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INSIDE JEB

Do homing pigeons navigate with gyroscope in brain?

A homing pigeon. Photo credit: Andreas Trepte (www.photo-natur.de).

Human communication has long been associated with an unlikely companion, the homing pigeon; but how these pigeons find their way home is still largely a mystery. 'There is widespread agreement that pigeons are able to determine and maintain flight (compass) directions based on solar and magnetic cues,' says Hans-Peter Lipp from the University of Zurich, Switzerland, and Kwazulu-Natal University, South Africa. However, another piece of the puzzle – how the bird determines its position, known as the map sense – was unclear. Dissatisfied with the current theories – that pigeons navigate via an odour or geomagnetic map – and after decades of experience working with pigeons in the Swiss Army, Lipp was intrigued when he encountered Valeryi Kanevskyi from the High-Technologies Institute, Ukraine. 'Valeryi had formulated a simplistic yet astonishing theory,' recalls Lipp. The Ukrainian had suggested that the birds could use their memory of the gravity field at their home loft for guidance. 'I realised that he had solved the map problem by one simple assumption: birds must have a gyroscope in their brain,' says Lipp. However, before Lipp and Kanevskyi could begin searching for the elusive gyroscope, the duo had to prove that the birds are sensitive to distortions in gravitational fields (p. 4057).

'[We needed] to show that gravity anomalies without geomagnetic contamination would be effective in misleading pigeons', says Lipp, and fortunately Kanevskyi and Vladimir Entin, knew of just such a location in the Ukraine: a massive circular meteorite crater filled with sediment where gravity was weaker than usual. The team wondered whether crossing the edge of the crater could disrupt a pigeon's gyroscope navigation system and send the birds off in the wrong direction. Lipp and Nicole Blaser were also lucky to find a family of pigeon fanciers – the Widergolds – in the nearby town of Novoukrainka, Ukraine, who could train the birds. Then, over a series of days the duo released 26 of the trained birds, each equipped with a light-weight GPS tracker, from the middle of the crater and waited anxiously for their return.

Of the 18 pigeons that made it home, seven birds struck out in the correct direction and managed to cross the edge of the crater without deviating much from the bee-line home. However, other birds that set off in more random directions seemed to become disorientated at the edge of the crater. And when the birds crossed a second gravity disturbance, they also lost their bearing, setting new ones that split off in three different directions. Sergei Guskov and David Wolfer then compared the flight paths of the birds that encountered the gravity distortions with birds that had an unhindered return home and found that the disturbed birds' routes were much more widely dispersed than the unhindered groups and showed that the birds veered off most severely when they crossed the edge of the meteorite impact.

The team suggests that the birds initially set a bearing home by comparing their home gyroscope setting with their local gyroscope reading. However, some birds initially set the wrong bearing, often taking several days to correct the error and return home, suggesting that they rarely use the alternative navigation strategy of regularly checking the difference between their actual and anticipated return routes.

So it seems that perception of gravity plays a major role in guiding pigeons home and Lipp is keen to find out more about the cellular mechanisms that allow the birds to detect the weak gravitational forces that keep them on the straight and narrow.

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Blaser, N., Guskov, S. I., Entin, V. A., Wolfer, D. P., Kanevskyi, V. A. and Lipp, H.-P. (2014). Gravity anomalies without geomagnetic disturbances interfere with pigeon homing – a GPS tracking study. *J. Exp. Biol.* **217**, 4057-4067.

Kathryn Knight

European vinegar flies cope better with alcohol breakdown to hold their liquor

At first glance vinegar flies and humans might not seem to have much in common, but both have a taste for alcohol. Some ancient humans used alcohol (ethanol) produced by yeast fermentation to sterilise water and James Fry from the University of Rochester explains that vinegar flies probably exploit alcohol's disinfectant properties for protection also. However, not all vinegar flies are equally resilient to alcohol. Flies that live in temperate latitudes, such as Europe, tend to be more alcohol resistant than flies from Africa, but it wasn't clear why temperate flies hold their alcohol better than their tropical cousins. According to Fry there are two possible explanations: one, that temperate flies are better at breaking down the toxin; and another, where temperate flies are simply less sensitive to alcohol. 'I wanted to look at the physiological basis of the difference,' says Fry (p. 3996).

