Take a Deep Breath!

It’s a complete mystery how penguins avoid getting the bends. The birds, which take a lung-full of air before leaving the surface, not only face an increased risk of decompression sickness but have to battle against increased buoyancy too. Katsufumi Sato wanted to know how they manage to plumb the depths against these odds. After recording over 1000 penguin dives, he has collected evidence that the animals ‘brake’ during the final stages of ascent, which could protect them from decompression sickness (p. 1189). They also appear to adjust the size of their last breath, so they’re carrying just enough air to last until their return to the surface.

Measuring a diving bird’s acceleration pattern as it swims through the water can tell you a lot about how hard the bird is working. The bird accelerates and decelerates with every wing beat. Sato realised that if he measured the acceleration profile he would have a record of the lift, drag and buoyancy forces acting on the penguin throughout the dive, as well as recording when the penguin flapped its wings to swim. Combining this information with knowledge about the bird’s depth and speed, the Japanese team realised that they could estimate how much air a diving bird was carrying as it returned to the surface.

These weren’t experiments that Sato could do in the lab, he had to head towards the Antarctic to work with King penguins that routinely dive to 300 metres to get the diving data. At first he attached the acceleration logger and a depth/speed logger to five penguins, and waited for them to return from their month long foraging trips. Unfortunately, only two of the loggers produced enough data to show that Sato was on to something, and by then the breeding season was coming to an end. Sato had to wait another year before he could return to the Antarctic to collect more data.

This time round Sato attached the modified data loggers to smaller Adélie penguins who’s foraging trips only lasted for a day. This time all of the modified data recorders worked well, and by the end of the season, he had recorded over 650 dives from ten birds.

Back in Japan, Sato noticed that the penguins flapped continually as they descended, but after the first half of the return, they stopped swimming, and took advantage of their natural buoyancy to glide back to the surface. Sato was also surprised to see that instead of bobbing to the surface like a cork, the penguins delayed their return by applying a ‘break’ and changing the angle they approached the surface. Sato thinks that this combination of tactics might help the birds to avoid decompression sickness.

When Sato compared the volume of the bird’s final breath with the depth the birds dived, he was startled by the strength of the correlation. Birds that went to greater depths took a much deeper breath than birds that stayed in the shallows. The only conclusion Sato could draw is that penguins plan every dive before they leave the surface. Buoyancy is the major problem the birds face until they have dived deep enough for their cargo of air to become compressed. Penguins that intend to stay in the shallows only take a small breath to keep their buoyancy to the minimum, while birds that have planned a deeper dive can take a much larger breath, because they only have to fight their increased buoyancy until the pressure has increased enough to compress the air. Then they are free to forage to their heart’s content!

Cruising Round the Coral

Coral seas are very crowded in comparison to the open ocean. Many reef fish manoeuvre slowly around the coral by holding their bodies rigid, and flapping their median or paired fins (MPF swimming). Fish that cruise around the oceans rarely need to make tight turns at low speeds, they tend to swim for long periods by flexing the body and tail fin (BCF swimming). Some coral fish are so well adapted to their cluttered environment that they can only power BCF swimming for short bursts. But looks can be deceptive! John Steffensen’s team from Helsingør, has proved that one coral reef specialist, the Piccaso triggerfish, is equally capable of both styles (p. 1253).

Terrestrial animals change gait to reduce energy costs as they move faster. But no one had ever compared the cost of slow gait MPF swimming with faster BCF swimming to see if fish used the same energetic trade-off to speed up. In fact, it wasn’t even clear if an MPF specialist could even switch to the high-speed gait for sustained periods of time. Most metabolic measurements had been made on sleek BCF swimmers. Steffensen decided that he needed to measure the metabolic rate of some MPF specialists to settle the matter, but the shores of Denmark are not covered with tropical coral reefs teeming with MPF swimmers.

