

Researching cuttlefish

The clever cephalopods



Cuttlefish on a coral reef

Key words

vision
colour change
convergent
evolution
cuttlefish

Biologists investigate animals with lifestyles and abilities that are very different from ours. Creatures such as echolocating bats or animals that can survive in water above 70°C open new perspectives in biology. At the University of Sussex, I am fortunate to be studying one of the most alien creatures on this planet – the cuttlefish. Cuttlefish are cephalopods, like octopus, squid, and nautilus. These creatures could not be more different from humans. They have three hearts and blue blood. They have no bones but capture their prey with elastic limbs equipped with suckers, inject it with venom and eat it with a bird-like beak. But for me their vision and camouflage is most remarkable.

Simplifying the complex world

Cuttlefish may differ from us in just about every possible way, but they do possess one similarity to humans. We look at each other with the same kind of spherical lens eyes. Cephalopods are molluscs, so their common ancestor with humans was most likely a worm-like animal, which was more or less blind, at most able to detect the presence or absence of light. The similarity of the cuttlefish visual system to that of humans arose independently through natural selection. This is what we term convergent evolution. In my laboratory, we investigate how the cuttlefish perceive their world. What are the similarities and differences to human vision?

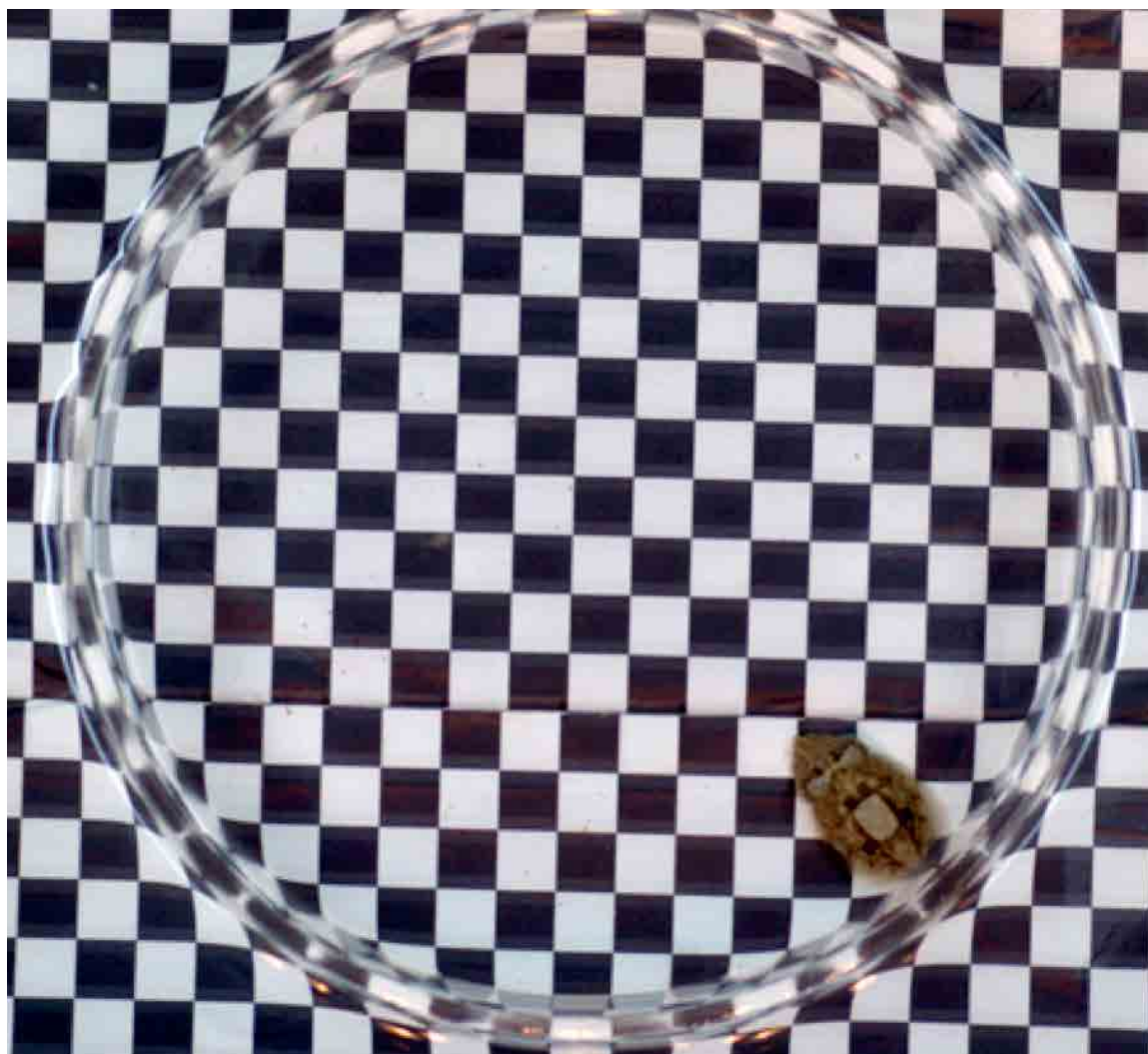


Figure 1
A cuttlefish
camouflaging on a
checkerboard.

The natural world is a complex scene. Think of a coral reef bed. There's a huge variety of colours and textures. When you add depth, it's easy to see how crazy it is how our brains can interpret these many factors into a 3D image. Trying to understand a visual system with such complexity seems daunting, but like any good scientist, we just need to reduce a visual scene into a smaller number of variables. In the case of cuttlefish, we regularly use checkerboards - see **Figure 1**. Checkerboards are simple backgrounds that vary in only two variables: size and contrast. We can scale the size or alter the contrast between the checkers and tease out how they respond to the scene.

