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

HOW THE WATER SPIDER USES ITS DIVING BELL

Stefan Hetz

Gazing into the depths of a pond, it's hard to miss the insects that whirl and zip beneath the surface. However, only one species of spider has joined them: the diving bell spider, *Argyroneta aquatica*. 'It is an iconic animal; I had read about the spider as a small boy in popular literature about ponds,' says Roger Seymour from the University of Adelaide. According to Seymour, each spider constructs a net of silk in vegetation beneath the surface and fills it with air carried down on its abdomen. The spiders spend their entire lives submerged and even lay their eggs in their diving bells. Having already used an oxygen-measuring device called an optode to discover how aquatic insects extract oxygen from water through thin bubbles of air stretched across their abdomens, Seymour was looking for other small bubbles to test his optode. 'The famous water spider came to mind,' remembers Seymour, and when he mentioned the possibility to Stefan Hetz from Humboldt University, Germany, Hetz jumped at the idea. Inviting Seymour to his lab, the duo decided to collect some of the arachnids to find out how they use their diving bells (p. 2175).

Sadly, diving bell spiders are becoming increasingly rare in Europe; however, after obtaining a permit to collect the elusive animals, the duo eventually struck lucky in the Eider River. 'My philosophy is to make some measurements and be amazed because if you observe nature it tells you much more than you could have imagined,' says Seymour. So, returning to the lab, the team reproduced the conditions in a warm stagnant weedy pond on a hot summer's day to find out how the spiders fare in the most challenging of conditions.

After watching the spiders build their shimmering diving bells, the duo gingerly poked an oxygen sensing optode into the bubble to see how the animal reacted. Miraculously, the spider was unperturbed, so they continued recording the oxygen level. 'Then it occurred to me that we could use the bubble as a respirometer,' says Seymour, to find out how much oxygen the spiders consume.

Taking a series of oxygen measurements in the bubble and surrounding water, the team calculated the amount of oxygen flowing into the bubble before calculating the spider's oxygen consumption rate and found that the diving bell could extract oxygen from the most stagnant water even on a hot day. Also, the metabolic rate of the aquatic spider was low and similar to the low metabolic rates of other spiders that sit waiting for prey to pass.

However, despite satisfying the spider's oxygen demands, the bubble continually shrinks because nitrogen diffuses back into the water, eventually forcing the occupant to venture to the surface to resupply the diving bell. So how long could the bubble survive before the spider had to dash up for air? Calculating the diffusion rate of nitrogen out of the bubble, Seymour and Hetz were surprised to find that the spiders could sit tight for more than a day. 'The previous literature suggested they had to come to the surface as often as every 20–40 min throughout the day,' comments Seymour, who adds, 'It is advantageous for the spiders to stay still for so long without having to go to the surface to renew the bubble, not only to protect themselves from predation but also so they don't alert potential prey that come near.'

10.1242/jeb.060731

Seymour, R. S. and Hetz, S. K. (2011). The diving bell and the spider: the physical gill of *Argyroneta aquatica*. *J. Exp. Biol.* **214**, 2175-2181.

Kathryn Knight

WHEN, AND WHEN NOT, TO ESTIMATE METABOLISM FROM HEART RATE

Energy is the currency of life and knowing how much organisms use as they go about their daily activities is essential for ecologists wishing to understand the complex interactions underpinning ecosystems. However, estimating energy consumption is far from straightforward, and most of the current methods have drawbacks. Beth Young and her colleagues from the University of British Columbia and Vancouver Aquarium, Canada, explain that many scientists convert heart rate measurements collected from active animals into energy expenditure. However, the calculation is based on measurements taken from animals in laboratory settings and the team says, ‘The artificial modes of locomotion and environments employed in these studies raise questions of applicability to animals that spend considerable time diving to depth.’ Curious to find out how reliable these estimates are for diving animals in their natural surroundings, Young and her colleagues measured the heart and oxygen consumption rates of Stellar sea lions foraging in open water and tested whether heart rate could predict an animal’s diving and average metabolic rates (p. 2267).

Training three sea lions to make a sequence of dives for fish to depths of 10 and 40 m, the team found that heart rate was a good indicator of average metabolic rate over a single dive and a series of dives, including the time spent at the surface catching their breath. However, heart rate was not a good indicator of the sea lion’s metabolic rate during the dive.

Also, the team found that the equations that they derived to predict oxygen consumption from heart rate were different for multiple dives and single dives. For single dives the equation was essentially the same as that for resting sea lions. However, the animals that dived repeatedly consumed more oxygen per heartbeat than the single divers, presumably because they accumulated a greater oxygen debt.

