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

ARCTIC CORMORANTS ARE TRUE SURVIVORS

Arctic great cormorants are poorly equipped to cope with harsh polar winters; they have very meagre fat reserves and their partly wettable plumage offers little insulation. Yet a small population of these diving birds stubbornly overwinters north of the polar circle, along the coast of Greenland. Suspecting that the birds have physiological or behavioural adaptations to survive in their hostile home, David Grémillet and his colleagues painstakingly collected physiological data from great cormorants for an entire year. Incredibly, they found that cormorants don't appear to have any such adaptations, yet still make it through the Arctic winter (p. 4231).

How does a warm-bodied diving bird with poor insulation survive in the Arctic? Grémillet reasoned that the birds could cope with the polar night (the period during the Arctic winter when the sun remains below the horizon) by depressing their metabolism or by decreasing the time they spend diving for fish in the freezing water. Grémillet travelled to Greenland to find out if cormorants adjust their physiology or behaviour to save energy during the winter. He caught ten cormorants nesting during the summer, and Grégoire Kuntz and Caroline Gilbert implanted tiny data loggers into the birds' abdomens to record their heart rate, body temperature and dive depth over a year.

The team returned the following summer, anxious to see if the birds had survived the dual perils of the harsh Arctic winter and the Inuit hunting season. Luckily, all ten had made it through the winter unscathed and were happily breeding again. Collecting the data loggers, the team first investigated whether the birds depress their metabolism during the winter. They expected to find that cormorants drop their body temperature in winter to reduce the temperature difference between their body and the environment and cut heat loss from their body. But the birds had a normal, steady temperature (38-41°C) year-round. A second tell-tale sign of depressed metabolism is a lowered heart rate, but the team found that the birds don't lower their heart rate during the winter.

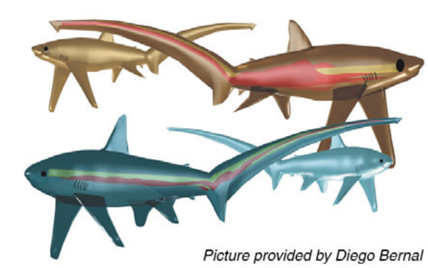
Since cormorants don't adjust their physiology, the team supposed that the birds adjust their behaviour instead and spend less time diving for fish in the winter. So they were shocked to discover that the birds did not spend less time diving during the coldest months of the year; instead, the birds spent more time swimming as the days got darker. 'This is probably because cormorants are visual predators, so during the dark polar night they can't see the fish as well and have to spend more time hunting', Grémillet says.

The team suspects that cormorants simply cannot afford to stop fishing if they want to survive the winter. When the team dissected unfortunate cormorants that had been trapped in fishing nets, they discovered that the birds are incredibly lean; their fat reserves would only last for three days. While marine mammals like seals rely on a thick layer of blubber for insulation and energy reserves, cormorants don't have this luxury. 'Cormorants are true athletes; they dive every day throughout the winter. The more we learn about these birds, the more amazing they seem', Grémillet concludes.

10.1242/jeb.01935

Grémillet, D., Kuntz, G., Woakes, A. J., Gilbert, C., Robin, J.-P., Le Maho, Y. and Butler, P. J. (2005). Year-round recordings of behavioural and physiological parameters reveal the survival strategy of a poorly insulated diving endotherm during the Arctic winter. *J. Exp. Biol.* **208**, 4231-4241.

NOT ALL THRESHER SHARKS KEEP WARM



In the fish world, it's normal to be cold-bodied and take on the temperature of your surroundings. But there are exceptions to every rule; tunas and lamnid sharks are endothermic, managing to keep their bodies warmer than the waters they live in. The common thresher shark, a large alopiid shark with a formidable tail that roams temperate and deep tropical waters, is also warm-bodied. Since all tunas and all lamnid sharks are endothermic, it seemed fair to suppose that the two other known thresher shark species, bigeye and pelagic threshers, are also warm-bodied. But Chugey Sepulveda, Diego Bernal and their colleagues reveal that bigeye and pelagic thresher sharks are nothing like their warm-bodied common cousins (p. 4255).

Most fish keep the red muscle that's used for swimming just beneath their skin and can't retain the heat their muscles produce, but tunas, lamnid sharks and the common thresher shark all keep their red muscles nestled deep inside their bodies, insulating their internal 'furnace' from the cold water. If bigeye and pelagic thresher sharks also bury their red muscle deep inside their bodies, Sepulveda and Bernal reasoned, then it's likely that these sharks are also warm-bodied.

