Inside JEB is a twice monthly feature, which 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

WHEN THE PRESSURE DROPS, BEES SUCK

Watching orchid bees (*Euglossia imperialis*) busily sucking up nectar from flowers in their native Panama and Costa Rica made Brendan Borrell from the University of California, Berkeley, wonder what factors affect how bees feed. Many bees feed with their tongues, but orchid bees sup nectar through a proboscis, a long tube which they fold up and flatten when not in use. To suck up nectar, a bee contracts muscles which expand a compartment inside its head. This reduces the air pressure inside the compartment and the proboscis relative to atmospheric pressure, forcing nectar up the tube. As well as the drop in pressure, the sweetness and viscosity of nectar also affects the rate at which a bee can slurp a snack. By enticing bees to feed from artificial flowers, Borrell investigated how nectar sweetness, viscosity and external air pressure affects a bee's feeding rate (p. 4901).

Capturing bees by luring them to baits, Borrell measured bees' feeding rates by weighing them before and after feeding to see how much of the sweet solution they consumed and by timing each meal. First he fed bees solutions containing different concentrations of sucrose. The feeding rate went down as the concentration went up, but sweeter solutions are more viscous, so Borrell wondered if bees were feeding more slowly in response to a solution's sweetness or viscosity.

Knowing that hawkmoths slurp faster as nectar sweetness increases, Borrell measured the bees' sucking rate while they fed on solutions with a constant viscosity, but different sweetnesses. Unlike hawkmoths, the bees' feeding rate didn't change, no matter how sweet the nectar was. Next Borrell tested the effects of increasing a solution's viscosity on feeding rate. While keeping sucrose concentration constant, he added an inert sugar called tylose, which makes solutions more viscous, but doesn't affect the sweetness. The bees' feeding rate went down as the viscosity increased, showing that a meal's viscosity influences how fast bees feed. Borrell explains that their ability to suck up nectar probably depends on how quickly the muscles inside the head compartment contract and how much force they produce to reduce the air pressure in the proboscis: thicker solutions are much harder to suck up.

Having shown that viscosity and not sweetness affects feeding rate, Borrell wanted to test how nectar intake rate would be affected by reducing atmospheric pressure. He reasoned that if he dropped external atmospheric pressure, the feeding rate for viscous nectars would decrease more than feeding rate for more liquid nectars because liquid nectars are much easier to drink. Placing bees inside a hypobaric chamber as they fed, he reduced atmospheric pressure from 100 kPa to 40 kPa, an equivalent move from sea level to the top of Mount Everest. But, the results didn't confirm his prediction. As atmospheric pressure decreased, the feeding rate declined by the same amount for viscous and runny nectars.

Borrell admits that this is a puzzling result, and suspects that it is because of the physical properties of the proboscis: it is similar to a collapsible tube, bulging or collapsing depending on the nectar flow rate. A bee has to keep the balance of forces in the proboscis just right to keep the nectar flowing; if not, it could go hungry.

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Borrell, B. J. (2006). Mechanics of nectar feeding in the orchid bee *Euglossa imperialis*: pressure, viscosity and flow. *J. Exp. Biol.* **209**, 4901-4907.

SWIMMING SECRETS

What do a sperm, a nematode and a lamprey all have in common? Apart from being good swimmers, they all use a similar type of movement to get around: 'eel-like', or anguilliform swimming, where swimmers propel themselves forwards by sending waves down the entire body. Scientists want to understand the link between body movements and the forces that propel the body forwards, as well as the efficiency of anguilliform swimming, explains Petros Koumoutsakos at ETH, Zürich, Switzerland. Together with colleague Stefan Kern he built a three-dimensional computer model of anguilliform swimming, and found that the computerised creatures swam in two distinctly different ways, depending on whether they are swimming to optimise efficiency of propulsion, or speed (p. 4841).

First the team built their computer model of a swimming eel-like fish. The model estimated the forces generated along the body and how these forces propelled the animals forward. Koumoutsakos explains that they allowed their model fish to flex and deform, but didn't program the fishes' exact body movements into their model as they wanted it to mimic nature, wondering: 'what kind of motion would evolutionary processes generate?' Instead, they programmed the model to select fish that swam with optimum efficiency, or optimum speed, and then examined the body movements that caused the fish to swim this way.

To select speedy or efficient swimmers, they put their computerised subjects through their paces by selecting 'parents', letting the computer program alter the fishes' body movements to produce 'children' with different swimming styles. The model then chose the children who swam the fastest, or the most efficiently, to be the parents of the next generation. The process continued through many cycles in the computer until swimming performance didn't improve any further.

The team found that swimmers 'bred' to be efficient, and those bred to be speedy, developed individual swimming styles. The bodies of efficient swimmers undulated from side-to-side down the entire body length, and the tail and the middle of the body generated the thrust needed to propel the animals forward. While this swimming style was more leisurely, the propulsion was more efficient than fast swimming. When the model selected speedy swimmers, the computerised eels kept the front part of the body straight during swimming, generating most of the thrust in the tail. They swam 40% faster than efficient swimmers, but their propulsion was 60% less effective. The model's results suggest that there is a link between body movements and swimming for different outcomes: quickly to pounce on unsuspecting prey or escape from hungry predators; or efficiently to travel long distances.

