INSIDE JEB

# Quolls slow down to avoid a crash

A northern quoll (*Dasyurus hallucatus*). Photo credit: Skye Cameron.

Northern quolls, small carnivorous marsupials native to northern Australia, have been wiped out in many parts of their original range. Predation by cats, foxes and dogs is partly to blame. That's why it's important to understand which factors determine quolls' ability to escape predators, says Robbie Wilson, a performance biologist at the University of Queensland, Australia. And that may involve some counterintuitive ideas. Quolls might be expected to run as fast as they can when trying to escape capture. 'But this ignores the fact that there are huge costs for running at your fastest speeds', says Wilson. 'It's likely that an animal running at top speed will not be able to turn or manoeuver as quickly.' To explore these trade-offs, Wilson teamed up with Melissa Wynn, Christofer Clemente and Ami Fadhillah Amir Abdul Nasir. 'We wanted to see how running speed constrains an animal's ability to make rapid turns, which are likely to be very important for escaping predators, and what morphological attributes determine how well an animal can turn', Wilson explains (p. 433).

When studying an endangered species, the first challenge is finding enough animals. Luckily, Groote Eylandt, an island off Australia's northeastern coast, remains a quoll stronghold. Using baited traps to capture 66 quolls, the team then put the marsupials through their paces in a specially designed racetrack consisting of two moveable channels joined with one of three removable angle structures (45, 90 and 135 deg) that allowed the team to challenge the animals' manoeuvrability. Then they chased quolls along the track with a polystyrene block and filmed their actions from above using a high-speed digital camera to explore how running speed affected the animals' chances of crashing when running around a corner.

As the team expected, quolls crashed more frequently when they approached a corner at high speed and when running around tighter corners. Then, knowing that higher running speeds increased the likelihood of the animal slipping, the team reasoned that quolls should choose to run more slowly when approaching a sharp corner, but do they slow down when negotiating tight turns in practice? It turns out that they do. When the team analysed footage of the running animals, they found that average turning speed decreased as the magnitude of the turn angle increased, and when negotiating 135 deg turns, quolls decreased their running speeds to around a third of their straight-line speeds. Finally, the team wondered how an animal's build may affect its agility. 'We expected that larger animals would find it harder to get around tighter corners', says Wilson, because they have to overcome greater angular momentum. But to their surprise, the team found this was not the case. Instead, they found that foot length was the strongest predictor of manoeuvrability. 'It appears that it's the foot size of the animals that constrains their ability to negotiate a corner successfully', Wilson explains. 'The larger the foot size, the greater their grip.'

The team concludes that an animal's running speed constrains its ability to make quick, rapid turns. 'This means that an animal should modify its speed when running away from a predator, optimising its combination of speed and manoeuvrability to maximise its chances of success', says Wilson. In other words, the quolls that are most likely to survive attacks by introduced predators are those that master the optimal compromise between speed and agility.

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**Wynn, M. L., Clemente, C., Nasir, A. F. A. A. and Wilson, R. S.** (2015). Running faster causes disaster: trade-offs between speed, manoeuvrability and motor control when running around corners in northern quolls (*Dasyurus hallucatus*). *J. Exp. Biol.* **218**, 433-439.

**Yfke Hager**

# Lungfish hear air-borne sound

The 21st century is a noisy place: sirens, alarms, cars, mobile phones; you have to go a long way get any peace. But for the first 100 million years after the earliest terrestrial ancestors heaved themselves on to land, they may have heard little of the surrounding soundscape. 'It is quite a different task to detect sound in water and air as the physical properties of these two media are very different', says Christian Christensen from Aarhus University, Denmark. Sound vibrations that are transmitted through water pass with ease into the bodies of aquatic animals, to vibrate minute granules (otoliths) in the animals' ears to produce the sensation of hearing. However, as soon as the first tetrapods emerged from the water, the water-borne mechanism of sound transmission may have failed as the vast majority of vibrations that are carried in air are reflected when they reach a body. How the modern tetrapod ear – which transforms aerial sound pressure waves into physical vibrations in the inner ear – evolved from these humble beginnings is something of a mystery. However, modern lung fish may hold the key to this puzzle. 'Lungfish are the closest living relatives of tetrapods', explains Christensen, who wondered whether they may hear sound using mechanisms that are similar to those of our ancient ancestors. So, Christensen and his colleagues, Jakob Christensen-Dalsgaard and Peter Madsen, began investigating the terrestrial hearing of these remarkable air-breathing fish (p. 381).

The researchers explain that the fish could use their air-filled lungs to convert pressure waves into vibrations – in much the same way as the ear drum (tympanum) converts sound pressure into physical vibrations – and so they designed a 2 m long steel tube that they filled with water to test the fish's hearing. By placing a loud speaker at one end of

African lungfish (*Protopterus annectens*). Photo credit: Cedricguppy – Loury Cédric [CC BY-SA 4.0], via Wikimedia Commons.

the tube and playing a pure note of one frequency in the water, they could generate a standing wave where the pressure was high at locations where the water particles were stationary and the pressure was low when the particles were moving most. Positioning an anaesthetised lungfish at various positions along the length of the tube – to vary the sound pressure acting on them – and measuring the fish's hearing by recording electrical activity in the brainstem, Christensen found that the fish were able to hear sound pressure at frequencies above 200 Hz, while hearing particle motion at lower frequencies.

