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.

## WHALE LUNGES DISSECTED


Malene Simon

Returning briefly to the surface for great lungfuls of air, whales' lifestyles had been a complete mystery until a small group of pioneers from various global institutions – including Malene Simon, Mark Johnson and Peter Madsen – began attaching data-logging tags to these enigmatic creatures. Knowing that Jeremy Goldbogen and colleagues had successful tagged blue, fin and humpback whales to reveal how they lunge through giant shoals of krill, Simon and her colleagues headed off to Greenland where they tagged five humpback whales to discover how the animals capture and consume their prey: krill and agile capelin. Attaching individual tags behind the dorsal fin on three of the whales – to record their stroke patterns – and nearer the head on the remaining whales – to better measure head movements – the team successfully recorded depth, acceleration and magnetic orientation data from 479 dives to find out more about the animals' lunge tactics (p. 3786).

Analysing the whales' acceleration patterns, Simon saw that as the whales initiated a lunge, they accelerated upward, beating the tail fins (flukes) twice as fast as normal to reach speeds of 3–4 m s$^{-1}$, which is not much greater than the whales' top cruise speeds. However, while the animals were still beating their flukes, the team saw their speed drop dramatically, although the whales never came to a complete standstill, continuing to glide at 1–1.5 m s$^{-1}$ even after they stopped beating their flukes. So, when did the whales throw their mouths open during this sequence?

Given that the top speed attained by the whales during the early stages of the lunge were similar to the animals' cruising speeds and the fact that the whales were beating their flukes much harder than usual to maintain the speed, the team conclude, 'The implication is that the mouth must already be open and the buccal [mouth] pouch inflated enough to create a higher drag when the high stroking rates… occur within lunges'. In addition, the team suggests that the whales continue accelerating after opening their mouths in order to use their peak speed to stretch the elastic ventral groove blubber that inflates as they engulf water. Once the buccal pouch is fully inflated, the whales continue beating their flukes after closing their mouths to accelerate the colossal quantity of water, before ceasing movement of their fins and slowing to a new speed of 1–1.5 m s$^{-1}$. Finally, the animals filter the water and swallow the entrapped fish over a 46 s period before resuming beating their flukes as they launch the next lunge.

Considering that humpback whales and other rorquals were thought to grind to a halt after throwing their jaws wide and that reaccelerating their massive bodies from a stationary start was believed to make lunge feeding extortionately expensive, the team's discovery that the animals continue gliding after closing their mouths suggests that lunge feeding may be cheaper than previously thought. However, the team concedes that despite the potential reduction in energy expenditure, lunge feeding is still highly demanding, although they suggest that the high-speed tactic is essential for the massive hunters to engulf their nimble prey.

10.1242/jeb.080606

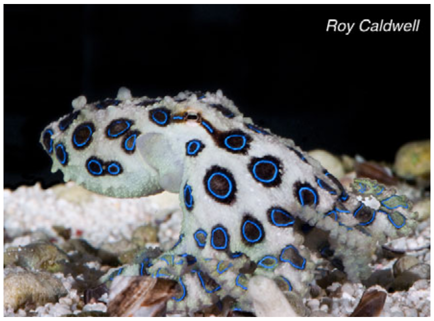
**Simon, M., Johnson, M. and Madsen, P. T.** (2012). Keeping momentum with a mouthful of water: behavior and kinematics of humpback whale lunge feeding. *J. Exp. Biol.* **215**, 3786-3795.

**Kathryn Knight**

## BLUE-RINGED OCTOPUS FLEXES MUSCLES TO FLASH FAST WARNING SIGNALS

They might be small and mild mannered, but don't be fooled; the blue-ringed octopus packs a powerful venomous punch. Luckily, says zoologist Lydia Mäthger, they give fair warning to any creature foolish enough to bother them. 'When they are disturbed, they flash about 60 iridescent blue rings as a warning signal', she explains. Filming the marine animals, Mäthger found that they can flash their rings in a third of a second. Wondering how they achieve such speedy signalling, she decided to take a closer look at their rings (p. 3752).

