Inside JEB 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

WHY ARE CETACEANS' VESTIBULAR SYSTEMS SO SMALL?

Of all of our six senses, balance is possibly the most underestimated. Lose it and you're in a bad way. Every terrestrial animal depends on three fluid-filled semicircular canals – part of the vestibular system that measures head rotation – buried in their skulls to keep them upright. Timothy Hullar, from the Washington University School of Medicine, explains that the size of an animal's vestibular system is closely related to its body size. However, whales' vestibular systems are much tinier than they should be. According to Hullar, a clinician who specialises in human balance disorders, there are several possible explanations for the whale's tiny balance system. These include Fred Spoor's suggestion, from University College London, that whales may have scaled down their semicircular canals to reduce their sensitivity. Hullar explains that this would allow whales and other cetaceans to extend the performance range of their vestibular systems and allow them to move their heads over large ranges where more sensitive larger vestibular systems would fail. Intrigued by this possibility, Hullar decided to test whether cetaceans move their heads more than similarly sized terrestrial mammals (p. 1175).

Knowing that the nearest modern relatives of cetaceans are two-toed mammals, Hullar realised that cattle would make a good comparison with dolphins. And living in Missouri, he could have access to cattle that are happy to buck their heads on demand: rodeo bulls. Discussing the possibility of getting access to rodeo bulls with a rancher who happened to be one of his patients, the rancher offered to put Hullar in touch with a neighbour who breeds the animals. Having explained to the bull trainer that he wanted to measure how much bulls move their heads, Hullar and his undergraduate student, Benjamin Kandel, drove down to the ranch in deepest Missouri to put a bull through its paces. 'Working with these animals I grew to have an appreciation for how big and ornery they are,' remembers Hullar. Carefully strapping three gyroscopes to the bull's horns while it was in the bucking-chute, the ranchers sent it bucking into the arena while Hullar and Kandel filmed the animal from the safety of a tower.

Having recorded the bull's head movements, Hullar had to find some dolphins, which seemed easier said than done in the landlocked Midwest, until he made contact with the Indianapolis Zoo where the dolphin team were very happy to help. Training the dolphins to swim up and down carrying the gyroscope array in their mouths and filming them as they did barrel rolls and fast turns, Hullar and Kandel were ready to find out whether the dolphins' head movements were more extreme than the bulls'.

Back in the lab, Kandel analysed the movies and gyroscope data and realised that instead of being more extreme, the dolphins' head movements were slightly less vigorous than the movements of the bucking bulls. So it seems unlikely that the dolphins scaled down their vestibular systems to decrease their sensitivity and increase the performance range to accommodate large head movements.

Whatever drove cetaceans to downsize their vestibular systems is still a mystery that Hullar is keen to solve. 'This is such a dramatic change in size that something important must have caused it,' says Hullar.

10.1242/jeb.043893

Kandel, B. M. and Hullar, T. E. (2010). The relationship of head movements to semicircular canal size in cetaceans. *J. Exp. Biol.* **213**, 1175-1181.

OCTOPUSES REACT CORRECTLY TO HDTV

Octopuses are intriguing creatures expressing what appear to be emotions and reactions to their environment with eye catching colour changes. However, finding out how these cephalopods respond to their environment is easier said than done. Movies of animals would seem to offer the best alternative for studying an individual's behaviour, as they are controllable (you can repeatedly show the same behaviour to many animals and track their responses) and they move realistically, unlike pictures, which are static and unrealistic. However octopus vision is relatively sophisticated, so previous attempts to get the cephalopods to interact with movies failed, probably because the TV images were not realistic enough for the animals on old-fashioned TVs. Renata Pronk and her colleagues from Macquarie University, Australia, realised that the recent development of liquid crystal high definition television (HDTV) could

overcome this problem, so they decided to test out the gloomy octopus's reactions to HDTV (p. 1035).

Teaming up with David Wilson to build a high definition video system where she could fine-tune the quality of the movies, Pronk filmed a tasty crab, another gloomy octopus and an intriguing jar ready to play the movies to other gloomy octopuses in an aquarium. Collecting wild octopuses from Sydney Harbour, Pronk and Robert Harcourt returned to the Sydney Institute of Marine Science to show the videos to the animals, but at first the animals didn't respond. Refilming the images at 50 frames s^{-1} and programming the system to refresh every line on the screen simultaneously – to maintain smooth edges on the moving images – Pronk replayed a movie of a crab walking to an octopus and waited to see whether it would react.

Amazingly it did. 'The octopus jetted towards the screen and tried to catch the crab and eat it. I thought, this is great, I've finally gotten the reaction I was hoping for!' says Pronk.

Having succeeded in finding movies that were convincing enough that the octopuses recognised the images and reacted, Pronk decided to find out whether the animals could be said to have a personality. 'Personality can be defined as behavioural differences between individuals that are consistent over time and across ecologically important contexts,' explains Pronk. So would a shy octopus always be a wallflower and aggressive animals remain assertive?