Next, he measured the volume of the air in the fish's lungs using computed tomography and found that the lung's resonant frequency was 320 Hz, which means that the lungs are perfectly attuned to generate the strongest vibrations at frequencies where the lungfish hear the sound pressure. 'This strongly suggests that pressure detection in lungfish is enabled through detection of the pressure-induced particle motion generated by the resonating air volumes in the lungs', says Christensen.

But would this mean that the fish could hear in air too? Christensen recorded the brainstem activity of the fish in response to airborne sounds ranging in frequency from 80 to 1280 Hz and the team were impressed to see that the fish could hear loud sounds (above 85 dB SPL) at frequencies up to 200 Hz. 'It was a surprise that the lungfish, being completely unadapted to hearing, were in fact able to hear airborne sound', says Christensen, who suspects that our earliest terrestrial may not have been as deaf as we thought. 'Even aquatic vertebrates with no middle ear adaptations to aerial hearing, such as the early atympanic tetrapod *Acanthostega*, may have been able to detect higher levels of low frequency airborne sound', he says.

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**Christensen, C. B., Christensen-Dalsgaard, J. and Madsen, P. T.** (2015). Hearing of the African lungfish (*Protopterus annectens*) suggests underwater pressure detection and rudimentary aerial hearing in early tetrapods. *J. Exp. Biol.* **218**, 381-387.

**Kathryn Knight**

# Mosquito body clock regulates winter shut down

For some species, surviving winter is too much of an ordeal to keep everything ticking over. So, as soon as the days reach a certain length, adult Northern house mosquitoes (*Culex pipiens*) prepare for their seasonal reproductive winter shut down (diapause), ready to re-commence reproduction in the spring. 'Much is known about the photoperiodic cues, endocrine signals and physiological changes that regulate and accompany diapause', says Megan Meuti from The Ohio State University, USA. However, little was known about the mechanism that the insects use to measure day length or how they convert the information into the hormone signals that orchestrate the insects' diapause. Although many insects are known to regulate body functions using a light-regulated circadian clock, it was not clear whether this mechanism triggered preparation for diapause in *C. pipiens*, so Meuti and her colleagues, Mary Stone, Tomoko Ikeno and David Denlinger, began investing the effects of day length on key components of the mosquito's circadian clock (p. 412).

The team explain that the expression levels of the five components of the molecular clock (*Clock*, *cycle*, *period*, *timeless* and *cryptochrome2*) rise and fall in relation to the length of daylight exposure over a 24 h period, so they decided to find out whether the clock continued running during diapause. Measuring expression of *period*, *timeless*, *cycle* and *cryptochrome2* in the brains of adult female mosquitoes that had been exposed to daylight periods of different length to stimulate the onset and duration of diapause, the team discovered that the mRNA levels continued cycling – even when the insects were plunged into the depths of winter. Meuti explains that the clock has to function throughout the seasons to ensure that the insect knows when to emerge from diapause and says, 'Our observations… support the circadian basis for diapause initiation and maintenance in *C. pipiens* and suggest that the rhythmic oscillations of these transcripts may be involved in continually measuring night length throughout diapause'. The team were a little perplexed when they discovered that expression of *cryptochrome* became reversed (peaking at night) after emergence from diapause; however, they suspect that this reflects that the insects are most active in the early morning.

Having confirmed that the insect's circadian clock plays a role in regulating diapause, the team began investigating the individual role of each of the clock's components. Injecting an RNA molecule designed to lock up the mRNA and prevent transcription of one individual component of the clock into young female adult mosquitoes and then monitoring the effect of the component loss on their fatness and fertility, the team found that females that were experiencing short daylight exposures – which should have induced diapause – failed to enter the condition when *period*, *timeless* and *cryptochrome* mRNA levels were reduced. However, when the team inactivated another component of the molecular clock – *pigment dispersing factor* – under long daylight conditions, the loss triggered diapause in insects that should have been able to reproduce.

'Our results implicate the circadian clock in the initiation of diapause in *C. pipiens*', says Meuti, who adds that she is keen to understand the complete diapause pathway, from the measurement of day length to the physiological mechanisms that allow the mosquitoes to survive the winter. Explaining that *C. pipiens* is a carrier of major diseases such as West Nile virus, St Louis encephalitis and filariasis, Meuti is hoping to use this knowledge against the insect to control disease transmission – by either averting diapause in winter or initiating diapause in other seasons.

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**Meuti, M. E., Stone, M., Ikeno, T. and Denlinger, D. L.** (2015). Functional circadian clock genes are essential for the overwintering diapause of the Northern house mosquito, *Culex pipiens*. *J. Exp. Biol.* **218**, 412-422.

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