

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

PYTHON MUMS SUFFOCATE EGGS



Picture by Dale DeNardo

Every parent knows how much they invest in their kids. But few devote as much to their young as Children's python mums, investing up to 30% of their body mass in a single clutch of eggs. This is a major incentive for each mum to ensure their offspring's survival by brooding the eggs until they hatch. According to Zachary Stahlschmidt and Dale DeNardo one of the main risks faced by the developing eggs is desiccation. They explain that without the mother's protection, the eggs lose water through their paper-thin cases 25–30 times faster than when mum is safely coiled around them. But at what cost? Could the mother's coils restrict her youngsters' access to air? Stahlschmidt and DeNardo decided to monitor the behaviour of brooding Children's python mothers while measuring oxygen levels in the enclosed clutches, to see if the mothers' coils restricted their youngsters' oxygen supply (p. 1535).

Monitoring the snake mothers' activity levels, Stahlschmidt filmed the reptiles for 12 hour periods during the early, middle and late stages of their eggs' development. According to Stahlschmidt, the snakes are inactive and tightly coiled around their eggs for 90% of the time; 'I watched the films on fastforward' he admits. The remaining 10% of the time, the snakes loosened their coils and adjusted their posture. And when Stahlschmidt correlated the oxygen levels in the clutch with the snake's activity, he realised the oxygen level dropped steadily while the mother was tightly coiled around, but increased dramatically within three minutes of the snake shifting position. There was a cost to protecting the eggs from desiccation; the eggs' air supply was restricted. But was the restriction sufficient to compromise the eggs' metabolism?

Measuring the metabolic rates of clutches of artificially incubated eggs at oxygen levels ranging from 10 to 20 kPa (21% – normal – oxygen), Stahlschmidt realised that the oxygen level inside the brooding

mother's coils was sufficient to meet the youngest fetuses metabolic demands. However, as the snake foetuses grew their metabolic demands increased, requiring 15.1 kPa oxygen to maintain their metabolism during the middle stages of development and 19.4 kPa oxygen towards the end of incubation. But the oxygen levels deep in the snakes coils fell below 15.1 kPa almost 20% of the time during the middle stages of development, and never rose above 19.4 kPa during the final days of incubation. While the eggs were occasionally oxygen starved during the middle stages of development, they were constantly starved of oxygen during the final stages of development. The pythons were prepared to risk suffocating their eggs to protect them from desiccation.

Surprised that the environment in the mother's coils was hypoxic during the final stages of the fetuses' development, Stahlschmidt wondered if the pythons might adjust their behaviour to increase their young's oxygen supply. But returning to the incubation footage, Stahlschmidt saw that the mother's behaviour was unaltered by the risk of oxygen deprivation. The mothers either seemed unaware of their offspring's low oxygen levels, or were unable to respond to the metabolic restriction in case their eggs dried out.

10.1242/jeb.019588

Stahlschmidt, Z. R. and DeNardo, D. F. (2008). Alternating egg-brooding behaviors create and modulate a hypoxic developmental micro-environment in Children's pythons (*Antaresia childreni*). *J. Exp. Biol.* **211**, 1535-1540.

HOW AFRICAN LUNGFISH SWIM THROUGH MUD

Rivers aren't always the permanent features that some of us take them for. In arid countries, river beds can be dry for years, and when a river dries up its occupants have little choice but to up-sticks and find water or burrow and aestivate to survive. According to Angela Horner from the University of Cincinnati, African lungfish have gone for the second option. But before the soupy river dries hard, the fish are left floundering in the mud. Which made Horner and her advisor Bruce Jayne wonder how fish swim through mud (p. 1612).

First Horner needed to find a see-through mud: easier said than done. Initially she tried cellulose, but it behaved more like a gel than mud. Eventually, after hours of Googling, Horner hit upon EZ[®]Mud DP, a transparent gunge used in the petroleum industry to stabilise oil drills; and best of all it was non-toxic. Horner could make transparent mud analogues with viscosities

ranging from 10 to 1000 cSt. Next she fitted electrodes down the left and right sides of eight fish to record the electrical activity in the white muscle as they swam through the fake mud. The team were ready to test out the fish's swimming technique, but would they swim in the experimental tank?

According to Horner, African lungfish are notoriously uncooperative, quite large and equipped with a vicious set of teeth, not the easiest of creatures to work with. But having carefully transported the wired-up fish to the swim tank, Horner and Jayne were pleasantly surprised when they began swimming. Horner filled the tank first with water and then with EZ[®]Mud DP at 10, 100 and 1000 cSt viscosities, before filming the fish and recording their muscle electrical activity.

