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.

BLUE WHALE-SIZED MOUTHFULS MAKE FORAGING SUPER EFFICIENT

When a blue whale dives to the krill fields where it feeds, it can remain submerged for anything up to 15 min. However, Bob Shadwick from the University of British Columbia, Canada, explains that blue whales may be able to dive for longer, because of the colossal oxygen supplies they could carry in their blood and muscles, so why don't they? 'The theory was that what they are doing under water must use a lot of energy,' says Shadwick. Explaining that the whales feed by lunging repeatedly through deep shoals of krill, engulfing their own body weight in water before filtering out the nutritious crustaceans, Shadwick says, 'It was thought that the huge drag effect when they feed and reaccelerate this gigantic body must be the cost'. However, measuring the energetics of blue whale lunges at depth seemed almost impossible until Shadwick and his student Jeremy Goldbogen got chatting to John Hildebrand, John Calambokidis, Erin Oleson and Greg Schorr (p. 131). Hoping to record feeding blue whale conversations, Calambokidis and his colleagues had skilfully attached hydrophones, pressure sensors and two-axis accelerometers to the elusive animals and tracked them to recover the valuable data. Shadwick and Goldbogen realised that they could use Calambokidis's measurements to calculate the energetic cost of blue whale lunges.

Analysing the behaviour of each whale, Goldbogen saw that dives lasted between 3.1 and 15.2 min and a whale could lunge as many as 6 times during a single dive. Having found previously that he could correlate the acoustic noise of the water swishing past the hydrophone with the speed at which a whale was moving, Goldbogen calculated the blue whales' speeds as they lunged repeatedly during each dive. Next the team had to calculate the forces exerted on the whales as they accelerated their colossal mouthful of water. Noticing that the whales' mouths inflated almost like a parachute as they engulfed the krill, Goldbogen tracked down parachute aerodynamics expert Jean Potvin to help them build a mathematical model to calculate the forces acting on the whales as they lunged. With Potvin on the team, they were able to calculate that the whales used between 3226–8071 kJ of energy during each lunge. But how did this compare with the amount of energy that the whales could extract from each gigantic mouthful of krill?

Goldbogen estimated the volume of the whales' mouths by searching the whaling literature for morphological data and teamed up with paleontologist Nick Pyenson to measure the size of blue whale jaw bones in several natural history museums. He also obtained krill density values from the literature – which are probably on the low side. Then he calculated the volume of water and amount of krill that a whale could engulf and found that the whales could consume anything from 34,776 kJ up to an unprecedented 1,912,680 kJ from a single mouthful of krill, providing as much as 240 times as much energy as the animals used in a single lunge. And when the team calculated the amount of energy that a whale could take on board during a dive, they found that each foraging dive could provide 90 times as much energy as they used.

Shadwick admits that he was initially surprised that the whales' foraging dives were so efficient. 'We went over the numbers a lot,' he remembers, but then he and Goldbogen realised that the whales' immense efficiency makes sense. 'The key to this is the size factor because they can engulf such a large volume with so much food in it that it really pays off,' says Shadwick.

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Goldbogen, J. A., Calambokidis, J., Oleson, E., Potvin, J., Pyenson, N. D., Schorr, G. and Shadwick, R. E. (2011). Mechanics, hydrodynamics and energetics of blue whale lunge feeding: efficiency dependence on krill density. *J. Exp. Biol.* **214**, 131-146.

PAINTED TURTLES VARY MAINTENANCE INVESTMENT OVER TIME

Every homeowner knows that maintenance is a major expense, and our bodies are no different. Most species make significant investments in maintaining systems that are essential for survival, but sometimes the costs are too high, leading animals to cut back on maintenance at certain times of the year and make do with second best. Lisa Schwanz and her colleagues from Iowa State University and the University of Pennsylvania say, 'Physiological maintenance has been widely studied in birds, mammals and invertebrate model systems, but much less is known about maintenance in ectothermic vertebrates'. Explaining that ectotherms tend to live longer than endotherms and experience significantly different physiological stresses, Schwanz and her co-workers decided to find out how painted turtles – ranging from hatchlings to aged adults – maintain their bodies throughout the year. The team measured the DNA damage repair efficiency and immune responses of painted turtles prior to hibernation, and then continued monitoring the immune response during hibernation and in the spring to find out how well they maintain two physiological systems that are essential for long-term survival (p. 88).

Collecting animals from the wild, the team took small blood samples from them before, after and during hibernation. Measuring the ability of the blood samples to repair DNA damage, the team exposed the pre-hibernation samples to UV light and analysed the amount of DNA damage sustained. They also counted the number of immune response cells – ranging from lymphocytes to heterophils – to find out how their levels vary at different times of year, as well as measuring the blood parasite levels, to find out how healthy the animals were, and several responses to infection.

Analysing a colossal amount of data, the team found that the hatchling's immune response was weaker than the adult's. However, when they looked at the older turtles' immune systems, they found that they were almost as well maintained as younger adults' immune systems – unlike the immune systems of elderly endotherms, which usually deteriorate with age. But, despite their well-maintained immune systems, the elderly turtles had higher levels of haemogregarine parasite infection, which could weaken them. And when the team compared the turtle's immune responses before, during and after hibernation they found seasonal fluctuations but no evidence that the immune response became stronger during hibernation.

