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

HEAT WAVE SUPER BUGS SUSCEPTIBLE TO SOME INFECTIONS

It's a typical summer evening: buzzing bees and chirruping crickets catch the last warm rays before sunset. But how will this idyllic scenario be affected by climate change? Shelley Adamo from Dalhousie University, Canada, says, 'Insects are poikilotherms, cold-blooded animals, so they are going to have an increase in their metabolic rate and that is going to have a large number of ramifications for ecosystems.' She explains that one of the consequences of ramping up metabolic rate in temperate zone insects is an increase in reproduction, 'And the assumption is that global warming is going to increase insect populations,' she says. However, Adamo was curious: would everything get better for insects in a warmer world? For example, how would an increase in reproductive rate affect their ability to fend off disease? Knowing that heat waves are predicted to become more extreme and occur more frequently with climate change, Adamo and her undergraduate student Maggie Lovett decided to find out how crickets cope with a warm snap (p. 1997).

'There are two ways their reproductive rate could go,' says Adamo. Either there could be a trade off and their immune function could decline or, the extra heat could improve the insect's immunity in addition to improving their fertility. 'No one had asked the question directly before,' says Adamo, so she and Lovett decided first to find out which temperature crickets prefer.

Offering the insects a choice of temperatures, from a comfortable 26°C to a scorching 38°C, Adamo found that the crickets preferred to settle at 28.1°C. Next, she created a mini heat wave – warming the insects to 33°C for 6 days – and then checked to see how the warmth had affected their fertility. Amazingly, the heat wave females began pumping out eggs, producing up to 66% more than the insects at 26°C. And when Lovett tested the eggs' quality they were every bit as good as those laid by the cooler females: and they developed faster. Even more surprisingly, the females gained weight, despite their colossal productivity.

Next, Lovett tested the crickets' immune function. Collecting haemolymph from the insects, she measured the activity of two key components of the immune response and found that the hot insects had a stronger immune system. Everything appeared to be better for these new super bugs, but how would they cope with a real infection?

Adamo gave the super bugs an injection of bacteria that was strong enough to kill 50% of normal crickets and waited to see how many died. Comparing the death rates of heat wave-treated crickets with those of crickets at normal temperatures, Lovett found that the insects' souped-up immune systems had dramatically improved the crickets' chances of surviving a *Serratia marcescens* infection, almost halving the death rate from 76.5% at 26°C to 47% at 33°C. However, it was a different matter for the super bugs infected with *Bacilus cereus*. Their death rate rocketed from 10% at 26°C to over 25% at 33°C. Instead of becoming more resistant, the super bugs had become more susceptible to the pathogen and their fertility suffered also.

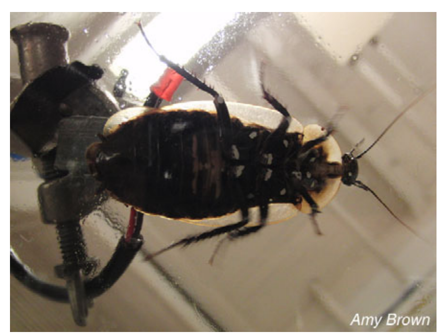
Adamo and Lovett had found the super bugs' Achilles' heal. Even though they reproduced better and appeared tougher than normal insects, the additional heat had made them more susceptible to certain pathogens. As well as possibly explaining why the insects prefer to remain at cooler temperatures, Adamo warns that increased susceptibility to specific pathogens could significantly impact future insect populations. While she suspects that some insects will benefit from global warning, others may become more vulnerable, with potentially catastrophic consequences for ecosystems and economies alike.

10.1242/jeb.060020

Adamo, S. A. and Lovett, M. M. E. (2011). Some like it hot: the effects of climate change on reproduction, immune function and disease resistance in the cricket *Gryllus texensis*. *J. Exp. Biol.* **214**, 1997-2004.