First, he exposed flies to simulated rotting fruit (cotton wool soaked in a weak sucrose solution with varying levels of ethanol) over 2 days to find out how much alcohol the flies could safely ingest and how much accumulated in their bodies. Measuring the flies' body alcohol levels, Fry could see that the levels in African flies were 2-3 times higher than those of the European flies; 'the African flies were breaking it down much less quickly', says Fry. And when Fry tested the activity levels of two enzymes that break down alcohol, alcohol dehydrogenase (ADH) and aldehyde dehydrogenase (ALDH), both enzymes were more active in the European flies

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than the African flies, helping the temperate insects to destroy the toxin more quickly.

But Fry explains that there is more to alcohol tolerance than simply destroying the toxin. 'The general complication is that you could make something more toxic when you enzymatically change a toxin,' says Fry, and in the case of alcohol, this means producing acetaldehyde and acetic acid. 'Acetaldehyde is very toxic, if you order it from a chemical company it has a skull and cross bones on it. Acetic acid on the other hand is in vinegar, which is not as toxic,' says Fry. He also explains that previous genetic studies had shown that African flies that bred with European flies to produce offspring with two African chromosomes and one European chromosome gained much of the alcohol resistance of European flies, despite retaining the weaker African ADH and ALDH enzymes. Was the European chromosome making the flies less sensitive to alcohol or was it making them better at coping with the toxic by-products of detoxification?

Fry obtained a specialised population of flies that could not detoxify alcohol and added the European chromosome. If the European chromosome was making the European flies less sensitive to alcohol, then the chromosome would protect them from alcohol accumulation. However, if the chromosome was somehow helping them to cope with the toxic by-products of alcohol detoxification, the flies would be as sensitive to alcohol as flies that had the African version of the chromosome. Measuring the flies' survival rates, Fry found that both types of fly were equally sensitive to alcohol.

So, the European chromosome helps the flies to be more resistant to alcohol by helping them to manage the toxic by-products of alcohol detoxification. Also, when Fry exposed the Europeanised flies to one of the by-products – acetic acid – they were more resistant to the toxin than the flies with the African chromosome, suggesting that European vinegar flies are better at coping with this alcohol break-down product to help them hold their liquor.

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Fry, J. D. (2014). Mechanisms of naturally evolved ethanol resistance in *Drosophila melanogaster*. *J. Exp. Biol.* **217**, 3996-4003.

Kathryn Knight

Future porcelain crabs in trouble

Porcelain crabs. Photo credit: Adam Paganini.

If you've ever had a fever, you'll know how rotten it feels when your temperature rises by even a few degrees. Now imagine yourself in the position of a porcelain crab on the California seashore as the tide withdraws. 'During low tide, air temperatures in the intertidal zone fluctuate dramatically over short periods of time (e.g. 20°C in 6 h)', says Jonathon Stillman from San Francisco State University, USA. And it could be about to get more uncomfortable as climate change tightens its hold, temperatures rocket and ocean pH falls. Stillman explains that most studies that have assessed the potential impact of climate change have analysed the effects of high temperature and reduced pH over extended periods. However, intertidal species experience massive temperature and pH variations on a daily basis. 'Scientists who study the effect of climate change on marine organisms have been clamouring for studies that look at multiple stressors that vary in an environmentally realistic sense,' says Stillman. So he and his student, Adam Paganini, set about building a simulated seashore to find out how porcelain crabs will cope in 2100 (p. 3974).