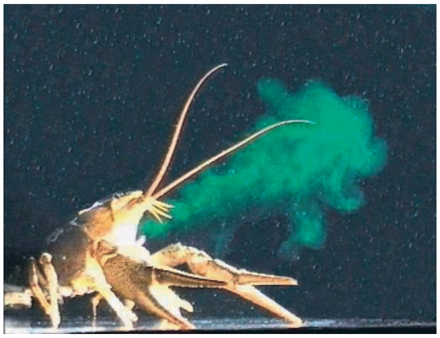
Steffensen, Keith Korsmeyer and Jannik Herskin relocated their lab to tropical Okinawa for a month. Once they’d reassembled the swimming respirometer in Japan, they collected triggerfish and parrotfish from the reefs, ready to measure the fish’s metabolic rates. The team gave the fish 12 hours to adjust to swimming in the confines of the respirometer before testing the fish’s swimming performance. As Korsmeyer increased the water speed every 30 minutes, the fish speeded up to match the increasing waterflow. They filmed the fish’s movements, watching for changes in the fish’s swimming style, while measuring their metabolic rate as they swam faster.

At slow speeds both species used their median or paired fins exclusively, but as the water flowed faster the two species opted for different strategies.

The parrotfish kept on determinedly flapping with their pectoral fins until they were finally forced to switch to BCF swimming for a short burst, before they became exhausted. The triggerfish, on the other hand, began alternating their MPF gait with a few flicks of the tail at relatively low speeds. The triggerfish easily speeded up, and began swimming strongly using a BCF stroke that they used to top up their median fin thrust. Most of the triggerfish cruised happily at $75\,\mathrm{cm\,s^{-1}}$, which is four body lengths per second. One remarkable fish swam vigorously at $90\,\mathrm{cm\,s^{-1}}$ for half an hour!

The other surprise came when Korsmeyer looked at the triggerfish’s metabolic rate as they switched to the high speed gait. Instead of dropping, the fish’s cost of transport rose.

At first sight this is confusing because terrestrial animals switch gait to save energy, not use more. But fish have to work harder than animals that move through air to push themselves through the viscous liquid. Korsmeyer suspects that the cost of transport goes up for the triggerfish because they top up median fin propulsion by recruiting an extra set of powerful high endurance muscles to power the undulating BCF gait.



A Clear Message

Crayfish fight all the time. They battle over food, shelter and females, but is more going on than meets the eye? Thomas Breithaupt knew that some wrestling crustaceans send each other warning signals in their urine. Could crayfish do the same? Having found a way of visualising the transparent urine, Breithaupt watched the crayfish fighting and realised that both crayfish urinated, but the victor signalled his physical superiority by urinating most (p. 1221).

Crayfish are nocturnal, and often live in cloudy water, so visual communication can be unreliable. Which is why Breithaupt suspected they were signalling to each other with their urine. But seeing an invisible signal is tricky. Breithaupt wasn't sure how to visualise the clear liquid until Eger suggested trying a diagnostic method that she had used when she was a nurse; injecting a coloured dye into the animal's circulatory system to colour its urine.

Once they'd successfully tinted the crayfish's urine, getting the animals to fight was simple. Just put two adult males together in a tank and they start gesturing at each other, ready to a battle. Breithaupt and Eger blindfolded the fighting crayfish, so they wouldn't be distracted by the clouds of visible urine, and videoed each crayfish clash.

After watching over 60 fights, Breithaupt realised that the winner always urinated more than the loser. When he analysed the loser's response, he saw the loser became more defensive every time its opponent urinated, although this wasn't obvious from watching the animals fighting. He also realised that no matter whether the crayfish had fought before, the loser always lost more quickly during the second duel, even if it was fighting a new adversary.

This tied in well with other experiments where Breithaupt had found that fights between crayfish that couldn't urinate went on and on! No matter how much the crayfish gestured and wrestled, they wouldn't give up fighting until they picked up the urine signals. Even though a crayfish's gesturing looks impressive, the visual message is nowhere near as intimidating as the chemical message from the urine. Breithaupt realised that the urine clearly signalled which of the fighters was going to win.

