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.

HOW CLIMBING LEAF BEETLES HANG ON


Picture by Thomas Endlein

Watch a spider or lizard scuttle across a ceiling, and you can't fail to be amazed by their gravity defying antics. But how insects and lizards remain attached is a hot topic in the world of adhesives. Somehow they anchor themselves to surfaces, yet are able to detach with ease to move freely: engineers and physicists would love to know how they do it. Walter Federle from the University of Cambridge explains that many insects' tarsal pads (pad like structures that insects stand on) are covered in microscopic hairs. When an insect lands splay legged on a wall or ceiling, they pull their legs inwards, towards their body, in such a way that the tips of the microscopic hairs lock on to the surface. When it starts walking, the insect simply stops pulling the leg inwards, allowing the hairs to detach before lifting the leg. But what happens when a beetle wants to clamber up a vertical surface? Instead of pulling towards the insect's body, its back legs appear to be pushing away from its body. They should detach, but they don't. Curious to find out how climbing insects scale walls without losing their footing, James Bullock and Walter Federle put climbing leaf beetles through their paces (p. 1876).

First the team took a close look at the three hairy tarsal pads at the ends of males' and females' legs. They found three hair types on the males' tarsal pads (pointed, disc shaped tips and spatula shaped tips) and two on the females' tarsal pads, which lacked the disc tipped hairs.

Next the duo filmed the insects' footwork through a microscope as they climbed up and down a smooth vertical surface. They found that the beetles were using the three tarsal pads on their front and rear legs completely differently depending on whether their feet were above or below their bodies as they climbed. The beetles mainly contacted the wall with the third tarsal pads on the front two legs (above the body) when ascending, as if walking on their toes. Looking at the insects' rear legs (beneath the body), Bullock and Federle could see that the climbers were mainly walking on their 'heels', contacting the wall with the first tarsal pad as they pushed themselves upwards. And when the beetles turned around and descended head first, they used the same foot contact pattern: the forelegs (beneath the body) contacted the wall *via* the heel pad, while the feet above the body (rear) hung on to the surface by the toe pads.

Next the team investigated the stiffness of the microscopic attachment hairs on each pad. Knowing that the best adhesives are very soft to allow them to mould to surfaces, Bullock and Federle measured the rigidity of the attachment hairs on each tarsal pad with a force transducer, and were surprised to find that the material they are made from is incredibly stiff, probably to protect them from wear and tear. However, each hair is extremely flexible because they are very thin, and the hairs on the third (toe) pads are softer than the first (heel) pad hairs, which makes the third pads good at sticking to rough surfaces, while the stiffer first pad hairs are good for pushing.

Finally, the duo measured the attachment forces generated by each pad on rough and smooth surfaces and found that the soft toe pads locked on tighter to rough surfaces. However the stiffer heel pads grip on more tightly than the toe pads when being pushed away from the body, which is exactly what they need to do when beetles climb a wall.

10.1242/jeb.033464

Bullock, J. M. R. and Federle, W. (2009). Division of labour and sex differences between fibrillar, tarsal adhesive pads in beetles: effective elastic modulus and attachment performance. *J. Exp. Biol.* **212**, 1876-1888.

SPIDERS DECORATE WEBS FOR CAMOUFLAGE

We aren't the only species that decorate our homes. Some orb web weaving spiders cover their webs in decorations including egg sacs, meal remnants, silk motifs and pieces of vegetation. The question of why spiders decorate their webs has puzzled scientists for more than a century, explains Daiqin Li from the National University of Singapore and Hubei University. It has been suggested that the decorations could deter predators by making the web's occupants look threatening, advertise the web's presence to protect it from damage, or attract tasty prey, but it wasn't clear why *Cyclosa mulmeinensis* decorated their webs. Curious to find out why these spiders decorate their webs with egg sacs and pieces of vegetation, Li and his student, Eunice Tan, decided to track predator and


Picture by Daiqin Li

prey activity around the webs to find out what effect the decorations had (p. 1832).

Travelling to Pulau Ubin island close to Singapore, Tan and Li searched for unadorned webs, webs decorated with egg cases and webs decorated with the remains of meals before filming them to find out how many insects flew in the vicinity of the web, how many were trapped and how often the web came under attack. After months of analysis of more than 170 h of film footage, it was clear that the decorated webs were far more effective at trapping prey than the unadorned webs. Webs decorated with meal remains trapped almost 2 insects per hour and egg sac decorated webs snagged more than 2.5 insects per hour. However, unadorned webs barely managed to trap 1 insect per hour.