When Horner and Jayne analysed the fish's swimming technique, they noticed that the fish only used their tails when swimming slowly through thinner fluids. However, as the viscosity increased the fish began wriggling their torsos too until they made swimming waves with the whole of their bodies, just like fast swimming eels. And when the fish were transferred to the thicker 'muds', they were no longer able to swim steadily at the lower speeds they had attained in thinner fluids. The team was initially surprised, but eventually realised that like real mud, EZ[®]Mud DP is a non-Newtonian fluid, which thins under force resulting in unsteady slow speeds. 'Sometimes they spin their wheels a bit' says Horner, describing how the fish sometimes swim hard until they suddenly burst free to swim through the thick mud.

The electrical recordings also showed how the fish use their muscles to power swimming. The team saw that the wave of electrical activity that moves down the fish's body was faster than the wave of physical movement. And as the viscosity increased, the electrical activity wave became even faster. Horner explains that by activating the muscle before it contracts, the fish prestiffen the body section when swimming through the thicker muds.

Horner says that understanding how African lungfish swim through mud is another piece in the puzzle of how fish swim. And while modern African lungfish are significantly different from our earliest tetrapod ancestors, they could help us eventually to understand how the first tetrapods dragged themselves out of the primordial sea.

10.1242/jeb.019547

Horner, A. M. and Jayne, B. C. (2008). The effects of viscosity on the axial motor pattern and kinematics of the African lungfish (*Protopterus annectens*) during lateral undulatory swimming. *J. Exp. Biol.* **211**, 1612-1622.

CATFISH PAY BUOYANCY PENALTY



Picture by André Werner

Otophysine fish are fantastically successful by any standards. Boasting over 8000 species, they have colonised the waters of every continent, except Antarctica. However, the only feature that otophysines have in common is an acute sense of hearing due to their tiny ear bones (Weberian ossicles) which transmit vibrations from the swim bladder to the inner ear. While otophysine lifestyles vary enormously, one of the otophysine orders, catfish, spend most of their time grubbing around on waterway bottoms. Which puzzled Ladich. Why would fish that lurk in the watery depths retain their swim bladders when they have no need for a buoyancy aid? 'They haven't kept it for nostalgic reasons' says Ladich. Realising that reducing the swim bladder's size to stick close to the floor could compromise the fish's sensitive hearing, Ladich and his student Walter Lechner decided to investigate various catfishes' hearing to see if there was any correlation between the

sensitivity of the fishes' hearing and the size of their acoustic apparatus (p. 1681).

As catfish are popular with aquarium owners, the pair identified eleven species that could be obtained relatively easily for Lechner to investigate the size and location of the fishes' swim bladders and ear ossicles. The team chose six catfish species with large swim bladders located in the fishes' trunk, while the remaining five had a pair of tiny swim bladders surrounded by a bony sheet located in their heads. Ladich admits that locating the Weberian ossicles was particularly tricky, as some were less than a millimetre long, but eventually it was clear that most of the fish with large swim bladders had 3 or 4 ossicles, while the fish with tiny paired swim bladders only had one or two. But what effect did this diverse range of hearing apparatus have on the fishes' hearing?