Cephalopods (squid, cuttlefish and octopus) are extremely colourful creatures, says Mäthger. 'They have two ways of changing colour', she explains. They can use chromatophores, small balloon-like pigment sacs that can be stretched or compressed by muscles, or they can use reflector cells such as iridophores, which are composed of stacked thin plates that reflect light by thin-film interference to generate iridescent colours, much like the spectrum of colours created by the thin surface of a soap bubble.


Roy Caldwell

Working with colleagues at the Marine Biological Laboratory in Woods Hole, Massachusetts, Mäthger first tested whether the iridophores of the blue-ringed octopus can actively produce blue iridescence. ‘Some animals can switch their iridophores on and off using chemical signals,’ explains Mäthger, ‘so we wanted to see if the blue-ringed octopus can too.’ Bathing blue-ringed octopus skin samples in a range of chemicals known to affect chromatophores and iridophores in other cephalopods and fish, she discovered that none of the chemicals had any effect: the structures retained their colour and never switched off. ‘Blue-ringed octopus iridophores are physiologically inert’, concludes Mäthger.

Next, she investigated the optical properties of the iridophores. She suspected that, like those of many other cephalopods, the iridophores of the blue-ringed octopus function as multilayer reflectors, which change colour when viewed at different angles. ‘In squid, for example, some iridophores appear red at normal viewing angles, but change colour from green to blue to UV when viewed at increasingly oblique angles’, explains Mäthger. Examining the light reflected from blue-ringed octopus skin samples from different viewing angles using a spectrometer, she saw that the iridophores displayed the shift to the UV end of the spectrum that is characteristic of multilayer reflectors. But other cephalopods that also have multilayer reflectors are more sluggish signallers, so the blue-ringed octopus must have another trick up its sleeve to produce its fast flashes.

To find out how the octopus pulls this off, Mäthger closely examined the skin structure around the blue rings using different microscopic techniques. She was surprised to discover that the iridophores are tucked into modified skin folds, like pouches, which can be closed by the contraction of muscles that connect the centre of each ring to its rim. When these muscles relax, and other muscles around the perimeter of the ring contract, the pouch opens to expose the iridescent flash. The octopus expands brown chromatophores on either side of the ring to enhance the contrast of the iridescence.

So, its highly elastic, muscular skin is the key to the signalling success of the blue-ringed octopus. ‘This signalling display method has never been seen before’, notes Mäthger. ‘A fast, conspicuous display under muscular control is an advantage to predators, who are warned before attacking a venomous creature, and of course to the octopus itself, as it avoids being eaten.’

10.1242/jeb.080598

**Mäthger, L. M., Bell, G., Kuzirian, A. M., Allen, J. J. and Hanlon, R. T.** (2012). How does the blue-ringed octopus (*Hapalochlaena lunulata*) flash its blue rings? *J. Exp. Biol.* **215**, 3752-3757.

**Yfke Hager**

## SOFT-SHELLED TURTLES EXCRETE UREA THROUGH MOUTH


Y. K. Ip

Chinese soft-shelled turtles are exquisitely adapted to their aquatic lifestyle, sitting contentedly on the bottom of brackish muddy swamps or snorkelling at the surface to breath. According to Y. K. Ip from the National University of Singapore, they even immerse their heads in puddles when their swampy homes dry up: which intrigued Ip and his colleagues. Why do these air-breathing turtles submerge their heads when they mainly depend on their lungs to breathe and are unlikely to breathe in water? Given that some fish excrete waste nitrogen as urea – in addition to ammonia – and expel the urea through their gills, the team wondered whether the turtles were plunging their heads into water to excrete waste urea through their mouths (p. 3723), where they have strange gill-like projections.

Purchasing turtles from the local China Town wet market and immersing them in water for 6 days, the team measured the amount of urea that passed into the turtles’ urine and found that only 6% of the total urea that the animals produced was excreted through the kidneys. Removing the turtles from the water and providing them with a puddle to dip their heads into, the team noticed that the turtles submerged their heads occasionally and could remain underwater for periods lasting up to 100 min. They also calculated the excretion rate of urea through the mouth by measuring the amount of urea that accumulated in the water and found that it was as much as 50 times higher than the excretion rate through the cloaca. And when the team injected urea into the turtles and measured their blood- and saliva-urea levels, they realised that the saliva-urea levels were 250 times greater than in the blood. The turtles were dipping their heads into water to excrete urea through their mouths.

