Inside JEB

Inside JEB, formerly known as ‘In this issue’, 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.

SMOOTHLY DOES IT

It has to be said, boxfish are neither sleek nor flexible. With a rigid bony carapace that covers most of their body and a boxy shape, they look pretty awkward compared to most fish. But looks aren’t everything. A novel combination of biological and aeronautical research has shown that water flows over the boxfish much like air does over the space shuttle, making them stable and able to swim more smoothly than you’d expect by looking at their ungainly build.

These efficient swimming patterns were first observed in nature. Boxfish are reef-dwellers, living in highly turbulent and unpredictable waters. Despite the constant buffeting of the currents, boxfish make only the slightest of deviations from their straight swimming paths. Rather than being cumbersome, these fish are obviously very manoeuvrable. So how do they manage it?

To answer this question Ian Bartol, working with Malcolm Gordon at UCLA and Morteza Gharib at Caltech, studied the hydrodynamic stability of the smooth trunkfish, choosing this boxfish for its simple shape (p. 725). One of the collaborators, Daniel Weihs, is an engineer who has an interest in locomotion. He recommended that they joined forces with engineers at Caltech, which gave the group the opportunity to use three different engineering methods to analyse boxfish stability. But this analysis required a model of the fish to be made, so Bartol had a frozen specimen CT scanned at a hospital, raising some eyebrows as he stood in queue!

This model was examined using digital particle image velocimetry (DPIV). In this experiment light reflecting particles are suspended in a water tunnel. As the water flow changes over the object, the movements of the particles are digitally tracked. This experiment showed vortices forming at certain points on the carapace. Two further experiments measured force and pressure changes on the carapace surface. The combined results excited the engineers, who spotted the similarity to flow patterns for delta-winged aircraft and meant that they could use this comparison for analysis. In each experiment Bartol tilted the model to look at the effect of pitch, the up/down movement, or yaw, side-to-side movement.

‘I was very happy to discover that all three methods collectively pointed to the fact that the carapace is important,’ explains Bartol. As the smooth trunkfish tilts, the shape of the carapace alters the water flow so that the fish is automatically stabilised. This self-correction holds many advantages for these fish. ‘It is important from a biological standpoint,’ says Bartol. ‘They save a lot on energy.’ It is also faster for the fish than using their fins to correct their position. The results hold more than biological interest. The project is partly funded by the Office of Naval Research who want to apply the results to autonomous underwater vehicles.

Bartol and his colleagues are now extending this work to other types of boxfish. But the carapace is only part of the story. ‘They swim by using complex motions of their five fins,’ he explains, so they are focussing on the effect that fin movements have on the carapace forces in live fish. Bartol is also looking at an improved method of DPIV – defocusing DPIV – that will allow him to study flow in three dimensions rather than two. ‘It’s a very new technique – it’s not even being used much in the engineering world.’ It certainly seems that such combined approaches can offer benefits to all involved.

10.1242/jeb.00157

Bartol, I. K., Gharib, M., Weihs, D., Webb, P. W., Hove J. R. and Gordon, M. S. (2003). Hydrodynamic stability of swimming in ostraciid fishes: role of the carapace in the smooth trunkfish *Lactophrys triqueter* (Teleostei: Ostraciidae). *J. Exp. Biol.* **206**, 725-744.

Sarah Tilley
London, UK

MATCHING SMELLS TO SENSORY CELLS

With the *Drosophila melanogaster* genome in the bag, the fruit fly has become an important tool for linking the physiology of olfaction with genetics. But although *Drosophila* has told us much about how insects detect odours, there are (surprisingly) huge gaps in our knowledge.

Until recently we hardly knew any of the chemical compounds that trigger the sensory structures on a fly's antennae. With such basic facts missing it is not surprising that much of the rest of the chain leading from detection to brain is a mystery.

According to Bill Hansson, a chemical ecologist at the Swedish University of Agricultural Sciences in Alnarp, this is because previous work was not focussed on substances relevant to the fly's ecology. 'People would just take compounds off the shelf,' he says, 'we had no idea what the odours meant for the animals.'

Now his team, with colleagues at the University of Cagliari in Monserrato, Italy have completed a systematic analysis of all *Drosophila*'s olfactory receptor neurons (ORN) (p. 715). The aim was to match each ORN to its ligand. Hansson accepts that a definitive answer is impossible because you can never be sure you haven't missed an important chemical. In vision, for example, the range of the electromagnetic spectrum sets the limits of what the animal can sense. 'But in the world of odours you have an unlimited number of structures,' he says.