Looking at the levels of DNA damage repair across the different age groups the team found that hatchlings had high levels of DNA damage repair, but juvenile and elderly turtles seemed to have no DNA damage repair mechanisms at all. The team suspect that the loss of DNA damage repair mechanisms is not a natural decline with age and suggest that turtles may have reduced levels of DNA damaging oxygen free radicals so they no longer require protection from DNA damage.

Schwanz and her colleagues say, 'Physiological maintenance across different immunological and non-immunological systems is not consistently determined by age, sex or season in the long-lived painted turtle,' and point out that the reptiles do not seem to suffer many of the ageing effects that elderly endotherms endure.

10.1242/jeb.054163

Schwanz, L., Warner, D. A., McGaugh, S., Di Terlizzi, R. and Bronikowski, A. (2011). State-dependent physiological maintenance in a long-lived ectotherm, the painted turtle (*Chrysemys picta*). *J. Exp. Biol.* **214**, 88-97.

WHISTLING CATERPILLARS STARTLE BIRDS

We're all familiar with the serenades that crickets sing and cicadas chirrup, but have you ever heard a caterpillar whistle? Jayne Yack from Carleton University, Canada, has – but only when it's under attack. 'I am fascinated with the idea that animals have many unusual forms of communication, so when we see caterpillars that are communicating with some of their predators with ultrasound, that interests me,' Yack explains. Surveying caterpillars from a wide range of Bombycoidea species to discover what sounds they make when feeling threatened, Yack's student, Veronica Bura, discovered that walnut sphinx caterpillars make an unusual squeak. Curious to find out how the caterpillars produce this sound, the duo decided to analyse the larvae's behaviour (p. 30).

Trapping adult female moths and collecting the eggs, Yack and Bura waited for the eggs to hatch and reared the larvae to the 4th and 5th instar on tree cuttings. Then the duo gently squeezed the caterpillars with blunt tweezers to see how they reacted. Sure enough the caterpillars made the strange squeak and when Yack and Bura analysed the squeak's frequency spectrum, they found that it spanned frequencies ranging from those audible to birds and humans up to ultrasound. But where were the sounds coming from?

Watching the squeaking caterpillars under a microscope, it was clear that the larvae were not opening their mouths and clicking their mandibles to make the sounds. However, they were pulling their heads back, compressing the body cavity. Wondering if the larvae were forcing air out of their spiracles to produce the sound, Yack suggested that Bura gently apply latex to cover all eight pairs of the caterpillar's abdominal spiracles and then uncover each pair systematically while disturbing the larva. 'Sound production did not occur until Veronica got to the 8th abdominal spiracle, but then they made sounds like before,' remembers Yack. And when the duo monitored air flow from the spiracles using lens paper and a laser vibrometer as the caterpillar squeaked, they only recorded vibrations coming from the 8th spiracles. So the larvae squeak by blowing air out of the 8th spiracles to produce trains of whistles lasted anything up to 4 s.

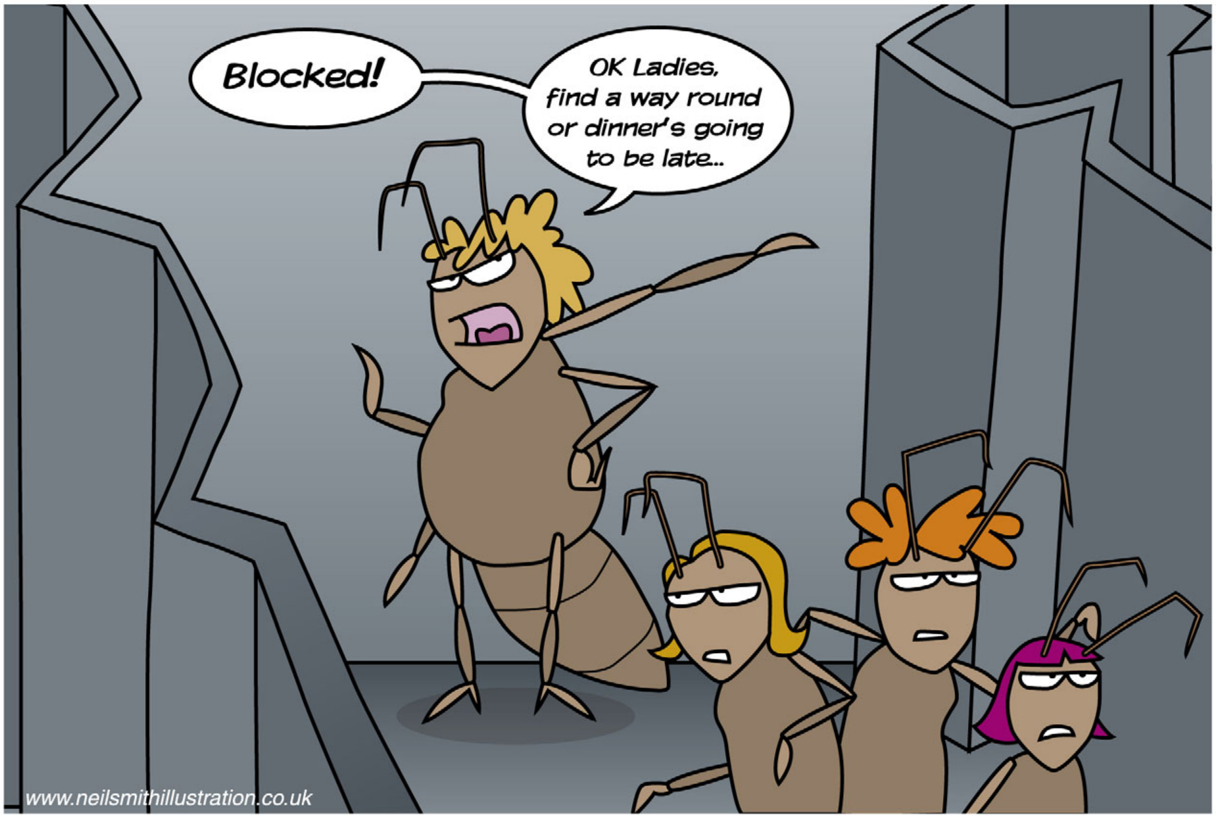
But why do the caterpillars whistle when it would seem to be a perfect way to advertise your presence to predators? Yack and Bura decided to find out by asking some birds. Teaming up with Vanya Rohwer and Paul Martin at Queen's University, Canada, who had captive yellow warblers – a native predator of the caterpillars – Bura and Yack put a caterpillar on a twig in a cage with a yellow warbler and patiently filmed the encounter. Amazingly, when the bird attacked the caterpillar, the caterpillar whistled and the bird dived for cover. The caterpillars were so successful at frightening off their predators that the birds did not eat a single one.

