Inside JEB is a twice monthly feature, which 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

WARM BRAIN, COLD BODY


Photo by Graham Mitchell

On the vast Wyoming plains, even the summer air temperature can fluctuate between 2°C and 38°C. It's a tough environment, and a challenge for any animal to keep its body temperature just right; but pronghorn antelope (*Antilocapra americana*) are right at home in the hot dry summers and cold, wet winters. Graham Mitchell and Amanda Lust from the University of Wyoming and their colleagues wanted to know if pronghorn, which evolved 25 million years ago, rely on the same thermoregulatory tricks as their more modern and better studied southern hemisphere relatives, such as springbok, which don't have to cope with such large summer temperature variations (p. 2444).

To find out how the pronghorn regulate body and brain temperatures over the course of a summer season, the team anaesthetised and operated on five captured animals to insert the temperature recorders: thermistors attached to data loggers. They put thermistors into the carotid artery and jugular vein, and also under the skin and into the abdomen, placing the data loggers under the skin nearby. To insert a thermistor into the brain, the team made a small opening in the skull and delicately pushed it between the two halves of the brain, nudging it close to the hypothalamus, which controls body temperature. Once the pronghorn had recovered from surgery, they roamed free in the research station for three months over the summer before the team collected the data loggers from the animals, and analysed the recorded temperatures together with climate data from a nearby a weather station.

The team found that pronghorns' body temperatures varied by up to 3–4°C. Taking a closer look at the correlation between the temperature in the carotid artery and environmental temperature, the team found that the maximum environmental temperature occurred around 7 h before the highest recorded carotid temperature. This suggests that, like springbok, the pronghorn allow their bodies to heat up during the day, meaning that they don't lose precious water trying to cool their bodies down. It also suggests that they could use this stored heat to stay warmer at night. The team suspect that an endogenous rhythm controls this fluctuation in body temperature, because the changes weren't closely correlated to sunrise or sunset time, or day length.

When the team looked at brain temperatures, they found that the pronghorn maintained a very constant brain temperature, which only varied by around 2°C. When they compared body and brain temperatures, they found that when the body temperature dropped below 37.5°C, the brain stopped getting colder, and when the body was more than 39°C, the brain stopped getting warmer. This suggests that the pronghorn have a brain warming mechanism which lets the body cool down, conserving energy. Likewise when it gets too hot the pronghorn don't waste water cooling their bodies down, focussing instead on cooling the brain. The team calculated that this brain warming and cooling was not related to changes in brain blood flow, and aren't yet sure of the exact mechanism.

While springbok can cool down their brains, they can't warm them up. So pronghorn can thermoregulate in much the same way as Springbok, but have the additional benefit of a brain warming mechanism which probably evolved in response to the colder temperatures in the pronghorns' environment.

10.1242/jeb.009001

Lust, A., Fuller, A., Maloney, S. K., Mitchell, D. and Mitchell, G. (2007). Thermoregulation in pronghorn antelope (*Antilocapra americana* Ord) in the summer. *J. Exp. Biol.* **210**, 2444-2452.

SLEEPLESS COCKROACHES

Long-term lack of sleep can make you feel a lot worse than a bit bad tempered and under the weather. It's something we just can't do without: deprived of sleep's restorative benefits, rats die prematurely. According to Richard Stephenson of the University of Toronto, 'Sleep presents one of the great mysteries that remain in biology'; researchers still aren't exactly sure what the function of sleep is. The metabolic rate in sleep deprived rats nearly doubles and they produce a lot of excess heat, so it's possible that lack of sleep affects the rats' temperature regulation. But other mechanisms could be at work, so to see if the rise in metabolic rate is to do with temperature regulation or not, Stephenson and his colleagues Karen Chu and James Lee investigated sleep deprivation in an animal that can't regulate its body temperature, the Pacific beetle cockroach (p. 2540).

Insects don't sleep in the same way that mammals do, but they do undergo periods of 'sleep-like rest' where they sit very still and don't interact with their environment. The team found in preliminary tests that a combination of a small movement and a puff of CO_2 alerted dozy cockroaches and kept them awake, probably because it exploits natural predator avoidance behaviour and the cockroaches never stop responding to the stimulus. They also found that sleep deprived cockroaches only needed 55 s to nod off again after being disturbed from a 2 min snooze. Normal roaches took 356 s, showing that sleep deprivation increases need for sleep.

