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

FLYING HIGH ON SUGAR

Picture by Kenneth C. Welch

Hovering hummingbirds have some of the highest metabolic rates ever recorded. Fuelled almost directly by the nectar they consume, hummingbirds easily maintain metabolic rates 10 times greater than the most highly trained human athletes. But hummingbirds aren't the only creatures that push the metabolic limits. A few varieties of bats also hover while sipping nectar. Knowing that the metabolisms of hummingbirds and nectarivorous bats have evolved to perform similar feats, Ken Welch, Gerardo Herrera and Raul Suarez wondered whether the bat's metabolism was more human-like, fuelling hovering flight with onboard stores, or hummingbird-like, fuelled with newly ingested sugar (p. 310). Travelling to Colima, Mexico, to work with Herrera, Welch and Suarez prepared to discover which fuel the bats had selected.

Trapping the Pallas' long-tongued bats at night with mist nets in a local banana plantation, the team gathered 12 of the tiny mammals ready to measure their metabolic rates. But before the team could put the hoverers through their paces, they had to find a way to distinguish whether the bats were burning fuel laid down earlier, or sugars consumed from nectar minutes before.

Welch explains that it is possible to distinguish whether animals are burning carbohydrate or fat by measuring the ratio of the carbon dioxide exhaled to the oxygen consumed. According to Welch, when the ratio is approximately 0.7, animals are burning fat. However, if the ratio rises to 1.0, the animal has switched from using fat as a fuel, to sugars or carbohydrates. Tempting the tiny mammals to hover with their heads in a bat-sized respirometry mask, the team measured the mammals' oxygen consumption and carbon dioxide production rates. Initially, the mammals burned fat, but the hovering bat's metabolism soon switched to burning carbohydrate almost exclusively.

But were the bats burning carbohydrates from their body stores, or sugars from nectar they had just ingested? Carbohydrates and sugars all contain carbon, and carbon is naturally found in 3 different forms in the environment (C^{12}, C^{13} and C^{14}). Welch explains that the ratio of C^{13}/C^{12} incorporated by plants into their structures depends on the plant's physiology; the C^{13}/C^{12} signatures of sugar cane and sugar beet are completely different. The teams' strategy was to feed the bats on a sugar beet-derived diet for several weeks before feeding them sugar cane sucrose while hovering. By measuring the C^{13}/C^{12} signature in their exhaled carbon dioxide, the team could distinguish whether the bats were burning recently consumed nectar or carbohydrates from sugar beet-derived body stores.

Storing the bat's breath in sealed vials, the team returned to their Santa Barbara lab to analyse the gas's composition and found that the hovering bats were burning the sugar cane sucrose they had consumed less than an hour earlier. Welch explains that the finest human athletes can only derive 30% of their energy from recently consumed sugars, but almost 80% of the bat's energy was coming from cane sugar consumed during the previous hour. Amazingly the bat's metabolism was more similar to a hummingbird's than a mammal's.

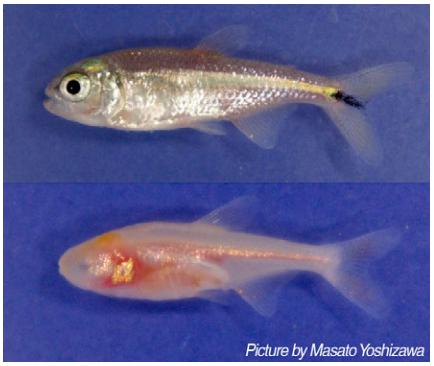
10.1242/jeb.016469

Welch, K. C., Jr, Herrera M., L. G. and Suarez, R. K. (2008). Dietary sugar as a direct fuel for flight in the nectarivorous bat *Glossophaga soricina*. *J. Exp. Biol.* **211**, 310-316.

BLIND LARVAE SENSE LIGHT

Masato Yoshizawa describes his discovery that blind cavefish larvae retain a shadow response as pure luck. Deprived of light for a million years, the fish had lost many of the characteristics associated with surface dwellers, including their eyes. Yet the tiny larvae clearly responded when a shadow passed slowly over them. Intrigued, Yoshizawa and William Jeffery began investigating the apparently impossible (p. 292).

But how had the team discovered this intriguing phenomenon? Cleaning out the bowls where Mexican tetra embryos develop into larvae, Yoshizawa had noticed that the larvae of surface-dwelling tetras reacted as he moved his pipette above them; they began swimming to the surface. Yoshizawa explains that *Xenpous* larvae seek shelter in shadows by swimming towards them. Could blind tetra larvae from


Picture by Masato Yoshizawa

cave-dwelling colonies be reacting in the same way? Yoshizawa explains that 'if they had the same response it would be interesting, and if there was no response, it would be reasonable'. So he held an object above the blind cavefish larvae's bowl; the tiny swimmers began to ascend. Despite having little or no reason to sense light and dark, the larvae moved towards the shadow. So how were they sensing the shadow?