But why were the decorated webs more successful at trapping prey than the plain webs? Either the insects were attracted by the decorations, or the decorations were behaving like camouflage, causing unsuspecting insects to blunder into the death trap. Tan and Li decided to take a look at the webs and their occupants from an insects' perspective.

Collecting spiders and their webs, the duo brought them back to the lab where they could measure the way that the spiders and their decorations reflected light. Based on their reflection measurements, the pair calculated the contrast between the spiders and a background, and the web decorations and the same background to see how well they stood out. The spiders, egg cases and meal remains were almost invisible. It was clear that the decorated web's success in trapping prey was due to camouflage

But spiders aren't always the predator. Sometimes they are the prey too, so Tan and Li wondered what effect the ornaments had on the number of attacks the webs endured. Looking back at the film they found that none of the undecorated webs were attacked, the webs adorned with prey remains endured two attacks while the egg sac decorated webs suffered one attack. And when the team calculated how well bird predators could see the spider and web decorations, it was clear that the decorations provided good camouflage from hungry birds too, although they aren't sure why the undecorated webs remained safe from predation without their camouflage protection.

10.1242/jeb.033456

Tan, E. J. and Li, D. (2009). Detritus decorations of an orb-weaving spider, *Cyclosa mulmeinensis* (Thorell): for food or camouflage? *J. Exp. Biol.* **212**, 1832-1839.

SQUID USE TWO MODES TO JET AROUND


Picture by Ian Bartol

The closest that most of us ever get to a squid is a pile of tasty calamari rings, but when Ian Bartol from the Old Dominion University, USA, looks at a squid he sees a remarkably agile swimmer. The nimble creatures propel themselves by rippling their fins and squirting jets of water from their mantles. However, very little was known about the fluid dynamics associated with these versatile swimmers' movements, and even less was known about how cephalopods' interactions with water change as they grow and develop. Curious to find out more about squid swimming techniques, Bartol and his student William Stewart, teamed up with Paul Krueger and Joseph Thompson to focus on how the animals jet around (p. 1889).

Bartol decided to visualise the propulsive jets produced by squid using a technique called digital particle image velocimetry (DPIV), where swirling jets in the water are visualized by thin planes of laser light reflected off microscopic beads floating in the water. Bartol and Stewart trained the squid ranging in dorsal mantle length from 3.3 to 9.1 cm to swim against currents ranging from 2 to 22 cm s^{-1} while filming their propulsive jets and analysed the fluid flows.

After months of painstaking analysis, Bartol and Stewart realised that the animals produce two distinct types of jet: a short efficient jet and a long powerful jet. The team also noticed that the squid often used their fins more frequently when generating the short-pulsed jet, possibly to augment the weaker jet's thrust.

Having identified these two different propulsive jets, the team realised that the squid relied more heavily on the long powerful propulsive jet than the short efficient jet, as the longer jet provided the most thrust. However, the smaller squid (with dorsal mantle lengths less than 5 cm) used relatively more short jets, even though they are less powerful. The team suspect that the squid reduce their use of short efficient jets as their mantles grow larger and the muscle's mechanical properties change.

However, when the team compared the two jetting styles with the animals' speeds, they were surprised to find that instead of switching gear from the low power jet to the high power jet as they speeded up. The squid seemed equally comfortable using both jet styles at all speeds, possibly resorting to using their fins to increase thrust at times when the low powered jet produced insufficient thrust.

'When the flexibility of jet dynamics is coupled with highly versatile fins, which are capable of producing multiple hydrodynamic modes as well, it is clear that squid have a locomotive repertoire that is far more complex than originally thought,' says Bartol, and he is keen to find out whether the squids' jet modes correlate with their fin motions as they jet around.

10.1242/jeb.033480

Bartol, I. K., Krueger, P. S., Stewart, W. J. and Thompson, J. T. (2009). Hydrodynamics of pulsed jetting in juvenile and adult brief squid *Lolliguncula brevis*: evidence of multiple jet 'modes' and their implications for propulsive efficiency. *J. Exp. Biol.* **212**, 1889-1903.