Finally, the team found both types of swimmer shed vortex rings and lateral jets of water behind them as they swam along, similar to those measured by researchers studying live swimming eels. Not only does the model show that electronic anguilliform swimmers modify their swimming style according to whether they want to swim quickly or efficiently, but also that the model will help researchers studying the forces in live swimming animals, which are difficult to measure.

10.1242/jeb.02649

Kern, S. and Koumoutsakos, P. (2006). Simulations of optimized anguilliform swimming. *J. Exp. Biol.* **209**, 4841-4857.

ULTRASONIC KATYDIDS

Searching for ultrasonically singing katydids in the Colombian rainforest, Fernando Montealegre-Z and Glenn Morris of the University of Toronto found some insects who can really hit the heights. Having transported the insects back to his hotel room in Cali, Colombia, Morris switched on his ultrasound detector and was astonished to discover that the insects were singing at an ultrasonic frequency of 130 kHz, higher than other ultrasonic singers he had recorded before at 83-106 kHz. Intrigued by the insect's 130 kHz ultrasonic song, Montealegre-Z and Morris teamed up with Andrew Mason to examine the song in more detail and find out how it was produced (p. 4923).

Almost all male katydids sing to serenade the ladies by rubbing their forewings together, and many sing ultrasonically above the 20 kHz upper limit of human hearing. One wing has a 'file', a modified vein with teeth on it, while the other wing acts as a 'scraper'. As the insect closes its wings, the scraper moves over the teeth at a certain frequency, causing the wings to oscillate and produce sound at the same frequency. As the wings close faster, the scraper travels faster over the teeth, producing higher frequency sounds, but this is limited by the speed of the wing muscle contraction. Would this method of sound production work for the high ultrasonic insects?

To investigate, the team recorded the katydid song using sound recording equipment capable of picking up bats' ultrasonic calls, and analysed the sound waves. They found that the insects sang a song containing trains of pulses, separated by silent intervals, at 123-129 kHz. This was in contrast to katydids singing ultrasonically at frequencies below 40 kHz, which produce calls made of continuous pulses.

To find out how the high ultrasonic singers' wings were moving to produce the sound, Montealegre-Z explains that the team used high-speed video recordings and stuck small pieces of reflective tape on the wings of some animals, using light-sensitive diodes to pick up the reflections off the moving wings while the insects were singing. This way, the team could correlate the speedy wing movements with the waves of sound. They found that the wing movements of high ultrasonic singers were too slow to account for the high frequency sound, so the team looked at the structure of the scraper more closely to see if anything in its structure could help explain the discrepancy.

Scrutinising the scraper under an electron microscope, they found that the scraper in high ultrasonic katydids was attached to a much larger piece of bendy cuticle than the scrapers in katydids that sing below 40 kHz. They suspect that this feature is responsible for a different sound producing mechanism: rather than continuously moving the scraper over a large portion of the file, the scraper gets stuck behind one of the teeth and bends, storing elastic energy as the wings slowly close. When the scraper can't bend any more, it springs forward very quickly over a group of teeth, generating a single ultrasonic pulse. This might help save the energy needed to contract the wing muscles at high speed, but does mean that the katydids can't produce a long-lasting pulse, as they need to pause the scraper between sound pulses to store up elastic energy.

One mystery still remains, though. Ultrasonic sounds don't travel well in dense, wet jungle, so the team are planning to investigate if the katydids are somehow exploiting their jungle environment to get the message across, or if their songs are falling on deaf ears.

10.1242/jeb.02650

Montealegre-Z, F., Morris, G. K. and Mason, A. C. (2006). Generation of extreme ultrasonics in rainforest katydids. *J. Exp. Biol.* **209**, 4923-4937.

IMMUNE COSTS OF INCUBATING EGGS

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Many parents will probably agree that raising a brood is a strain, but a female eider duck has a tougher job than most. A female duck sits tight when incubating her clutch without eating a morsel, losing weight in the process. Scientists have shown that acquired immunity – when the immune system makes antibodies in response to invading pathogens – decreases in female ducks during the fast. Researchers suspect that the stress hormone corticosterone, which causes the body to break down proteins for energy during the final stages of the fast and which also affects immune responses, might be responsible. To investigate, Sophie Bourgeon and Thierry Raclot at CNRS, Strasbourg, France, implanted corticosterone pellets under the skin of incubating ducks to find out how extra corticosterone affects ducks' immunity (p. 4957). The implanted ducks lost 35% more weight than ducks with no implants, and the levels of immune system proteins called immunoglobulins, which include antibodies, decreased by twice as much. These results suggest that corticosterone plays an important role in affecting female ducks' immunity while they are incubating their eggs.

10.1242/jeb.02651

Bourgeon, S. and Raclot, T. (2006). Corticosterone selectively decreases humoral immunity in female eiders during incubation. *J. Exp. Biol.* **209**, 4957-4965.

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