Yoshizawa and Jeffery reasoned that it could be one of two ways. Although the adult fish lack functioning eyes the embryos begin developing eye structures early in their development, before they are lost again later. Could the larvae's eyes pick out the shadow? Or maybe the cavefish larvae had retained another light sensitive organ, the pineal gland. Yoshizawa decided to test if he could detect the photosensitive pigment rhodopsin using an antibody sensitive to forms of the protein found in the pineal gland and eye. Choosing cave and surface-dwelling larvae that reacted to shadows, Yoshizawa treated them with the antibody and checked where it detected rhodopsin: the pineal gland, and not the eyes, harboured the photosensitive pigment. And when he tested the shadow responses of surface and cavefish larvae whose eyes had been removed, they retained their shadow response only if they retained the pineal gland too: the pineal gland was the light sensitive organ that sent the larvae towards cover.

But why have the cavefish preserved a light sensitive organ and a shadow response after a million years of natural selection? Yoshizawa and Jeffery aren't sure, but they have plenty of ideas. For a start, caves aren't always dark; it depends how deep into the system you are, and sometimes there are cave-ins and light floods in. But Yoshizawa points out another possibility; the pineal gland supplies the body with melatonin, a key reproductive and seasonal growth hormone. Yoshizawa suspects that the selective pressure to retain the body's melatonin supply was greater than the passive accumulation of errors which could have led to the pineal gland's loss. So the larvae's light sensitivity could just be a case of serendipity. Whatever the reason, the cavefish larvae don't seem concerned; whenever Yoshizawa casts a shadow, they head for it.

10.1242/jeb.016477

Yoshizawa, M. and Jeffery, W. R. (2008). Shadow response in the blind cavefish *Astyanax* reveals conservation of a functional pineal eye. *J. Exp. Biol.* **211**, 292-299.

DAMSELFISH SEE COLOUR


Picture by Ulrike Siebeck

Anyone lucky enough to dive on a coral reef knows they are truly breath taking. And the colours must be even more vibrant to the species that live there. Or are they? Ulrike Siebeck explains that although many marine species have several photoreceptors that detect light of different wavelengths, there was no direct evidence that they actually perceive colour; 'you need behavioural experiments to demonstrate that fish are using it' says Siebeck. So she teamed up with Guy Wallis and Lenore Litherland and headed off to Lizard Island Research Station on the Great Barrier Reef to test out Ambon damselfish's colour vision (p. 354).

According to Siebeck, capturing the yellow fish was relatively straightforward. Equipped with a hand net and Ziploc bag, she and Litherland went SCUBA diving, trapping fish on the island's reefs ready to test their colour recognition skills. But learning how to train the fish was far more tricky; the team had to get into 'fish psychology' to learn how to tell the fish what to do. Fortunately the fish turned out to be quick learners, 'possibly because they are territorial and quickly recognise novel objects placed in their territory' explains Siebeck. According to Siebeck the damselfish try to nudge intruders out of their territory. So she and Wallis took advantage of this behaviour and trained each fish to nudge 10 times at a coloured latex finger before rewarding them with a fish food snack. Having trained one group of fish to recognise a rubber finger painted yellow and another group to recognise a finger painted blue, Siebeck and Wallis offered each fish a choice between blue and yellow fingers and watched to see which colour the fish opted for. Amazingly the yellow trained fish selected the yellow finger on 95% of occasions, and the blue trained fish got the blue finger more than 91% of the time.

