Inside JEB 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

OCEAN NAVIGATION: SMELLING YOUR WAY HOME

Francesco Bonadonna

There are no mountains or other visual landmarks in the middle of the Atlantic Ocean, and if you find yourself without a map or GPS, chances are it's not going to be easy finding your way home. However, for a Cory's shearwater, navigation in this featureless environment is just another run-of-the-mill exercise. These birds spend most of their lives wandering the oceans, but every year they will return to the same small island to breed. Although it's like finding a needle in a haystack, these birds have no trouble. So, how do they do it? It's a question that fascinates Anna Gagliardo, from the University of Pisa, Italy. She explains that there are two potential cues that could aid their long-haul flights – their sense of smell or the natural geomagnetic field. But which cue is it? In collaboration with the researchers from her own university as well as the University of the Azores, Portugal, the Max Planck Institute for Ornithology, Germany, and the CNRS/CEFE, France, Gagliardo visited a colony of breeding Cory's shearwaters on the remote Portuguese Azores archipelago to find out how shearwaters made it back to their colony after being displaced (p. 2798).

During 2 years out in the field, the team captured 24 shearwaters, only catching birds that had just returned after a foraging trip to relieve their partner from egg incubation duty. Some of the birds were then given a GPS tracker and a magnet, as Gagliardo explains: 'We manipulated their magnetic sense by using very strong cylinder-shaped magnets. The cylinder rolled inside a box that was glued on the head of the animal so the magnetic field masked the geomagnetic field and in addition it was not constant because the magnet moved.' Other birds were given satellite transmitters and rendered temporarily anosmic (without a sense of smell) by lavaging their nostrils with a zinc sulphate solution. The birds were then placed on board a cargo ship heading east back to Portugal's capital, Lisbon.

After 24–39 h at sea the birds were released about 800 km away from their colony. Unaware that the team was looking after their eggs in their absence, all the birds set off, eager to get back to their nests. The team was then able to monitor what routes the birds took home either by GPS or continuous satellite updates. All the birds with magnets and a full sense of smell returned home. They were clearly able to successfully orientate themselves and navigate their way back to the nest, with all birds taking very similar and closely spaced routes. However, it was a different story for the birds without a sense of smell, recalls Gagliardo: 'The results are very clear; the anosmic birds were unable to pinpoint the colony, they wandered around the ocean for thousands of kilometres and they were completely confused. Some of them did come back, but only after a long and winding trip.'

Gagliardo acknowledges that the results weren't entirely unexpected and that she always suspected that sense of smell was key to oceanic navigation in shearwaters. She admits this as she explains why only anosmic birds were given a satellite transmitter: 'GPS [units] must be recovered in order to download the data from the log, but they are cheaper so we thought we'll take the risk, because it's very unlikely that these birds [with magnets] won't come back.' It seems the risk paid of and it's clear that Cory's shearwaters use their large noses to find home, although what exactly they smell is the next mystery to be solved.

10.1242/jeb.090555

Gagliardo, A., Bried, J., Lambardi, P., Luschi, P., Wikelski, M. and Bonadonna, F. (2013). Oceanic navigation in Cory's shearwaters: evidence for a crucial role of olfactory cues for homing after displacement. *J. Exp. Biol.* **216**, 2798-2805.

Nicola Stead

THE COST OF STAYING COOL FOR ELEPHANTS

During the hot summer months, there's nothing quite like a nice refreshing dip in a pool, and it would seem that elephants agree. In fact, in some areas, elephants will rarely stray far from water, and have even been, albeit controversially, called a water-dependent species. But are they really water dependent and if so what drives this dependence? Is it caused by a necessity to cool down? Robin Dunkin, a researcher from University of California, Santa Cruz, USA, explains that although elephants have numerous tricks to stay cool, such as using their enormous ears as fans and/or radiators, sometimes this just isn't enough: 'As soon as temperatures get above body temperature these non-evaporative forms of heat loss don't really work anymore. They can actually gain heat through those same pathways and so they end up having to rely on evaporative cooling.' While elephants

cannot use evaporation of sweat to cool down, Dunkin found that elephants' hides seem to be more permeable to water than most animal skins. With the help of her supervisor, Terrie Williams, she decided to investigate whether staying cool is a driver for the elephant's water dependence and, if so, how elephant overcrowding, which causes costly damage to the landscape, could potentially be controlled by managing water availability (p. 2939).

Dunkin began by measuring how much water elephants lost by evaporation from their skin over a range of temperatures, from a chilly 8°C to a toasty 33°C. To do this, she recruited the help of 13 trained African and Asian elephants from three nearby zoos. Dunkin measured water loss from evaporation by passing a stream of air over their skin and measuring the water content of the air before and after.

