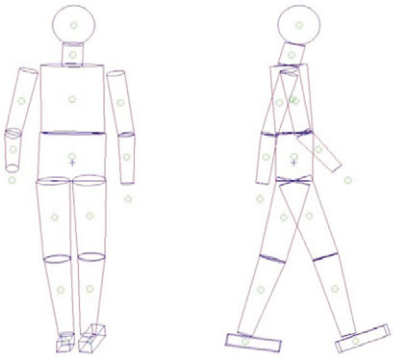
Inside JEB is a twice monthly feature, which highlights the key developments in the *Journal of Experimental Biology*. Written by science journalists, the short reports give the inside view of the science in JEB.

Inside JEB

THE ROLE OF ANGULAR MOMENTUM IN WALKING



Hugh Herr, from the Massachusetts Institute of Technology Media Laboratory, designs state-of-the-art prosthetic limbs and mobility aids. But to do this, he has to understand how we move; 'I study humans to build synthetic versions of humans' he says. However, none of the recent studies of human walking have considered the effects of angular momentum as we move, and only one study, based on measurements of a single step by H. Elftman in 1939, has attempted to measure angular momentum directly. As a comprehensive model of walking is the holy grail of biomechanists, prosthetics designers and robotic engineers, Herr and postdoc Marko Popovic decided to make the first accurate measurements of angular momentum during steady walking (p. 467). Recruiting ten fit young walkers, Popovic and Herr fixed markers to each individual's body before filming them as they walked steadily across a force plate, ready to calculate the angular moment of each subject's trunk, limbs and head to get a better understanding of the role of angular momentum in walking.

Which was when the hard work began. Having digitised each subject's limb, trunk and head positions, Popovic and Herr built a complex computer model to calculate each body segment's angular momentum while sauntering at steady speed. According to Herr, 'the challenge is to get realistic mass distributions in the limbs… the shape has to be right.' He adds 'it was an insane amount of work', but after months of painstaking computation, the team had calculated the angular momentum of each individual's 16 body segments, and were ready to see how angular momentum varied during steady walking.

Plotting each individual's whole-body angular momentum, the team could see that it fluctuated slightly, but was essentially zero throughout a walking cycle at steady speeds, despite the large angular momentums generated by the swinging limbs and other body segments. Herr explains that opposing limb movements cancel each other's momentum in three dimensions, and he suspects that whole-body angular momentum is minimised to reduce the metabolic cost during steady walking.

Herr also compared his results with current walking models. He explains that walking is often modelled as an inverted pendulum; the foot acts as the pivot and the body's entire mass is represented at a single point mass at the end of the pendulum. According to Herr's measurements, the inverted pendulum model works well; the body can be considered as a single point mass. However the inverted pendulum model fails when you assume that pressure exerted by the foot acts at a single fixed pivot point; it incorrectly predicts the forces acting on the body's centre of mass unless the pressure point is modelled as moving along the foot.

Herr also emphasises that walkers only minimise their angular momentum, with minor fluctuations around zero, while they're walking steadily. Ask them to do a turn from the Ministry of Funny Walks and it's a completely different matter. In those circumstances walkers have to modulate their angular momentum to counteract destabilising forces and maintain their balance. Herr admits that it isn't clear **how** walkers modulate the body's angular momentum to improve balance and manoeuvrability, but he says that 'I hope this study will motivate additional studies in the field'.

10.1242/jeb.016873

Herr, H. and Popovic, M. (2008). Angular momentum in human walking. *J. Exp. Biol.* **211**, 467-481.

MIDGES DEHYDRATE TO WEATHER WINTER

Here's a good Trivial Pursuit™ question: what is the largest entirely terrestrial animal on Antarctica? Answer: a midge, *Belgica antarctica*. Sizing up at 5 mm, the flightless adults crawl around like ants during their brief lives. However, the larvae remain submerged near the surface of the Antarctic soil for two years, waiting for the brief summer's return. Michael

Elnitsky and Richard Lee were curious to know how the hardy larvae successfully survived not one, but two Antarctic winters. They already knew that the insects could survive freezing solid to –15°C, but they suspected that the secret of the insect's resilience may also reside in its remarkably leaky skin. Could the insects survive by desiccating in the dehydrating environment (p. 542)? Elnitsky and his colleagues headed south to find out how the larvae weather winter.

Travelling to the USA's Palmer Station on the Antarctic Peninsula, Elnitsky, Scott Hayward, Joseph Rinehart, David Denlinger and Lee spent several weeks crawling through the summer mud, flipping over rocks searching for the bright purple larvae. Elnitsky explains that the larvae can be hard to find, but fortunately they tend to cluster in groups of up to several hundred. It was simply a matter of flipping enough stones before the team had sufficient 4th-instar larvae ready for the week-long journey north.