'We were very surprised; we didn't think the birds would react like that. They were scared,' says Yack. 'If you put yourself in the bird's place you have limited foraging time, you're hunting around the foliage and you find something that is cryptic, you attack it and then it goes "wee" – I can guarantee you'd abandon it and start looking for something else,' she says. So walnut sphinx caterpillars whistle at their predators to startle them away before resuming the quiet life, tucked away in the foliage.

10.1242/jeb.054155

Bura, V. L., Rohwer, V. G., Martin, P. R. and Yack, J. E. (2011). Whistling in caterpillars (*Amorpha juglandis*, Bombycoidea): sound-producing mechanism and function. *J. Exp. Biol.* **214**, 30-37.

ANT STRATEGIES FOR NEGOTIATING OBSTACLES



Ants are notoriously good at finding the most direct route to food. Laying down volatile pheromones to guide their colleagues, ant colonies eventually home in on the most direct path as pheromone is lost from longer paths and added to more heavily used shorter routes. Finding the optimal paths through networks is also a challenge for human delivery agents, telephone routers and systems analysts, so software engineers have turned to trail-blazing ants for inspiration to solve these problems. Chris Reid and Madeleine Beekman from Sydney University, Australia, and David Sumpter from Uppsala University, Sweden, explain that one network-solving algorithm uses virtual ants to lay down virtual pheromone trails to identify the most direct route through, but it doesn't do well when networks continually change, as they do in real life. However, ants have faced constantly changing landscapes for millions of years, so Reid and his co-workers decided to find out how Argentine ants identify the optimal route through a changing network when they presented the insects with the Towers of Hanoi puzzle (p. 50).

Of course the team didn't ask the ants to start moving puzzle discs between pegs. Instead, they converted the task into a graph of possible moves and converted that in turn into a maze of hexagons. Having initially allowed a colony of ants to explore the maze and lay down pheromones (short-lived foraging pheromone and long-lasting exploration pheromone), the team then placed food at the end of the maze and filmed the ants as they tried to identify the optimal route through the maze to the food while the team blocked off routes and opened up alternatives.

The ants had little problem coping with change. Initially, the insects found the shortest route, scurrying along the outer edge of the maze to the food source. However, when the team blocked this route and opened up another through the middle of the maze, the ants changed course, zigzagging across the maze, perpendicular to their original route until they found the alternative. The team suspects that both pheromones played critical roles, with short-lived foraging pheromone allowing the ants to respond quickly when the route changed and long-lived exploration pheromone rapidly stabilising the optimal route. Also, when an ant encountered an obstacle, Reid and his colleagues noticed that she began searching for a route around the blockage, rather than retracing her steps. The team suspects that the ants don't just rely on geometry to identify paths and negotiate obstacles; they use an internal compass to help them reach their goal. Finally, the trio hopes that their new discovery that ants use multiple pheromones and possibly compasses will inspire software engineers to develop alternative ant-based algorithms to solve complex dynamic network problems.

10.1242/jeb.054171

Reid, C. R., Sumpter, D. J. T. and Beekman, M. (2011). Optimisation in a natural system: Argentine ants solve the Towers of Hanoi. *J. Exp. Biol.* **214**, 50-58.

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