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Inside JEB

HUMMINGBIRDS MAKE FLYING BACKWARDS LOOK EASY


Nir Sapir

Backing up usually isn't easy, yet when Nir Sapir observed agile hummingbirds visiting a feeder on his balcony in Berkeley, California, he was struck by their ability to reverse. 'I saw that they quite often fly backwards', he recalls, adding that they always reverse out of a bloom after feasting. However, when he searched the literature he was disappointed to find that there were hardly any studies of this particular behaviour. 'This was a bit surprising given that they are doing this all the time', Sapir says, explaining that the tiny aviators visit flowers to feed once every 2–10 min. 'I thought that this was an interesting topic to learn how they are doing it and what the consequences are for their metabolism', Sapir says, so he and his postdoc advisor, Robert Dudley, set about measuring the flight movements and metabolism of reversing hummingbirds (p. 3603).

Capturing five Anna's hummingbirds at a feeder located just inside a University of California Berkeley laboratory window, Sapir trained the birds to fly in a wind tunnel by tricking the birds into feeding from a syringe of sucrose disguised as a flower. He then filmed each bird as it hovered to feed before returning to the perch when satisfied. Knowing that the bird would return to the feeder again soon, Sapir turned on the air flow when the hummingbird arrived, directing the 3 m s^{-1} flow so that the bird had to fly backwards against the wind to remain stationary at the 'flower'. Then he repeated the experiment with the syringe feeder rotated through 180 deg while the hummingbird flew forward into the wind to stay in place.

Analysing the three flight styles, Sapir recalls that there were clear differences between forward and backward flight. The hummingbirds' body posture became much more upright as they flew backward, forcing them to bend their heads more to insert their beaks into the simulated flower. In addition, the reversing birds reduced the inclination of the plane of the wing beat so that it became more horizontal. And when Sapir analysed the wing beat frequency, he found that the birds were beating their wings at 43.8 Hz, instead of the 39.7 Hz that they use while flying forward. 'That is quite a lot for hummingbirds because they hardly change their wing beat frequency', explains Sapir.

Repeating the experiments while recording the birds' oxygen consumption rates, Sapir says, 'We expected that we would find high or intermediate values for metabolism during backward flight because the bird has an upright body position and this means that they have a higher drag. Also, the birds use backward flight frequently, but not all the time, so we assumed that it would not be more efficient in terms of the flight mechanics compared with forward flight.' However, Sapir was surprised to discover that instead of being more costly, backward flight was as cheap as forward flight and 20% more efficient than hovering. And when Sapir gently increased the wind flow from 0 m s^{-1} in 1.5 m s^{-1} steps he found that their flight was cheapest at speeds of 3 m s^{-1} and above, although the birds were unable to fly backwards above 4.5 m s^{-1}.

Describing hummingbirds as insects trapped in a bird's body, Sapir adds that the fluttering flight of hummingbirds has more in common with insects than with their feathered cousins and he is keen to find out whether other hovering animals such as small songbirds and nectar-feeding bats can reverse too.

10.1242/jeb.080002

Sapir, N. and Dudley, R. (2012). Backward flight in hummingbirds employs unique kinematic adjustments and entails low metabolic cost. *J. Exp. Biol.* **215**, 3603-3611.

Kathryn Knight

CHOCOLATE MAKES SNAILS SMARTER

Type the word 'superfood,' into a web browser and you'll be overwhelmed: some websites even maintain that dark chocolate can have beneficial effects. But take a closer look at the science underpinning these claims, and you'll discover just how sparse it is. So, when University of Calgary undergraduate Lee Fruson became curious about how dietary factors might affect memory, Ken Lukowiak was sceptical. 'I didn't think any of this stuff would work', Lukowiak recalls. Despite his misgivings, Lukowiak and Fruson decided to concentrate on a group of compounds – the flavinoids – found in a wide range of 'superfoods' including chocolate and green tea, focusing on one particular flavonoid, (-)epicatechin (epi). However, figuring out how a single component of chocolate might improve human memory is almost impossible – too many external factors


Ken Lukowiak

influence memory formation – so Lukowiak turned to his favourite animal, the pond snail *Lymnaea stagnalis*, to find out whether the dark chocolate flavonoid could improve their memories (p. 3566).

Lukowiak explains that the molluscs can be trained to remember a simple activity: to keep their breathing tubes (pneumostomes) closed when immersed in deoxygenated water. He explains that pond snails usually breathe through their skins, but when oxygen levels fall, they extend the breathing tube above the surface to supplement the oxygen supply. However, the snails can be trained to remember to keep the breathing tube closed in deoxygenated water by gently tapping it when they try to open it, and the strength of the memory depends on the training regime.

