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

RUDOLPH'S COOLING STRATEGY REVEALED

Kia Karup Hansen

Insulated in a luxuriously thick winter coat, reindeer are perfectly prepared for the gripping cold of an Arctic winter. But the pelt doesn't just keep the cold out, it keeps the warmth in too: which is fine when the animals are resting, but what happens when they are active and generating heat? Usain Bolt would never sprint in a fur coat so how do exercising reindeer avoid overheating? Arnoldus Blix from the University of Tromsø, Norway, explains that the animals have three tactics: panting with their mouths closed to evaporate water from the nose; panting with the mouth open to evaporate water from the tongue; and activating a cooling system that selectively cools the blood supply to the brain. But how do they coordinate these different strategies for protection? Intrigued, Blix and his colleagues Lars Walløe from the University of Oslo, Norway, and Lars Folkow, also from Tromsø, decided to monitor reindeer brain temperatures, breathing rates and the blood flow through several major blood vessels in the head, to find out how active reindeer keep cool in winter (p. 3850).

'Reindeer are the best animals to work with; once they trust the trainer they will do anything for you,' explains Blix. So, the team trained reindeer to trot at 9 km h^{-1} on a treadmill in temperatures from 10 to 30°C to get the animals warmed up while they recorded the animals' physiological responses. In the early stages of the run their breath rate rocketed from 7 breaths min^{-1} to an impressive 260 breaths min^{-1}. Blix explains that the animals were inhaling chilly air through their noses and evaporating water from the mucous membranes to cool blood in the nasal sinuses before sending it back to the rest of the body through the jugular vein to keep their temperature down.

However, as the animals continued exercising and generating more heat, they switched to panting, throwing their mouths wide open and flopping their tongues out like dogs. 'The tongue is large, vascularised and well circulated,' explains Blix, and adds, 'They moisturise the tongue so you have evaporation which also takes heat away from the blood'.

Monitoring the reindeer's brain temperature, the team noticed that the blood flow through the animal's cooling tongue peaked when the brain's temperature reached a critically high 39°C, at which point the reindeer switched to their third tactic. They began selectively cooling the brain by diverting cooled venous blood – which came from the nose – away from the body and up into the head, where it entered a network of heat exchanging blood vessels to cool the hot arterial blood destined for the brain to protect it from overheating.

Blix admits that initially he had not thought that this strategy would work. 'Only 2% of the respiratory volume went through the nose when they resorted to open mouth panting,' he says. However, when he calculated the colossal amounts of air inhaled by the exercising animals – coupled with the low air temperatures – it was clear that the reindeers were able to inhale sufficient cold air through their noses to keep their brains cool, but only as a last resort once the other cooling tactics were no longer sufficient.

So Blix and his colleagues have discovered how heavily insulated reindeer prevent themselves from overheating and how Rudolph keeps cool every Christmas Eve.

10.1242/jeb.066621

Blix, A. S., Walløe, L. and Folkow, L. P. (2011). Regulation of brain temperature in winter-acclimatized reindeer under heat stress. *J. Exp. Biol.* **214**, 3850-3856.

Kathryn Knight

HEAD MOVEMENTS GIVE AWAY FORAGING BEHAVIOUR

When a hunter embarks on a chase, they skilfully balance the energy they consume against the energy gained devouring their quarry to make the most of each meal. Sum up each individual's balancing act and you begin to see how entire ecosystems function. Yet measuring the number of times a hunter successfully traps prey is easier said than done, especially when the predator is submerged beneath the waves. Nobuo Kokobun and colleagues from the National Institute of Polar Research, Japan, and the Korea Polar Research Institute, explain that resourceful scientists have used various ingenious approaches to measure penguin prey capture rates, although with varying degrees of success, so the team decided to take a different approach. Knowing that penguins open their beaks to trap prey, the researchers decided to find


Nobuo Kokubun

out whether they could measure the birds' head movements to identify successful prey encounters (p. 3760).

Designing tiny custom-built accelerometers that could be strapped to the foreheads of gentoo and chinstrap penguins, the team headed south to Antarctica to test them on free-ranging birds. Fitting the penguins with the accelerometer headbands and camera backpacks to film the penguins' encounters with prey, Kokobun and his colleagues released the animals for a day's foraging before successfully retrieving the data loggers.

Back in the lab, the team scrutinised the 19,648 camera images collected by the diving birds for evidence of the penguins' favourite snack, krill, carefully analysed the bird's head movements in 3-dimensions and found a strong correlation between forward thrusting movements and their encounters with patches of krill. 'The underwater head movement corresponded well with prey encounter detected by bird-borne cameras, suggesting that head movement (especially in the surge axis [forward thrust]) may be related to prey capture attempts in response to prey encounter opportunities,' say Kokubun and his colleagues.

