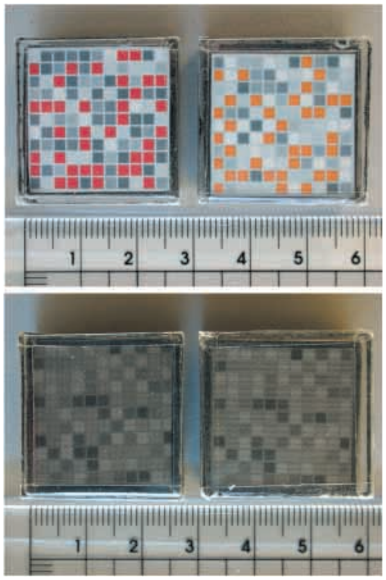
A Colourful World



Since infancy, our world has been like a vibrant painting, mixed from a palette of optic primary colours: red, blue and green. But for birds, the planet is a much more lurid place. Our feathery friends cannot only see our spectrum but beyond into the UV. Colour photoreceptors in the retina called cones are stimulated by light. In Man, the relative activity of three cone types measures the amount of red, green and blue wavelengths, and determines which 'colours' we see. The combined output of these cones measures total brightness. Some birds like quail have a fourth blue cone with sensitivity into the UV, whereas others like starlings posses a fourth cone for UV alone. It has long been known that birds can detect UV, but no one was sure whether birds see it as colours or as increased brightness. Emma Smith, Verity Greenwood and Andrew Bennett set out to investigate this dilemma by giving starlings and quail a series of UV 'colour-blindness' tests, and found that birds can actually see UV colours (p. 3299).

The birds were shown eight tiled squares, covering food wells, and were taught to associate a certain colour with a food reward. Smith was disappointed early on when the birds refused to learn but soon realised that if she weighted the squares, the birds became more precise in their behaviour. Moving a weight introduces a 'cost to being wrong,' she explains. But progress was still painstaking, as the starlings dashed about like excitable children and the quails got fed up and fell asleep!

Firstly, the birds had to learn to choose between a tile with a UV tint and a tile without. Tiles like this would look identical to you and me but are discernable with UV vision. Some birds were trained to select the UV tile and some the non-UV tile. The fact that the birds could learn to pick the correct tile proves that they can tell the difference between them. In other words, the birds can detect the presence of UV. Nevertheless, this test cannot determine whether the birds are seeing UV colours or just a brighter looking tile.

The second experiment also used UV versus non-UV tiles, but this time the absolute brightness was randomly variable, so that there were no rules to learn. Only UV colour was controlled and could be used as a cue to tell which tile was which. These tiles still look identical to Man and can only be told apart by an animal that can see UV as a colour.

Smith and colleagues watched as both bird species successfully learnt all experimental tasks, confirming the birds' UV colour-vision. Countless extra tests guaranteed that the birds were really seeing colours, and were not cheating the system by using smell or texture cues instead.

Although the group were originally teased for choosing quail, often seen as dim-witted animals, both bird species were very successful at learning the visual tasks. Smith feels this work provides the first watertight study showing that birds can see UV as a colour and hopes it will lead on to more colourful research.

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Diffusion Hits Obstruction

It is easy to forget how crowded cells are. The criss-crossing cytoskeletal network is punctuated by organelles and macromolecules so that the only molecules that can freely diffuse between the structures are small molecules. But the organisation of complex cellular environments is determined by cellular function. While all types of muscle produce movement by contraction, the differing speeds and strength of contractions, as well as their voluntary or involuntary control, determines their underlying structure. Research has found, however, that the diffusion of metabolites across muscle fibres occurs in much the same way, whether the muscle comes from lobster, fish or mammals (p. 3377).

Stephen Kinsey and Timothy Moerland follow the movement of metabolites in intact muscle fibres using pulsed-field gradient nuclear magnetic resonance. Using this popular technique, Kinsey and Moerland calculate the displacement of molecules in the fibre by magnetically labelling their position and tracking them over time. 'Time is essentially equivalent to space,' explains Kinsey, as diffusion has a constant speed through a given medium. Seeing how diffusion changes with time, however, means that intracellular barriers that impede diffusion can be identified, along with their size. In this case giant muscle fibres from the spiny lobster were used, because of their characteristic size and structure which simplifies the identification of such barriers.

