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.

BATS LOCATE FLUTTERING INSECTS WITH ECHOLOCATION


Brock Fenton

Over the course of evolution, bats have developed two different echolocation strategies. Some species emit single calls and wait for the reflection (echo) to return before calling again; otherwise, they could not hear the echoes above their loud calls. They are low duty cycle or intermittent echolocators. However, other species call more continuously. Brock Fenton from University of Western Ontario, Canada, explains that bats that have opted for this Doppler radar-like (high duty cycle) strategy can distinguish between their calls and weak echoes arriving at the same time because the echoes have changed frequency (pitch). This is due to the Doppler effect, where sound waves emitted by a bat flying toward an object become compressed, raising the frequency of the reflection and allowing the bats to distinguish between their own cries and the returning higher pitched reflection.

As well as allowing bats to call continually, this shift in frequency could also help bats to detect fluttering targets: specifically, tasty moths and insects. Fenton explains that a target's fluttering wings could modify the returning echo so that the pitch oscillates up and down like a wailing siren, allowing the bat to pick out a fluttering target against the background of single-toned reflections generated by static objects such as leaves. However, no one had tested whether bats that evolved continual radar-like echolocation can detect fluttering targets against cluttered vegetation. So, Brock Fenton and student Louis Lazure set out to test whether radar-like bats are better at trapping fluttering targets in vegetation than intermittent callers (p. 1131).

Requiring a reliable source of flutter to test the bats' responses, the pair built a robot by attaching a piece of masking tape to a wire and spinning the wire to simulate an insect's fluttering wings. Then they tested the robot, affectionately dubbed Robo-moth, by playing simulated bat cries to it while it fluttered at different rates, and recording the reflections to make sure that a bat could detect the robot's echoes. Then Lazure travelled to Taiwan to try Robo-moth out with real bats. Locating Robo-moth in forests that they knew were heavily used by foraging bats, Lazure recorded the echolocation cries of inbound bats and filmed their responses to the fluttering fake.

Over 23 nights, Lazure recorded 2727 passing bats and identified that 2382 of them were radar-like echolocators while the rest used intermittent echolocation calls. Of the 446 bats that reacted to Robo-moth and tried to attack, 442 were radar-like echolocating bats: lesser horseshoe bats, great roundleaf bats and woolly horseshoe bats. They also noticed that the horseshoe bats seemed more sensitive to the siren-like echoes than the great roundleaf bats.

So, radar-like echolocating bats are better at detecting fluttering prey in cluttered forests than intermittent echolocators and Fenton suspects that the radar-like bats have a better chance of capturing their prey because they continually monitor their victim's progress.

Repeating the experiments in Belize – one of the homes of the only radar-like echolocating bat (Parnell's moustached bat) in the Americas – the duo recorded five Parnell's moustached bats and 370 intermittent echolocating species flying past Robo-moth. According to Fenton, the Parnell's moustached bats attacked Robo-moth as often as the Taiwanese radar-like echolocators; however, he was surprised that four intermittent echolocators – woolly bats and tube-nosed bats in Taiwan and two other species of moustached bats in Belize – also succeeded in attacking Robo-moth. Fenton suspects that these bats may be evolutionary intermediates that could help us understand why bats evolved this radar-like strategy for detecting prey in forests.

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Lazure, L. and Fenton, M. B. (2011). High duty cycle echolocation and prey detection by bats. *J. Exp. Biol.* **214**, 1131-1137.