Returning with the larvae on ice to Lee's Ohio laboratory, Elnitsky tested the insects' dehydration tolerance by simulating an idealised Antarctic environment. Placing the larvae in small plastic tubes and then placing the tubes inside larger sealed vials, each filled with a few grams of ice, the team slowly cooled the vial from –1°C to –3°C over a period of days. Measuring the larvae's water levels and body fluid melting point after 14 days at –3°C the team found that the larvae had lost 40% of their body fluids. Their body fluid melting point had also dropped to –3°C. And when Elnitsky measured the levels of antifreeze compounds in the larvae's body fluids, he found that they had increased by approximately 10 fold. The larvae had equilibrated their body fluid vapour pressure with the vapour pressure of the ice and dehydrated so they could no longer freeze. And when Elnitsky gently warmed the larvae to 4°C and supplied them with water, more than 95% of the larvae revived. The insects could survive dehydration, but how would they fare under more natural conditions?

This time Elnitsky placed the larvae in direct contact with Antarctic soil at three different moisture levels before freezing the soil and slowly cooling to –3°C. Measuring the insects' body fluid levels after a fortnight in the icy conditions, Elnitsky found that the larvae in dry soil had remained in equilibrium with the dry environment and dehydrated. However, the larvae in the moist soil couldn't dehydrate; they quickly froze solid and retained high body fluid levels.

So it appears that Antarctic midge larvae have two strategies – freeze tolerance and dehydration – to survive the harsh Antarctic winter, which could be the answer to another good Trivial Pursuit™ question.

10.1242/jeb.016899

Elnitsky, M. A., Hayward, S. A. L., Rinehart, J. P., Denlinger, D. L. and Lee, R. E., Jr (2008). Cryoprotective dehydration and the resistance to inoculative freezing in the Antarctic midge, *Belgica antarctica*. *J. Exp. Biol.* **211**, 524-530.

FUEL DELIVERY SYSTEM HIJACKS IMMUNITY

Picture by Shelley Adamo

It's happened to us all; you work your socks off for that big deadline and when it's over, you're felled by a bug. Why? Because a window of vulnerability has opened. Stress hormones pounding through your system interfere with your immune system, leaving you prone to infection. And we're not the only ones. According to Shelley Adamo, most creatures' immune systems take a tumble after stress. However, **why** immune systems fail when you are vulnerable wasn't clear. Could the immune system fail because of a physiological constraint, such as competition between key survival systems for a shared component? Adamo explains that one of the insect's key lipid transport proteins (lipophorin III) also plays a major role in immunity by detecting bacterial infection. Could lipophorin III, which supplies fuel during periods of high energy demand, be the lynch pin that lets the immune system down? Teaming up with colleagues Janet Ross, Russell Easy and Neil Ross, Adamo needed to prove that losing lipophorin III to the energy transport system compromised the insect's resistance (p. 531).

First the team measured the insects' free lipophoprin III level after allowing the crickets to fly for 5 min and found that they plummeted by 46%. And when the team measured the crickets' free lipophorin III after exposure to infection, it fell even further. Both situations reduced the amount of free lipophorin in the insects' haemolymph.

But was the energy delivery system hijack of the immune system's protein leading to compromised resistance? If so, the insect's immunity would suffer when it activated the lipid delivery system to fuel flight. Knowing that adipokinetic hormone activates fuel delivery and reduces the amount of lipophorin III in the haemolymph, the team tested the cricket's resistance to infection after a dose of adipokinetic hormone. The cricket's resistance dropped by 20%. The insects needed free lipophorin III to fight infection, but Adamo still needed convincing that the fuel delivery system was depleting the insect's lipophorin III supplies.

The team decided to offer the flying insects an alternative fuel source. The team reasoned that the flying insects wouldn't resort to lipids if supplied with an alternative fuel (trehalose), so could maintain their haemolymph lipophorin III levels and reduce their susceptibility to infection. Dosing crickets with trehalose, the team exposed them to infection after flying, and recorded their resistance. The trehalose-dosed insect's survival rate was much better than untreated crickets. Amazingly, increased free lipophorin III levels had protected the insects from infection.