Having shown that a foraging penguin's success rate could be measured by keeping track of its head movements, the researchers suggest that this method could also be applied to other predators. However, they sound a note of caution – pointing out that birds move their head for reasons other than feeding – and add that this method could have powerful applications in aquatic environments where visibility is often limited. 'Together with other information such as GPS locations, the method will help advance our understanding of the relationship between the environment and the foraging behaviour of small- or medium-sized predators,' says Kokubun and his colleagues.

10.1242/jeb.066795

Kokubun, N., Kim, J.-H., Shin, H.-C., Naito, Y. and Takahashi, A. (2011). Penguin head movement detected using small accelerometers: a proxy of prey encounter rate. *J. Exp. Biol.* **214**, 3760-3767.

Kathryn Knight

LEECHES' SENSORY SENSITIVITY SHIFTS WITH AGE


Cindy Harley

Famed for their medicinal uses in ages past, leeches love nothing more than a juicy blood meal. But before they can sink their jaws into a succulent snack, most leeches have first to find a victim. Cynthia Harley and colleagues, Javier Cienfuegos and Daniel Wagenaar, from the California Institute of Technology, USA, explain that many aquatic predators, including leeches, locate prey using the tell-tale water waves produced by the victim's movements. But other things make waves too, like rain and falling objects, so how do hungry leeches distinguish between distracting environmental noise and signs of tasty life? According to Harley, many aquatic predators only react to specific water wave frequencies, which are characteristic of their prey of choice. However, leeches are known to switch their dining preference as they mature, gorging on fish and amphibians when young while opting for more nutritious mammalian blood as adults. So, do leeches have a water wave frequency preference and, if so, which senses do they use to detect the vibrations and does their use alter with age? Intrigued, the trio began analysing leeches' responses to water waves (p. 3801).

Harley explains that leeches can sense water waves in one of two ways: either with vibration-sensitive hairs on their bodies or by using simple light-sensitive eyes that pick up the shadows of passing waves. So the team devised a series of tests where they could generate real waves and the optical illusion of waves while monitoring whether or not hungry juvenile, adolescent and adult leeches headed toward the wave's source.

Generating waves using a plastic disc driven by a loudspeaker vibrating at frequencies ranging from 2 to 24 Hz, the trio filmed the leeches in natural light and found that the adults responded most strongly to mid-range frequencies between 8 and 12 Hz. However, the juveniles seemed to prefer 2 Hz, although they reacted to every frequency to some extent. So, the leeches did have preferences, and they changed as the animals aged.

Next, Harley and her colleagues tested the leeches' reactions to the sensation of waves alone, and then to the visual effects of the passing wave shadows in still water, to find out whether individual senses were tuned to particular wave frequencies.

First, they switched off the lights and filmed the animals using infrared. Deprived of the waves' passing shadows, and depending on mechanical sensation alone, all of the age groups responded most strongly to 12 Hz waves and headed toward the vibrating disc. However, when the team suspended a dummy tank above the leeches' tank and cast shadows from the dummy tank's waves over the leeches in calm water, the leeches reacted most to the 2 Hz waves.

The leeches seem to use their visual sense for picking up low frequency water waves and vibration-sensitive hairs to pick up higher frequency passing waves. And when the team tried out-foxing the leeches by generating 12 Hz mechanical waves at one location while showing them 2 Hz wave shadows originating from a different point, they found that the adults only homed in on the mechanical source of the waves, while the juveniles were equally happy to focus on both the mechanical and the visual wave sources.

