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

PLANTHOPPERS SYNCHRONISE LEGS WITH MECHANICAL LINKAGE

Tiny planthopper insects are among the most impressive jumpers in the insect world. Experiencing a remarkable 700 ***g*** force as they take off, the 20 mg athletes can accelerate to 5.5 $m\,s^{-1}$ in 1 ms. They're gone in the blink of an eye, which fascinates Malcolm Burrows from the University of Cambridge. 'Doing very fast things poses particular problems, not only for their nervous systems, but also the skeleton and the muscles,' says Burrows. He explains that it is impossible for muscular contraction to deliver power fast enough to launch these ballistic leaps. 'A muscle can do one of two things. It can contract extremely rapidly, but then it doesn't generate much power, or, it can contract slowly and generate lots of power,' explains Burrows. And, as if that wasn't difficult enough, planthoppers have to coordinate their hind legs to push off within 30 μs of each other, less than one-third of the duration of an action potential, otherwise they spin hopelessly out of control. Curious to find out how the minute insects have solved the dual problems of producing enough power and coordinating their hind legs, Burrows decided to film the insects' leaps with an extremely high-speed camera (p. 469).

Travelling to Aachen in Germany, he collected the tiny insects from an ivy plant in the garden of his colleague, Peter Bräunig, and filmed the insects jumping at 30,000 frames s^{-1}. Analysing the high-speed footage, Burrows could see that the insects initially pull their legs up under their body, where they hold them cocked for several seconds before the legs are released suddenly, sending the insect sailing into the air.

Having filmed natural jumps, Burrows wanted to get a closer look at the insects' jumping action, so he restrained the tiny jumpers on their backs in Plasticine and tickled their legs to get them to try to leap. Focusing on the insect's pleural arches, part of the insect's thorax, he could see that the structures bent as if they were storing energy. And when Burrows shone UV light on this region, he could see the telltale blue fluorescence produced by the elastic protein, resilin, which could store energy as the pleural arches are deformed. He had found the elastic storage mechanism that powers the insect's lift-off.

According to Burrows, once the insect has cocked its leg, huge muscles in the thorax contract slowly, bending and storing the energy in the elastic pleural arches, ready to be released in an instant as the pleural arches recoil and the insect suddenly leaps; just like the release of energy stored in an elastic catapult.

Having found the insect's catapult mechanism, Burrows began looking for the synchronisation system that coordinates the hind legs' simultaneous push-off and realised that small protrusions from the top part of each hind leg touched as the legs were cocked. Could this mechanical linkage provide the synchronisation necessary to prevent the leaping insects from spinning?

Filming a dead insect as he tried to move one of the legs by pulling on its tendon, Burrows was amazed to see that both legs moved in perfect synchrony. 'I had to bring Peter into the lab and tell him "Have a look at this! Am I seeing something or what?"', laughs Burrows. With no neural or muscle activity to move the dead insect's legs, it was clear that the mechanical linkage between the two legs was responsible for both legs pushing off simultaneously.

Having found the planthopper's unique mechanical linkage that synchronises the legs, Burrows is keen to find out more about the neural systems that control the insect's super-fast leaps. He says 'there's a lot of fun ahead'.

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Burrows, M. (2010). Energy storage and synchronisation of hind leg movements during jumping in planthopper insects (Hemiptera, Issidae). *J. Exp. Biol.* **213**, 469-478.

TENTACLED SNAKES SENSE FISH EDDIES

When most people think of tentacles they don't think of snakes: but not Ken Catania from Vanderbilt University. He is fascinated by the strange tentacle structures on the upper lip of tentacled snakes. 'When I first saw them I thought what the heck are those tentacles for,' recalls Catania. He is also impressd by the snake's remarkable ability to outsmart fish. They startle unsuspecting victims into fleeing straight into their hungry jaws, and they also have voracious appetites, consuming large numbers of fish. 'I am absolutely amazed by this

behavioural specialisation for detecting and catching fish,' says Catania. Having previously worked with another tentacled animal, the star nosed mole, Catania wondered whether the snake's tentacles could be used to detect the subtle water movements generated by fish. 'Other people have thought this before, but nobody had done any experiments to confirm the idea,' says Catania, so he set out to solve the mystery of the serpent's tentacles (p. 359).

Teaming up with Duncan Leitch and Danielle Gauthier, Catania decided to investigate the nerves in the tentacles. Using microscopy, the trio could see tiny nerve branches travelling across the middle of the tentacle. 'This is interesting because it is a clue to the tentacle's function' says Catania. He explains that nerves involved in taste or touch sensations usually travel close to the surface, but by crossing the tentacle they are better placed to detect when water currents deflect the tentacle. But this was just a smoking gun; Catania needed real evidence that the tentacles were sensitive to deflection.

Using von Frey hairs to gently deflect the tentacles and then measuring the tentacle's responses in the trigeminal ganglion, the team found that the tentacles were remarkable sensitive, responding to even the tiniest displacement produced by the finest hair. They also mapped the tentacle's inputs to the snake's optic tectum (the region of the brain that receives sensory inputs and then directs the behavioural responses) and found that the region of the optic tectum that received signals from the tentacles was close to regions that responded strongly to visual inputs. The two senses must be highly integrated, which made Catania wonder how well the snakes could hunt by one sense alone.

Fooling the snakes into hunting by vision, the team showed the snakes a movie of a cartoon fish swimming beneath the tank and waited to see if the fish would strike. Sure enough, they did, although the snakes soon became bored of striking at an unrewarding computer screen. Next, the team switched off the lights and filmed a snake in infrared light as a hapless goldfish swam within range. The snake struck successfully. It could hunt by tentacle-sense alone, although Catania suspects that it is less accurate.