To narrow down the search the team looked at compounds from six fruits – banana, litchi, mango, papaya, passion fruit and pineapple. They separated each fruit sample into its chemical components using gas chromatography. The stream of chemicals was split in two and directed simultaneously over mounted flies and into a mass spectrometer. That way, recordings of the firing rate of individual ORN's from a tungsten microelectrode inserted into the cells could be tied to particular components of the odour. Refining the method proved to be tough because of the miniature target for the electrode. 'It's hell,' says Hansson, 'It gave rise to a lot of problems and a lot of swearing in the lab.'

Of the hundreds of chemicals in each sample only a handful brought a response – never more than eight for any one fruit and only 27 in total. So it seems the flies are able to detect key components of useful odours. Also, each ORN typically responded strongly to a single primary ligand, while giving a weaker response to structurally similar chemicals.

In many cases, the ecological relevance of the ligands is clear. For example, acetoin and isoamyl alcohol are microbial breakdown products and ethyl hexanoate and isoamyl acetate are typical fruit volatiles. In behavioural experiments, typically the flies would be indifferent to low concentrations, attracted to intermediate concentrations and repelled by high concentrations. Only one odour (1-hexanol) acted as a repellent across the whole range. This compound is given off by green plant tissue and unripe fruit, so it makes sense that the flies avoid it.

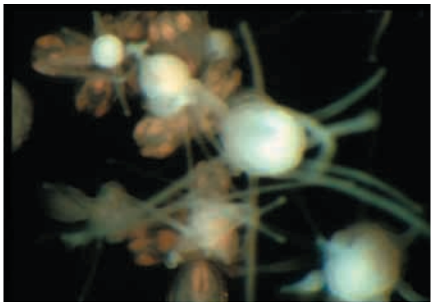
The authors speculate that flies are able to detect potential food sources at a distance by responding to a few key odours with high specificity. He says the next step will be to isolate the genes involved and make comparisons with olfaction in other closely related *Drosophila* species.

10.1242/jeb.00156

Stensmyr, M. C., Giordano, E., Balloi, A., Angioy, A.-M. and Hansson, B. S. (2003). Novel. natural ligands for *Drosophila* olfactory receptor neurones. *J. Exp. Biol.* **206**, 715-724.

James Randerson
London, UK

ROS RELOCATES MOUTHS



The trick to making the most of your mouth is keeping it close to food, which isn't a problem if you can pick yourself up and wander over to the next meal. But life isn't that straightforward for simple hydroids that make their homes on rocks and other creature's shells. Where ever food appears, they have to grow feeding structures at the food source 'otherwise they'll have a short and unhappy life', says Neil Blackstone. But how does the presence of food trigger this response at a time of plenty? Knowing that some organisms signal metabolic changes with reactive oxygen species generated by their mitochondria, Blackstone wondered if the hydroid colonies might be using the same signalling approach to control where they place their mouths. By altering reactive oxygen species generation at key mitochondrial sites and watching how the colonies grew in response, Blackstone has evidence that reactive oxygen species play a signalling role in hydroid colony development (p. 651).

A hydroid colony only needs a few happily feeding polyps to supply nutrition to the rest of the colony. Muscular structures at the base of the feeding polyp contract, consuming energy to pump the food to the rest of the colony's inhabitants. As the feeding polyp's metabolic demand rises, a chain of electron transporting proteins maintains the ATP-generating proton gradient across the mitochondria's membrane. But some of the electrons are picked up from the electron transport chain by oxygen molecules to generate reactive oxygen species such as peroxide. As the feeding polyp's metabolic demand rises it produces less reactive oxygen species, while polyps that are further from the food source have a lower metabolic demand and consequently higher levels of reactive oxygen species. Which made Blackstone suspect that the reactive oxygen species' gradient could regulate the polyps' development.