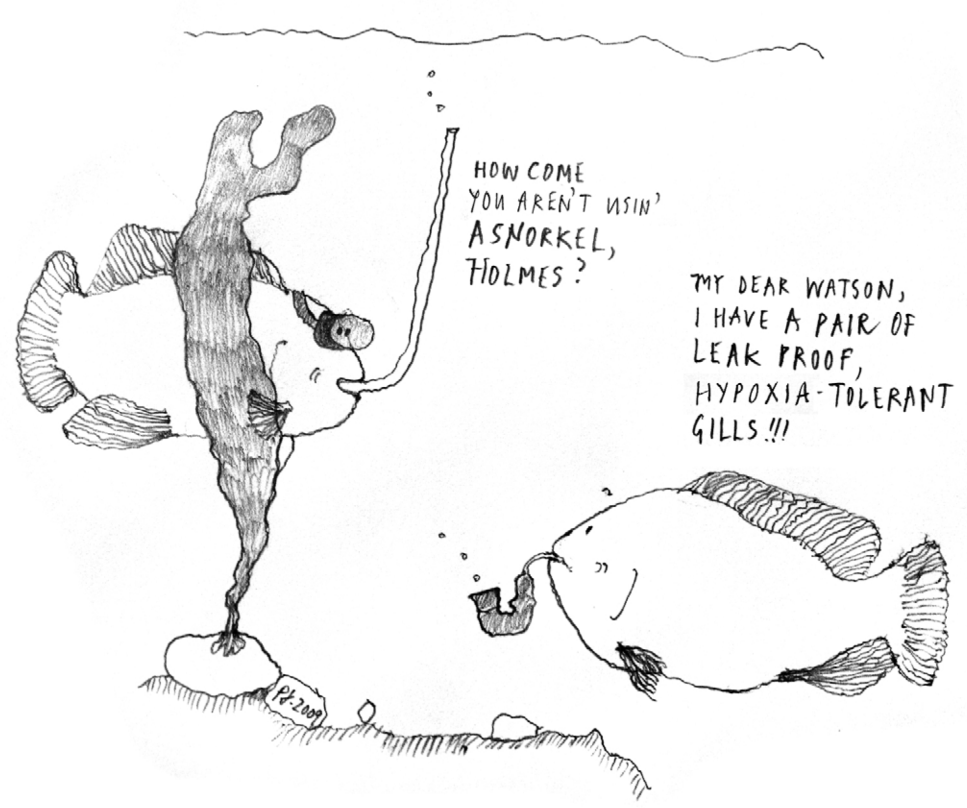
CORRECTION:

DOLPHINS MAINTAIN ROUND THE CLOCK VIGILANCE

In the article entitled 'Dolphins maintain round the clock vigilance' (doi: 10.1242/jeb.032524) published online on 1 May 2009, the phrase 'Knowing that the dolphins' binocular vision is limited' should have read 'Knowing that the dolphins' vision is monocular'.

10.1242/jeb.033738

HYPOXIC OSCARS CLOSE ION CHANNELS TO KEEP SALT IN



Pete Jeffs is an illustrator living in Paris

Fresh water fish constantly battle to get enough oxygen. But as oxygen levels fall and fish make their gills more permeable to take up the gas, they are at increasing risk of losing sodium to their dilute environment. Retaining salts while satisfying their oxygen demands is particularly challenging for Amazonian oscars, which frequently encounter dangerously low oxygen levels. Having previously found that the fish breathe much harder as oxygen levels fall, but they somehow protect their sodium levels by reducing the flow from their bodies, Chris Wood and an international team of collaborators from Canada, the USA, Belgium, the UK and Brazil decided to take a closer look at salt flows across oscar gills (p. 1949).

Reducing the oxygen levels in the oscars' water and comparing the hypoxic fish with fish that had received a normal oxygen supply, the team measured sodium and water flow in and out of the fish's gills, checked their breathing rates and gill permeability and looked at the fish's gill structure by scanning electron microscopy. Calculating the oscars' sodium flows, they found that the flows in and out of the fish's gills reduced enormously when the oxygen levels fell, protecting the fish's internal sodium levels. Wood and his colleagues explain that shutting down active ion uptake and passive ion leakage to an equal extent would result in significant energy savings for the fish, as ion transport is metabolically costly.

But how do the fish change their gills' sodium permeability while continuing to transport sufficient oxygen? Having looked at the structure of the gills over several hours of exposure to hypoxia, the team suspect that the fish close ion transport channels in the membranes of gill surface cells in order to reduce ion transport and conserve energy. The team saw that pavement cells move over the sodium pumping cells (mitochondria-rich cells), to reduce the mitochondria-rich cells' exposure to water and reduce sodium flows into and out of the gill.

10.1242/jeb.033472

Wood, C. M., Iftikar, F. I., Scott, G. R., De Boeck, G., Sloman, K. A., Matey, V., Valdez Domingos, F. X., Duarte, R. M., Almeida-Val, V. M. F. and Val, A. L. (2009). Regulation of gill transcellular permeability and renal function during acute hypoxia in the Amazonian oscar (*Astronotus ocellatus*): new angles to the osmorespiratory compromise. *J. Exp. Biol.* **212**, 1949-1964.

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