Knowing this, the team reasoned that the animals must produce a specialised class of protein transporters in their mouths to expel the waste and, as these transporters can be deactivated by phloretin, the team decided to test the effect of phloretin on the turtle’s ability to excrete urea. When the turtles were supplied with phloretin in their puddle of water, they were unable to excrete urea from their mouths when their heads were submerged. And when the team analysed the turtles’ cDNA, they found that the animals carried a gene that was very similar to urea transporters found in other animals. Finally, they checked to see whether the turtles express this gene in their mouths and found evidence of the mRNA that is necessary to produce the essential urea transporter, allowing the reptiles to excrete urea waste through the mouth.

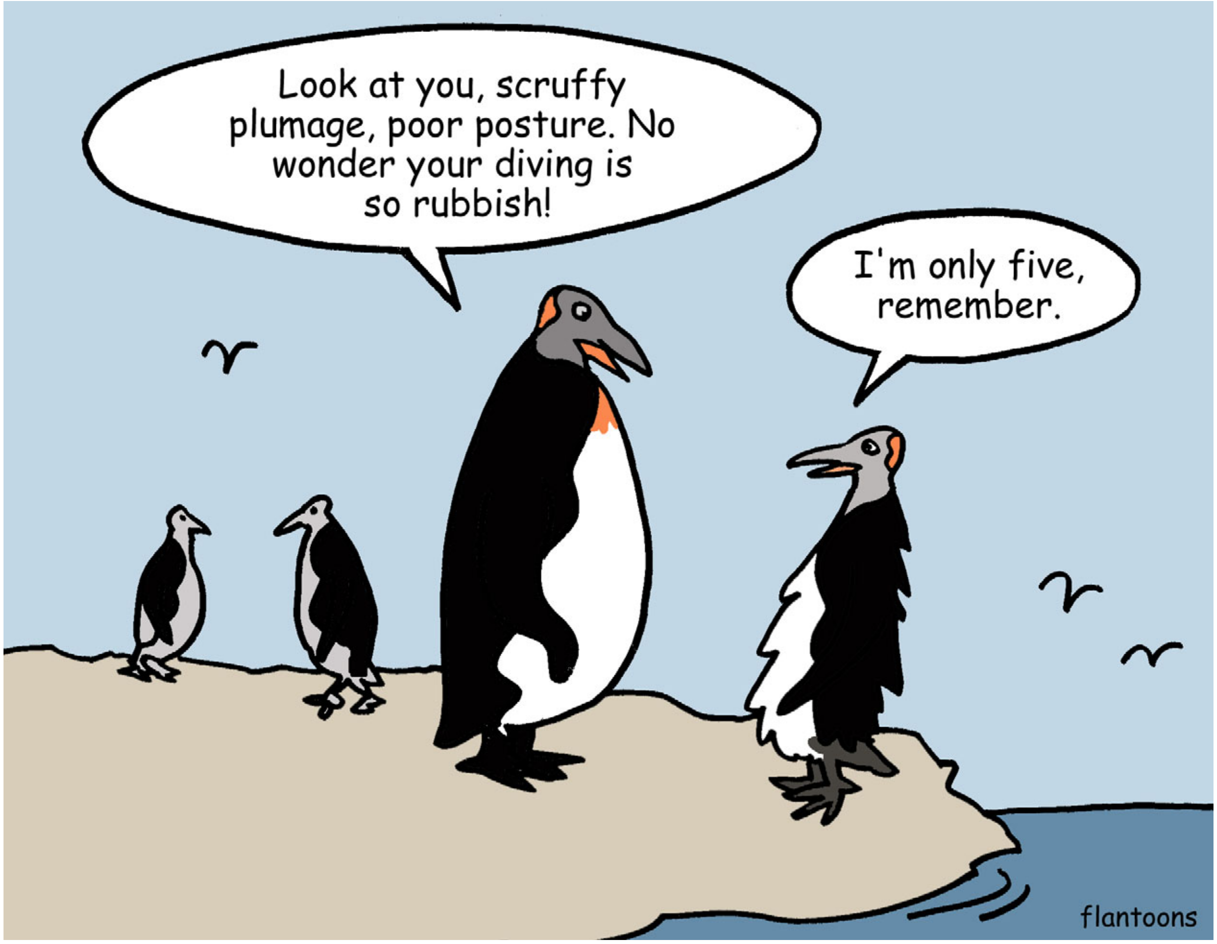
So, why do Chinese soft-shelled turtles go to such great lengths to excrete urea through their mouths when most other creatures do it through their kidneys? Ip and his colleagues suspect that it has something to do with their salty environment. Explaining that animals that excrete urea have to drink a lot, they point out that this is a problem when the only water available is salty – especially for reptiles that cannot excrete the salts. The team says, ‘Since the buccopharyngeal [mouth and throat] urea excretion route involves only rinsing the mouth with ambient water, the problems associated with drinking brackish water… can be avoided’.

