Inside JEB 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.

Inside JEB

TARANTULAS SHOOT SILK FROM FEET

Climbing is possibly one of the riskiest things an adult tarantula can do. Weighing in at anything up to 50 g, the dry attachment systems that keep daintier spiders firmly anchored are on the verge of failure in these colossal arachnids. 'The animals are very delicate. They wouldn't survive a fall from any height,' explains Claire Rind from the University of Newcastle, UK. In 2006, Stanislav Gorb and his colleagues published a paper in *Nature* suggesting that tarantulas may save themselves from falling by releasing silk threads from their feet. However, this was quickly refuted by another group that could find no evidence of the silk. Fascinated by spiders and intrigued by the scientific controversy, Rind decided this was too good a challenge to pass up: she had to find out whether tarantulas shoot silk from their feet (p. 1874).

Teaming up with undergraduate Luke Birkett, Rind tested how well three ground-dwelling Chilean rose tarantulas kept their footing on a vertical surface. Gently placing one of the animals in a very clean aquarium with microscope slides on the floor, the duo cautiously upended the aquarium to see if the tarantula could hang on. 'Given that people said tarantulas couldn't stay on a vertical surface, we didn't want to find that they were right,' remembers Rind. But the spider didn't fall, so the duo gave the aquarium a gentle shake. The tarantula slipped slightly, but soon regained its footing. So the spider had held on against the odds, but would Rind find silk on the microscope slides?

Looking at the glass by eye, Rind couldn't see anything, but when she and Birkett looked closely under a microscope, they found microscopic threads of silk attached to the microscope slide where the spider had stood before slipping.

Next, Rind had to prove that the silk had come from the spiders' feet and not their web-spinning spinnerets. Filming the Chilean rose tarantulas as they were rotated vertically, Rind, Benjamin-James Duncan and Alexander Ranken disregarded any tests where other parts of the spiders' bodies contacted the glass and confirmed that the feet were the source of the silk. Also, the arachnids only produced their safety threads when they slipped.

But where on the spiders' feet was the silk coming from? Having collected all of the moulted exoskeletons from her Mexican flame knee tarantula, Fluffy, when she was young, Rind looked at them with a microscope and could see minute threads of silk protruding from microscopic hairs on Fluffy's feet. Next, the team took a closer look at moults from Fluffy, the Chilean rose tarantulas and Indian ornamental tarantulas with scanning electron microscopy and saw minute reinforced silk-producing spigots, which extended beyond the microscopic attachment hairs on the spiders' feet, widely distributed across the foot's surface. Rind also looked at the tarantula family tree, and found that all three species were only distantly related, so probably all tarantula feet produce the life-saving silk threads.

Finally, having noticed the distribution of the spigots, Rind realised that tarantulas could be the missing link between the first silk-producing spiders and modern web spinners. She explains that the spread of spigots on the tarantula's foot resembled the distribution of the silk spigots on the abdomen of the first silk spinner, the extinct *Attercopus* spider from 386 million years ago. The modern tarantula's spigots also looked more similar to mechanosensory hairs that are distributed over the spider's entire body, possibly making them an evolutionary intermediate in the development of silk spinning. So, not only has Fluffy settled a heated scientific debate but she also may be a link to the silk spinners of the past.

10.1242/jeb.059402

Rind, F. C., Birkett, C. L., Duncan, B.-J. A. and Ranken, A. J. (2011). Tarantulas cling to smooth vertical surfaces by secreting silk from their feet. *J. Exp. Biol.* **214**, 1874-1879.

Kathryn Knight

MUSCLE TRIGGERS AEROBIC DIVE LIMIT

Breathing heavily at the edge of an ice hole, an Antarctic emperor penguin prepares to dive. Taking a last gulp of air, the bird descends and may not emerge again for another 20 min. The penguin initially carries sufficient oxygen in three stores – the blood, lungs and myoglobin in muscle – to sustain aerobic metabolism. However, around 5.6 min after leaving the surface, lactate begins appearing in the penguin's blood and the bird crosses the so-


Cassondra Williams

called ‘aerobic dive limit’, switching to anaerobic metabolism in some tissues. So what triggers this transition?