Dunkin found that as temperatures rose, the amount of water lost by evaporation from the skin increased exponentially. However, Dunkin explains that hot air can carry more water and, which in itself can drive more evaporation. Dunkin found that, even after correcting for this, overall cutaneous water evaporation was still high at higher temperatures. After treating the elephants to an invigorating and cooling shower, Dunkin saw that evaporation rates increased further – presumably the elephants were using this additional water source to increase evaporative cooling. Overall, Dunkin also found that during the summer months the elephants increased their skin's permeability. Altogether, Dunkin's findings suggest that elephants are more concerned with using water to cool themselves down than conserving it and any extra water from wallowing or a shower is gratefully accepted.

Next, Dunkin used her data to model just how important evaporative cooling was for an elephant's thermal budget. Even at low temperatures evaporative cooling played a role, but by the time temperatures reached 29–32°C it was the only option left to elephants wanting to cool down. At these higher temperatures it's likely that they become dependent on water for nearly all cooling. Dunkin's findings suggest that: 'Water dependency is too simple an idea, and it's really more climate dependent than that. So, they're tethered to water but the length of that tether is climate dependent.' For example, Dunkin estimated that an elephant in subtropical South Africa would need to dedicate just 22 l day^{-1} of water to cooling, whereas an elephant in the semi-arid Namibian savannah would need almost five times that, incurring a water debt of at least 100 l day^{-1}. Dunkin explains that: 'By understanding how climate drives the elephant's dependence on water, we may open up better management strategies for game reserves faced with elephant overcrowding.' After all, you can have too much of a good thing, be it water or elephants.

10.1242/jeb.090969

Dunkin, R. C., Wilson, D., Way, N., Johnson, K. and Williams, T. M. (2013). Climate influences thermal balance and water use in African and Asian elephants: physiology can predict drivers of elephant distribution. *J. Exp. Biol.* **216**, 2939-2952.

Nicola Stead

BENT BACKBONES AREN'T STIFF ENOUGH FOR BASS

If you talk to Bryan Nowroozi, who has just completed his PhD investigating the role of the fish's spinal column, he will readily confess the reason for undertaking his PhD: 'I was always interested in how anatomy plays a role in animal performance and how changes in anatomy across various species, with regards to the vertebral column, have an impact on the different forms of locomotion.' Nowroozi goes on to explain that his father, a medical doctor also interested in spines, may have sparked his interest in the field but it was his PhD supervisor, Elizabeth Brainerd at Brown University, USA, who encouraged him to focus his attention on how bending of the vertebral column could help propel a swimming striped bass (p. 2833).

Nowroozi was particularly interested by how much a curved spine could contribute to body stiffness during swimming, explaining that 'by increasing stiffness, the force required to bend the body increases, and ultimately swimming speed can also increase'. But how much bending is needed to generate stiffness? Nowroozi recounts some of his earlier studies: 'I dissected out joints from all regions [of the vertebral column] – the cervical region, the abdominal region and the caudal region – and subjected them to mechanical testing experiments, where I was able to quantify the amount of stiffness that they generated during a lateral [sideways] bending motion.' He found that laterally bending the joints more than 15 deg resulted in substantial body stiffness, with abdominal joints becoming the most stiff. However, the question remained – how much did they bend during swimming?

To investigate, Nowroozi decided to use 2D X-ray videoing. So, donning a lead apron, he used a small rod to give a swimming bass a small fright and induce the characteristic C-shaped startle response. By filming the vertebral movements using an X-ray emitter and a camera placed above and below the tank, he could then calculate how much each vertebral joint was bending: 'You see a fair amount of bending in the vertebra 8 to vertebra 15 region, which corresponds to more or less the anterior abdominal region, and that correlated nicely with what's thought to occur in previous studies', he explains. To his surprise, in some cases he also found that the cervical joints also bent substantially, which he suspects is due to the fright occurring close to their heads. The biggest surprise, however, was that none of the joints were laterally bending more that 12 deg.

During his study, Nowroozi also used a 3D X-ray videoing system developed by his supervisor to investigate the movements in more detail. He recalls it wasn't easy, as he had to surgically implant six tantalum metal markers on to two adjacent vertebrae and although most fish made it out of the 'operating room', Nowroozi found that the markers just wouldn't stay in place. However, after 4 years of hard work, Nowroozi had perfected the technique, and he could track the rotations of the markers laterally, as well as dorsoventrally (up and down) and axially (around the spine). He confirmed that the joints did not bend laterally more than 12 deg, but he also found that laterally bending was the only substantial movement the vertebrae made; both axial and dorsoventral rotations were less than 2 deg.

