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.

MANATEES SHOULD HEAR LOOMING DANGER

Grazing sea grass along the subtropical Florida coast, manatees would seem to have an idyllic life; that is until a passing motorboat shatters their peace. But motorboats and other watercraft pose an even greater threat, injuring the peaceable mammals with their propellers, or shattering their ribcages and puncturing their lungs in collisions. Joe Gaspard from the Mote Marine Laboratory and Aquarium, USA, explains that it isn't clear why the animals are so vulnerable to human activity. Although their vision is known to be extremely restricted in the turbid water, Gaspard points out that sound is absorbed less in water than in air, potentially allowing it to travel farther. It also travels five times faster in water than in air, theoretically warning the animals earlier of an approaching threat. However, it wasn't clear whether manatees have the ability to hear looming watercraft above the cacophony of their natural environment. Teaming up with Gordon Bauer, Roger Reep and David Mann, and a group of trainers from the aquarium, Gaspard decided to test the hearing of two captive manatees, Buffett and Hugh, to find out what they are capable of hearing (p. 1442).

'Buffett and Hugh are very cooperative and picked up on the elements of the study quickly', remembers Gaspard, who worked with Kim Dziuk, Adrienne Cardwell and LaToshia Read to train the animals to swim down to a listening station 1 m beneath the surface. Switching on a light to indicate to the animals that a test was about to start, the team then trained the manatees to touch a yellow response paddle in return for a tasty fruit or vegetable snack when they heard a sound. They also trained the manatees to stay in place (in return for another snack) when they heard nothing. Once Hugh and Buffett had got the task in hand, the team tested their hearing by selecting a particular sound frequency (pitch) and gradually lowering the volume of the sound until the manatee could no longer hear it. Plotting these 'hearing thresholds' on a graph, the team could see that the manatees had good hearing between 8 and 32 kHz and could even hear sounds as low as 0.25 kHz – so long as they were quite loud. However, they were even more amazed when Buffett appeared to be able to hear ultrasonic frequencies as high as 90.5 kHz. 'Buffett did the task but refused to continue once we got to that frequency, so we think it was aversive or annoying', Gaspard recalls.

Intrigued by the manatees' apparently sensitive hearing, the team then tested how well the mammals performed when the sounds were accompanied by background noise. Playing test tones – ranging from 4 to 32 kHz – against background noise of the same pitch, the team recorded the difference between the volume of the tone and background noise when the manatee could no longer distinguish the tone. Plotting the critical ratio – the level at which the background noise swamped the manatee's hearing – against pitch for each animal, the team saw that the manatees struggled to hear lower and higher pitched sounds above background noise. However, their hearing was much sharper at 8 kHz – the frequency at which manatees communicate – where they could still distinguish tones that were only 18.3 dB louder than the background.

So, it appears that manatees should be able to hear approaching motorboats above background noise and Gaspard is curious to find out why the animals do not appear to respond in time. 'Manatees are good at sleeping and eating and some of these elements may overwhelm their auditory sensitivity', suggests Gaspard.

10.1242/jeb.073056

Gaspard, J. C., III, Bauer, G. B., Reep, R. L., Dziuk, K., Cardwell, A., Read, L. and Mann, D. A. (2012). Audiogram and auditory critical ratios of two Florida manatees (*Trichechus manatus latirostris*). *J. Exp. Biol.* **215**, 1442-1447.

Kathryn Knight

MICROALGAE KEEP SEA URCHINS AT BAY

Sea urchins are voracious eaters, destroying kelp beds as they graze. However, devastated kelp beds can re-generate on wave-swept surfaces where sea urchins have more difficulty clinging on. Shigeru Kawamata from the National Research Institute of Fisheries, Japan, explains that sea urchins grip bare rocks with flexible foot suckers that mould to most surfaces. But how would sea urchins fare if the shore were coated in fine mats of slippery microscopic algae? Suspecting that microalgal surfaces could deter sea urchins from moving over them, Kawamata decided to test how well *Strongylocentrotus nudus* sea urchins move across and graze on thin mats of microalgae (p. 1464).

Encouraging algal mats to grow on sections of simulated seabed, Kawamata replicated the seashore in a flow tube where he could reproduce the waves' surging motion. Attaching young kelp to algae-encrusted seabed sections and algae-free sections, Kawamata released sea urchins into the flow tube. He then filmed the sea urchins' activity as they travelled around the flow tube while he adjusted the wave velocity from 10 to 40 cm s^{-1}.

At the lowest wave velocity (10 cm s^{-1}), the sea urchins had no problems gripping onto the slippery algal mats. However, as the water velocity increased, the sea urchins moved more slowly on the slippery surface. They also had increasing trouble hanging onto the algal surfaces at the moderate wave velocities and often became dislodged. And when Kawamata checked how well the young kelp plants had survived, he found that the algal mats had kept the sea urchins at bay, protecting the young kelp that were out of the sea urchins' reach, while the kelp that were attached to algae-free surfaces were decimated. However, at the highest wave speed, 40 cm s^{-1}, even the sea urchins in the alga-free environments had difficulties feeding as the waves buffeted the kelp.