Breithaupt thinks that gesturing can make a timid crayfish appear more aggressive than it feels, but its urine cannot lie. The animal can't disguise the metabolic products that signal its weaker physical state. Once a weak opponent picks up a whiff of the superiority-signal, it knows that it's up against a real champion and decides to quit before the going gets really tough.

Having proved that crayfish urine carries the smell of success, Breithaupt wants to isolate the pheromone that puts the weaker crayfish in their place. He believes that crayfish pheromones could prove to be a good starting point for unravelling the complex neural circuitry that links the crayfish's olfactory system to the well-established behaviours that they provoke.

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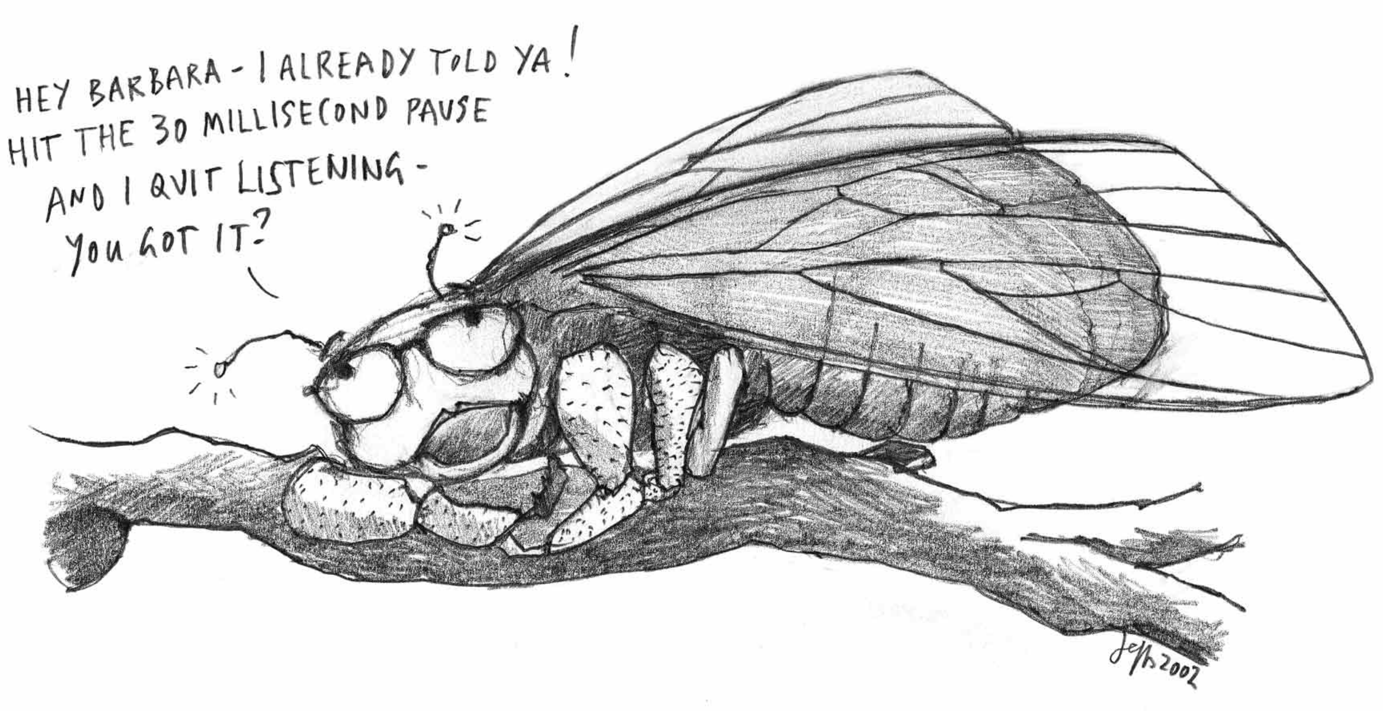

Singing Cicadas

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