Alternatively, we may also use image statistics. The combination of simpler variables can get exponentially difficult as you increase the number of variables. Even more difficult is understanding complex patterns and textures. To understand complex natural scenery, we need a way to look way to represent a natural scene more easily. In this way, we can use digital images from a camera. Just like a computer screen, the image is made up of hundreds or thousands of pixels. Each pixel is represented by colour values of red, green, and blue.

Think of an image as a giant matrix. We can use various algorithms and statistics to alter these values to understand more complex relationships

in the natural environment and how the visual system interprets it. After altering the image, we can present it to the cuttlefish and see how they respond. For example, if you refer to **Figure 2**, you see three textures in their original state and phase randomized. When the phase information is randomized, the detailed information, such as well defined edges, for object recognition disappears and the images appear cloudy.

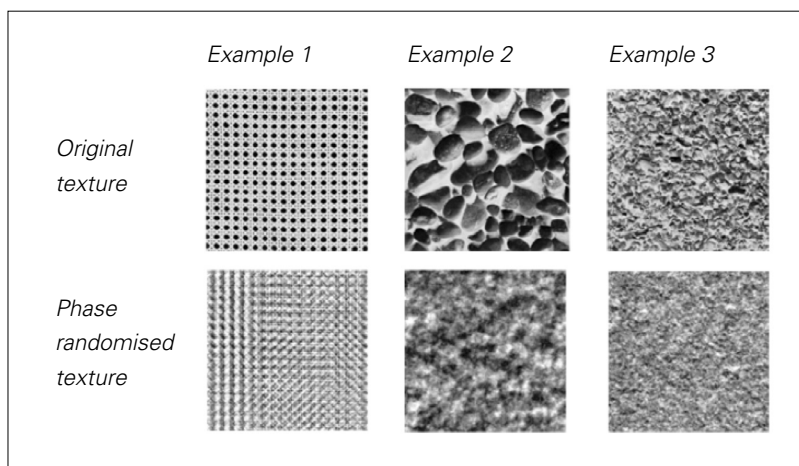


Figure 2 An example of using image statistics to alter an image. The top row shows the original image and the second row demonstrates how randomizing the phase of an image can distort the edges in an image making it blurry.

I just want to blend in

When we examine human vision, we are able to ask the person in question what they see; we have the opportunity for a verbal response. Unfortunately, we are unable to ask the cuttlefish this question. You're more likely to be inked at. Instead, we can use another aspect of cuttlefish biology to tease out the answers to these questions. We achieve this through investigating their rapid adaptive camouflage.

