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

WHY DIVERS HAVE DIMINUTIVE WINGS

Picture provided by E. S. Bridge

When it comes to diving, penguins probably are the unrivalled champions of all birds. Their body is a work of wonder that nature has endowed for a perfect plunge into the ocean blue: the smooth contours, strong flippers, and small pointed wings. Some of these traits are directly selected for improved diving ability but others may be merely evolutionary artefacts. Many researchers believe that small wings reduce drag underwater and, therefore, are better suited for diving. Indeed, many aquatic birds that dive to forage also have small, pointed wings. But until recently, these were merely perfunctory observations and hearsay, with no concrete evidence of the supposed benefits of small wings. Studying the effects of wing areas on diving is a tricky business; cross-species studies never give fair comparisons. This is why Eli Bridge of the University of Minnesota decided to study the effect of altered wing size on puffins during the bird's drastically brief moulting season (p. 3003).

Bridge's 'laboratory' was SeaWorld California where a large number of puffins are housed as part of an exhibit called 'The Penguin Encounter'. The puffins live in a naturalistic habitat with a large pool that allows them to dive underwater. Bridge used two pairs of video cameras to film the bird's diving activity by mounting one camera in front of the pool's viewing window, and the other above the pool pointing straight down. In this way, Bridge could plot the bird's movement in three dimensions and calculate diving parameters such as dive speed and angle of descent.

After hundreds of hours of video footage and laborious calculation, Bridge found that instead of improving the bird's diving performance, wing moult had an unexpectedly adverse effect. During moult, the birds dived a shorter distance with each flap of the wings, and energy output from the wing movement, as measured by work per flap, was also reduced, especially when both primary and secondary feathers were missing. However, Bridge discovered that the puffins seemed to compensate for the impairment by more frequent flapping, diving at the same speed as when their plumage was intact. Bridge believes that the moulted bird's impaired diving ability along with the period of flighlessness caused by wing moult could explain the drive to minimize the moulting season and reduce the period when their ability to forage and avoid predators is compromised.

But if reduced wing areas do not improve diving ability, what drives evolution to select for small, pointed wings in many aquatic birds? Apparently birds with small, pointed wings are adept at high-speed, long-distance flight, essential for rapid movement between specialized habitats. But this comes at the cost of manoeuvrability; small, pointed wings cannot generate lift at low speed, so rapid vertical escape takeoffs are impossible. This is not a big problem for most diving birds because their open aquatic habitats prevent close approach by undetected predators. Similarly, when the birds slow down to land, their small wings stall easily and lose lift. Fortunately, high-speed hard landings are more acceptable on water than on solid surfaces. Bridge's findings suggest that the bird's aquatic habitats relax the constraints on the evolution of small, pointed wings. In other words, those birds can afford to trade manoeuvrability for high-speed flight.

10.1242/jeb.01175

Bridge, E. S. (2004). The effects of intense wing molt on diving in alcids and potential influences on the evolution of molt patterns. *J. Exp. Biol.* **207**, 3003-3014.

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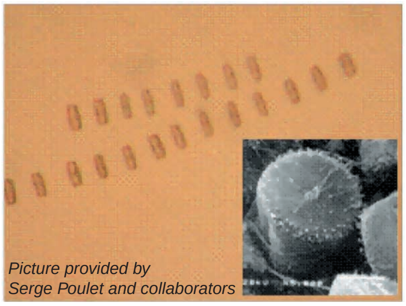
PLANKTON WARS

No matter how pure they look, seas, rivers and even puddles are havens for microscopic organisms such as diatoms. These single-celled algae make up a significant proportion of phytoplankton species in many marine and freshwater environments. In fact, they seem to act as the grass of the ocean, providing food for a wide range of animals from zooplankton to larger invertebrates. However, at certain times of the year these apparently benign algae proliferate out of control, forming algal blooms. One explanation for this phenomenon is that a minority of diatoms may be toxic, harming the predators that feast on them and allowing the algae to



proliferate unchecked. Serge Poulet from Roscoff, France, explains that these toxic diatoms have evolved sophisticated defences against being eaten by producing aldehydes. Curious to know how these diatomic aldehydes bring about their deadly effects, Poulet and his research team decided to investigate the effects of an aldehyde, decadienal, on one of the diatom's predators, the copepod (p. 2935).

Poulet explains that his initial fascination lay not with the flourishing algal blooms, but with the copepods that dine on them. He knew that copepods that consume toxic diatoms seemed to suffer fertility problems; some of their eggs fail to develop or hatch, while any larvae that develop are deformed. But it wasn't clear how the diatoms wreaked their damage.

Poulet and his team monitored the effects of an aldehyde, decadienal, on a variety of marine and non-marine specimens and found that while most of the organisms were vulnerable to the aldehyde, some bacteria and fungi were resistant to the chemical. Were the yeast and bacteria protected by their tough cell walls? The researchers exposed yeast lacking a key cell wall component to decadienal, and found that the yeast were as vulnerable as the copepods that had originally piqued his interest. Poulet suspects that the yeast and bacteria may be protected from the toxic effects of decadienal by low cell permeability, while higher organisms such as copepods that lack substantial cell walls are vulnerable to the aldehyde's toxic effects.