Kathryn Knight

COCKROACHES TROT AND AMBLE WITH TRIPOD GAITS



If you want to design a robot that's good at getting out of tight corners, what creature would you base it on? According to John Bender from Case Western Reserve University, USA, cockroaches are great walkers and exceptionally stable when negotiating rugged terrain. 'It would be great to design robots that walk like cockroaches, but how do they control their legs?' puzzles Bender. Curious to understand how the cockroach brains control their movements, Bender joined Roy Ritzmann's laboratory to begin studying how cockroaches walk.

Teaming up with engineers Brian Tietz, Kathryn Daltorio and Roger Quinn, Bender designed and built a large arena that the cockroaches could explore while the team recorded their antics (p. 2057). Then Bender calculated each insect's route and speeds and was surprised that instead of moving over a continuum of speeds, the insects had two natural paces: a fast 30 cm s^{-1} trot and a slower 10 cm s^{-1} amble.

'Next, we wanted to see what it was about the cockroach and the environment that pushed them into one speed zone or another and we found that it was simply whether they were in contact with the wall or not,' says Bender. Also, when he calculated the insect's Froude number (the ratio of an animal's potential energy to kinetic energy) at speeds intermediate between the amble and trot, the value was 0.4: similar to the values where all animals switch from a walk to a trotting gait. The insects seemed to have two distinct gaits, but how different were the movements that produced them? Bender and his colleagues needed to take a closer look at the cockroach's footwork.

Filming all six of the insects' legs in 3D at 500 frames s^{-1} while the tethered insects walked on an oiled glass plate, Bender captured every detail of their walking patterns. Then he checked whether the insects were using the same walking styles as they had in the arena. They were, so the team could analyse the high-speed movies to find out how the ambling and trotting gaits differed.

Working with Elaine Simpson, Bender painstakingly digitised each image and calculated the position and joint angles for 30 of the insects' leg joints at both speeds. Bender explains that typically cockroaches walk with a tripod gait: they always keep one tripod of legs (the foreleg and hindleg from one side and the middle leg from the other) in contact with the ground, alternating the tripods as they walk. When the team scrutinised the insect's fast and slow walking styles, they were amazed to see that they were both tripod gaits; the main difference was the degree of coordination between the legs. 'When they transition from an amble to a trot you see the coordination tighten up. In the ambling gait it is a very sloppy tripod, but when you switch into the trotting gait then all of a sudden everything is crisp clean and well coordinated,' says Bender.

So why do the insects amble slowly when close to walls and trot fast across open spaces? Bender suggests that the insects use different control systems. He suspects that the trotting gait is generated by a central pattern generator, where the rhythmic movements are internally generated in a neural circuit with little feedback from the environment when scampering across open spaces. However, he thinks that the slower amble is more feedback sensitive with each leg talking to the others to come up with a consensus of what they should do to get out of tight corners.

10.1242/jeb.060038

Bender, J. A., Simpson, E. M., Tietz, B. R., Daltorio, K. A., Quinn, R. D. and Ritzmann, R. E. (2011). Kinematic and behavioral evidence for a distinction between trotting and ambling gaits in the cockroach *Blaberus discoidalis*. *J. Exp. Biol.* **214**, 2057-2064.

Kathryn Knight

ELASTIC ENERGY STORAGE DOES NOT SOLELY DETERMINE OPTIMAL STRIDE FREQUENCY

When training as a cross-country runner during her college days, Kristine Snyder recalls her coach telling her to run at a specific stride frequency and wondering where the number came from. 'The reality is that optimal stride frequency varies from person to person,' says Snyder, who adds, 'If you can run at a stride frequency that is going to minimise your metabolic cost – the optimal stride frequency – that is going to allow you to go farther and faster.' But what determines an individual's optimal stride frequency? 'There has been this idea in the literature for a while that the reason our optimal stride frequency is optimal is because our elastic energy storage is maximal at that frequency,' explains Snyder, but no one had successfully tested this theory. Intrigued by the problem at a scientific and personal level, Snyder teamed up with Claire Farley at the University of Colorado, USA, to find out whether elastic energy storage determines optimal stride frequency (p. 2089).