Cuttlefish are the camouflage masters of the world. They are unrivalled in the animal kingdom. They are capable of altering the colour, pattern, and texture of their whole bodies in under a second! This remarkable capability is due to the fact that the cuttlefish's skin is directly connected to their brain. The skin is under the control of motor neurons. The nerve signals control muscles, known as chromatophores, which contract and expand to form the myriad stripes, spots, and other pattern formations on the skin. This is akin to the motor neurons in human facial expression. A cuttlefish can switch its whole body colour at the same speed at which a human can smile or frown.

We can use this camouflage system as a behavioural output to understand how they see the world. The information from the environment comes into the eyes, into the brain, and directly to the skin – see **Figure 3**. More importantly, we can utilise these camouflage masters to understand other visual systems, including that of humans. Any animal that has a visual predator requires camouflage. It's important to prevent being eaten and to hunt effectively. We can investigate the similarities between the camouflage patterns and the environment to understand what makes them blend in so well. Even better, we can fine-tune our analyses to the specific visual capabilities of a range of predators to do this. In essence, we can attempt to understand how other animals view the world.

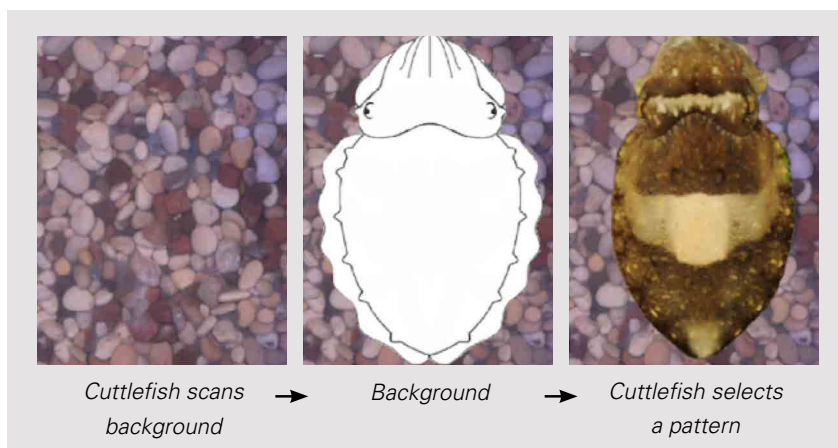


Figure 3 A cuttlefish will select a pattern by examining elements in the background and choosing the camouflage pattern best suited to that environment.

Vision, ecology, and beyond

What we learn from cuttlefish vision and camouflage extends well beyond human vision and perception. Our research easily extends into the wider concepts around evolution and ecology. For example, the

camouflage of an animal is intrinsically tied to the ecology of the animal. The colourful coral reefs in the Great Barrier Reef allow the giant Australian cuttlefish (*Sepia apama*) to exhibit a whole rainbow of colours and patterns, both beautiful to behold and effective camouflage for the environment. In contrast, the species I study, the common cuttlefish (*Sepia officinalis*, see **Figure 4**), lives in the English Channel. Lacking coral reefs, these cuttlefish's camouflage relies on more earthy tones, such as brown, black, white, and tan. The environment plays a crucial role in the development of not only vision, but also the way animals look.



Figure 4 The common cuttlefish – you may have seen bones from this species lying on beaches around the UK.

I highly recommend any student interested in biology or other science fields to find a concept that fills them with passion and awe. My own attachment to cuttlefish lies within their rapid colour changing capabilities. It still seems like magic to me as their patterns shift instantly. Find your passion and talk to researchers in the field about how to get involved. There are many internships, work placements, or volunteer positions in research labs. If those are not immediately available, build on your skill sets as a researcher to be competitive.

Growing up in the middle of the United States, I lived hours away from the ocean. I never even saw the ocean until my young teens. The passion I had allowed me to find what necessary skills were needed to pursue my goals. I worked on many other animal systems until I could develop the skills and knowledge to do what I do today. I hope you find your passion too.

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Look here!

Some remarkable films of cuttlefish changing their shape and colouration at high speed:

<https://www.youtube.com/watch?v=h5CYvgYVqQ0>

<https://www.youtube.com/watch?v=WhYD-ylPAZo>