10.1242/jeb.080614

**Ip, Y. K., Loong, A. M., Lee, S. M. L., Ong, J. L. Y., Wong, W.P. and Chew, S. F.** (2012). The Chinese soft-shelled turtle, *Pelodiscus sinensis*, excretes urea mainly through the mouth instead of the kidney. *J. Exp. Biol.* **215**, 3723-3733.

**Kathryn Knight**

# OLD PENGUINS CUT FORAGING COSTS AND INVEST IN YOUNG



For their size, birds have a relatively long lifespan. Tiny birds routinely outlive similarly sized mammals, which means that they continue reproducing into relatively old age. Maryline Le Vaillant and colleagues from several European institutions explain that all reproducing animals have to trade off investing in their own survival against that of their offspring, possibly allowing longer lived species to indulge more in their own survival during their early years at the cost of their own young. However, Le Vaillant and her co-workers suggest a possible alternative reason for older king penguins' reproductive success: they may simply be better at foraging and providing for their chicks because they are better divers. Explaining that no one had compared the diving performances of mature and less experienced king penguins, the team travelled south to the Crozet Archipelago in the Indian Ocean. Recording the dive depths and acceleration patterns of 5-year-old (young breeders) and 8/9-year-old (experienced breeders) penguins during their vast foraging odysseys, the team was able to estimate the penguins' diving costs (p. 3685).

Having found that the duration and depth of the old and young penguins' dives were essentially the same, the team focused on the descending and ascending leg of each bird's dive. They noticed that the older birds had to work harder than the youngsters early during their descents, but had a relatively easy return to the surface. However, the younger birds had to work harder than the older animals as they swam deeper, and they continued swimming hard during the ascent until the final 50 m, when the two groups put in the same amount of effort.

Explaining that king penguins often dive in groups led by older – more experienced – animals and that penguins adjust the amount of air they take down depending on their predicted dive strategy, the team suspects that experienced penguins inhale more than novice foragers before a dive and so have to work harder during the descent because of their increased buoyancy. However, the old-timers get an almost free ride back to the surface. In contrast, the younger penguins seem to be working hard against drag during most of their dives and Le Vaillant and colleagues suggest that this could be due to several factors, including scruffier plumage, poor dive posture and less direct dive trajectories, resulting from their inexperience.

'The dive strategy adopted by older king penguins ostensibly contributes to reduce their swim efforts and should decrease their foraging effort', the team concludes, potentially allowing older parents to invest more in their chick's success than novice mums and dads.

10.1242/jeb.080622

**Le Vaillant, M., Wilson, R. P., Kato, A., Saraux, C., Hanuise, N., Prud'Homme, O., Le Maho, Y., Le Bohec, C. and Ropert-Coudert, Y.** (2012). King penguins adjust their diving behaviour with age. *J. Exp. Biol.* **215**, 3685-3692

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