DISCONTINUOUS BREATHING PROTECTS FROM OXYGEN DAMAGE

Small insects have some of the highest metabolic rates on the planet, yet many routinely hold their breath for tens of minutes. So, why do they do that when creatures with lower metabolic rates have to breathe continually to meet their oxygen demands? Tim Bradley from the University of California, Irvine, explains that insects were thought to seal their breathing tubes to protect themselves from dehydration. However, in 2005 Bradley and Stefan Hetz suggested that insects may hold their breath to regulate the amount of damaging oxygen in their bodies. Since then Bradley has been trying to find out whether insects breathe discontinuously to protect themselves from dehydration or the harmful effects of oxygen. 'A number of papers have attempted to examine the issue of water balance by looking at desert insects. The argument was that insects from a dry environment should show an exaggerated discontinuous breathing pattern because they have to conserve water in such an extreme manner. But, the results have been mixed,' explains Bradley. So, he and Heidy Contreras decided to look at the problem from a different perspective. They monitored the breathing patterns of waterstriders that live in humid environments to find out whether they use a discontinuous breathing pattern (p. 1086). 'One simple hypothesis would be that they shouldn't use discontinuous breathing at all because they don't face the problem of dehydration,' says Bradley.

Collecting waterstriders from a mountain stream and bringing them back to the laboratory, Bradley and Contreras recorded the insect's breathing patterns in dry and humid conditions and at three different temperatures (to vary the insects' metabolic rates and oxygen demands) by measuring the amount of carbon dioxide exhaled. In humid conditions, the duo saw that the insects with high metabolic rates at 30°C breathed continuously to meet their metabolic demands. However, the insects with the lowest metabolic rates (at 10°C) breathed discontinuously. Even though the atmosphere was humid enough to protect the insects from dehydration, they still breathed discontinuously.

The duo also compared the breathing patterns of waterstriders with the same metabolic rates (at 20°C) in humid and dry environments and found that they were identical. The insects' breathing patterns would have been different if they were regulating them to conserve water, so the insects were not modifying their breathing patterns to protect themselves from dehydration. They must be regulating their breathing patterns to prevent oxidation damage when their metabolic rates are low.

Bradley explains that the insect respiratory system is so efficient at delivering oxygen that it can open for just a minute when the insect's oxygen demands are low and saturate the body with oxygen. Then the spiracles have to close as the insect consumes oxygen, returning it to a safe level. Instead of detecting humidity to protect the insect from dehydration, the insect's respiratory system detects oxygen and carbon dioxide levels and closes when oxygen levels are dangerously high.

'I would hope that this paper puts an end to the notion that the insect is monitoring water vapour and changing its respiratory behaviour,' says Bradley. He adds, 'We understand the whole animal pattern of respiration but what we are now trying to do is to understand what is going on at the level of the spiracles: when do they open and close, how far do they open, what nerves control that, where is the location of the oxygen sensor and the carbon dioxide sensor; but those are tough questions to answer.'

10.1242/jeb.057281

Contreras, H. L. and Bradley, T. J. (2011). The effect of ambient humidity and metabolic rate on the gas-exchange pattern of the semi-aquatic insect *Aquarius remigis*. *J. Exp. Biol.* **214**, 1086-1091.

DARTERS SIT TIGHT IN BOUNDARY LAYER


Rose Carlson

Sitting comfortably on a riverbed might seem to be an easygoing lifestyle, but you try doing it in a fast running stream. Yet tiny North American darters appear to be perfectly at home holding still in fast flowing water, apparently without gripping on. Rose Carlson from Fordham University, USA, explains that she is fascinated by how animals' body shapes evolve. She says, 'I was interested in whether darters' body and fin shape might contribute to their ability to stay on the bottom.' She explains that environmental factors often drive an animal's evolution, so she and George Lauder from Harvard University decided to find out more about the turbulent fluid flows the fish frequent (p. 1181).

'This project started out being very exploratory. We just wanted to describe the patterns of flow over different substrates,' says Carlson. Placing simulated riverbeds in a flow tank and shining a plane of laser light in the water as it flowed at speeds ranging from 0 to 31 cm s^{-1}, Carlson and Lauder were able to visualise the turbulent flows as the water rushed over the surfaces. Comparing the flows over the gravelly river beds with the flow over a smooth Plexiglas surface, Carlson and Lauder were surprised to see that water close to the gravel flowed much slower than water in the main body of the 'river'. This region of relatively tranquil water above the Plexiglas increased from a few millimetres to almost 2 cm as the water tumbled over the gravelly riverbeds. And when the duo introduced a large rock into the flow, the water behind the obstruction even began flowing backward slightly. Friction between the water and the coarse surface was slowing the flow near the riverbed significantly to produce a tranquil boundary layer, but how could this help the darters?

