

Hide and Seek (and Signal) (p. 2113)

Pretty patterns on your skin are great for camouflage, but can they tell more than tales of concealment? The loliginid family of squid congregate in schools that

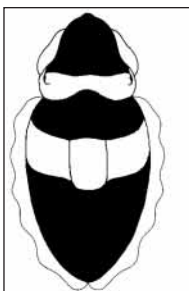
can be found at depths as great as 400 m. Most of these squid are effectively transparent, making them almost invisible at these depths, yet they have all of the specialised camouflage mechanisms found on their opaque cousins. One of these structures, the iridophore, consists of stacks of chitin plates that are separated by cytoplasmic spaces. When visible light enters these structures it is reflected. If the optical thickness of the plates and spaces separating them is one quarter of the wavelength of some of the wavelengths of incident light, only that wavelength will be reflected from the interface. The rest of the light will be transmitted into the squid's body. Consequently only certain colours will be reflected by the iridophore. This will change depending on the angle that it is viewed from, making some iridophores appear red in certain directions, but green in others. At depths of several hundred meters, most of the red light is lost from the spectrum, so reflections from iridophores in the sea will be limited to the blue/green part of the spectrum.

Iridophores are distributed on the surface of the squid's body, forming stripes along the back and arches over the eyes. Lydia Mäthger was intrigued by these bright structures and decided to test how they reflect. Because the squid has little need for camouflage, she wondered if the squid were using the light patterns to communicate with each other, and whether they also help to conceal the animal.

What she found was that iridophore strips on different parts of the body reflected light in different directions. Many of the iridophores on the squid's trunk reflect certain colours of light perpendicular to the axis of the squid's body. This makes the stripes along the squid's sides very conspicuous to other creatures at the same depth. However, the fluorescent layers above the eyes reflect light upwards. She thinks that the brightly lit patterns are probably saying 'Look, I'm here and I'm one of us' to other loliginid squid of the same species in the vicinity. Fortunately, these bands of colour are completely invisible from other directions, so they won't attract predators.

Mäthger also noticed that some of the iridophores on the squid's back were not very reflective and allowed most of the light into the transparent body. But the ventral iridophores are cunningly oriented to collect light after it has passed through the squid's body, focusing it beneath the squid, so that predators lurking below won't see a shadow when a squid passes by.

'Squid are fascinating', says Mäthger. If you've ever had the privilege of seeing them in the sea, you'll know they're clearly beautiful too. But their shiny iridophores are more than decoration; they are signals and salvation all rolled into one.



Masters of Disguise (p. 2119)

According to Roger Hanlon 'when you're a tasty hunk of protein in the ocean, everyone's after you', which just about sums up life for most cephalopods. Staying out of the limelight and blending in with the surroundings is probably the best way of avoiding ending up as lunch. Cephalopods do this by being masters of disguise. They predominantly use two camouflage tactics: either taking on a

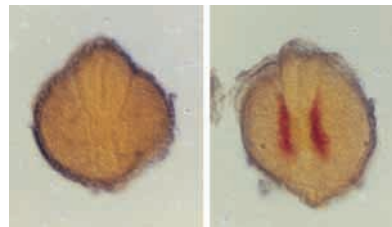
colouration pattern that generally resembles the background (general resemblance), or distracting the eye from the body line by drawing attention to a feature that imitates a part of the surroundings (disruptive colouration). Octopuses and cuttlefish have a sophisticated range of coloured skin patches that are under direct neural control. This allows them to change their skin pattern instantaneously to merge in with the substrate, even though they are colourblind.

Cephalopods have between 15 and 45 changeable body patterns, depending on the species. The cuttlefish, *Sepia pharaonis*, has close to 40, including a white square region on its back that can easily be mistaken for a light-coloured pebble against a rocky background. The cuttlefish activates this patch in response to white features in the area. Hanlon and C.-C. Chiao decided to test which elements in a regular background such a checker board pattern, would provoke the 'white square' response.

Of course, this is the hardest test you can give a cuttlefish. 'I guess these repeated patterns make them uncomfortable', says Chiao, who spent many hours waiting for the animals to settle before they could maintain a persistent body pattern. He faced them with different sized checks, ranging from 2.6 mm to 26 mm, to see which size would provoke the strongest response. In the next test, he looked to see how they responded to contrast, and in the third he measured the minimum number of white checks on a black background that stimulated the cuttlefish to switch on the white patch.

From the first experiment, he found that the grid pattern that gave the strongest response was slightly smaller than the cuttlefish's white patch (13 mm). Larger and smaller checks only produced the mottled or uniform patterns of general resemblance. When Chiao tested the response to checks at different contrast, he found little response when the contrast was below 20 %, but as the checks became brighter the cuttlefish's white patch became brighter too. In the final experiment, he found that it only took four white boxes in a black background to produce the white patch, showing that the animal is very 'clued in' to white objects in the environment.

It seems that the cuttlefish is reacting to the contrast and size of a white object, not necessarily its shape; after all, perfect squares don't appear all that often on the seabed. Ultimately, Hanlon's aim is to quantify the stimuli that produce specific patterning responses, and eventually understand the neural mechanisms that control such elegant reactions. And the cuttlefish had better stick to impersonating pebbly backgrounds; that's what it's best at.



