Survey. They tested their idea that the mites' extreme environment – low temperatures and extreme variation in temperature – makes them very responsive, or 'plastic', when it comes to acclimating to new temperatures (p. 593).

To survive in Antarctica's cold conditions, arthropods like the lichen mite must adapt to colder temperatures, especially when the mercury drops well below freezing. To do this, they empty their guts, concentrate their body fluids and accumulate small molecule anti-freezes in their tissues so that the liquid in their bodies cools down to below water's freezing point, but without forming ice crystals which wreak havoc in delicate tissues.

To find out how mites acclimated at different temperatures would cope in the cold, the team exposed animals to temperatures of 5°C or 10°C for one week. They measured their cold hardiness by determining their supercooling point, which is the temperature where ice crystals start to form in body fluids. They found that the supercooling points were lower for mites acclimated at 5°C than mites who had spent a week at 10°C, showing that acclimation at colder temperatures makes mites more cold hardy.

Having shown that the mites could adapt to changes in temperature over the course of a week, the team tested how the mites responded to temperature changes over the course of a month. They put groups of mites feeding on rocks in containers and then measured how their cold hardiness changed as the temperature changed outside. They found that over a month, cold hardiness improved as the temperature dropped, showing that the mites could adjust to colder temperatures over longer timescales too. Knowing that starvation can affect cold hardiness, they found that starving the animals acclimated at 10°C and 5°C made them more cold hardy, probably because starved mites have no material in their guts to provide sites for the formation of damaging ice crystals.

Then to find out how the animals would cope when they rapidly dropped the temperatures, they looked at their rapid cold hardening response, where animals become more cold hardy if they have been exposed to a brief cold snap beforehand. Dropping the temperature to 0°C, –5°C or –10°C didn't increase the cold hardiness of 5°C acclimated mites, because they already had low supercooling points; however, when they repeated the experiment on mites acclimated to 10°C, cold hardiness improved after 2 h at their new temperatures; the supercooling point became up to 15°C colder. This is the fastest rapid cold hardening response seen in any animal, showing that the mites are not just plastic but 'superplastic' when it comes to acclimating to the cold. Not only that, but they didn't lose this hardiness once they were returned to their acclimation temperature.

But what is causing the mites to cope so well in the cold? Analysing the mites' gut contents, they found that acclimated mites did indeed have emptier guts than those who weren't acclimated. This means that they can supercool without ice forming in their guts, and have a fighting chance of survival in their extreme environment.

10.1242/jeb.02721

Hawes, T. C., Bale, J. S., Worland, M. R. and Convey, P. (2007). Plasticity and superplasticity in the acclimation potential of the Antarctic mite *Halozetes belgicae* (Michael). *J. Exp. Biol.* **210**, 593-601.

HARD DIETS BUILD BONE

Photo by Matthew Ravosa

According to evolutionary morphologist Matthew Ravosa, you can learn a lot about an animal by looking at how it chews. Fascinated by the evolution of the feeding apparatus in primates and other mammals, Ravosa wanted to know more about how diet affects jaw joints, because this might help him understand the structure of ancient fossil jaws. To probe further, Ravosa teamed up with colleague Sharon Stack at the University of Missouri School of Medicine to investigate how rabbit jaw joints adapt to soft and hard diets (p. 628).

The team already knew that rabbits fed the equivalent of jaw-breaking sticky toffee for a few weeks developed stronger and denser jaw bones to support the harder-working muscles. But no-one had looked at longer term changes before, and these might not necessarily be the same as short-term changes because animals' responses to their environment changes as they age. To examine longer term changes in bones and cartilage, the team fed one month old weanling rabbits on mushy powdered rabbit pellets, or on tough hay and whole pellets. After the rabbits had munched their way through their specialised diets for four months, the team measured the bone dimensions in two joints vital for chewing: the temporomandibular joint (TMJ), which is a hinge joint connecting the lower jaw to the main portion of the skull; and the symphysis, which is the joint between the two lower jaw bones, situated at the 'chin'. This joint is fused in humans and higher primates, but unfused in lower primates.