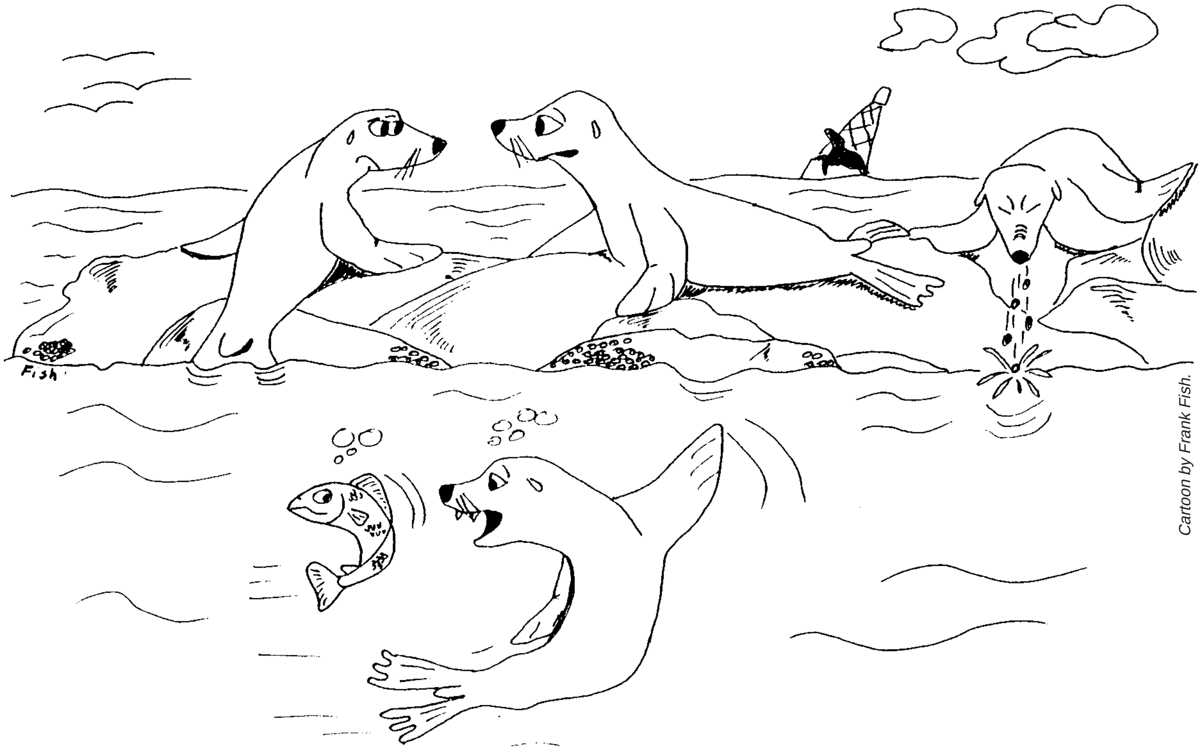
Blackstone decided to manipulate the levels of ROS produced by the hydroid's mitochondria with drugs to see if altered ROS levels affected the way a hydroid colony developed. Taking genetically identical hydroid colonies, Blackstone watched how they grew as he altered their ROS levels. Sure enough, colonies that produced high and low levels of ROS developed as he had expected, with colonies that produced low levels of ROS developing densely packed structures with many mouths. So mitochondrially generated ROS probably carried part of the signal that drove the colonies' development. But Blackstone was puzzled when he looked at colonies that were treated with a drug that should have produced intermediate levels of ROS; they developed as if low ROS levels were signalling another feast on hand. However, Blackstone explains that this apparently confusing result might help him to close in on the point in the electron transport chain where the developmental signal originates.

10.1242/jeb.00155

Blackstone, N. W. (2003). Redox signaling in the growth and development of colonial hydroids. *J. Exp. Biol.* **206**, 651-658.

Kathryn Phillips

PUTTING THE ‘G’ INTO AGILITY



Cartoon by Frank Fish.

Evolution is strange! Does it make sense to be able to pull a 5 ***g*** force turn if you get motion sick?

Sea lions are hardly the most gainly animals on land, but when they slide into the sea, their clumsy gait is transformed, and there’s no doubt which environment suits them best as they twist and turn through the waves. Although sea lions haven’t gone to the same lengths as other mammals that returned to the ocean, what makes these mammals one of the ocean’s most agile swimmers? Frank Fish decided to find out how sea lions manoeuvre around tight turns to catch their next meal (p. 667). Working with Jenifer Hurley and Daniel Costa in California, Fish videoed two sea lions as they swam back and forth in a large tank, ready to analyse the animals’ contortions as they turned back on themselves.

As the animals swam to and fro, they kept their bodies streamlined by keeping their fins tucked in. But as soon as they needed to turn, they moved their flippers away from their side, inclined their heads and suddenly flipped round, turning their bodies into a tight U shape before resuming their efficient streamlined position once they were heading back the way they had just come. When Fish calculated the force exerted on the animal’s body as they turned tail in less than half a second, he discovered that turning sea lions can pull as much as 5 ***g*** force during a turn! But how do sea lions outmanoeuvre other sea dwelling mammals? As Fish explains, sea lions are more agile, simply because they are less stable in the water.

10.1242/jeb.00154

Fish, F. E., Hurley, J. and Costa, D. P. (2003). Maneuverability by the sea lion *Zalophus californianus*: turning performance of an unstable body design. *J. Exp. Biol.* **206**, 667-674.

Kathryn Phillips
kathryn@biologists.com