



### More Than a C With a Twist

Most people recognise that jumpy feeling when they're startled, and fish are no different. Caught by surprise, they react in one of two ways, either curling round into a C shape to make a quick get away, or sweeping into an S with a tail flick to flee. The C-start is so predictable that it has become a standard of motor neural control, with a single neuron triggering the response. Everyone thought

that the S response was just a variation on the C theme, with an extra flick of the tail. But when Melina Hale started measuring muscle activity while startling the fish into an S-start, she realised that the fish were using a different neural circuit to the C-start (p. 2005), making the S-start very intriguing from her 'comparative' perspective.

When Hale began this study, the neural control of C- and S-starts seemed to be pretty well understood. Catch a fish off guard, and the Mauthner neuron in the brain fires a single action potential that forces all the muscles down one side of the fish to contract abruptly, bending the fish's body into a C shape. It seemed natural to assume that the same neural controls were driving the S-start, while the tail drifted passively to convert the C into an S.

But fish don't keep these rapid reactions just for making a fast get away; they also use them for ambushing prey. Hale wondered whether the neural controls behind the feeding response were the same as the escape response. Because it isn't easy to directly measure neural activity as the fish spring into action, she recorded muscle activity in the hope that it might tell her whether there were differences in the neural control of feeding versus fleeing.

Hale fitted electromyography electrodes to a fish that could happily twist into S and C shapes, ready to start collecting data. But as soon as the fish recovered from surgery, she noticed something was wrong. The fish wouldn't feed with the electrodes in place, so she couldn't test the difference between feeding and startle responses. But the fish still produced C and S starts when she startled them, so she changed direction and decided to compare both startle responses directly. After collected EMG data for C and S startle responses Hale realised that they were completely different! Maybe there was more to the S start than she had thought.

Using a high-speed camera, she began filming the fish as she measured their muscle activity so that she could accurately correlate each muscular spasm with the fish's movements. Instead of seeing a single massive contraction down one side of the fish, she measured contractions on both sides. Hale knew that it was unlikely that the Mauthner neuron could trigger a response like this. Some other neural circuit was responsible for this behaviour. Hale remembers that this was 'incredibly exciting'. She realised that her discovery allows her to do the ultimate comparative analysis as the S-start provides a simple system to compare to the model C-start neural circuit.

Ultimately, the goal is to identify the nerves involved in the S-start circuit. Meanwhile, Hale is optimistic that some well-known neurons could turn up in the circuit, but the Mauthner neuron probably won't.



### Feathers Reveal Their True Colours

Birds exploit a wide variety of pigments to produce dramatic effects, and their

vivid plumage has always fascinated man. By using the reflective properties of the feather's materials, birds have extended the range of visual effects by creating 'structural colours' that produce shimmering iridescent effects. These structural colour effects are produced by reflection, in a similar way to the brightly coloured rings in oily patches. Daniel Osorio realised that although a great deal was known about the pigmented colouring, no one had a systematic understanding of the reflected spectral properties of feathers. If he was going to get any idea of how birds exploited their extended pallet of colours, he had to develop some way of systematically analysing a feather's reflected spectra. Together with graduate student Abi Ham, they built an optical system where they control the feather's orientation under a moving light source to collect the definitive spectral signatures (p. 2017).

Each feather's barb is made up of microscopic layers of melanin, keratin and air. Light reflects off the boundaries between each layer, so that some wavelengths become stronger while others vanish, giving each feather a characteristic spectrum. Most feather's colours are produced by a combination of pigmentation and reflected optical properties, but some feather's colours are produced by the structural colour effect alone.

Osorio and Ham constructed a system where they could record the intensity of each reflected wavelength as a light source moved over a feather. Through a collaboration with another team at Sussex, they had access to plumage from 15 different species ranging from the dowdy pigeon to the brilliant kingfisher. Ham and Osoria chose five types of feathers to investigate the range of visual effects produced by structural colouration. By collecting a diffuse spectrum that was reflected off a single point and then slowly rotating it to see how the spectrum varied at different angles, the two scientists collected the complete spectral features for each feather.

Comparing the range of frequencies that produced each feather's colours, Osorio and Ham realised that some feathers reflected a narrow band of wavelengths, while others reflected a wider slice of the spectrum. The other remarkable feature of the feathers was the directionality of the reflected colour. Hummingbird feathers looked completely black from some directions, while the feather's vivid colour only appeared at certain discrete angles. This surprised Osorio, because it meant that the microscopic mirror structures that reflect specific colours aren't always aligned with the feather's surface.

Having established that his new approach to measuring a feather's colour is extremely effective, Osorio is beginning to look beyond individual feathers and at the net effect of iridescence on an individual's plumage. It isn't clear whether there is real information in a bird's reflective display or the reflected colours are simply a cheap way of getting attention, but Osorio's method for collecting spectral data offers the first systematic approach to seeing feathers in their true light.

### Fast Fuel

Some fish sprint better than others, but even the Carl Lewises of the fish world have to keep going for long periods at more sedate speeds. Fish power slow swimming with red muscle, which is packed with mitochondria that generate energy rich ATP. Mitochondria can oxidise both lipids and carbohydrates to drive ATP production. Out of the two fuels, lipids produce more energy than carbohydrates, but carbohydrates release their energy more quickly. Chris Wood wondered which fuel the red muscle consumes

as the fish change pace. Working with a team of students, they tested how the fish metabolise lipid and carbohydrate at different stages of an endurance swim. To their surprise, the fish kicked off by consuming carbohydrate, but switched to lipid metabolism once they'd established a steady pace (p. 2067).