To test how the cockroaches coped with sleep deprivation, the team placed them in cylinders equipped with food and water. The sleep deprived cockroaches received a CO_2 puff and a 2 s, 1 cm rotation of the cylinder every minute to keep them awake. The other group received the same number of puffs and rotations in the day, every 30 s for 3 hours in each 6-hour period, giving them four 3-hour rest periods each day.

To measure how the sleep deprivation was affecting survival, the team counted the number of dead cockroaches each day. The normal roaches died at a rate of 1 every 7.7 days for the whole experiment. The sleep deprived roaches all survived up to day 17, but after that started dying at 1 every 1.57 days, showing that sleep deprivation increased the risk of dying young.

To find out how sleep deprivation affected metabolic rate, the team removed the cockroaches from their containers at the end of each week and put them individually into a specially designed respirometer to measure oxygen consumption, and hence their metabolic rate. While metabolic rates were the same at the beginning of the experiment, in the sleep deprived group metabolic rates were 82% higher after 35 days. This shows that the metabolic rate rockets in sleep deprived insects, suggesting that in cockroaches at least, there is a change in metabolism which results from the sleep deprivation, and which isn't related to temperature regulation. To try and get to the bottom of the mystery, researchers 'will need to find the source of the heat', Stephenson says.

10.1242/jeb.008995

Stephenson, R., Chu, K. M. and Lee, J. (2007). Prolonged deprivation of sleep-like rest raises metabolic rate in the Pacific beetle cockroach, *Diploptera punctata* (Eschscholtz). *J. Exp. Biol.* **210**, 2540-2547.

TO CLICK OR NOT TO CLICK?


Photo by Heather Proctor

When a bat is cruising around looking for its next meal it sends out its ultrasonic pulses and listens carefully to the tell-tale echoes of a moth fluttering by. Despite the sophistication of a bat's echolocation system, moths have a few defences of their own. The dogbane tiger moth responds to a bat's attacking clicks with clicks of its own when the bat gets too close, either interfering with the bat's echolocation or warning the bat that it faces a bitter mouthful. However the moth has to choose very carefully when to click at a bat; too early draws unnecessary attention to itself, and leaving it too late is very risky. James Fullard and colleagues at the University of Toronto and Cornell University investigated which aspects of a bat's calls the moths use to decide whether to defend themselves or not (p. 2481).

A bat can vary many of the characteristics of its echolocating calls, such as the frequency or intensity of the calls. It also alters the duration of the individual pulses or the time between the start of each pulse, known as pulse period, which in turn affect the duty cycle, which is the percentage of the total time a calling bat is making a sound. A moth could use any of these characteristics to identify an attacking bat, but the question is, which one?

First the team recorded from the moths' auditory neurons to test their response to different frequency sounds, and find their auditory threshold. They found while moths' auditory neurons are sensitive between 30 and 50 kHz, they didn't show any difference in their clicking behaviour to different frequencies, showing that moths are essentially tone deaf.

Having ruled out frequency, they turned to a technique which allowed them to test if moths could tell the difference between two sets of bat calls. They attached the moths to a pin with wax and suspended them above a speaker in a dark room, before repeatedly playing a sequence of bat pulses to them and recording their clicking response. Once the moths had habituated – stopped responding to the bat signals – they changed one or more aspects of the signal to see whether the moths could tell the difference and start clicking again.