Cassondra Williams from the Scripps Institution of Oceanography explains that the animals were thought to cross the aerobic dive limit when one of their three oxygen stores became exhausted. However, when Paul Ponganis measured oxygen levels in the blood and lungs of penguins after long dives, the animals had oxygen to spare. That only left the muscle as the potential trigger. Williams explains that diving animals were thought to isolate their muscle from the circulatory system, leaving oxygen stored in the tissue as its only source of aerobic metabolism while submerged and forcing it to switch to anaerobic respiration once the supply was exhausted. So, she and Ponganis teamed up with Jessica Meir to travel to Antarctica to measure muscle oxygen levels in diving emperor penguin muscles to find out whether depleted muscle oxygen supplies trigger the aerobic dive limit (p. 1802).

However, before their departure, Williams had to design a near-infrared spectrophotometer to record the penguins’ muscle oxygen stores as they dived in the wild. After two trying years of technical development and testing, Williams was able to travel south with her colleagues to surgically implant the spectrophotometers in the pectoralis muscles of emperor penguins. They also attached time–depth recorders to the animals’ backs to track their dive profiles. Finally, the team ensured that the animals would return with their precious equipment by drilling an isolated hole in the sea ice – to which the penguins were guaranteed to return – before releasing 16 of the implanted animals to go foraging for a day or two.

After successfully retrieving all of the spectrophotometers and dive recorders and returning the penguins to their colony, Williams began analysing the data and found that the penguins had been actively foraging beneath the ice. Of the 50 dives that Williams successfully recorded, 31 exceeded the emperor penguin’s calculated dive limit.

Next, Williams plotted the muscle oxygen profiles over the course of each dive and identified two distinct patterns. In the first, the oxygen levels fell continually, approaching zero around the point when the birds crossed the aerobic dive limit. Williams says, ‘This profile certainly supports the hypothesis that muscle oxygen depletion is the trigger of the aerobic dive limit.’ However, when the team saw the second plot, they were surprised that, after initially falling, the oxygen levels plateaued for several minutes before falling again to almost zero. They realised that blood must be flowing into the muscle to replenish the oxygen supply during the middle phase of the dive, delaying the onset of the aerobic dive limit.

Finally, having confirmed that the dive muscles are the source of the aerobic dive limit, Williams calculated the muscle oxygen consumption rate for dives with the first oxygen depletion pattern and was amazed to see that it was only $12.4\,ml\,O_2\,kg^{-1}\,muscle\,min^{-1}$: 1/10th the value calculated for penguins swimming in an artificial flume and only 2–3 times their resting metabolic rate. ‘I think this metabolic rate is impressive. You can see how hard they are working underwater but they are efficient swimmers and very hydrodynamic,’ says Williams.

10.1242/jeb.059428

Williams, C. L., Meir, J. U. and Ponganis, P. J. (2011). What triggers the aerobic dive limit? Patterns of muscle oxygen depletion during dives of emperor penguins. *J. Exp. Biol.* **214**, 1802-1812.

Kathryn Knight

SEALS SENSE DIFFERENT SHAPES THROUGH WAKES

Hunting in the North Sea, harbour seals often encounter murky water that impedes their vision; but it doesn’t affect their ability to chase prey. Extending their vibration-sensitive whiskers, the mammals are almost as efficient at pursuing their quarry as they would be if guided by sight. Wolf Hanke and his colleagues from the University of Rostock, Germany, are fascinated by how harbour seals perceive the world through their flow-sensitive vibrissae. Having already found that seals can pick up and follow fish wakes up to 35 s after the prey has passed and knowing that a fish’s size and shape can dramatically affect its wake structure, graduate student Sven Wieskotten decided to find out how well seals can distinguish between the wakes of objects with different shapes and sizes (p. 1922).

