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Inside JEB

SPARROWS' FAT-FUELLED FLIGHT

Jay McFarlan

On a thousand-mile road trip from Ontario to Mississippi, exercise physiologist Jay McFarlan developed a newfound respect for white-throated sparrows. Each autumn these tiny birds leave their breeding grounds, the boreal forests of northern Ontario, Canada, to migrate as far south as the Gulf of Mexico. 'During our 17-hour drive, it struck me as an amazing feat that these birds travel this entire distance on their own wing power,' McFarlan says. So how do they accomplish it?

Migrating birds must rely on their 'spare tyre' to fuel their flight, McFarlan explains, because fat is the most weight-efficient fuel for long journeys. But from what we know about mammals, this shouldn't be possible: during high-intensity endurance exercise, mammals burn carbohydrates rather than fat. If mammals can't burn fat during high-intensity exercise, how do birds manage it? To fuel flight, fatty acids from a bird's fat stores must pass across the muscle cell membrane to reach the mitochondria – the cell's powerhouses. Christopher Guglielmo of the University of Western Ontario, Canada, suspected that migrating birds must ramp up the production of proteins that shuttle fatty acids across the muscle cell membrane (p. 2934).

Two such transport proteins, fatty acid translocase and plasma membrane fatty acid-binding protein, are known to exist in mammals – but do they also exist in birds, and are they more abundantly expressed during migration? To find out, McFarlan and Guglielmo teamed up with Arend Bonen of the University of Guelph, Canada, one of the first researchers to characterise these transport proteins in the muscles of exercising mammals. First, the team caught wintering white-throated sparrows in Mississippi and migrating birds in Ontario during spring and autumn, and took samples of their chest muscles. Using the online chicken genome to locate avian DNA sequences homologous to the mammalian transport proteins, they were able to identify these proteins in white-throated sparrow muscle tissue. 'This is the first evidence that these proteins exist in non-mammals,' says McFarlan. 'The fact that these genes are so highly conserved across species speaks to their important physiological function.'

Next, the team investigated whether sparrows express more of these genes during migratory seasons. Sure enough, mRNA expression of these genes in birds caught during spring and autumn was 70% to 1000% higher than in those caught during the winter, while protein expression of one of the genes was 110% higher during migration than during the winter. So not only are these genes expressed in birds, but they are particularly highly expressed during migratory seasons, enabling faster fat transport to the muscles' mitochondria. To make use of this increased fuel influx, migrating birds also need to boost their ability to metabolise fatty acids. To test whether birds have this ability, the team measured the maximal activity of three key fat-oxidising enzymes, and found that enzyme activity also increased dramatically in the sparrows' muscles during migration. 'All the steps in the chain are neatly matched,' McFarlan says.

To cope with the gruelling demands of migration, it appears that birds crank up fat transport to their muscles and bolster their ability to burn fat. 'Our results suggest that simple biochemical changes can have a big impact on an animal's performance,' McFarlan concludes.

Yfke Hager

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McFarlan, J. T., Bonen, A. and Guglielmo, C. G. (2009). Seasonal upregulation of fatty acid transporters in flight muscles of migratory white-throated sparrows (*Zonotrichia albicollis*). *J. Exp. Biol.* **212**, 2934-2940.

ANTS TAKE DISTANCE MEASUREMENT IN THEIR STRIDE

Scurrying across the desert floor, the Sahara Desert ant, *Cataglyphis fortis*, spends its life foraging for food. But with few landmarks to guide them back to their nests, the insects are dependent on their internal navigation systems for a safe return home. One of their strategies is to record exactly how far they have strayed. Harald Wolf from the University of Ulm, Germany, explains that the ants sum the distances that they cover in each step so that they know how far they have gone. But whether they record distance by keeping track of the rhythmic electrical nerve impulses that control their leg muscles or monitor the positions and movements of their legs, wasn't clear. Curious to find out how robust the ant's pedometer is, Wolf and his colleagues, Matthias Wittlinger and Kathrin


Kathrin Steck

Steck, decided to see if they could effectively 'break' it. Could they create a situation where the pedometer failed?

Travelling to Tunisia, Wolf and his colleagues put the desert ants through their distance measuring paces. Knowing that foragers often lose limbs and antennae in skirmishes with ants from other nests, and yet continue foraging for the colony, Wittlinger decided to test whether the insects' pedometers continue to function despite injury (p. 2893).