'We decided to see what would happen if we could reduce elastic energy storage, which may allow us to determine what happens when it is present,' says Snyder. She explains that when you run on the flat you store elastic energy in your tendons as your foot strikes the ground and recover a great deal of this energy when you push off again. However, when running up an incline, the energy stored in the tendons as the foot lands is insufficient to lift you up the slope when you push off next, so muscle provides the additional energy. Conversely, when descending a hill more energy could be stored in the tendons than is needed, so the muscles dissipate the excess to maintain a constant speed. Essentially, Snyder and Farley could alter runners' maximal elastic energy usage by making them run uphill or downhill to find out if elastic energy usage sets a runner's optimal stride frequency.

The duo decided to measure the metabolic effects of running at different stride frequencies on flat and inclined surfaces. They reasoned that if elastic energy storage is a significant factor in determining a runner's optimal stride frequency then the metabolic rates of athletes running at different stride frequencies on sloped surfaces would vary less than the metabolic rates of athlete's running at different stride frequencies on a flat surface.

Recruiting outstanding runners from Boulder, Colorado, Snyder identified each runner's preferred stride frequency and set a metronome ticking to test whether they could run at 85%, 92%, 100%, 108% and 115% of their natural running frequencies. 'They really strongly did not like using anything besides their preferred frequency,' remembers Snyder, but having established that they could, she measured their metabolic rates as they ran at each frequency on the flat and angled treadmills.

Plotting the athlete's metabolic rates against their stride frequencies for each of three treadmill angles, the duo expected each parabola to have a different gradient if the optimal stride frequency was determined by the runner's ability to store elastic energy. However, the parabolas were all very similar: optimal stride frequency is not determined solely by elastic energy storage.

In that case, what does set a runner's optimal stride frequency? 'I think we have a combination of things,' says Snyder. She suspects that optimal stride frequency occurs at intermediate stride frequencies where the athlete's metabolic cost is lowest – as runners' muscles work harder at low and high stride frequencies and they also have to work harder to push off at high stride frequencies.

10.1242/jeb.060046

Snyder, K. L. and Farley, C. T. (2011). Energetically optimal stride frequency in running: the effects of incline and decline. *J. Exp. Biol.* **214**, 2089-2095.