Showing the octopuses a movie of a crab on one day to see if the animal would try to catch it and repeating the show on several occasions over a period of days, Pronk found that the octopuses' responses were consistent on a particular day. However, reshowing the movies some time later often produced different reactions. For example, an octopus would be very excited on one day, but less enthusiastic on another occasion. And when she tried to get the animals riled up with movies of another octopus or pique their interest with an object that they hadn't seen before (the jar) octopuses that responded eagerly one day were equally as likely to show little or no interest the next.

The octopuses seemed to demonstrate personalities, but they were not consistent over a period of time. 'We term this "episodic personality" because over the course of the experiment their personality traits would change in response to the same stimuli,' says Pronk.

Having succeeded in convincing octopuses to respond to movies and found that their personalities vary over time, Pronk is keen to find out more about other octopus behaviours, including their communication, learning and social interactions, using her octopus-convincing movie system.

10.1242/jeb.043935

Pronk, R., Wilson, D. R. and Harcourt, R. (2010). Video playback demonstrates episodic personality in the gloomy octopus. *J. Exp. Biol.* **213**, 1035-1041.

RECIPE FOR HAGFISH SLIME DISCOVERED

Hagfish don't score high on the fish charisma scale. They are very unattractive, have a reputation for devouring victims from the inside out and, if attacked, they instantly release litres of repulsive slime. However, despite their repelling habits, Douglas Fudge from the University of Guelph is intrigued by hagfish slime. He says 'It's like nothing else in biology because they produce it so quickly and in such large quantities and it's reinforced with fibres.' Fudge has been working on the material properties of hagfish slime ever since his PhD and explains that the creatures exude a viscous milky white secretion – pre-slime – packed full of microscopic packets (vesicles) carrying a highly absorbent glycoprotein called mucin. These vesicles suddenly explode upon contact with seawater, releasing the mucin and producing mature slime. But how do hagfish prevent the mucin vesicles from exploding inside their slime glands before the vesicles contact seawater? Fudge wondered if something in the pre-slime was stabilizing the vesicles to prevent them from rupturing too soon. Teaming up with undergraduates Julia Herr and Tim Winegard, the trio decided to find out what hagfish pre-slime is made of (p. 1092).

'Tim is our hagfish wrangler extraordinaire who worked out how to work with fresh slime,' says Fudge. Fishing the animals out of holding tanks and slipping them into anaesthetic, Winegard gently stimulated the animals and collect samples of the milky pre-slime for analysis. Spinning the pre-slime in a centrifuge, Winegard separated it into three layers with protein fibres at the bottom, mucin vesicles in the middle and the clear fluid that they were suspended in at the top. Sending the clear fluid to Mike O'Donnell at McMaster University and Paul Yancey at Whitman College for chemical analysis, Fudge discovered that the fluid contained very high levels of two methylamines, TMAO and betaine, as well as a variety of inorganic ions including potassium, sodium and chloride.

Having found the recipe for hagfish pre-slime fluid, Fudge was curious to find out whether it might stabilise the mucin vesicles before they contact seawater. Reasoning that the TMAO and betaine in the fluid would have a higher osmotic pressure than the vesicles and should dehydrate the vesicles and prevent them from rupturing, Fudge and Herr decided to test whether the methylamines could stabilise the vesicles. But even when Herr added solutions of 1200 mmol l^{-1} of TMAO and betaine to the vesicles, most of the vesicles exploded within 20 s of contact, while others took longer to burst.