But how was the toxic aldehyde mediating its effects once it had penetrated the cell wall? The scientists decided to take a closer look at the aldehyde's effects on vulnerable oyster blood cells. A battery of tests revealed that decadienal affects the cytoskeleton and causes apoptosis, as well as inhibiting other cellular processes. Poulet explains, 'the biological toxicity of these aldehydes is due to the double bond within them – they have a high affinity for biological molecules.' It is likely that decadienal reacts indiscriminately with enzymes in many physiological pathways within the oyster cells, causing a wide range of noxious effects. The observations from other organisms, such as the copepods' fertility problems, are probably also due to widespread interference with many cellular processes.

These results suggest that under normal circumstances toxic diatoms make up a small but harmful minority of phytoplankton. But Poulet warns that subtle changes in the environment, perhaps due to human activity, can cause dramatic rises in toxic diatom populations, which have knock-on effects for animals higher up the food chain.

10.1242/jeb.01173

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HOW CALCIUM DANCES THROUGH CRAYFISH

If you wear your skeleton on the outside, there's only one option when you need to grow; either stay cramped or lose the shell. In the weeks before a crayfish sheds its exoskeleton, its body moves a massive amount of calcium out of the cuticle and stores it as small chalky pebbles in part of the stomach. Once the old skeleton has been shed, those pebbles, known as gastroliths, drop into the stomach acid. The calcium is carried right back and deposited in the new cuticle, and is topped up with extra calcium extracted from the environment. Without their skeleton, crayfish are soft like jelly. But the calcium piles on so fast you can feel a papery shell develop within hours of having lost the last. This large-scale calcium transport across cells is an astounding feat of physiology, especially when you consider the fine balance of calcium ions maintained in cells. Michele Wheatly and Yongping Gao, at Wright State University in Dayton, Ohio, have described and sequenced one important gene involved in the process, which produces a protein that pumps calcium out of cells. They have shown that crayfish cells increase production of this protein before and after shedding (p. 2991) and they are beginning to understand how regulation of this and other proteins controls cellular calcium levels.

Free calcium ions are crucial intermediates in signalling processes inside every cell. To keep communication lines free of interference, cells have to maintain low background calcium levels in the cytoplasm, using a complex system of calcium homeostasis. In some circumstances, such as when mammals produce milk or crustaceans moult, large amounts of calcium have to move through cells; then, the regulation system is put to the test and begins to reveal its secrets. 'Problems of calcium homeostasis are implicated in all kinds of medical conditions, including cardiovascular disease and Alzheimer's,' says Wheatly. 'The proteins involved are coded by ancient genes, so what happens in crayfish can tell us a lot about how [the proteins] work in humans.' Crayfish living in freshwater occupy an extreme environment in calcium terms, compared to their marine counterparts. Levels of calcium available to them from the surrounding water are low, so calcium recycling is especially important.

Wheatly and Gao studied one of four Plasma Membrane Calcium ATPases (PMCA3) present in most animals. This protein sits across the external membrane of cells and exports calcium. They found the protein's gene in the freshwater crayfish genome using stretches of sequence from human and rodent versions. After sequencing the gene, they watched its behaviour during the moult cycle, by testing dissected crayfish tissues for the RNA version of the gene, and the protein itself. As they expected, in cells transporting the calcium, more PMCA3 was produced before the moult, and just after the moult, than inbetween moulting. What they did not expect was that this pattern was also found, to a lesser extent, in crayfish tissues not involved in the mass calcium transport, such as muscles. Wheatly's team are now working on the genetic regulation of other proteins that move calcium from the cell cytoplasm into the folds of internal membranes known as sarco-endoplasmic reticulum, effectively hiding it. Regulation of the two proteins seems to be linked – as one goes up the other goes down. 'The way the system is regulated is almost like a dance,' Wheatly enthuses.

10.1242/jeb.01174

Gao, Y. and Wheatly, M. G. (2004). Characterization and expression of plasma membrane Ca^{2+} ATPase (PMCA3) in the crayfish *Procambarus clarkii* antennal gland during molting. *J. Exp. Biol.* **207**, 2991-3002.