While other groups have made diffusion measurements in muscle, only Kinsey and his collaborators have unambiguously measured the direction. By carefully aligning fibres in the magnetic field, Kinsey and Moerland found that the metabolite arginine phosphate – necessary for ATP transport – diffuses more slowly across the muscle fibre than along its long axis. After eliminating the effect of the large membrane around the fibre, and the mitochondria, which lie around the edge of the fibre, they decided that the only barrier of the right size that could be causing this effect was the sarcoplasmic reticulum, which releases the calcium ions that initiate muscular contraction. Interestingly, the diffusion measurements agree with those from goldfish and mammalian muscle, suggesting that the sarcoplasmic reticulum acts as a common diffusive barrier in many muscle types.

The abdominal muscles in the spiny lobster are used to rapidly escape predators, but the large distances that metabolites have to diffuse across means that the recovery from contraction is slow. Surely this is a disadvantage? 'It's a mystery to me why these cells are so large,' says Kinsey. One possibility is that recovery is limited by factors other than diffusion distance. Alternatively, evolution may have reached a balance between the amount of contractile machinery and a porosity that allows metabolite diffusion. However, it may simply be that by weighing in at around one kilogram, these lobsters are simply big enough to defend themselves without having to recover quickly after an encounter with a predator.

Considering a complex whole cell system, it is hardly surprising that such work is generating more questions than answers at this early stage. Kinsey and Moerland want to look further at the contractile recovery system in crustacean muscle, paying special attention to the effects of diffusion. It will be exciting to see whether the general characteristics of diffusion in specialised cells hold up under closer scrutiny.

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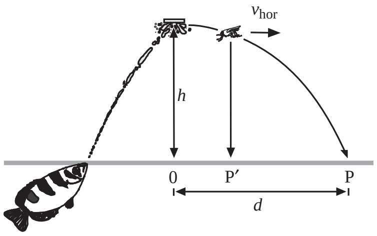

Archer Fish Outstanding in the Outfield

Ever since Stefan Schuster heard about Archer fish as a small boy, he's been hooked! Schuster is fascinated by the fish's ballistic expertise; they can knock an insect off its perch at a range of 50 cm with a single jet of water. He's also amazed by their rapid retrieval response. Having dislodged its target, the successful assassin has to compete with bystanders to reach the tasty morsel first. What impressed Schuster was the speed and accuracy of the fish's reaction, precisely estimating the insect's point of impact in a fraction of a second. Were the fish keeping an eye on the victim as it fell, or had they instantaneously calculated the tumbling insect's flight path? Schuster needed to get his own private school of Archer fish to find out which approach they used. After investing in a 600 litre tank, and five fish, Schuster and his colleagues, Sam Rossel and Julia Corlija, videoed the fish's reactions as a dislodged fly began falling, and realised that the fish instantaneously calculate the prey's point of impact, based on two simple ballistic parameters measured within the first 100 ms of the fall (p. 3321).

Anyone who's ever watched a game of cricket or baseball understands the 'outfielder problem'; how to track a projectile moving in three dimensions as it falls toward you. Humans solve the problem by tracking the image of a soaring ball on the retina, but would that work for a fish that has to compensate for optical distortions? Schuster suspected that the Archer fish had come up with an alternative solution. Because they reorientate almost instantaneously towards the point of impact, Schuster knew that the fish must somehow calculate where the fly will land, either by extrapolating the trajectory based on the first instant of the fall, or by calculating the position where the fly will land, based on a few simple ballistic parameters.