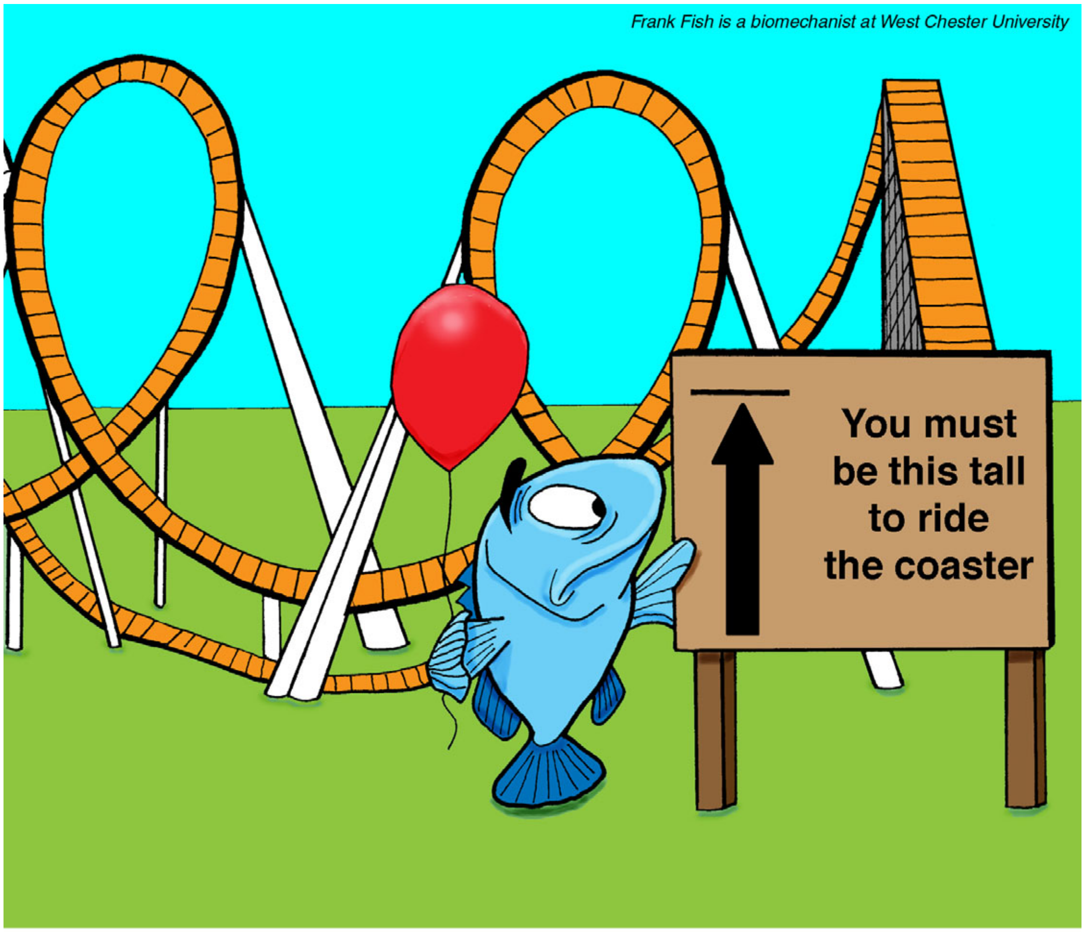
Maybe something else in the fluid was stabilising the vesicles; but when Herr made a solution containing all of the known constituents of the slime fluid from off the shelf chemicals, the vesicles still ruptured. 'This was not what we were expecting,' says Fudge, so Herr collected some of the natural fluid from the pre-slime and tried that to see if it prevented the vesicles from bursting. Amazingly it did not.

So the pre-slime fluid was not able to stabilise hagfish mucin vesicles and prevent them exploding before contact with seawater. Having found the recipe for hagfish pre-slime, Fudge is still keen to find out why hagfish mucin vesicles do not rupture in the animal's slime glands, what mechanisms are at play when the vesicles rupture in seawater and why some vesicles rupture faster than others.

10.1242/jeb.043919

Herr, J. E., Winegard, T. M., O'Donnell, M. J., Yancey, P. H. and Fudge, D. S. (2010). Stabilization and swelling of hagfish slime mucin vesicles. *J. Exp. Biol.* **213**, 1092-1099.

GROWING SLOW IS AN ADVANTAGE WHEN FOOD IS SCARCE



Paul now wished that he could have grown faster and was not starvation tolerant.

Fish grow continually throughout their lives and it would seem to be an advantage to grow big as soon as possible, not only to escape predators but also to begin breeding earlier. So why, in that case, do some individuals continue to grow slowly when it would seem to put them at a disadvantage? David McKenzie and his colleagues wondered whether there were costs to rapid growth, and in particular whether fish that grow slower may tolerate starvation better than faster growing individuals (p. 1143).

Working with a captive population of European sea bass, the team fed the fish for 3 weeks, before fasting them for a further 3 weeks and then repeated the cycle once more while monitoring the fish's weight and calculating their growth rates. They found that the fish that grew most rapidly when fed were the ones that suffered the most weight (mass) loss when deprived of food.

Collecting the fish that lost the least weight and tolerated food deprivation best, and those that grew fastest when food was plentiful, the team compared the fish's physiology to find out if the fish that tolerated food deprivation had a lower metabolic rate and the faster growing individuals had a higher metabolic rate; but they did not. However, the faster growing fish were able to digest meals more rapidly than the slower growing individuals that tolerated fasting well.

The team suspects that the faster growing individuals take a 'boom and bust' approach to life, consuming and growing fast to get ahead in times of plenty and putting up with the consequences of their high energy lifestyle when food is scarce. Meanwhile, the smaller individuals grow more slowly because they cannot consume food as rapidly as fast growing individuals, but starvation takes less of a toll on them, presumably because their metabolic costs are lower when food is scarce. So growing slowly may not be such a disadvantage for fish when the food supply is unreliable.

10.1242/jeb.043927

Dupont-Prinet, A., Chatain, B., Grima, L., Vandeputte, M., Claireaux, G. and McKenzie, D. J. (2010). Physiological mechanisms underlying a trade-off between growth rate and tolerance of feed deprivation in the European sea bass (*Dicentrarchus labrax*). *J. Exp. Biol.* **213**, 1143-1152.

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