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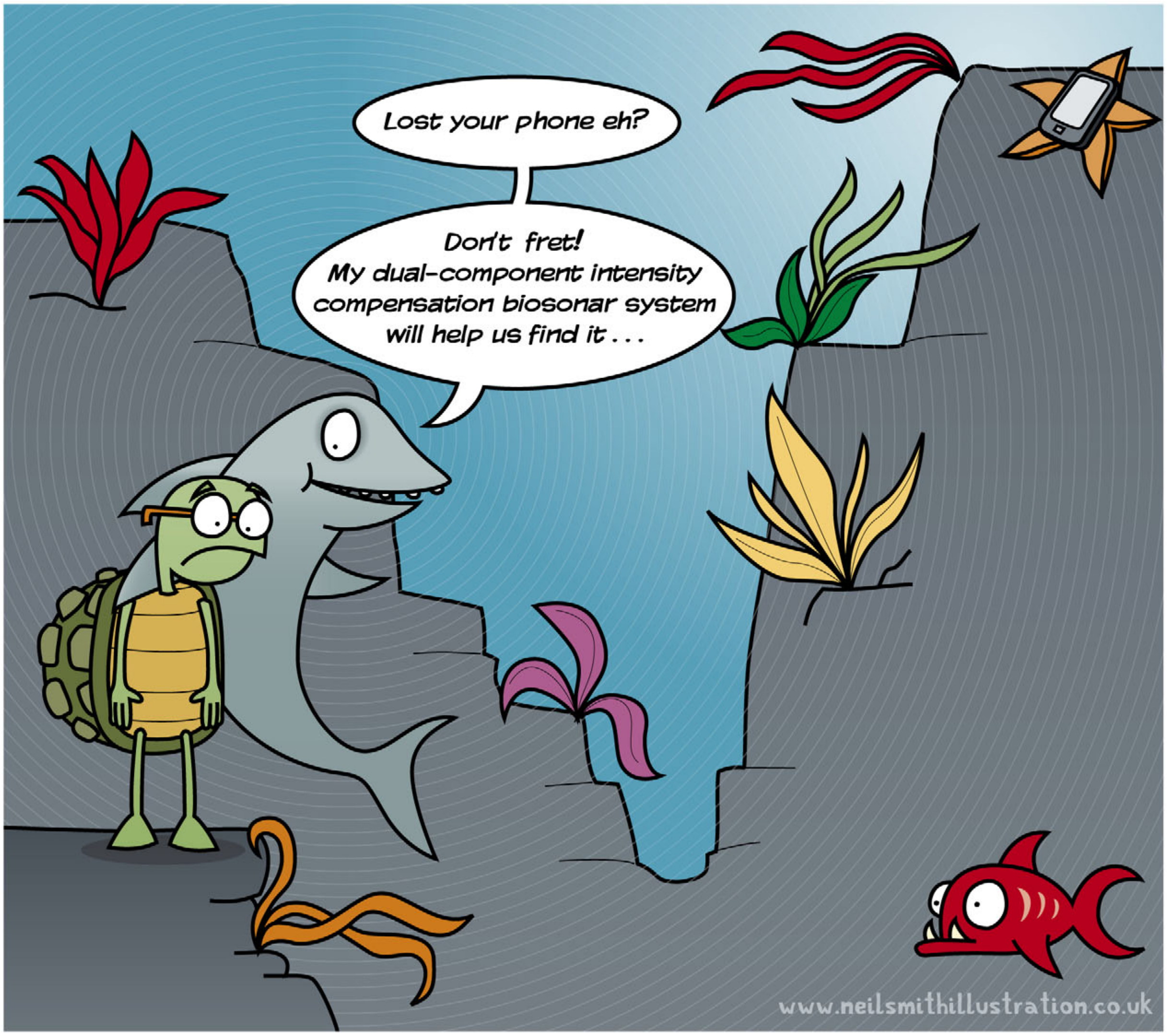
ATLANTIC BOTTLENOSE DOLPHINS USE DUAL-COMPONENT BIOSONAR FOR ECHOLOCATION



For visual animals, it's hard to understand how echolocating creatures perceive the world. Yet dolphins successfully hunt and communicate through a system of clicks and high-pitched whistles. So what do these echolocation calls sound like to dolphins? Songhai Li, Paul Nachtigall and Marlee Breese tested the hearing of an Atlantic bottlenose dolphin named BJ as she listened to echoes of her own echolocation clicks reflected from various sized cylinders placed 2–6.5 m in front of her nose (p. 2027). Recording BJ's electrical brain responses with a suction-cup recording electrode just behind her blowhole, they could see that the echoes and calls both triggered brain activity, although the responses to the echoes were weaker. The team also saw that the responses to the fainter echoes became stronger as the objects became more distant, 'Demonstrating an overcompensation of echo attenuation,' they say. And when the team measured the strength of the dolphin's echolocation clicks, they found that calls became louder as the cylinders became more distant. The team says, 'The results demonstrate that a dual-component biosonar control system formed by intensity compensation behaviour in both the transmission and receiving phases of a biosonar cycle exits synchronously in the dolphin biosonar system.'

10.1242/jeb.060053

Li, S., Nachtigall, P. E. and Breese, M. (2011). Dolphin hearing during echolocation: evoked potential responses in an Atlantic bottlenose dolphin (*Tursiops truncatus*). *J. Exp. Biol.* **214**, 2027-2035.

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