The team set up a tank where they could tantalise the fish with flies that never reached the water, to see what information the fish needed to get them to the impact zone in time. First they videoed the fish as they rushed towards a free falling fly. Next they attached the fly to a thin filament, so that it fell for a few moments before being jerked back from the hungry mouths. If the fish needed to track the fly's entire descent, the aborted fall would have stopped the fish from rushing, but they kept on going, even though the fly was left suspended in midair. Finally, the scientists tested the fish by making the fly-target slide horizontally across a glass plate above the fish at the speed it would have begun falling. Amazingly, the fish still converged at the position where the fly should have landed if it fell downwards, so the fish weren't extrapolating, they were calculating!

Schuster believes that the fish estimate the insect's height and initial velocity within 100 ms of dislodging the fly. But as the successful archer is competing with fish that are equally as quick on their fins, it is always the closest fish that catches this outfield trophy.

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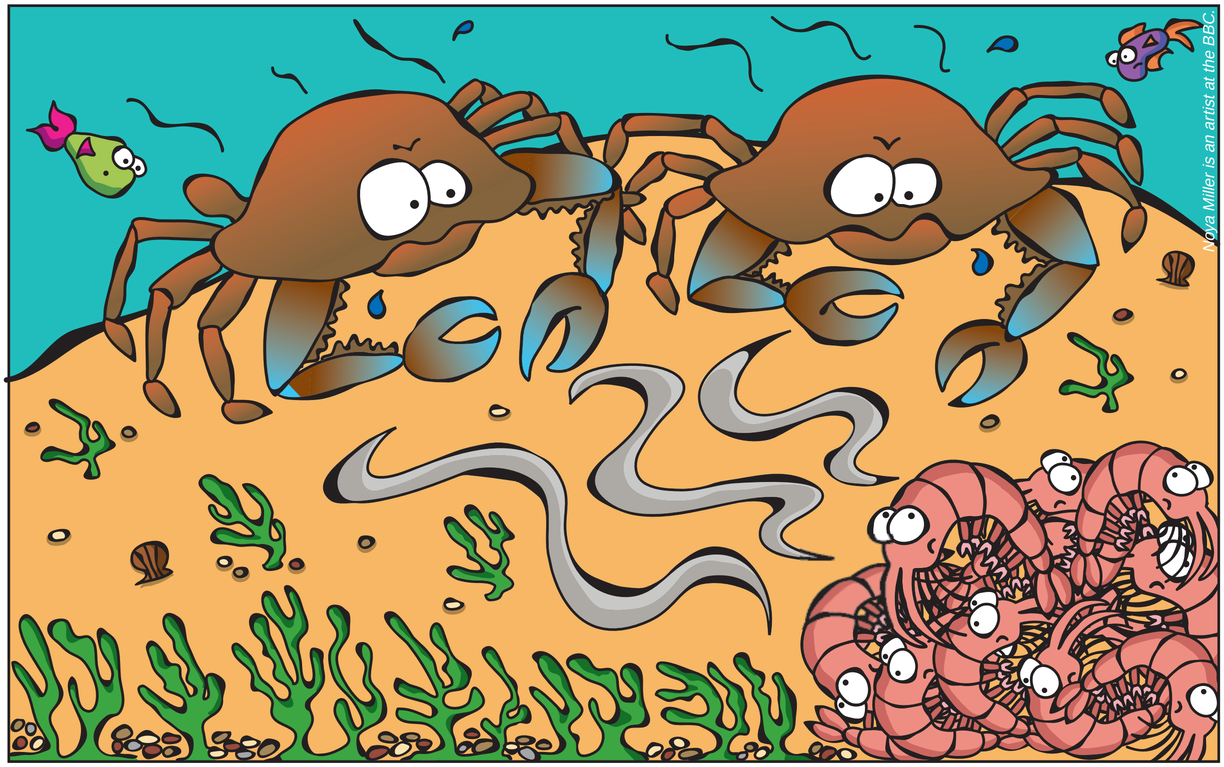
Nova Miller is an artist at the BBC.

Crabs Follow Their Senses

Weissburg, M. J. and Dusenbery, D. B. (2002). Behavioral observations and computer simulations of blue crab movement to a chemical source in a controlled turbulent flow. *J. Exp. Biol.* **205,** 3387-3398.