Teaming up with Henry the harbour seal at the Marine Science Centre, Germany, Hanke, Wieskotten and their colleagues, Lars Miersch and Guido Dehnhardt, began testing Henry’s ability to distinguish between the wakes of differently sized paddles. The researchers blindfolded Henry and covered his ears, then they swept a paddle through a large box in Henry’s enclosure and allowed him to enter it 3 s later. Having trained Henry to press a target outside the enclosure when he recognised the wake of a standard paddle and to press a different target when he recognised the wake from a larger or smaller paddle, the team found that Henry could distinguish between paddles that differed by as little as 2.8 cm in width.

Then, the team tested which aspects of the wake the seal picked up on. ‘We randomised the speeds of the paddles so that the maximum flow velocity wasn’t a distinguishing cue for the widest paddles, but the structure of the wake had to be recognised by the seal and he could do that too, but with slightly less accuracy,’ remembers Hanke.

Next, the team varied the paddle shapes and asked Henry to distinguish between the wakes of triangular, cylindrical, flat and undulating paddles. The seal successfully distinguished between the flat and cylindrical paddles, the flat and undulating paddles and the undulating and cylindrical paddles after they were swept through the enclosure. However, he had problems distinguishing the triangular paddle from the undulating or cylindrical shapes.

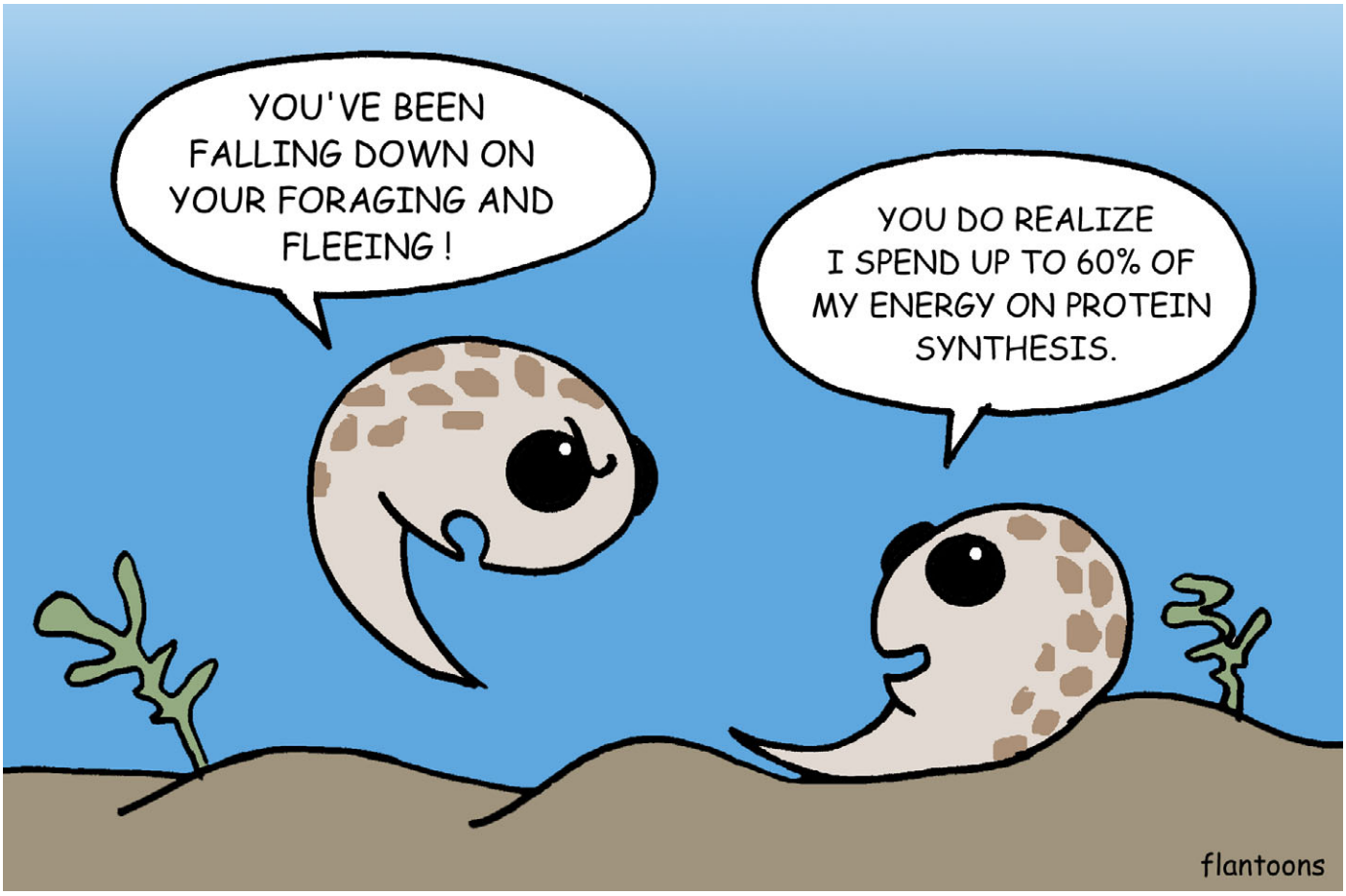
Having found that Henry can distinguish between the wakes of different passing objects and investigated the structure of each paddle’s wake with digital particle image velocimetry, Hanke says, ‘It is difficult to tell which part of the wake serves the animal most and which aided only a little.’ So, Hanke is keen to test Henry’s responses to single vortices to find out which wake components might give a fish’s size and shape away. He explains that hunting seals have to optimise the amount of energy that they ingest while hunting so, if a seal can distinguish between small skinny fish – which cost too much to pursue – and the perfect lunch based on their wakes alone, that could improve its hunting efficiency enormously.