Constructing the coast simulation from a series of pumps and individual acrylic cylinders, each of which became home to a porcelain crab, the team drained water from the cylinders at 12:00 h each day, to simulate low tide, inundated the cylinders at 18:30 h to mimic the tide's return and lowered the pH each night before allowing it to return to normal around dawn to recreate the natural nocturnal pH dip that occurs along the California coast. 'The aquarium system was difficult to design and construct', admits Paganini, adding, 'the biggest challenge…was manipulating the pH on a daily high tide cycle and having the pH return to equilibrium before the low tide'. However, after a year of fine tuning, Paganini was able to simulate the modern environment – by allowing the air temperature to rise from 11°C to 25°C – and moderate climate change – by warming the air temperature still further to 30°C. In addition, he lowered the water pH each night from pH 8.1 to 7.6 to recreate the current environment and lowered it more – to 7.1 – for simulations of the future. Then, after allowing the crabs to adapt to the conditions for 17 days, Paganini began assessing the impacts that each environmental scenario had on the animals by measuring their oxygen consumption (respiration rate), and their heart rate while he increased the temperature.

Teaming up with Nathan Miller to analyse the data, Paganini and Stillman could see that the increase in temperature had a more significant impact on the crabs than the drop in pH. They also saw that the crabs that experienced the hottest low tide temperatures and largest nocturnal pH fluctuations were in the most trouble, reducing their respiration rates by 25% – suggesting that they had a reduced energy budget. The team also suspects that these 'future' crabs were investing more energy in general body maintenance, as they were able to tolerate slightly higher air temperatures than the modern-day crabs.

Based on the complicated range of responses that the team observed, Stillman says, 'Our current findings suggest that acclimatization capacity may be beneficial in the short-term yet detrimental in the long-term'. He adds, 'We think that in the future crabs may have less energy available for growth, reproduction and behaviour', and he hopes that this approach of simulating the environmental variability in current and future seashores is exactly what the climate change community has been looking for.

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Paganini, A. W., Miller, N. A. and Stillman, J. H. (2014). Temperature and acidification variability reduce physiological performance in the intertidal zone porcelain crab *Petrolisthes cinctipes*. *J. Exp. Biol.* **217**, 3974-3980.

Kathryn Knight

Correction: Double pole cross-country skiing more like sliding run

There was an error in the title of this article (doi: 10.1242/jeb.115378). It should be 'Diagonal stride cross-country skiing more like sliding run'. I apologise for this mistake.

Kathryn Knight

Bat body temperature does not affect memory

Sleep deprivation not only plays havoc with your life, but it also wrecks your memory. Ireneusz Ruczyński from the Mammal Research Institute, Poland, explains that sleep deprivation may affect our ability to consolidate memories, by transferring them from the short- to long-term memories. And, it turns out that animals that hibernate to conserve energy may suffer similar problems. 'Both REM sleep and slow wave sleep are reduced during torpor', say Ruczyński and Theresa Clarin from the Max Planck Institute for Ornithology, Germany, adding that animals that have recently emerged from hibernation spend a lot of time sleeping to repay the deficit. However, the jury was out about the effect of torpor and hibernation on rodent memories: some species seem to form long-term memories fine while the memories of others are impaired. Intrigued by the possibility that the low body temperature associated with torpor could impact memory formation, Ruczyński and his colleagues began testing the memories of chilled great mouse-eared bats (p. 4043).

Keeping bats at either 22°C or 7°C, Ruczyński, Clarin and Bjoern Siemers trained them to find food in a maze. Both groups of bats also had to learn the location of a dry perch when they were placed in a wet arena. Testing the animals' memories of the location of food in the maze and where the perch was in the wet arena, the team found that the bats' memories were equally good; their body temperature did not affect their ability to form memories. The team says, 'The lack of clear cognitive effects caused by the decrease in body temperature could be explained by a bat's life history', pointing out that bats live in complex environments and that this could have forced them to develop compensating mechanisms that ensure that their memories are sound.

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Ruczyński, I., Clarin, T. M. A. and Siemers, B. M. (2014). Do greater mouse-eared bats experience a trade-off between energy conservation and learning? *J. Exp. Biol.* **217**, 4043-4048.

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