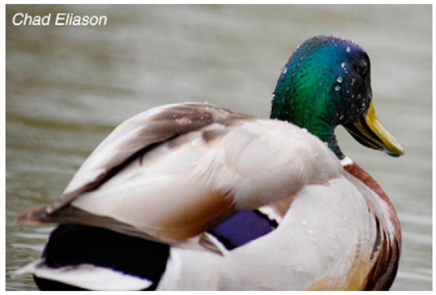
So, heart rate measurements can be used to estimate average metabolic rate in diving sea lions, but only over complete dive cycles where the recovery period is also included. The team admits, ‘Logistically, it is not always possible to distinguish single recovery dive cycles from dive bout cycles in free-ranging animals,’ and recommends that physiologists calculate the average metabolic rate over a dive bout to provide the most accurate metabolic rate estimates.

10.1242/jeb.060756

Young, B. L., Rosen, D. A. S., Hindle, A. G., Haulena, M. and Trites, A. W. (2011). Dive behaviour impacts the ability of heart rate to predict oxygen consumption in Steller sea lions (*Eumetopias jubatus*) foraging at depth. *J. Exp. Biol.* **214**, 2267-2275.

Kathryn Knight

IRIDESCENT PLUMAGE COSTS MORE TO MAINTAIN



Chad Eliason

Some males put a lot of effort into getting their gal. Peacocks invest in stunning tails while yellow wagtails brag about their fitness with costly vivid plumage. But what messages do male mallards send to dowdy mates with their iridescent feathers? Chad Eliason from the University of Akron, USA, explains that brash displays are costly and broadcast a male’s quality. ‘If there are no costs of the colour then it can’t be a way to show that better quality males can produce brighter colours,’ says Eliason. He explains that these shiny colour effects are generated by flat structures in the feather in the same way that the colours on soap bubble surfaces are produced. However, these so-called structural colours are probably cheap to produce, so what costs do they impose to allow a male to show off his prowess? Knowing that the flat barbule structures that produce iridescence might make the feathers more vulnerable to wetting, Eliason and his principle investigator Matthew Shawkey wondered whether iridescent feathers come with a hidden cost: increased maintenance (p. 2157).

‘Most species of duck have a bright colourful iridescent region on their wing in males and females,’ explains Eliason, so the duo decided to find out how water repellent this iridescent patch is relative to dowdier barbs on the same flight feather. Having removed the feather’s naturally occurring oil with ethanol, Eliason gently placed a 10 μl droplet of water on the dull portion of the feather, photographed it and measured the contact angle between the bottom of the drop and the feather. The droplet was almost perfectly spherical: the brown barbules repelled water well as the duo had expected. However, when Eliason placed another droplet on the feather’s iridescent violet barbs, the droplet spread and the contact angle dropped from 145 deg to 109 deg. The flat iridescent barbules were less hydrophobic, but how much of an effect would the feather’s structure and colour have on its ability to repel water?

Looking at the structure of iridescent feather patches with a microscope, measuring their hydrophobicity with water droplets and measuring the reflected colour, Eliason and Shawkey found that the feathers with the flattest barbules produced the deepest violet tones and were the least hydrophobic. So, the most vividly coloured feathers were the least water repellent, but at what cost?

According to Eliason, some water repellent surfaces are able to self-clean. ‘Water droplets roll off the surface and carry the dirt with them,’ he says. So, if the iridescent feathers were less water repellent would they be more difficult to keep clean?

Eliason dusted dull and iridescent feathers with microscopic silica particles, produced a gently falling mist of droplets from a hand spray, held the feathers at an angle and waited to see if the droplets could wash the feathers clean. Not surprisingly, the dull feathers emerged relatively well: the mist successfully removed 50–80% of the silica particles. However, the iridescent portion of the feathers did not self-clean, retaining up to 90% of the dust. They would require significant preening to remain in tip-top condition.