Carlson realised that the fish were almost the same height as the newly discovered region of reduced flow. This layer of slower flowing water was deep enough to shelter the fish and help them sit tight, but the fish must be modifying the fluid flows in some other way to help them stay put. Working with Lauder, Carlson began visualising the fluid flows around the darters' pectoral fins as the fish held them out wide while they sat still on a simulated riverbed and a Perspex surface.

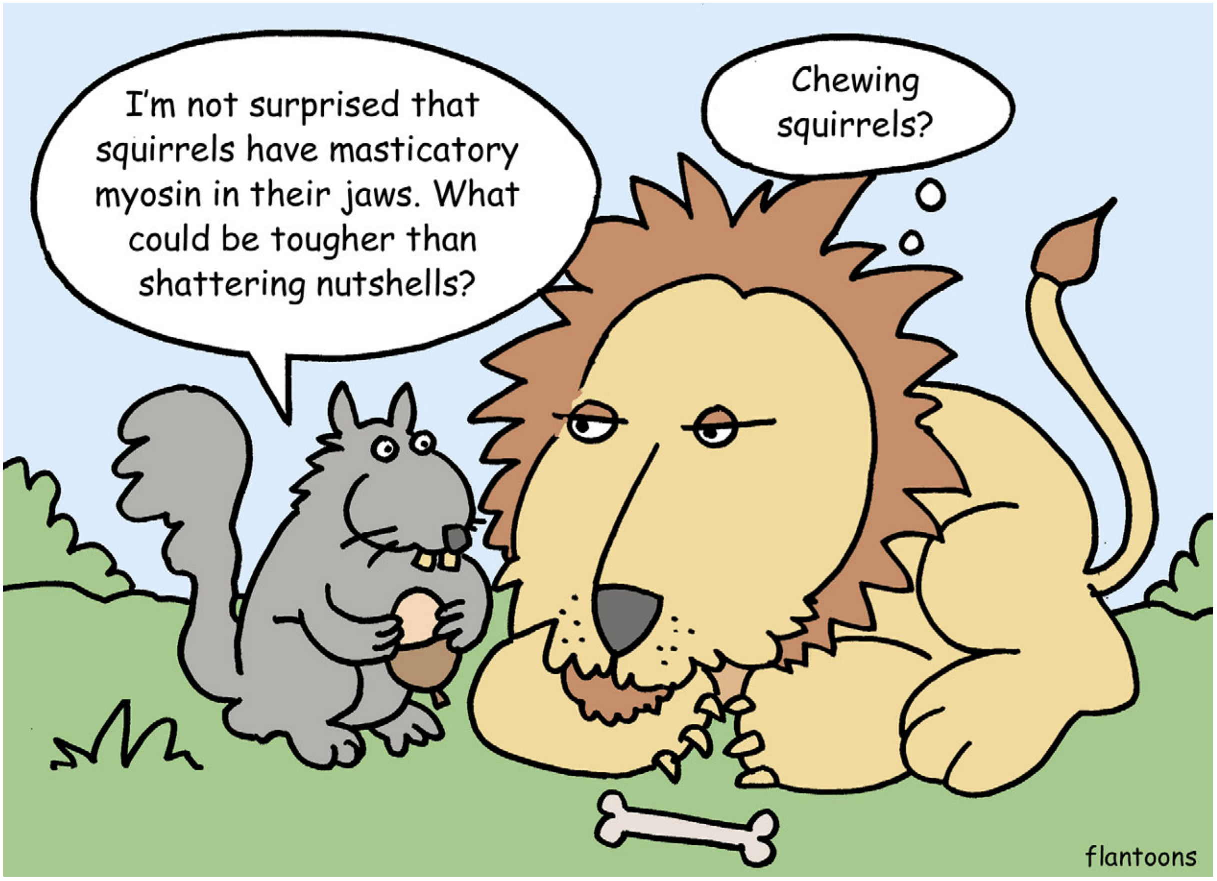
According to Carlson, some fish, such as sharks, produce downward directed forces with their pectoral fins; however, when she and Lauder analysed the flow patterns trailing from the darters' widespread fins, they were surprised to see that they were not producing enough force to pin the fish to the bottom, even in the slow flowing water. 'They are probably using some other mechanism to generate a lot of friction between themselves and the substrate, and those frictional forces are probably the important force helping them to stay in place,' she says.