First, Fruson identified an epi concentration – 15 mg ml^{-1} pond water – that didn't affect the snails' behaviour; 'We have to be sure that we're not looking at wired animals', chuckles Lukowiak. Then, the duo tested the molluscs' memories. Explaining that a half-hour training session in deoxygenated water allows the snails to form intermediate-term memories (lasting less than 3 h) but not long-term memories (lasting 24 h or more), Fruson and Lukowiak wondered whether epi would improve the snail's memories, allowing them to form long-term memories after shorter memory training. Amazingly, when Fruson plunged the molluscs into deoxygenated water to test their memories a day later, they remembered to keep their breathing tubes closed. And when the duo provided the snails with two training sessions, the animals were able to remember to keep their breathing tubes shut more than 3 days later. Epi had boosted the molluscs' memories and extended the duration, but how strong were the epi-memories?

According to Lukowiak, memories can be overwritten by another memory in a process called extinction. However, the original memory is not forgotten and if the additional memory is stored weakly, it can be lost and the original memory restored. So, Fruson and Lukowiak decided to find out how strong the epi-boosted memory was by trying to extinguish it. Having trained the snails, the duo then tried to replace it with a memory where the snails could open their breathing tubes. However, instead of learning the new memory, the epi-trained snails stubbornly kept their breathing tubes shut. The epi-memory was too strong to be extinguished.

The duo also found that instead of requiring a sensory organ to consolidate the snails' memories – like their memories of predators triggered by smell – epi directly affects the neurons that store the memory. So, Lukowiak is keen to look directly at the effect that epi has on memory neurons and adds that the cognitive effects of half a bar of dark chocolate could even help your grades: good news for chocoholics the world over.

10.1242/jeb.080036

Fruson, L., Dalesman, S. and Lukowiak, K. (2012) A flavonol present in cocoa [(–)epicatechin] enhances snail memory. *J. Exp. Biol.* **215**, 3566-3576.

Kathryn Knight

ACHILLES TENDON UNAFFECTED BY LONG RUNS

Posited as one of the main adaptations that allowed early humans to adopt a terrestrial lifestyle, the Achilles tendon has played a significant role in our evolution. 'It is one of the special characteristics in the human body that facilitate our endurance running and it may have assisted in the pursuit of prey', says Jussi Peltonen and colleagues from the University of Jyväskylä, Finland. However, this critical tendon has an unfortunate tendency to rupture, leading many scientists to query why it is so vulnerable to damage when it has played such an essential role in our survival. Explaining that Achilles tendons rupture when they have lost stiffness, the Finnish team wondered whether long-distance endurance exercise might weaken the

Tero Takalo-Eskola

tendon, reducing its stiffness to make it increasingly vulnerable to damage (p. 3665).

Measuring the stiffness of the Achilles tendons of runners before and shortly after the Finlandia Marathon (42 km) and Half Marathon (21 km), the team found that the tendon's stiffness hadn't changed at all. Despite repeatedly stretching and releasing the enormous tendon over the 20,000 strides that it took most of the competitors to complete the longer course, their Achilles tendon showed no sign of fatigue, maintaining a stiffness of around 200 N mm^{-1}. However, after completing the race, the athletes did show signs of physical fatigue, running less efficiently and consuming more oxygen during a brief run an hour after completing the marathon. In addition, many of the runners had adjusted their running style, with some switching from running on their toes to landing on their heels, while others switched to running with a more flat-footed gait.