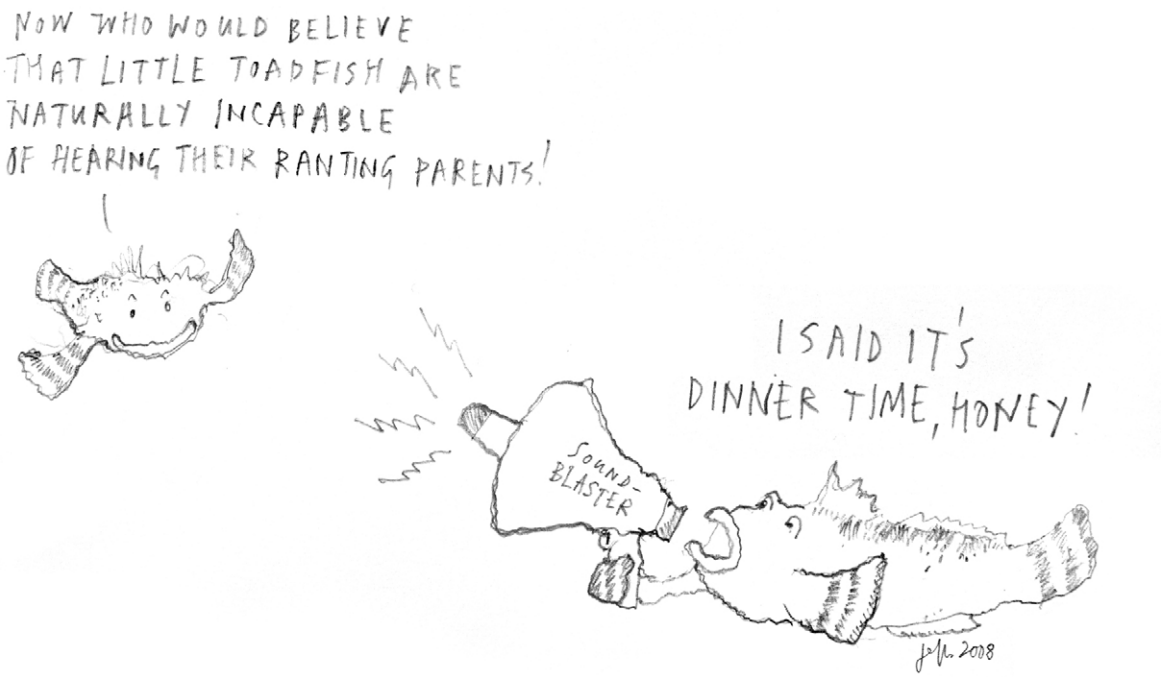
That left one test to try before Adamo was sure that lipophorin III was the key to the cricket's immunosuppression. Could a dose of the free protein restore a stressed insect's failing resistance? The team administered lipophorin III to crickets, and tested their postflight resistance: it was restored. Finally Adamo was convinced that the insect's fuel delivery system was kidnapping free lipophorin III from the immune system, leaving it vulnerable to infection.

Adamo is very excited about this discovery, and says that 'this result could have interesting ramifications'. According to Amano, stress induced immunosuppression is widespread across all phyla, and competition between the immune system and other key physiological systems could prove to be wide spread and 'explain the paradox of stress induced immunosuppression' she says.

10.1242/jeb.016907

Adamo, S. A., Roberts, J. L., Easy, R. H. and Ross, N. W. (2008). Competition between immune function and lipid transport for the protein apolipophorin III leads to stress-induced immunosuppression in crickets. *J. Exp. Biol.* **211**, 531-538.

SPEAK UP, TOADFISH KIDS CAN'T HEAR YOU



Pete Jeffs is an illustrator living in Paris

With a repertoire of 4 distinct grunts and croaks, the Lusitanian toadfish is relatively garrulous by fish standards. However, little is known about the way the fishes' voice changes as they grow, and even less about the way their hearing develops with age. Raquel Vasconcelos and Friedrich Ladich decided to record toadfish calls and test the hearing of fish ranging from a few months up to 8 years old to see how their communication skills develop (p. 502). The team found that as the fish aged, their voices became deeper and louder. However, the youngest fish were almost always silent; only one grunted, and it was the largest of the youngsters. And when the pair tested the fishes' hearing, they realized that the adults had no problem hearing each other, but the young juveniles' hearing was too insensitive to hear the weak, high voices of youngsters of their own age. Vasconcelos and Ladich suspect that the youngsters do not communicate vocally until their voices are deep enough and loud enough for them to hear each other.

10.1242/jeb.016881

Vasconcelos, R. O. and Ladich, F. (2008). Development of vocalization, auditory sensitivity and acoustic communication in the Lusitanian toadfish *Halobatrachus didactylus*. *J. Exp. Biol.* **211**, 502-509.

Kathryn Phillips
kathryn@biologists.com