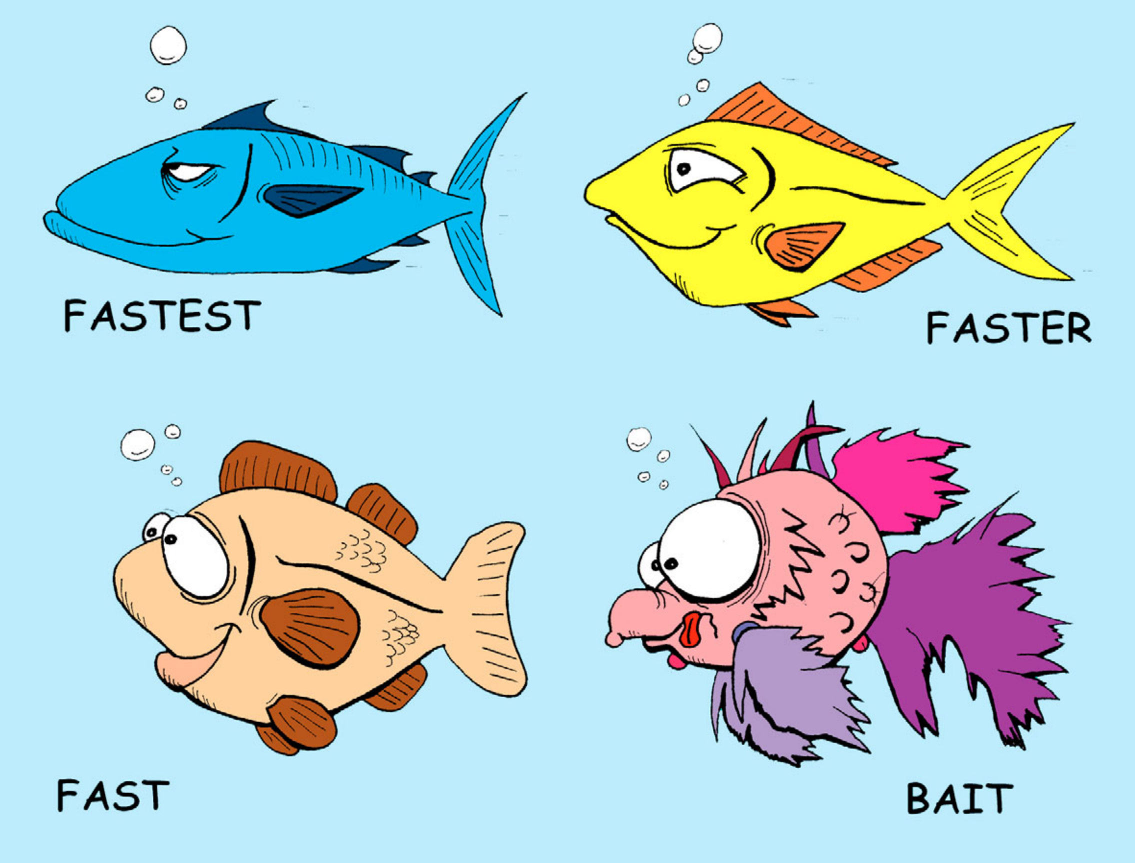
They found that once the moths had habituated to a particular signal, they had to change the duty cycle by 60% or more before the moths started responding again. Next they tested to see how the moths responded to varying duty cycles, and found that they were most sensitive to pulse periods of 20 ms. They were less sensitive to longer and shorter pulse periods, showing that the response was tuned.

Finally to show that pulse period was the primary parameter that the moths were responding to, they habituated the moths to 'searching' bat signals and then tested them with 'attacking' bat signals. Both signals had the same duty cycle, but the pulse period changed as the bats switched from searching to attacking. They found that the moths responded very strongly to the switch between a searching and attacking bat, showing that pulse period is the defining feature they use to identify when they are in danger. However they also found that their response was influenced by the intensity of the signal. If an attacking bat is pulsing to another insect 30 m away, then the moth is not going to respond because the intensity is too low, and it doesn't want to draw attention to itself. But if the intensity is right, and the bat is bearing down on the moth and bombarding it with high intensity, short period signals, it will click to avoid being snatched and eaten.

10.1242/jeb.008979

Fullard, J. H., Ratcliffe, J. M. and Christie, C. G. (2007). Acoustic feature recognition in the dogbane tiger moth, *Cycnia tenera*. *J. Exp. Biol.* **210**, 2481-2488.

MODEL SWIMMERS



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Fish come in all shapes and sizes, from short and fat to long and thin and variations in between. Despite this diversity, researchers are relatively adept at predicting how well fish can swim from their body shape. But tropical coral reef fish are the most diverse in the oceans, and their juveniles vary widely in their swimming ability. Rebecca Fisher and Derek Hogan took on the challenge of exploring the relationship between body shape and swimming ability in the juveniles of 100 species of tropical fish from 26 families (p. 2436). Having measured the fastest sustainable swimming speed of each fish, they then measured the dimensions of the fishes' bodies and fins. They found that a simple model which took into account the length and depth of the body, and the dimensions of the caudal fin at the back of the fish could accurately predict swimming performance. Different body dimensions explained 69% of the variation between different fishes' swimming performance, and the model worked equally well on all of the species, which came from reefs as far apart as the Caribbean and the Australian Great Barrier Reef. The model's success means that it can be used to predict swimming ability in small juvenile fish, which are very difficult to study in the lab.

10.1242/jeb.008987

Fisher, R. and Hogan, J. D. (2007). Morphological predictors of swimming speed: a case study of pre-settlement juvenile coral reef fishes. *J. Exp. Biol.* **210**, 2436-2443.

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