Taking into account each animal's size, they measured the bones' external dimensions and found that the rabbits on the harder diet had 10% thicker bones than their peers on the soft diet. Soft-diet rabbits don't use their muscles much; 'it's the equivalent of sitting on the couch all day', says Ravosa, so their bones aren't as thick. Aided by engineer Stuart Stock, the team used micro CT scans to peer inside each bone, finding that the bones from hard-diet rabbits were thicker than they were expecting on the inside: by up to 20%. Micro CT also told the team how biomineralised, and therefore how dense, each bone was: hard-diet rabbits had stronger and denser bones because when the TMJ and symphysis joints are overworked, the bone bulks up to compensate.

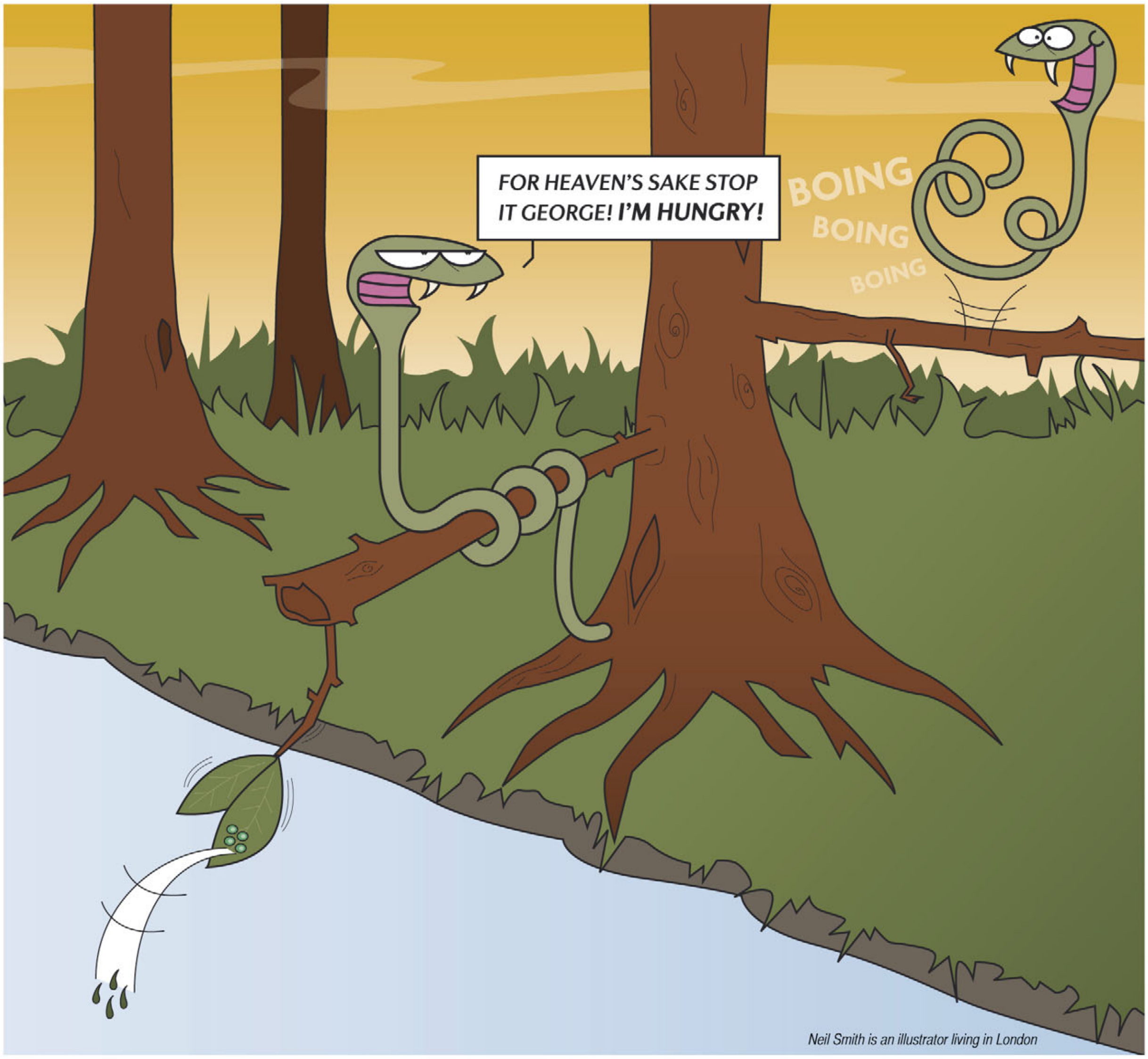
Next, the team compared how the cartilage fared on the two diets. Cell biotechnician Ravinder Kunwar measured the amount of type 2 collagen and molecules called proteoglycans in the cartilage. These give cartilage its rubbery quality and strength, helping it resist compression. Expecting to find over-expression of these two proteins in the cartilage of hard-diet rabbits, which would help the joints cope with their extra strain, the team actually found that there was less of these proteins in the cartilage, and more cell death at the end of the bone. Wear and tear had taken its toll; 'they looked like joints in older animals' says Ravosa. However, 'some aspects of the bony morphology could compensate for the cartilage' he adds. In the older animals, the symphysis was beginning to fuse, which hadn't been seen before. This would stiffen the joint and overcome some of the effects of damaged cartilage.