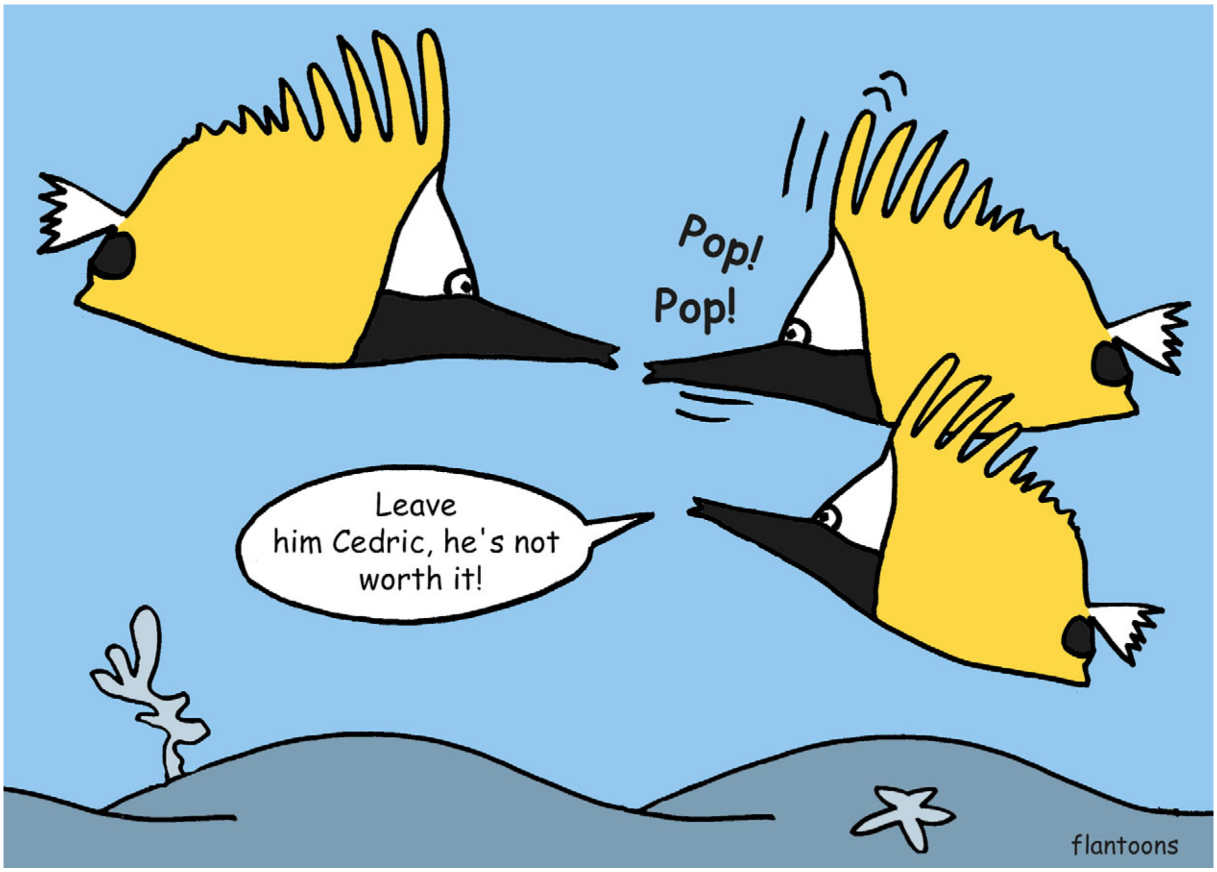
So their reliance on the sensory systems shifts with age: juvenile leeches depend on both senses, while adults place more emphasis on their mechanical sense to locate a wave's origin and hopefully a tasty mammalian meal.

10.1242/jeb.066787

Harley, C. M., Cienfuegos, J. and Wagenaar, D. A. (2011). Developmentally regulated multisensory integration for prey localization in the medicinal leech. *J. Exp. Biol.* **214**, 3801-3807.

Kathryn Knight

ANTAGONISTIC BUTTERFLYFISH POP



Whether defending a harem or a monogamous mate in the wild, forcepsfish and longnose butterflyfish warn competitors away with a single percussive popping sound followed by a flick of the head. Kelly Boyle and Timothy Tricas from the University of Hawai'i at Mānoa say, 'Sounds may reflect physical attributes of the sound production mechanism, be constrained by body size and therefore control signal reliability during agonistic behaviours.' However, it was unclear how both species produced their sound effects and what information the threatening pop conveys (p. 3829). Introducing a competitor into the territory of a forcepsfish or longnose butterflyfish in a laboratory aquarium, Boyle and Tricas filmed and recorded the defender's response and found that the fish began generating the sound well before tossing the head back: instead of producing the popping sound, the head flick was a by-product of the sound production mechanism. Analysing the fish's muscle activity, the duo saw that muscles in the jaw and neck are activated to pull back the pectoral girdle, ribs and rear half of the swim bladder to initiate the sound, before releasing the head so that it is jerked back even faster than is seen when snapping at prey. The duo also found that the largest forcepsfish produced the loudest and longest pops. 'Forcepsfish sounds may be accurate indicators of size and condition that are related to resource holding potential during social encounters,' they say.

10.1242/jeb.066779

Boyle, K. S. and Tricas, T. C. (2011). Sound production in the longnose butterflyfishes (genus *Forcipiger*): cranial kinematics, muscle activity and honest signals. *J. Exp. Biol.* **214**, 3829-3842.

Kathryn Knight
kathryn@biologists.com

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