Sepulveda and Bernal teamed up with Nick Wegner and Jeff Graham to find out if all threshers have the same red muscle distributions. Since live thresher sharks are very difficult to catch, the team bought some dead thresher sharks from commercial fisheries. They froze the sharks, sliced them into thin transverse sections and took a digital image of each slice. Reconstructing a 3D computer model of each species, the team visualized red muscle distribution all along the length of the sharks' bodies. But as soon as they cut open the first bigeye and pelagic threshers, the team spotted that these sharks are clearly nothing like their common cousin. The red muscle of both bigeye and pelagic threshers runs just beneath the skin and is mainly distributed towards the tail end of the body, while in the common thresher shark the red muscle runs along the backbone and is concentrated at the head end of the body. 'We didn't expect to see such a big difference', Bernal recalls, 'so our first thought was that the fisheries had sold us the wrong species.' But a DNA analysis soon confirmed that they really were inspecting the right species.

The team also found another clear difference among the three thresher species. Tunas, lamnid and common thresher sharks retain the heat produced by their red muscles using vascular counter-current heat exchange systems that short-circuit heat loss to the environment. But when the team examined the bigeye and pelagic thresher sharks' vascular systems to look for these modifications, they found no evidence of such heat exchangers. This finding, together with the team's observation that bigeye and pelagic thresher sharks don't keep their red muscle near their body core, means that it's very unlikely that these two species are warm-bodied.

The team concludes that the common thresher shark is the only thresher species with the anatomical specializations for red muscle endothermy. Why and how these specializations evolved in common threshers but apparently not in bigeye and pelagic threshers is a mystery that the team is now delving into.

10.1242/jeb.01937

Sepulveda, C. A., Wegner, N. C., Bernal, D. and Graham, J. B. (2005). The red muscle morphology of the thresher sharks (family Alopiidae). *J. Exp. Biol.* **208**, 4255-4261.

ELECTROSENSE TELLS PADDLEFISH THE TIME

Picture by Michael Hofmann

The passive electrosensory system is one of the most primitive sensory systems found in vertebrates. When prehistoric creatures crawled onto land, they lost the ability to detect the weak electric fields of objects around them. But the sense is still used today by a smattering of fish species, such as the paddlefish. This ancient fish lives in murky waters and uses the tens of thousands of electroreceptors scattered along its rostrum, a long paddle-shaped snout, to track down tasty water fleas. Michael Hofmann, Boris Chagnaud and Lon Wilkens took a closer look at the paddlefish brain to find out how these extraordinary fish detect their minute prey (p. 4213).

The team examined the responses of neurons in the paddlefish brain to search for evidence of spatial information processing pathways that are commonly found in other sensory systems. They recorded from the paddlefish's lateral line nerve fibres, which run from the electroreceptors in the skin to a region of the hindbrain called the dorsal octavolateral nucleus (DON), the first processing station of electrosensory information in the paddlefish brain. To see how paddlefish process the information from their electroreceptors, the team compared these recordings to those from neurons in the DON.

Given that some sort of mapping is common in most sensory systems, the team suspected that the paddlefish electrosensory system incorporates a topographic map of the fish's body surface. In other words, they expected to find a topographic relationship between the electroreceptive regions in a fish's skin and the position of the corresponding neurons in its DON that respond when these skin regions are stimulated. To investigate whether paddlefish have a topographic map, the team simulated a water flea by moving silver wires surrounded by an electric field along a paddlefish's body. Using an electrode to record the response of the fish's DON neurons, they moved the 'water flea' to various skin locations and observed when they got the best response from the DON neurons. To their surprise, they didn't find any correspondence between the stimulated skin locations and the locations of the DON neurons that responded. They conclude that, unlike most other sensory systems, the paddlefish electrosensory system lacks a topographic map. Instead, there must be some other mechanism of organization that allows the fish to pinpoint its dinner.

Then the team discovered something rather unexpected. As they moved the 'water flea' along the paddlefish's body, they noticed that the DON neurons respond to changes in the electric field's signal strength over time. 'The skin's electroreceptors are a 2D array, and the touch sense normally operates in the 2D plane. But electroreceptors can also detect objects at a distance, thus adding a third dimension', Hofmann explains. The team proposes that paddlefish compute this third dimension by analysing the time domain of a passing signal; that is, the DON neurons process how quickly the 'water flea' passes by and use this information to calculate the prey item's distance. They conclude that a paddlefish's electrosensory system processes information about the time course of a passing prey item's electric field to enable the fish to close the appropriate gap between itself and its dinner.

10.1242/jeb.01936

Hofmann, M. H., Chagnaud, B. and Wilkens, L. A. (2005). Response properties of electrosensory afferent fibers and secondary brain stem neurons in the paddlefish. *J. Exp. Biol.* **208**, 4213-4222.

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