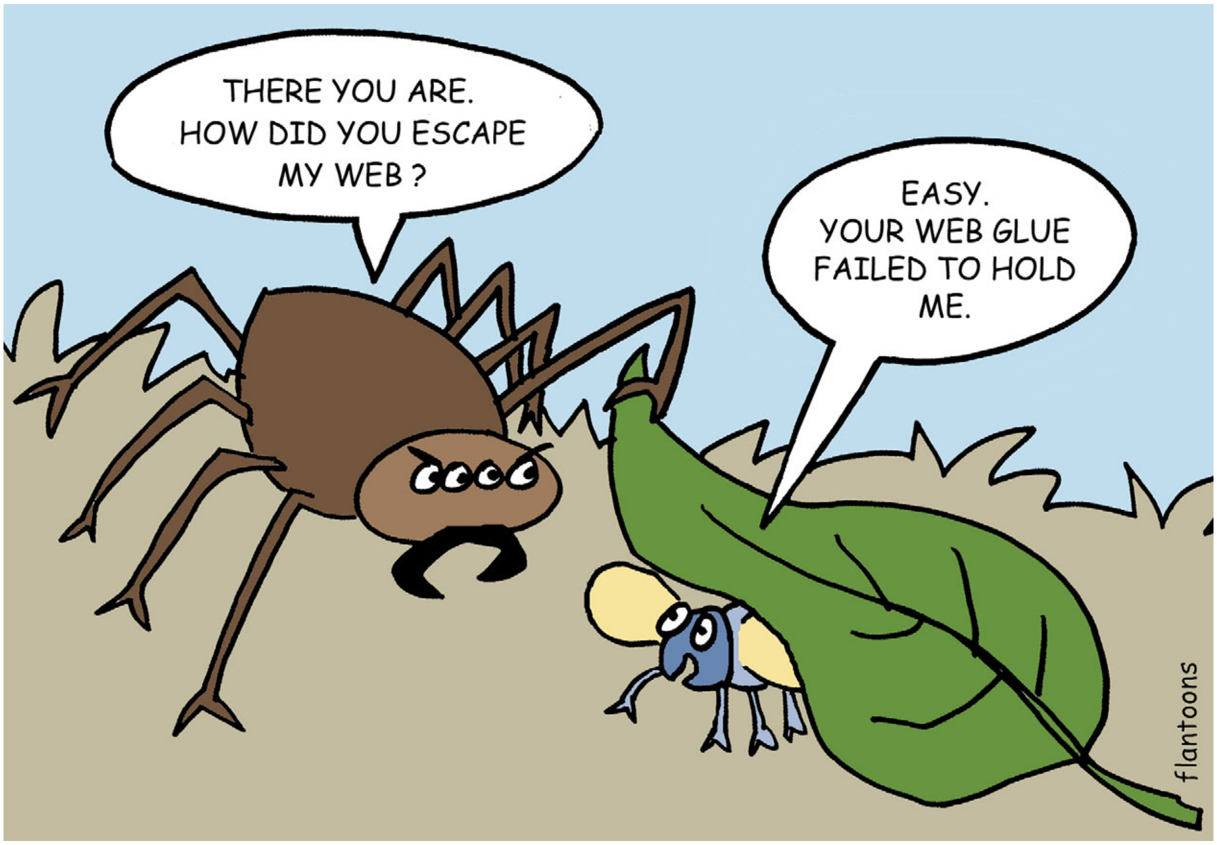
So iridescent feathers probably impose a maintenance cost on males that opt for the deepest, showiest colours, and Eliason and Shawkey are keen to look at the influence of environmental factors on the evolution of iridescent colours and the impact that their costs may have on their location in a bird’s plumage.

10.1242/jeb.060749

Eliason, C. M. and Shawkey, M. D. (2011). Decreased hydrophobicity of iridescent feathers: a potential cost of shiny plumage. *J. Exp. Biol.* **214**, 2157-2163.

Kathryn Knight

WEB GLUE RELEASES RATHER THAN BREAKING



The fate of any hapless insect blundering into a spider's web is almost certainly sealed. Ensnared by sticky spirals, most victims can only wait until despatched by the web's occupant. However, some prisoners successfully break free. Brent Opell from Virginia Tech is fascinated by spider webs. He explains that elastic glycoproteins, in the adhesive droplets distributed along the sticky spiral, attach to the web's prisoner and the outermost droplets stretch until eventually letting go rather than damaging the web. But which aspect of the droplet fails? Opell explains that either the drop could break in two, or the glycoprotein adhesive could release from the surface of the captive. Intrigued, Opell and his colleagues Harold Schwend and Stephen Vito measured the stickiness of threads from orb-webs spun by the orchard spider, labyrinth spider and spinney micrathena using materials that have different surface energies (p. 2237). These materials ranged from Teflon, renowned for its non-stick characteristics and low surface energy, to plastic food wrap, whose high surface energy causes it to stick readily to surfaces. Finding that the stickiness of spider threads was directly related to the surface energy of the materials to which they adhered, Opell and his colleagues conclude that instead of breaking in two as force on the droplets increases, the glycoprotein glue within the elongating droplets releases from the surface, saving the web from destruction.

10.1242/jeb.060723

Opell, B. D., Schwend, H. S. and Vito, S. T. (2011). Constraints on the adhesion of viscous threads spun by orb-weaving spiders: the tensile strength of glycoprotein glue exceeds its adhesion. *J. Exp. Biol.* **214**, 2237-2241.

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