First, the team trained ants to run from their nest along a featureless 10 m channel to a foraging site well stocked with cookie crumbs. Once the ants had set the distance between the nest and crumb site in their pedometers, the team intercepted the insects, quickly removed the lower half of two of their four rear legs, allowed them to stock up on cookie crumbs, set them running along a parallel identical channel and asked them where they thought the nest was. If the insects' pedometers were damaged by the loss of their lower limbs, the foragers would begin searching for the nest in the wrong place, but if their pedometers were functioning accurately, the ants would begin searching for the nest 10 m from the crumb supply.

The ants always began searching for the nest after travelling the correct distance along the channel. And when the team completely removed two of the insects' four rear legs, the ants 'returned' successfully to the site where their pedometers told them the nest should be.

So the ant's pedometer seemed to be unaffected by limb loss but how would the insects fare while trying to negotiate uneven terrain? The team inserted corrugations along the entire length of the channel leading from the nest to the cookie crumb store to see how the insects coped with being wrong-footed by the uneven surface. The distances between two corrugation peaks ranged from a little more than one stride up to as much as two strides. Would the ants returning along the flat parallel channel overshoot the nest's location because of the additional distance travelled or would they take it all in their stride?

Again the ants were unperturbed. Despite stumbling and losing their footings on the outbound journey, the ants never lost track of their distance from the nest.

So how do the Tunisian desert ants keep track of the distances that they have travelled? Wolf suspects that the ants monitor sensory signals from the legs that actively bear weight and is keen to find out where these signals originate. He also admits that he was surprised that the ants' pedometers could not be disturbed, no matter what the team did.

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Steck, K., Wittlinger, M. and Wolf, H. (2009). Estimation of homing distance in desert ants, *Cataglyphis fortis*, remains unaffected by disturbance of walking behaviour. *J. Exp. Biol.* **212**, 2893-2901.

LIZARDS SENSE SUN COMPASS WITH PARIETAL EYE


Giulia Beltrami

Rats are quite content going for a swim, and scientists have capitalised on that to learn about the rodent's spatial memory. The animals can learn to swim to a platform submerged a few millimetres beneath the surface of a shallow pool, surrounded by familiar objects that help them get their bearings. But can the same aquatic approach be used to find out more about how lizards navigate? Augusto Foà and colleagues from the Università di Ferrara, Italy, decided to see whether ruin lizards (*Podarcis sicula*) that swim occasionally are able to find a ledge submerged just below the surface of a pool using only the sun for guidance (p. 2918).

Setting up a small outdoor pool surrounded by a high screen the team gently released individual lizards into the warm shallow water and trained them to locate a platform just above the surface of the water. Once the lizards were comfortable locating the ledge, Foà submerged it, released each lizard back in the centre of the pool and waited to see if it could still locate the ledge; it did. Finally the team took away the ledge, placed each lizard in the water in a random orientation and waited to see if the animal would home in on the correct location, despite the missing ledge. Each lizard looked around for a few moments and then doggy paddled over to the edge where the ledge should have been.

Having convinced themselves that the lizards could learn to find the platform in the pool as much as seven days after training, the team tested whether the reptiles were using the sun as a compass to locate the ledge by changing the animals' body clocks. Shifting some of the lizards' clocks back by 6 h and shifting others forward by 6 h, the team then released the lizards into the pool and checked which direction the animals thought their ledges were in. The lizards whose clock had been shifted back thought that the ledge was further round to the right, while the lizards whose body clock had been shifted forward thought the ledge was further round to the left. The animals were using the sun as a compass to locate their ledges.

Finally the team set out to test how the lizards sense the sun's position. Knowing that several scientists have suggested that the reptiles sense the sun as a compass with their parietal eye, situated on the top of their heads, the team decided to test whether the lizards could locate their ledges without their parietal eyes. Having covered the 'eye' with a paint blind and released the lizards in the centre of the maze, the team saw that the animals no longer headed decisively towards the ledge but headed off in random directions. And when the team repeated the experiment, but this time removed the sensory organ, the lizards also headed off in random directions, confirming that the lizards sense the sun as a compass with their parietal eye.

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Foà, A., Basaglia, F., Beltrami, G., Carnacina, M., Moretto, E. and Bertolucci, C. (2009). Orientation of lizards in a Morris water-maze: roles of the sun compass and the parietal eye. *J. Exp. Biol.* **212**, 2918-2824.

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