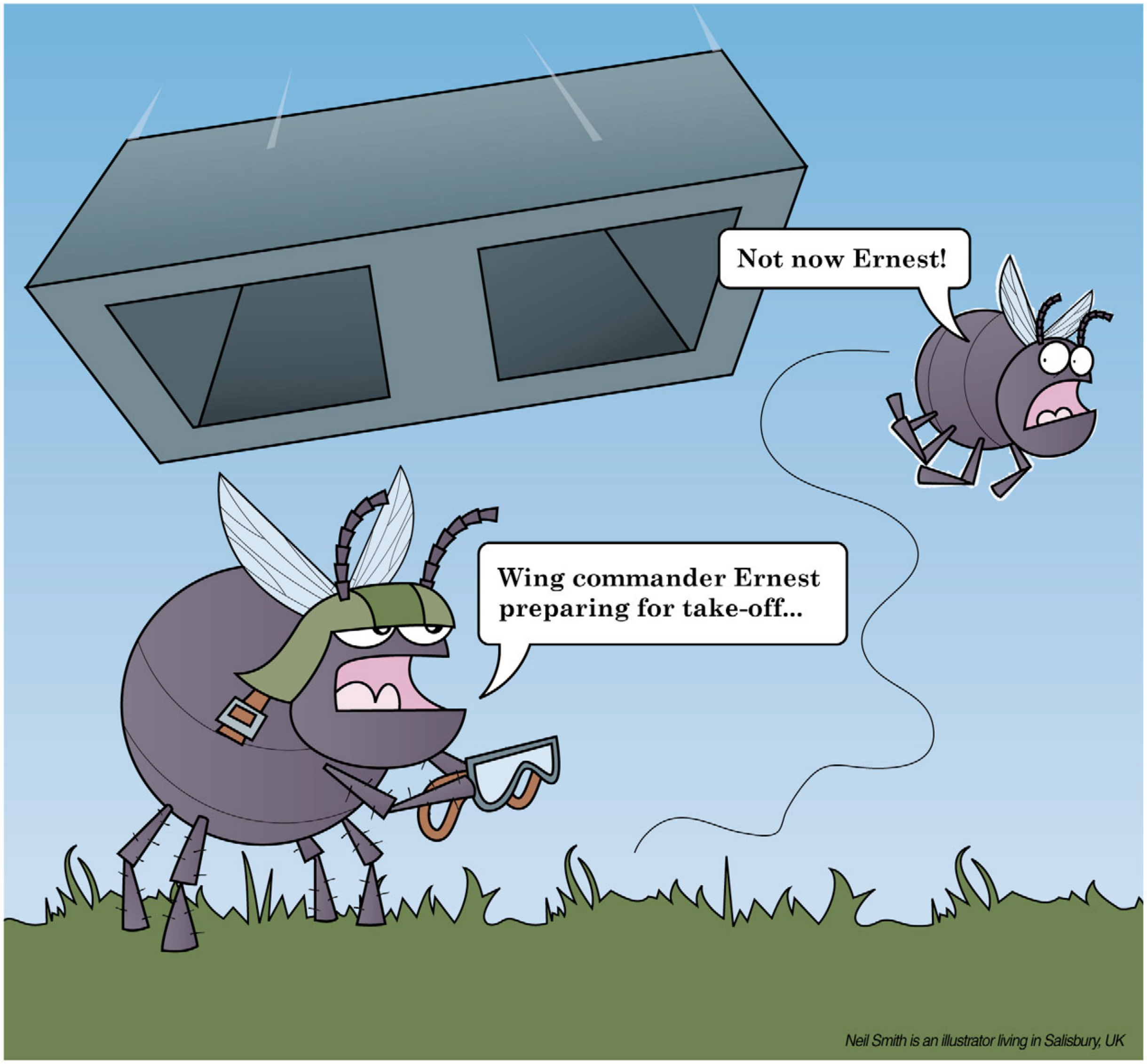
But were the fish simply differentiating between light and dark colours, or genuinely distinguishing between blue and yellow? Siebeck and Wallis added black or white paint to the yellow and blue paints to darken or lighten the colours before testing whether the fish could distinguish the different shades. Offering the fish a choice between their trained colour and one of three shades of the other, the fish correctly nudged at their trained colour over 90% of the time. And when the team offered the fish a choice between a lighter or darker shade of their trained colour and the distractor colour, they successfully selected the colour they'd been trained to recognise almost 90% of occasions. Finally Siebeck offered the fish the choice between a shade of their trained colour and a shade of the distractor colour. Again the Damselfish consistently recognised their trained colour, regardless of brightness: they have colour vision. 'We were very excited that they could do it so well' says Siebeck.

Having found that the fish are remarkably quick learners, and that their colour vision is surprisingly accurate, Siebeck is confident that the damselfish can teach us more about how they see their vibrant watery world.

10.1242/jeb.016485

Siebeck, U. E., Wallis, G. M. and Litherland, L. (2008). Colour vision in coral reef fish. *J. Exp. Biol.* **211**, 354-360.

TAKE-OFF TRADE OFF



When a fly launches itself from a surface, it has a choice of techniques; it can simply fling itself into the air when startled, or it can coordinate its first wing beat with a jump for a stable voluntary departure. The two approaches are governed by different neural pathways linking the insect's brain to its wings and legs. However, the escape pathway, coordinated by the giant fibre interneurons, is essentially a reflex and much simpler than the voluntary take-off pathway. Gwyneth Card and Michael Dickinson wondered why flies have developed two take-off pathways when one would seem sufficient (p. 341). Analysing high speed film of both techniques, the team realised that beating the wings during a voluntary take off results in a slow but controlled departure. However, when the flies launched themselves by leaping to escape, they only unfurled their wings several wing beats later, resulting in a fast but relatively chaotic take off. Card and Dickinson suspect that the flies trade off stability for speed during an escape. And having scrutinized the flies' preparations for take off, the team propose four possible independent take-off pathways, suggesting that flies could tailor their escape to a threat's significance.

10.1242/jeb.016493

Card, G. and Dickinson, M. (2008). Performance trade-offs in the flight initiation of *Drosophila. J. Exp. Biol.*, **211**, 341-353.

Kathryn Phillips
kathryn@biologists.com