

## OUTSIDE JEB

## Going torpid to pass through hard times



Endothermy, the maintenance of a high and relatively stable body temperature via internal heat production, comes at a high energetic price, so some mammals use torpor – a controlled decrease in metabolic rate and body temperature – to decrease metabolic costs during energetically challenging times. For a long time, torpor use was believed to be the sole preserve of a small number of Northern Hemisphere small mammals that resorted to torpor during the lean winter months or cold nights. However, more recently, species from the tropics and subtropics have been added to the list of animals that conserve energy by becoming torpid when food and other resources – such as water – become scarce. Fritz Geiser's research group at the University of New England, Australia, has recently expanded our understanding of how mammals employ torpor to survive in highly unpredictable environments, with two recent studies which investigated how some animals respond to natural disasters that suddenly restrict foraging opportunities.

In the first study, led by Claire Stawski, the team observed the effects of fire, an ever increasing threat to terrestrial fauna, on a small, nocturnal marsupial insectivore, the brown antechinus. They implanted body temperature data loggers into the animals in a section of Guy Fawkes River National Park that was scheduled for a controlled burn. As the fire was managed, it burnt the undergrowth, where the antechinus forage, while leaving the large trees, where most of the animals nested, untouched. This meant that while the

majority of the animals survived the fire, their foraging was restricted immediately after the fire. Interestingly, rather than move to a nearby unburnt section of the forest following the fire, the animals remained in their original, burnt, habitat. During this period they significantly decreased their nocturnal activity, and increased their use of daytime torpor. The authors suggested that this increase in torpor may allow the animals to save energy in addition to affording them greater protection from an influx of invasive predators to the site after the fire.

The second study, led by Julia Nowack, used a similar approach and followed sugar gliders, small tree-dwelling marsupials. In comparison with the antechinus, the gliders used torpor less frequently, although they tended to use it more often on windier nights when their ability to glide between trees to forage was impeded. During the study, a cyclone with wind speeds in excess of  $45 \text{ km h}^{-1}$  hit the study site, bringing heavy rainfall (95 mm on the first night). On that occasion, the majority of the sugar gliders reduced their body temperature and entered torpor early in the evening when they would usually be foraging. However, most rewarmed and resumed normal activity the following evening. The authors estimated that the torpid animals reduced their energy use by up to 67%, which made up for the lack of foraging opportunities when grounded by the high winds.

Both of these studies demonstrate that species that use torpor opportunistically have an advantage when faced with unexpected natural disasters. In both cases, the use of torpor resulted in energy savings that compensated for the animals' inability to forage. The authors suggest that the ability to reduce body temperature and reduce energy consumption would give these species a competitive advantage over strictly homeothermic species that maintain a costly stable body temperature. They also suspect that this is one possible reason why heterothermic species with lower cost lifestyles have fared better than metabolically costly

homeotherms since the European colonization of Australia.

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Nowack, J., Rojas, A. D., Körtner, G. and Geiser, F. (2015). Snoozing through the storm: torpor use during a natural disaster. *Sci. Rep.* **5**, 11243.

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## The fittest fish escape trawling



Humans have used trawling nets to catch fish for hundreds of years, making us one of the most effective predators for certain fish species. It is well known that we can shape characteristics of fish populations through 'fishery-induced evolution', where we catch the most desirable and largest fish from the population while trawling. Much less is known about an individual fish's vulnerability to trawling. For example, are some fish consistently more likely to be captured? And, might this capture vulnerability be due to aspects of their physiology already known to be important for evading natural predators in the wild, like metabolic rate and swimming performance?

Shaun Killen, Julie Nati and Cori Suski, of the University of Glasgow, UK, and the University of Illinois at Urbana-Champaign, USA, set out to answer these questions using a population of minnows in a swim tunnel outfitted with a trawling net. While you might think it is less optimal to test such questions using a surrogate species in the laboratory, Killen and

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colleagues point out that these questions would have been impossible to answer with large-scale trawling in the wild.

Knowing that quick, anaerobically powered movements such as darting are often used by fish to avoid predators and could be used to avoid oncoming trawls, the team measured various aspects of metabolism after exhaustively exercising fish. They measured how much extra oxygen each fish consumed after exercise before returning to their baseline metabolic rate (metabolism for everyday functions). Then, the researchers grouped fish in shoals and assessed their ability to resist capture in the trawl when the water flow was set to a constant speed of  $38 \text{ cm s}^{-1}$ . Finally, the authors assessed swimming performance when they increased the water flow rate to simulate the fish trying to escape and measured the speed at which the fish switched from aerobic swimming (smooth and sustained movement) to anaerobic swimming (burst and glide movement). This switch was a measure of aerobic or endurance performance, and could be important for fish out-swimming a trawl net. They also measured the speed at which the fish failed to sustain anaerobic burst swimming and was unable to continue swimming in order to evaluate the animal's anaerobic power.

The researchers first found that a fish's vulnerability to trawl capture was highly repeatable as the same fish were captured repeatedly across multiple trawling sessions. The fish that avoided capture also had greater anaerobic capacity and anaerobic swimming performance, they consumed more oxygen after exercise and were able to sustain burst and glide swimming at greater speeds: so anaerobic movements could be important for escaping an approaching trawl. In addition to increased anaerobic performance, fish that avoided capture had greater aerobic swimming performance and they maintained smooth locomotion at higher water speeds. The authors suggest that aerobic endurance could be important for out-swimming trawls after their initial approach.