So, microalgal mats could play a crucial role in helping to re-establish sea urchin-devastated kelp beds as the animals are unable to graze on kelp when they cannot get a grip on the slippery algal surface. Kawamata is keen to find out whether microalgal mats also protect established kelp from sea urchin damage.

10.1242/jeb.073064

Kawamata, S. (2012). Experimental evaluation of the anti-attachment effect of microalgal mats on grazing activity of the sea urchin *Strongylocentrotus nudus* in oscillating flows. *J. Exp. Biol.* **215**, 1464-1471.

Kathryn Knight

INSECT CUTICLE TOUGHER THAN BONE

Jan-Henning Dirks

Insect cuticle is one of the most common and versatile materials on the planet. Comprising limbs, joints, wings and even transparent eye sections, cuticle adapts to take on almost any role that insects require. But little was known about the mechanical properties of this remarkable material. 'There have been a few studies to understand its stiffness and strength but none have ever studied the fracture mechanics', explains Jan-Henning Dirks from Trinity College Dublin, Ireland. Intrigued by the material's extraordinary versatility, Dirks and his colleague, bone fracture mechanics expert David Taylor, decided to find out just how strong and stiff locust legs are (p. 1502).

However, instead of just investigating the mechanical properties of isolated sections of leg cuticle, Dirks and Taylor decided to analyse the strength and stiffness of intact leg segments. 'If you want to understand the biomechanical implications of a structure, you don't only want to know the material properties but how is it implemented in the structure', says Dirks.

Quickly removing a locust tibia and inserting it into a tensile testing machine, Dirks filmed the leg while compressing it along its length until it buckled and snapped. But when he calculated the leg's stiffness – the resistance to bending – based on the force at which the leg failed, Dirks was surprised. The stiffness was only 3.05 GPa, a fraction of the 9.0 GPa measured by Martin Jensen and Torkel Weis-Fogh 50 years earlier. Perplexed, Dirks checked the equipment and samples and repeated the stiffness measurements using a different method, but the stiffness was always 3.05 GPa. Then he realised that it had taken Jensen and Weiss-Fogh an hour to make their stiffness measurements. Could the leg have dried out and stiffened in the additional time?

Repeating the stiffness measurements anything from 15 to 180 min after removal of the leg, Dirks noticed that the leg dried quickly and as it dried it stiffened, reaching a maximum stiffness of 8.94 GPa 2 h after removal. So the stiffness of active kicking and jumping locusts' legs is far less than had been believed. And when the duo measured the hydrated leg's strength, it was also significantly lower (72.05 MPa) than that of the desiccated legs (217.41 MPa). Essentially, the stiffness and strength of insect cuticle can be tuned, depending on the material's moisture content.

Next, Dirks and Taylor decided to test the limb's toughness – its resistance to fracture. 'Locusts have to withstand leg defects so that they can still jump even if they have a small notch from fighting', explains Dirks.

Making a small incision in the limb and bending it until the leg fractured, Dirks measured the force at which the limb failed and calculated the toughness. It was an incredible 4.12 MPa $m^{1/2}$. And when he calculated the amount of energy required to tear insect cuticle apart, it was an impressive 5.56 kJ m^{-2}. 'That is as high as antler and higher than bone, and cuticle achieves this without using a mineral phase. It is basically just chitin and protein', says Dirks.