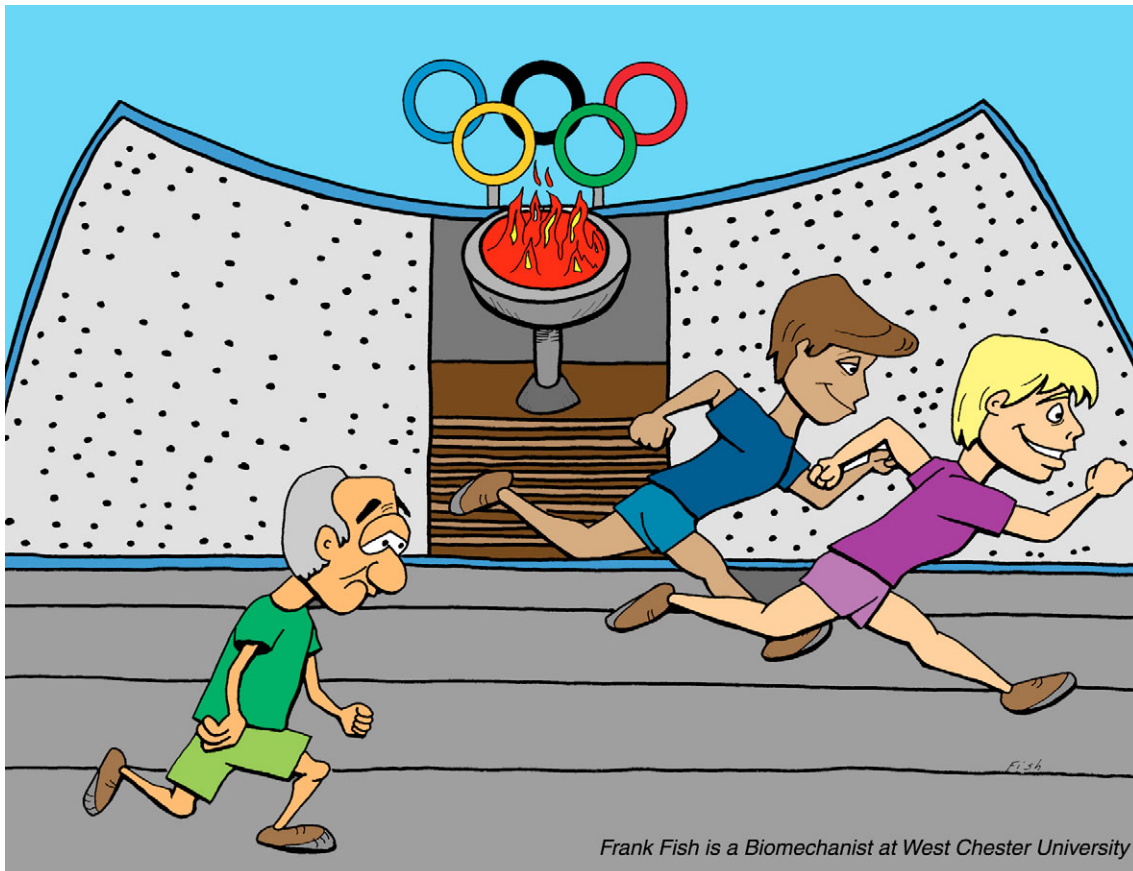
Isolating individual catfish in a tank in a darkened room, Lechner played the fish sound at pitches ranging from 50 Hz up to 5 kHz. He monitored the fishes' hearing responses by measuring brainwaves through their skin as he decreased the sound's intensity. At frequencies below 1000 Hz, there was little difference between the fishes' hearing sensitivity, but as Lechner raised the frequency above 1000 Hz, a clear difference emerged. The high frequency hearing of the fish with large swim bladders and 3 or more Weberian ossicles was significantly more sensitive than the fish with tiny paired bladders. It was clear that the fish which had reduced their swim bladders to limit their buoyancy had paid a price when it came to picking up high frequencies.

The hearing of bottom dwelling catfish is so important that they have retained their swim bladders despite the buoyancy penalty. And even though the hearing of catfish with tiny paired swim bladders is worse than catfish with large swim bladders, it is still significantly better than that of many other fish.

10.1242/jeb.019539

Lechner, W. and Ladich, F. (2008). Size matters: diversity in swimbladders and Weberian ossicles affects hearing in catfishes. *J. Exp. Biol.* **211**, 1681-1689.

MUSCLES MAKE ENERGY TRANSFER ASYMMETRIC



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When people run, their movement can be modelled as if they are bouncing along like a pogo stick. Runners convert kinetic and potential energy into elastic energy stored in their tendons and muscles as they fall, which is then converted back into kinetic and potential energy as they bounce up; just like the energy stored and released from the springs in a pogo stick. Knowing that muscles' properties change as we age, Giovanni Cavagna, Mario Legramandi and Leonardo Peyré-

Tartaruga decided to compare the mechanical work done by elderly and young runners to see how the natural asymmetry in running energy transfer changes with age (p. 1571). They found that the asymmetry was exacerbated in the older runners because their muscles generate less force while shortening (before take-off) than they do when stretching after landing. Given the differences in the runners' performances, the team suspect that the physiological

properties of our muscle-tendon units are responsible for the natural asymmetry of energy transfer during the take off and landing phases of a running stride.

10.1242/jeb.019570

Cavagna, G. A., Legramandi, M. A. and Peyré-Tartaruga, L. A. (2008). The landing-take-off asymmetry of human running is enhanced in old age. *J. Exp. Biol.* **211**, 1571-1578.

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