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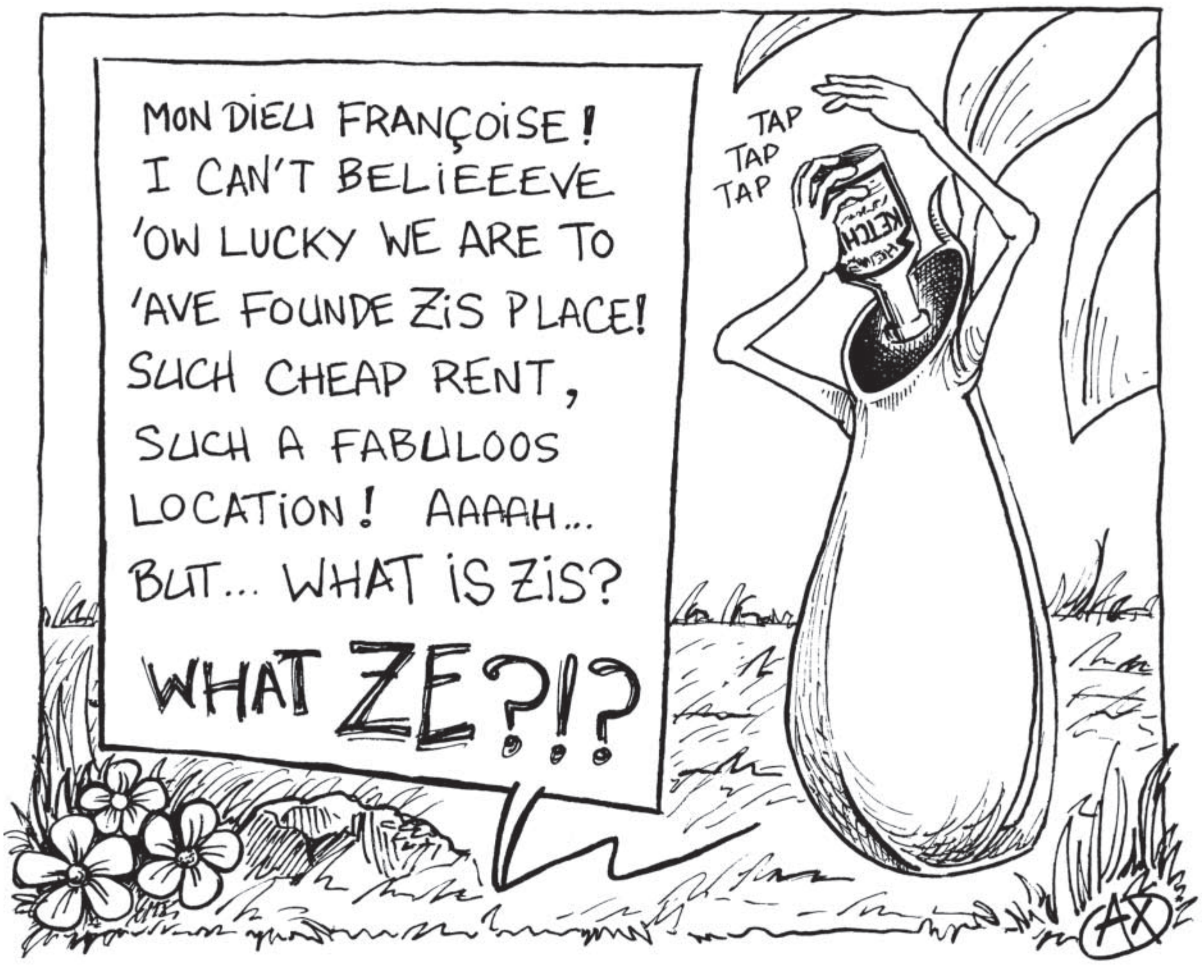
INSECTS GET A GRIP IN PREYING PITCHER



A couple of newly-wed French flies wind up taking a wrong turn in life.

Axle Innis is a postdoctoral fellow in New Haven, Connecticut, USA

Safely rooted, most plants' nutritional requirements are amply supplied by their local environment. But where the pickings are poor and nitrogen is scarce, some species have opted for an unorthodox dietary alternative. They've become carnivorous, developing specialised appendages to trap and digest unsuspecting victims. How one group of carnivorous plant – pitcher plants – detain their victims intrigues Elena and Stanislav Gorb in Stuttgart, Germany (p. 2953).

Focusing on *Nepenthes ventrata*'s pitcher, they investigated the surface properties of the plant's digestive gland tissue. Testing the tissue's surface properties on insects equipped with claws or adhesive pads, the Gorbs' team found that insects with specialised attachment pads could cling easily to the pitcher's rough digestive surface, while insects with claws alone probably couldn't get a grip unless they dug into the pitcher's walls. And the plant's digestive juices didn't seem to affect the ability of flies to get a grip, although bugs found the surface slippery when coated in the plant's secretions.

The team suspects that 'the glandular surface is probably not responsible for prey capture and retention', and the insect's fate is most likely sealed by the pitcher's upper waxy surface and lid.

10.1242/jeb.01176

Gorb, E., Kastner, V., Peressadko, A., Arzt, E., Gaume, L., Rowe, N. and Gorb, S. (2004). Structure and properties of the glandular surface in the digestive zone of the pitcher in the carnivorous plant *Nepenthes ventrata* and its role in insect trapping and retention. *J. Exp. Biol.* **207**, 2947-2963.

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