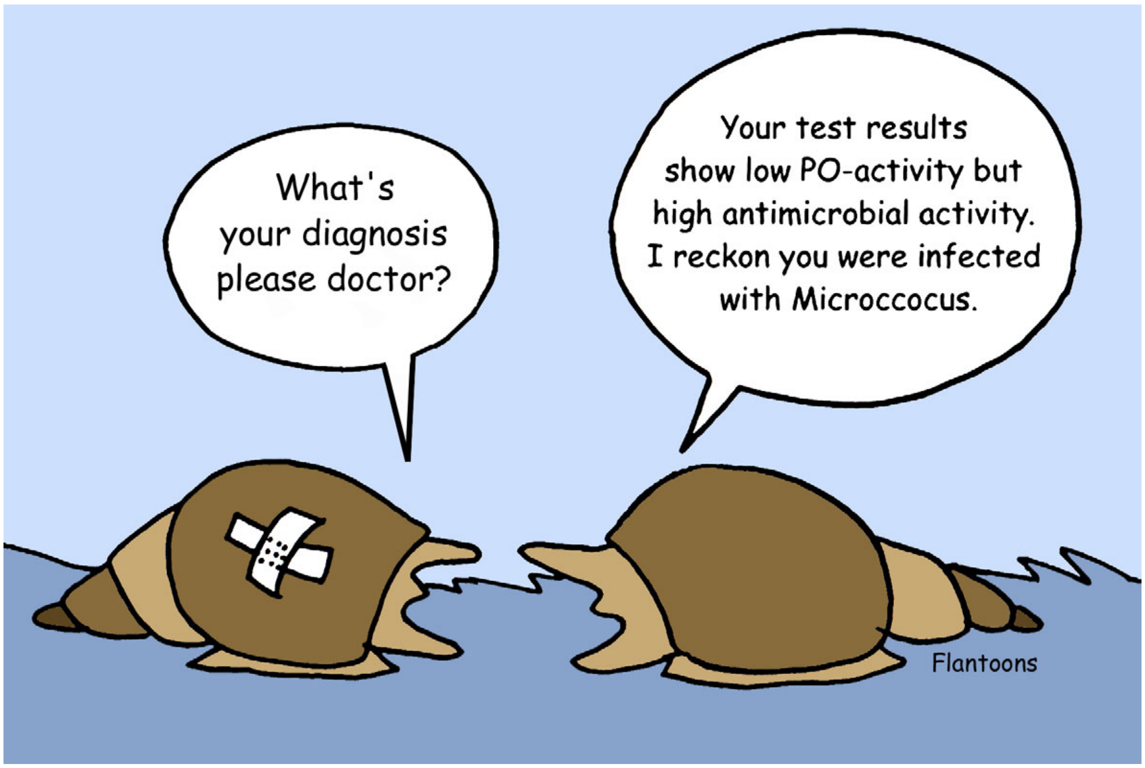
In conclusion, Nowroozi thinks the spinal bending doesn't contribute to whole-body stiffness during swimming, at least in striped bass. Upon reflection, he suggests that his study highlights that you need to combine kinematic and mechanical testing studies to understand the role a joint plays – just because the vertebrae can physically bend more than 15 deg doesn't mean they will!

10.1242/jeb.090431

Nowroozi, B. N. and Brainerd, E. L. (2013). X-ray motion analysis of the vertebral column during the startle response in striped bass, *Morone saxatilis*. *J. Exp. Biol.* **216**, 2833-2842.

Nicola Stead

FEELING ILL: A SNAIL'S COMPLEX IMMUNE SYSTEM



All animals are plagued by parasites of some variety, but parasites all have one thing in common – profiteering at their host's expense. Naturally, hosts aren't too happy about this and will engage their immune systems to fight back. However, the outcome of the ensuing battle can also be affected by ecological and environmental factors. These factors can then modify the host–parasite relationship, causing changes in host's life choices as well as driving evolution. However, this growing field of ecoimmunology – immunology in the context of ecology – has been hampered by limited knowledge of how different immune elicitors activate the immune system. Without this knowledge, knowing which elicitor to use for your specific experiment can be tricky, so Otto Seppälä and Katja Leicht both from Eawag, Switzerland, decided to investigate how the freshwater snail *Lymnaea stagnalis* reacted to different threats (p. 2902).

The team injected their snails with two different types of lyophilized bacteria, *Escherichia coli* and *Micrococcus lysodeikticus*, as well as ground-up gonads from an unlucky snail infected with a trematode parasite. Some snails escaped these treatments and just received innocuous injections of snail saline or ground-up uninfected gonads. Six hours post-treatment, the duo collected haemolymph samples and began testing the immune reaction, looking at phenoloxidase and antimicrobial activity. Merely pricking the snail and injecting harmless snail saline induced phenoloxidase activity but to their surprise injection with trematode-infected gonads didn't increase this reaction. What's more, this activity decreased when the snails were injected with bacteria. This may represent a trade-off between phenoloxidase activity and antimicrobial activity, as this latter immune response was heightened after *Microccous* infection.

Next, the duo kept their snails in either clean water or bacteria-ridden water and repeated the same measurements of the immune system. This time, the presence of micro-organisms induced a strong phenoloxidase response but no antimicrobial activity. Their results overall highlight the complexity of the snail's immune system, with trade-offs occurring between different pathways. It seems that the immune system of the snail remains a mystery!

10.1242/jeb.090506

Seppälä, O. and Leicht, K. (2013). Activation of the immune defence of a freshwater snail *Lymnaea stagnalis* (L.) by different immune elicitors. *J. Exp. Biol.* **216**, 2902-2907.

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