Fishing for Muscle (p. 2097)

The differences between fish and landlubbers run more than 'scale' deep. The muscles of terrestrial creatures have bundles of different fibre types

clustered together. However, fish muscle types are segregated, with muscle fibres restricted to a specific area and function. The outer muscle is designed for slow, continuous swimming, while the deeper layer of muscle is dedicated to short bursts of vigorous activity. The way these structures develop has been studied in zebrafish and trout, and the differentiation pattern in zebrafish was taken as the gold standard for muscle development in fish, and it goes like this.

Early in the embryo's development, structures called somites form. These structures are the precursors of both types of muscle

tissue and of some skeletal structures. A second embryonic structure called the notochord develops close to the somites. The notochord releases signalling molecules called Hedgehogs that trigger a cascade of events in receptor cells, which commits those cells to develop into slow muscle tissue. The cells then migrate radially, towards the surface of the somite, where they continue on their developmental pathway to become slow muscle fibres. Once the slow muscle precursor cells have migrated, the remaining somitic cells begin to develop into a deep layer of fast muscle fibres.

But in trout, Pierre-Yves Rescan and his team have found that isn't quite the whole story. He used *in situ* hybridisation to show the presence of RNA transcripts of fast and slow myosin in somitic cells, and tracked how the cells changed character and migrated as the embryo developed. The clever trick was to test for both fast and slow myosin transcripts at the same time, and this is when they spotted that something else was going on. Instead of finding somitic cells that began to differentiate as slow muscle cells and then migrated to the surface of the somites, they found that all cells had the characteristics of fast muscle cells. Only the cells that picked up the hedgehog signal later transformed into slow cells and began to migrate radially.

So, instead of somitic muscle cells taking one of two different pathways, they all start out as fast muscle cells, and then a subset of them take on slow muscle characteristics and migrate to form the superficial slow muscle. Although the patterning of muscle development doesn't differ between zebrafish and trout, the timing of muscle development does. Rescan points out that Hedgehogs definitely initiate differentiation of slow muscle cells, but now it's not clear why, or how, all somite cells start off going down the path of fast cell differentiation.

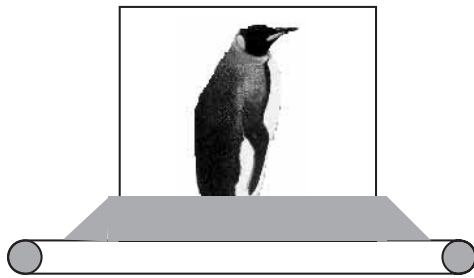
This doesn't knock the zebrafish off its perch as one of the developmental biologists' favourite model systems. But it's a lesson in keeping an open mind. Model systems don't always hold up in all situations.

extended periods of time, but before it could be used in the field, it had to be tested in a controlled environment. Guillaume Froget and colleagues set about calibrating the system with king penguins in the Crozet Archipelago. If the bird's heart rate turned out to be a good measure of its metabolism, then this would offer a robust solution to the problem of tracking the penguin's metabolic rate while it is off roaming the seas.

Froget calibrated the system using four groups of birds: male and female penguins that had been fasting and inactive while guarding the nest, or had just returned full from a shift at sea. He recorded the heart rate and oxygen consumption for all four groups of birds while resting and walking on a treadmill at speeds ranging from 0.3 km h⁻¹ to 2.5 km h⁻¹. Using these data, he found that heart rate and metabolic rate were correlated in all four sets of birds, but that the correlation was different for resting, fasting males than it was for the other three groups of birds. Having established that a correlation existed, he checked that he could estimate metabolic rate from the heart measurement alone by exercising the birds on the treadmill at randomly allocated speeds, calculating the expected oxygen consumption from the measured heart rate and comparing it with the measured amount of oxygen that the penguins consumed. So long as Froget knew the sex of the bird and whether it had been active or inactive and fasting, he was able to measure their metabolic rate based on heart rate alone!

A technical problem has been solved, but through this study it turns out that fasting and inactivity affects the king penguin's heart rate and metabolism. Finding how this relationship varies during the fast and foraging trip, when the penguin rebuilds its body fat stores, is another challenge to be added to the ever-lengthening list of questions about metabolism and physiology under extreme conditions.

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**Working Out,
Penguin
Style
(p. 2133)**

How would you feel if a trip for a take-out meal included a 1,000 km round trip, diving to

enormous depths, and spending all of the time in water at temperatures barely above freezing? Pretty discouraged, but this prospect doesn't daunt king penguins. It's just normal foraging for them. The astounding aspect of this feat is not their incredible endurance, but the depth and duration of each dive. King penguins regularly descend to depths greater than 300 m for as long as 7.5 min and must surely exhaust the penguin's supply of oxygen and force it to respire anaerobically for the remainder of the dive. However, anaerobic respiration is energetically costly. Mammals that switch to anaerobic respiration require relatively long recovery times between dives, yet king penguins are able to dive many times in rapid succession. Somehow the penguin must be able to extend its aerobic dive limit, presumably by slowing its metabolic rate and conserving oxygen.

Measuring the metabolic rate of an animal that embarks on such an odyssey is a tricky prospect. The question was whether measuring heart rate was going to be a good indicator of oxygen consumption and metabolic rate. Patrick Butler and Anthony Woakes at the University of Birmingham, designed a heart rate monitor that can be fitted to penguins to collect heart rate data for