Having found that darters take advantage of slow flowing water in the boundary layer to remain in place, Carlson is curious to find out more about how this could have shaped the explosion of darter species in North America. She explains that there are over 240 species and says, 'There is an important phenomenon that often precedes adaptive radiation [when new and ecologically diverse species appear], which is the availability of unoccupied ecological space.' Carlson would like to find out whether the darters' reduction in size and loss of a swim bladder allowed them to occupy the tranquil – and under-used – boundary layer, giving them the 'ecological opportunity' to diversify into the wide range of species we see today.

10.1242/jeb.057307

Carlson, R. L. and Lauder, G. V. (2011). Escaping the flow: boundary layer use by the darter *Etheostoma tetrazonum* (Percidae) during benthic station holding. *J. Exp. Biol.* **214**, 1181-1193.

HOW SQUIRRELS MODULATE MASTICATORY MYOSIN TO SHATTER SHELLS



When a lion tears apart its quarry, it may have more in common with a nut-nibbling squirrel than you think. Peter Reiser from Ohio State University, USA, explains that when muscles contract, two muscle filaments slide past each other. One of the muscle filaments is made up of a protein called myosin, and this protein is specially adapted in the jaws of carnivores to give them their deadly bite. So imagine Reiser's surprise when this muscle protein turned up in the jaws of a hard-core vegetarian: the grey squirrel. Initially perplexed by this discovery, Reiser soon realised that instead of neatly nibbling away at nuts, grey squirrels obliterate them, in much the same way that carnivores clamp their jaws around their victims. Despite their vegetarian lifestyle, grey squirrels need as much jaw power, to shatter nuts, as a carnivore does. Having made this initial discovery, Reiser was curious to discover whether carnivores and rodent jaws have other proteins in common. Explaining that muscular contractions are regulated by two proteins, troponin and tropomyosin, both of which could modulate bite strength, Reiser decided to find out whether the rodent jaw versions of these proteins are carnivore-like or more similar to those of other rodents (p. 1077).

Separating jaw and limb muscle components of 27 species – ranging from rodents and marsupials to bats, omnivores and carnivores – on electrophoresis gels, checking their identities using antibodies and measuring the proteins' masses, Reiser and his colleagues found that almost all of the rodents had the carnivore type of myosin in their jaw muscles. However, when Reiser and his co-workers analysed the expression patterns of the different forms of troponin and tropomyosin, they found that the rodents produced a different form of tropomyosin from the carnivores, and the marsupials' troponin and tropomyosin proteins were intermediate between the two.

Comparing the animals' dining habits with their troponin and tropomyosin patterns, Reiser suspects that having rodent-like troponin and tropomyosin allows rodents to nibble hard and fast while having carnivore-like proteins allows meat eaters to grip on hard for long periods. However, Reiser points out that omnivores and carnivores have similar distributions of both proteins despite their different dining habits, while the marsupials all have similar protein expression patterns despite having a wide range of diets. He is keen to find out more about the contractile performance of jaw-closing muscles to better understand the protein expression patterns that he has found.

10.1242/jeb.057299

Bicer, S., Patel, R. J., Williams, J. B. and Reiser, P. J. (2011). Patterns of tropomyosin and troponin-T isoform expression in jaw-closing muscles of mammals and reptiles that express masticatory myosin. *J. Exp. Biol.* **214**, 1077-1085.

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