Catania admits that he is a little surprised at how good the snakes are at hunting by vision alone, given their remarkable adaptation to detecting fish-generated eddies. 'I think they are using every sense that they have to the maximum,' says Catania, and adds 'because the snakes eat so much I suspect there is strong selective pressure for them to use every trick in the book, which is why they have evolved this extra [tentacle] sense for detecting fish.'

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Catania, K. C., Leitch, D. B. and Gauthier, D. (2010). Function of the appendages in tentacled snakes (*Erpeton tentaculatus*). *J. Exp. Biol.* **213**, 359-367.

GROUSE COMMUNICATE STATE OF HEALTH WITH RED COMBS

Parents of teenagers know just how much preening goes on before a date, and animals are no different: male peacocks display their impressive tails, blue footed boobies flash their feet and male red grouse get out an impressive pair of red combs above their eyes. Francois Mougeot from the Estación Experimental de Zonas Áridas in Spain is intrigued by the messages conveyed by the elaborate sexual ornaments that birds have evolved. 'I am interested in which sort of quality these ornaments emphasise and how does it work so that it gives a reliable message,' explains Mougeot. Knowing that the immune systems of birds infected with parasites increase the levels of damaging oxidising agents in the birds' blood, and that these oxidising free radicals could be mopped by a red pigment, carotenoid, which is also found in the birds' combs, Mougeot and his collaborator, Stuart Piertney from the University of Aberdeen, wondered whether the eye combs of healthy uninfected birds would reflect their fitness relative to infected individuals. The duo decided to take a close look at some male red grouse combs (p. 400).

At the time that Mougeot began the study, he was working in Aberdeen, so he drove down to the British Army base at Catterick Moor in North Yorkshire, to trap some male grouse. Dazzling the birds at night with a bright light, Mougeot, Jesus Martínez-Padilla and Lucy Webster attached radio transmitters to the animals, collected a blood sample, photographed and measured the size of the combs and waited until the birds had defecated so that they could assess the number of parasites that each bird was carrying. Then they gave half of the birds a drug to clear the parasites from their intestines and left the rest of the infected birds untreated.

After releasing the birds, the trio returned to the moor two weeks later to find out how the birds had done. Tracking them down at night by following their radio signals, the team photographed and measured the combs again and collected another blood sample from each bird before removing the transmitter and returning the birds to the moor.

So how had the birds' combs faired? The combs of the uninfected birds were clearly brighter and larger than the birds that were still infected with parasites. And when Jonathan Blount in Exeter, UK and Lorenzo Pérez-Rodríguez in Ronda de Toledo, Spain, analysed the blood samples they could see that the uninfected birds were suffering significantly less oxidative damage than they had before their infection was treated. The team also noticed that the birds that reduced their oxidative damage most had brightened their combs the most.

'Oxidative stress does mediate the relationship between parasites and the coloration,' says Mougeot; so the brightness of male red grouse combs seems to be a reliable indicator of the bird's fitness and could tell females how strong a potential suitor's immune system is. Mougeot also suggests that the carotenoids could play a role in the birds' defence systems. He explains that carotenoids could act as antioxidants so that, instead of diverting carotenoids to brighten their combs, the infected birds have dim combs because they retain carotenoids in the blood to combat infection-induced oxidative stress. Alternatively, the carotenoid levels of infected birds could be lower than healthy birds because the carotenoids are damaged by oxidation, dimming their combs. Either way, the combs of infected birds are dimmer and probably a turn-off for red grouse eligible bachelorets.

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Mougeot, F., Martínez-Padilla, J., Blount, J. D., Pérez-Rodríguez, L., Webster, L. M. I. and Piertney, S. B. (2010). Oxidative stress and the effect of parasites on a carotenoid-based ornament. *J. Exp. Biol.* **213**, 400-407.

RED FLAT BARK LARVAE VITRIFY TO SURVIVE –150°C

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When the long hard northern winter sets in, insect larvae have two options: beat the ice or perish. Some insects tolerate ice formation while others avoid freezing and cheat death by stuffing themselves full of antifreeze compounds. However, insects that live in the extreme latitudes may have to go to even greater lengths to survive; their supercooled body fluids may transform into a viscous glass (vitrify) at extremely low temperatures to avoid freezing. Todd Sformo and colleagues from the University of Alaska Fairbanks, the University of Notre Dame and 21st Century Medicine, Inc., explain that larvae from some Alaskan populations of the red flat bark beetle seem to remain unfrozen at temperatures as low as –80°C, and they wondered whether the larvae may have opted for the vitrification option. Curious to find out how overwintering larvae survive, Sformo and his colleagues measured the antifreeze protein activity, water and glycerol contents as well as the change in heat capacity of the larvae's bodies as they cooled to find out if their body fluids were transformed into a glass (p. 502).

Amazingly, the larvae did not freeze, even at temperatures as low as –150°C; instead of forming ice crystals, their body fluids vitrified to protect them from damage. They also found that the larvae lost body fluids as the temperature fell, increasing their glycerol levels to an impressive 4–6 $mol\,l^{-1}$.

The team explains that as summer turns into autumn the larvae begin producing antifreeze proteins to protect them down to –20°C, before beginning to dehydrate, which raises their glycerol and antifreeze concentrations even further for protection down to –40°C. Finally, as the winter temperatures fall even further, they lose more body fluids, raising their glycerol concentrations to such an extent that their body fluids turn into a viscous glass at –58°C, protecting them all the way down to –150°C.

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Sformo, T., Walters, K., Jeannet, K., Wowk, B., Fahy, G. M., Barnes, B. M. and Duman, J. G. (2010). Deep supercooling, vitrification and limited survival to –100°C in the Alaskan beetle *Cucujus clavipes puniceus* (Coleoptera: Cucujidae) larvae. *J. Exp. Biol.* **213**, 502-509.

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