10.1242/jeb.059410

Wieskotten, S., Mauck, B., Miersch, L., Dehnhardt, G. and Hanke, W. (2011). Hydrodynamic discrimination of wakes caused by objects of different size or shape in a harbour seal (*Phoca vitulina*). *J. Exp. Biol.* **214**, 1922-1930.

Kathryn Knight

DIGESTING DINNER COSTS LARVAE DEAR



Life as a larva is risky: you're on the menu for many species. Yet it's the time when you need to put most of your effort into growing and developing, rather than simply staying alive. So exactly how much energy do fish larvae invest in growth and development and how much energy does that leave for other processes, such as swimming and foraging? More specifically, how much do they invest in costly protein synthesis when their energy resources are limited? Ian McCarthy and Lee Fuiman explain that protein synthesis is a major metabolic cost when digesting and processing a meal. The duo decided to measure protein synthesis rates in red drum larvae as they digested brine shrimp dinners to find out how much of their energy budget they invest (p. 1821). Plotting the larval protein synthesis rates for 24 h after the larvae fed, McCarthy and Fuiman found that the fractional protein synthesis rates (the amount of free amino acid converted into protein) rose from 16% day^{-1} prior to eating to a staggering 48% day^{-1} around 8 h after the meal, before falling back to 12% day^{-1} 16 h later. And when the duo calculated the amount of energy that the larvae invested in digesting dinner, they were amazed to see it rocketed to 61% of the larvae's oxygen consumption during the peak periods of protein synthesis.

The duo say, 'Although suggested as energetically impossible in larval poikilotherms, our results show that rates [of protein synthesis] in excess of 30% day^{-1} can be attained by larval fish for a few hours.' They also add that diverting this enormous amount of energy to protein synthesis could impact on other activities, such as foraging and fleeing.

10.1242/jeb.059436

McCarthy, I. D. and Fuiman, L. A. (2011). Post-prandial changes in protein synthesis in red drum (*Sciaenops ocellatus*) larvae. *J. Exp. Biol.* **214**, 1821-1828.

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