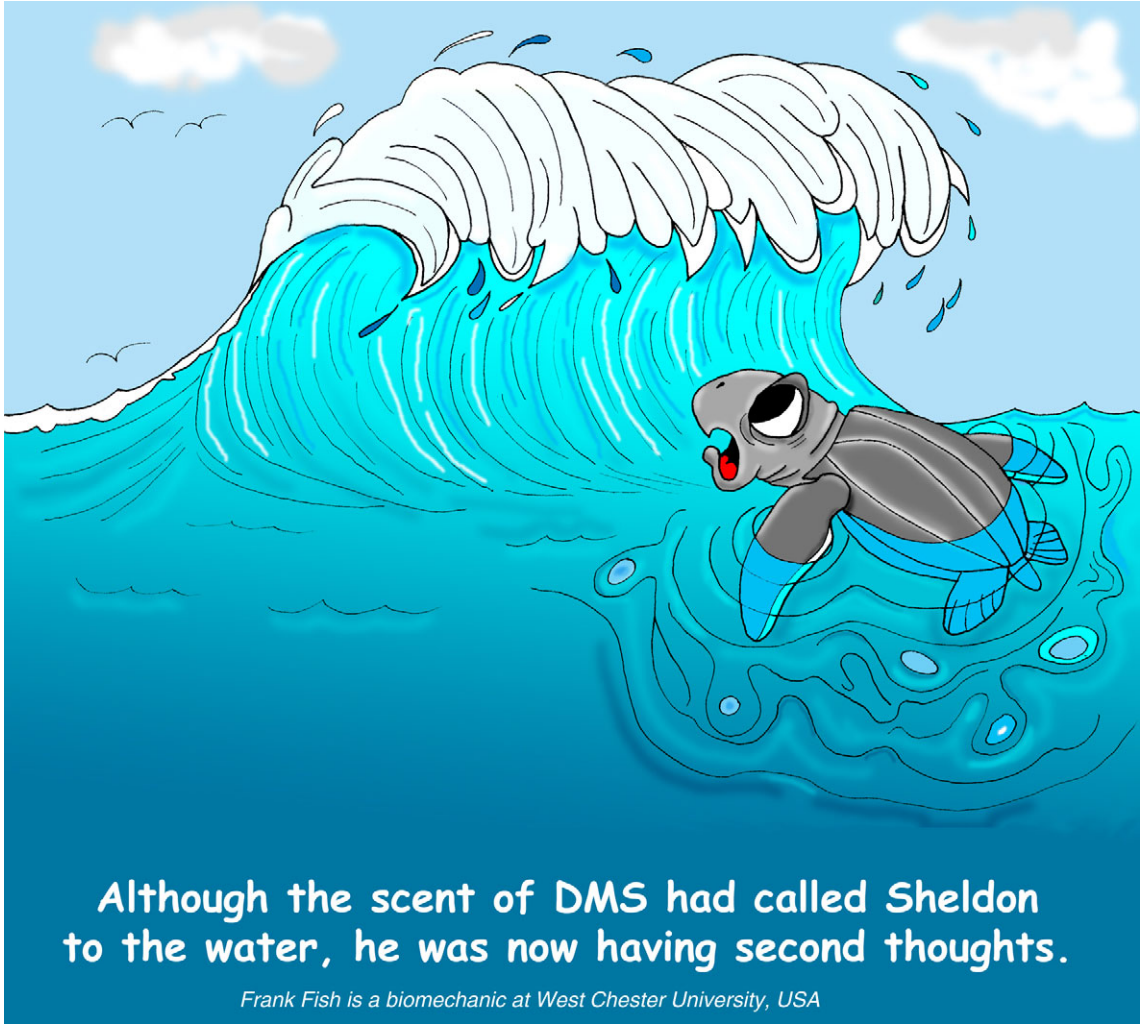
'The Achilles tendon of physically active individuals seems to be able to resist mechanical changes under physiological stress. We therefore suggest that natural loading, like in running, may not overstress the Achilles tendon or predispose it to injury', says the team, adding that poor-quality footwear and incorrect technique probably pose a more significant threat.

10.1242/jeb.080051

Peltonen, J., Cronin, N. J., Stenroth, L., Finni, T. and Avela, J. (2012). Achilles tendon stiffness is unchanged one hour after a marathon. *J. Exp. Biol.* **215**, 3665-3671.

Kathryn Knight

HATCHLING LOGGERHEAD TURTLES PICK UP DMS



Within minutes of breaking out of their shells, newly hatched loggerhead turtles embark on what is possibly the longest known migration. Spanning entire ocean basins, crossing barren dead zones and verdant ocean frontal systems, the young voyagers must rapidly identify and fill up in lush foraging grounds in preparation for leaner times ahead. So how do these turtles identify fertile foraging grounds? Explaining that loggerheads dine on jellyfish – which congregate to feast on colossal photyplankton blooms – Courtney Endres and Ken Lohmann from the University of North Carolina at Chapel Hill, USA, add that the photoplankton release a distinctive odour, dimethyl sulphide (DMS), into the air when consumed. As other oceanic foragers are known to home in on this scent when pursuing prey, the duo decided to test whether loggerhead turtles can also pick up the odour of DMS (p. 3535).

Allowing 5-month-old juveniles to swim in an open arena, Endres and Lohmann flooded the airspace above the water with odours ranging from jasmine, cinnamon and lemon to DMS, as well as unscented water, and filmed the youngsters' responses to find out whether they responded to novel odours or specifically to DMS.

Having invited Stacy Zhang and Julie Gassmann to count how long each turtle poked its nose above the surface, it was clear that the turtles spent significantly more time sniffing the DMS odour than the novel odours wafting over them. 'The failure of turtles to respond to cinnamon, jasmine and lemon odours implies that the response elicited by DMS is not a generalized response to all novel airborne odorants', the duo says.

Suggesting that DMS odour could help the turtles to identify foraging areas and remain within them, the duo is keen to find out whether the reptiles actively exploit the cue and whether they use other odours to keep them on track during their vast odyssey.

10.1242/jeb.080044

Endres, C. S. and Lohmann, K. J. (2012). Perception of dimethyl sulfide (DMS) by loggerhead sea turtles: a possible mechanism for locating high-productivity oceanic regions for foraging. *J. Exp. Biol.* **215**, 3535-3538.

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