Killen's team is the first to identify that physiological traits can determine a fish's vulnerability to capture by a trawling net and that this vulnerability is very consistent. While more research is needed to fully understand the relationship

between various aspects of exercise physiology and capture, they have provided an intriguing first investigation. Their results suggest that fisheries have the potential to shape physiological traits in heavily trawled fish populations. Indeed, by capturing all the 'slow-pokes' we might be causing our most consumed fish to be better at escaping our trawl sweeps.

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## A framework for fatalism in the fly



Friedrich Nietzsche was horrified by the concept of eternal recurrence, the possibility that the universe repeats itself infinitely in structure and experience. As a solution to this existential burden, Nietzsche proposed that man abandon idealism and embrace *amor fati* – a love of fate. Now, a recent paper from Richard Mann's lab at Columbia University has reclaimed human idealism by re-examining the fundamental structure of fate itself. Specifically, they asked the question: given the extreme diversity of neurons in the brain, what factors determine a neuron's unique and highly specialized fate?

Jonathan Enriquez and colleagues addressed this question by studying the development of motor neurons in the *Drosophila* ventral nerve cord, a region of the fly's central nervous system analogous to the vertebrate spinal cord. The ventral nerve cord is home to the motor neurons that control movements of the leg – each of the fly's six legs contains 14 muscles, which are wired up to approximately 50 motor neurons.

Although each of these leg motor neurons is unique in structure and function, most of them develop from just two neuronal stem cells, or neuroblasts. Thus, the same stem cell gives rise to a diverse but manageable group of neuronal cell types. The fact that each of these motor neurons is uniquely identifiable in every fly suggests that their development is under careful genetic control.

To identify the genetic factors that determine a motor neuron's identity, Enriquez and colleagues searched for expression of unique transcription factors – proteins that regulate gene expression by binding to specific DNA sequences. Within the fly genome, there are ~750 genes that can be differentially spliced to produce ~2000 unique transcription factors. Using antibodies against several hundred of these transcription factors, the authors were able to identify genetic signatures for each of the different motor neuron types generated by a particular neuroblast. They found that each neuron expressed a unique, though overlapping, combination of transcription factors. This result suggests that parental stem cells assign functional identity to their daughter neurons using a combinatorial code of transcription factors, which is then expressed throughout the neuron's life – from stem cell differentiation into adulthood.

Although the existence of a combinatorial code is interesting, a deeper question is how the individual elements within the code contribute to a neuron's fate. Does the development of a neuron's morphological identity require a full complement of transcription factors? Or does each transcription factor contribute in some marginal way to a neuron's final identity?

The authors investigated the nature of the combinatorial code in two elegant ways. First, they removed a single transcription factor (called *pb*) from the code. This manipulation affected only those motor neurons that normally express *pb*, by altering both their dendritic and axonal morphology. Second, they expressed *pb* in a separate neuroblast, which does not normally express this transcription factor. Overexpression caused these motor neurons to acquire some morphological characteristics of *pb*-expressing neurons, though these neurons retained many aspects of their original identity.

Overall, these experiments demonstrate that each transcription factor instructs the development of specific morphological characteristics. Collectively, the ensemble of transcription factors specifies a unique morphological identity for each neuron. These results point to a general mechanism for producing morphological diversity among neurons. In addition, they suggest that our world may be just as eternally predetermined as Nietzsche imagined, but it still feels good to have cracked a piece of the underlying code.

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## Elite sprinters push forward



Elite sprinters captivate audiences with their blazing speed and acceleration, pushing off the blocks and propelling

themselves to world records and gold medals. With each step, the ground reaction force pushes the runner up and forwards until they reach the finish line. This is why high net horizontal ground reaction force, summed over each step, is the strongest predictor of sprinting performance. Of course, that is the net effect of the ground reaction force impulse: it must push forward if the sprinter is to go forward. The instantaneous ground reaction force at any given point in a runner's step, and at different times while accelerating during a race, is slightly more complicated. After the initial push off the blocks, as the foot makes contact with the ground, there is firstly a braking impulse in which the ground pushes the runner in the reverse direction. Over the course of the step, the ground reaction force changes orientation from backwards to forwards, outstripping that small rearwards component and driving the runner forward. In other words, there are two phases to each step: a braking component and a pushing component.

With this in mind, we return to the elite sprinters. How do these outstanding athletes accelerate quickly? This is the question asked by Jean-Benoît Morin and a team of international collaborators working at the French Institute of Sport in Paris. The team noted that there are two possible ways elite sprinters may be increasing their acceleration capacity: they can 'push more', generating higher ground reaction forces in the forwards direction, or they can 'brake less',

minimizing the ground reaction forces in the backwards direction. (Or, they could employ both strategies.)

To determine how elite sprinters accelerate so quickly, the team measured the ground reaction force impulses over multiple steps across the length of a 40 m sprint for nine sprinters ranging from international level (elite) to French national level (sub-elite) competitors. By measuring the different components of ground reaction force, the researchers could see which aspects of that force best predicted sprint time.

They found that even with a low sample size, there was a high correlation between sprint performance (mean velocity) and both the net horizontal ground reaction impulse and the positive component of the horizontal ground reaction impulse. In other words, the fastest sprinters had a bigger push-off with each step. There was no correlation between the negative ground reaction force impulse and average velocity; so, although the better sprinters were pushing more, they were not necessarily braking less.

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