Next Ravosa wants to understand how the jaw joints adapt in even older rabbits, to see if the symphysis fuses further. The results 'could help explain the evolution of increased symphysis fusion in primates' he explains, 'it could have been due to diet'.

10.1242/jeb.02722

Ravosa, M. J., Kunwar, R., Stock, S. R. and Stack, M. S. (2007). Pushing the limit: masticatory stress and adaptive plasticity in mammalian craniomandibular joints. *J. Exp. Biol.* **210**, 628-641.

DECISIONS, DECISIONS



Neil Smith is an illustrator living in London

Deep in the Panamanian jungle, red-eyed treefrogs lay their eggs on leaves above water. These eggs are a tasty snack for snakes, but the developing embryos have a trick up their sleeve to avoid being eaten. When they feel the tell-tale vibrations of a snake attack, they hatch prematurely and drop into the water below. But this strategy can be risky: if embryos hatch too early, they might escape from the snake's jaws, but they are at greater risk of being munched by predators in the water below. Embryos decide when to hatch by sampling information about vibrations, using their duration and the gaps between vibrations to help them make potentially life-saving decisions. If they don't wait long enough, though, they might not gather enough information to make an informed decision; if they wait too long, however, they are more likely to become a snake's snack.

Interested to know what strategy the frog embryos use to make hatching decisions, Karen Warkentin and colleagues at Boston University and the Smithsonian Research Institution, Panama, vibrated clutches of eggs in patterns which they knew induced similar amounts of hatching (p. 614). They varied vibration cycle length – vibration duration and the gaps between vibrations – and found that embryos hatched sooner when there were more cycles of vibration in a shorter space of time, but if the vibration cycles were longer, they didn't sample as many cycles before hatching. This shows that the embryos are balancing a trade-off between how valuable information is to them, and how risky it is to obtain that information: they don't hang around too long and risk being eaten, even if they haven't sampled as much information.

10.1242/jeb.02723

Warkentin, K. M., Caldwell, M. S., Siok, T. D., D'Amato, A. T. and McDaniel, J. G. (2007). Flexible information sampling in vibrational assessment of predation risk by red-eyed treefrog embryos. *J. Exp. Biol.* **210**, 614-619.

Laura Blackburn
laura@biologists.com