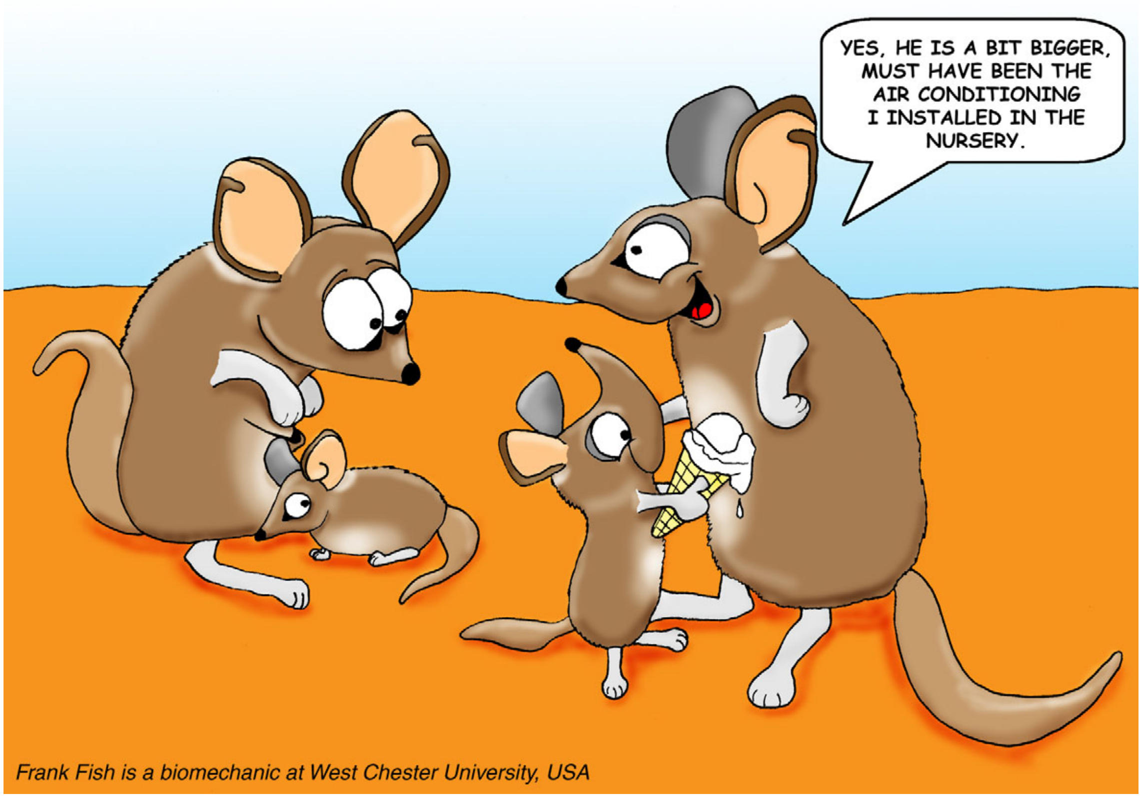
Admitting that he is amazed that insect cuticle is so tough, Dirks says, 'Usually if you want a high fracture toughness you have a high stiffness'. However, he suspects that there is a trade off between the various mechanical properties, allowing the leg to be strong enough to weather the extreme forces of take-offs and kicking while resisting fractures. 'You could make the leg much stiffer but it would probably become less strong', he says. And, having discovered that humidity is a factor that contributes to the remarkable versatility of the material, Dirks is now keen to understand how altering the moisture content of cuticle fine tunes its astonishing mechanical properties.

10.1242/jeb.073080

Dirks, J.-H. and Taylor, D. (2012). Fracture toughness of locust cuticle. *J. Exp. Biol.* **215**, 1502-1508.

Kathryn Knight

DUNNARTS' DEVELOPMENT ADAPTS



With the IPCC predicting global temperature rises of 0.2°C per decade, many species are facing an uncertain future. How they will respond and whether they have the flexibility to adapt is unclear. Alexander Riek from the University of Göttingen, Germany, and Fritz Geiser from the University of New England, Australia, explain that temperature is already known to have a dramatic effect on animals, with related creatures from higher latitudes tending to be larger than animals from the tropics. But what effect could temperature have on an animal's development? As minute baby marsupials can be exposed to a wide range of temperatures during development, the duo decided to find out how developing at different temperatures affects dunnart pups (p. 1552).

Explaining that dunnart pups are born 12 days after fertilization into a rather exposed open pouch, the duo collected new dunnart mums and transferred them to temperature-controlled rooms, at either 16 or 22°C, until their youngsters were weaned 2 months later. Measuring the independent youngsters' vital statistics, the duo found that the cold-reared pups had longer bodies and heads than their warm-reared counterparts: even though the animals weighed the same regardless of the temperature. Also, the team found significant differences in the animals' metabolic rates depending on the temperature to which they were exposed during development. At cooler temperatures the cold-reared animals had a lower metabolic rate than the warm-reared animals, although the two groups had essentially the same metabolic rate at 30°C. Finally, when the team assessed how often the youngsters became torpid to conserve energy, they found that at an environmental temperature of 16°C, the cold-reared animals used torpor more often and for longer than the warm-reared youngsters.

So, the young dunnarts had responded quite dramatically to the colder conditions, which not only affected their body shape but also had an effect on their metabolism. Riek and Geiser say, 'A rapid adjustment to environmental conditions… could be a major determinant in a species' ability to cope with climate change', and they suspect that animals that hibernate or conserve energy through torpor may have sufficient metabolic versatility to be able to adjust rapidly to environmental change. 'Animals employing some form of energy-saving mechanism stand a better chance of surviving during adverse climatic or environmental conditions', they say.

10.1242/jeb.073072

Riek, A. and Geiser, F. (2012). Developmental phenotypic plasticity in a marsupial. *J. Exp. Biol.* **215**, 1552-1558.

Kathryn Knight
kathryn@biologists.com