Jeff Richards, a graduate student in Wood's group, was already familiar with the way that white muscle metabolises fuel for high-speed performance. Having designed a battery of tests to unravel the mysteries of anaerobic metabolism in white muscle, he turned his attentions to oxygen driven metabolism in the red muscle's mitochondria.

Working with a summer student, Ashley Mercado, they collected trout and put them into a swim tunnel where they could control the fish's speed. They set them swimming at 30% and 60% of their top speeds, to see how their muscles performed during a slow endurance swim. Then they tested the fish by turning the swim tunnel up to an unsustainable 90% of their top speed. At fixed times during each swim, they anaesthetised the fish, and quickly sampled the muscle to catch a snap shot of the muscle's metabolic status.

Richards and Cheryl Clayton searched for enzymes and metabolic products that would tell them which fuel the red muscle had turned to at different stages of the three swimming tests. Pyruvate dehydrogenase is a key mitochondrial enzyme that only functions

when the cells are consuming carbohydrate. By measuring the amount of an intermediate compound that is produced by metabolism of both fuels Richards and Clayton could tell whether the fish was using lipid or carbohydrate to drive their performance.

After months of intense biochemical analysis, the scientists were surprised to see that within the first few minutes of a slow endurance swim, the fish's red muscle opted for carbohydrate fuel, rather than the energy rich lipid. But after 15 minutes, the fish switched from fast release carbohydrate to energy rich lipid to power their progress. At unsustainably high speeds, the fish supplemented their red muscle with power from the white muscle, and switched back to carbohydrate metabolism in the red muscle, to give them an extra boost.

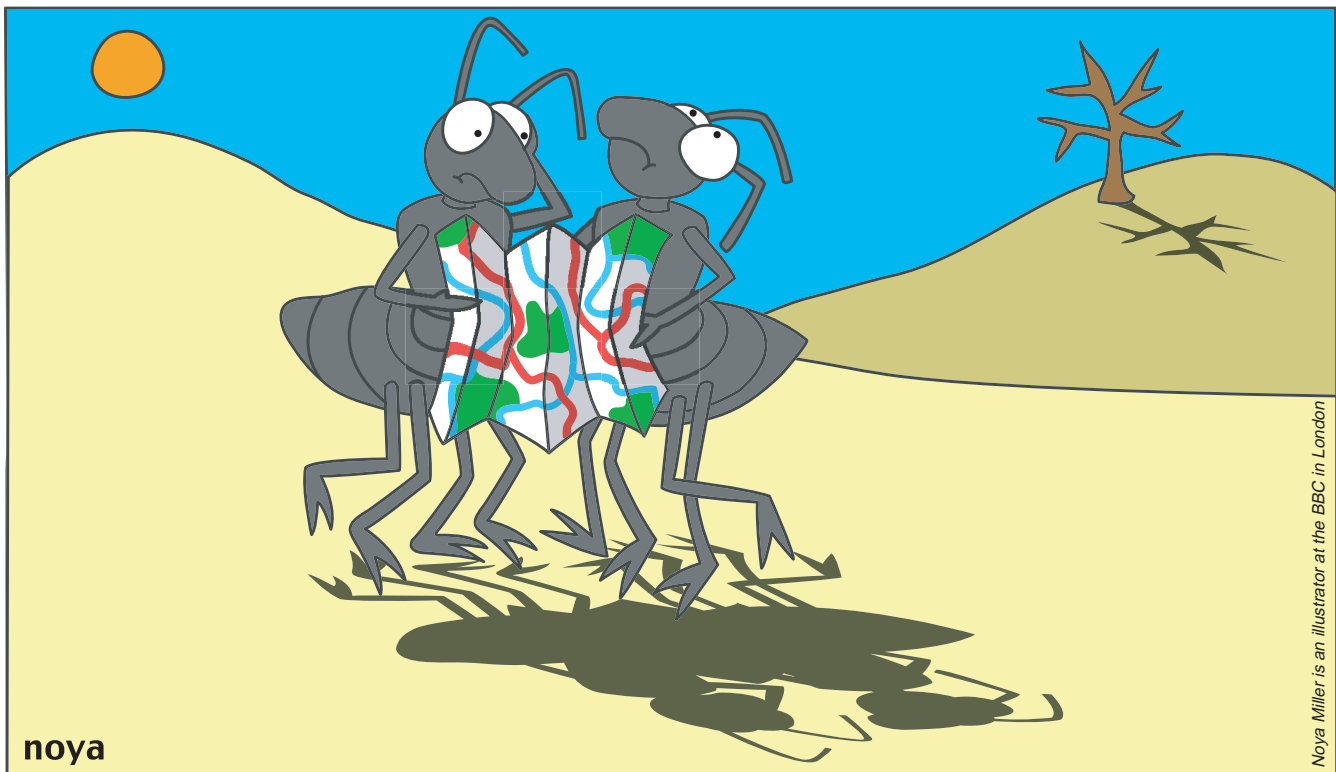
Richards admits that he is surprised by the way the fish switch back to carbohydrate fuel when the need arises. He says 'to my knowledge, no study has ever focused on how the red muscle of fish chooses its fuel.' Having pinned down which fuels are used when, Wood and other scientists are keen to find out how the fuels are delivered and how muscle cells regulate key enzymes in both metabolic pathways.

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"No use looking up there mate, the map says it's this way!"

### Ants find their way home

Åkesson, S. and Wehner, R. (2002). Visual navigation in desert ants *Cataglyphis fortis*: are snapshots coupled to a celestial system of reference? *J. Exp. Biol.* **205**, 1971–1978.