Trapping the fantastic light

Technology is harnessing the secrets of sea creatures, writes Emma Young

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The lobed comb jellyfish that loiters in Australia's coastal waters is by any standard an unlikely candidate to trigger the next technology boom. But where some see a hapless, tendrilled blob, others see the future of computing.

The reason for researchers' optimism lies in the dazzling flashes of colour that streak down the creatures' tentacles. New work by researchers in Australia and the UK has now revealed a remarkably simple technique behind the display, one that physicists would love to adapt. If they get it right, they believe communications and computer technology will be transformed.

Ross McPhedran at the University of Sydney and Andrew Parker at Oxford University, have found that the jellies use what are known as photonic crystals to produce their iridescence. These crystal structures control precisely which colours of light they reflect, and it is this fine manipulation of light that excites physicists. Synthetic photonic crystals could form the basis of new, faster computer chips based on the control of light, rather than electrons. Photonic crystals could also be used to massively speed transmissions through networks of optic fibres, and to increase from 40 to perhaps 10,000 the number of channels of information that can be carried by a single optic fibre. They could also be used to create "permanent" colour photographs - because, unlike chemical pigment, colours generated physically by photonic crystals don't fade.

"In my opinion it's hard to overestimate the future importance of synthetic photonic crystals," says Peter Vukusic of the thin film photonics group at Exeter University. "They will underpin the workings of much of our communication, computing and optical technology industries."

Research directed at creating photonic crystals began in the late 1980s. At the time no one suspected the same structures might be found in nature. In fact, natural examples were unknown until four years ago. Then, while based at the Australian Museum in Sydney, Andrew Parker was going through the rubble of a museum field collection and a volunteer asked him to take a closer look at a particularly spectacular, intensely red spine from a sea mouse (which, despite the name, is a bottom-dwelling, scavenging worm). Parker took the spine to McPhedran's lab to probe its structure. It turned out to be the first confirmed case of a photonic crystal in nature.

Since the sea mouse discovery, published in Nature in 2001, other teams have found photonic crystals in butterfly wings, weevils - and now in the lobed comb jellyfish. Jian Zi and his team at the Surface Physics Laboratory in Shanghai, China, reported the discovery of photonic crystals in feathers in the peacock's tail in October 2003. "The physical mechanisms and colouration strategies in peacock feathers are simple and ingenious," Jian says. Simple variations in the number and spacing of rods in a lattice of crystals create the colours and govern their intensities.

Not all of nature's photonic crystals are the same. Some are planar structures, some tiny balls called nanospheres. Some have hexagonal cells while others, such as those now discovered in the lobed comb jellyfish, have parallelogram-shaped building blocks. The symmetry of the crystals in the jellyfish, Bolinopsis infundibulum, means that the tentacle colour is dependent on the direction from which it's viewed. From one angle, it might flash white light - but from another, it displays rainbow-coloured iridescence. The jelly might arrange its tentacles to produce white light flashes when seen from below - mimicking the appearance of light reflecting off waves above it, and so acting as camouflage - and bright colours as a warning signal, the team speculates.

The natural photonic crystal field is young, and it's not yet clear to what extent these designs are used in nature. "But the more we look, the more we find," McPhedran says. Since the crystals are such efficient reflectors, they would have the greatest advantages over pigments in low light conditions, so might be expected to be more common in animals that live in the sea or function at night, says Parker.

But the development of synthetic versions is still very much in the research stage. So the task now is to learn from nature. Parker's team plans to look at the sea mouse genome, to identify genes that code for its photonic crystals. It might then be possible to modify the genome to breed sea mice that produce made-to-measure crystals for human use. They're also trying to work out how the most minute components of the sea mouse crystals unite to form nanotubes, and how those nanotubes assemble into the wall of a spine. This work will boost efforts to create synthetic versions, he says.

"Sometimes the animal crystals are so intricate, on such a small scale, that we can't make them accurately," he says. "But animals make them perfectly. If we can copy the self-assembly processes within animal cells, then we would have a technological breakthrough."

Learning from Mother Nature

· The **colour-changing capabilities of cuttlefish** have been borrowed to create a **"camouflage" gel**, with potential military uses. As well as changing pigments in its skin, the cuttlefish also reflects back the predominant light wavelength in its immediate environment. This mirror-like system helps the cuttlefish to blend with its background. And it is this reflective method that has been adapted by a team at the University of Bath Centre for Biomimetics and Natural Technologies.

· Research to understand **geckos' ability to walk up walls** has inspired the development of a **super-strong adhesive**. Minute hairs on geckos' toes interact at a molecular level with a surface, allowing it to stick to almost anything. Replicating the tiny hairs provides a new approach to adhesion which could even be used to help robots move around in space, where suction will not work, say US researchers at the Lewis and Clark College in Portland, Oregon. It could also be used to create non-slip gloves or climbing equipment.

· **Heat sensors** based on beetle organs are being developed by US Air Force researchers. The infra red-sensing organs are on the body of **Melanophila acuminate beetles**, which need to seek out smouldering wood to feed. The idea is that the new sensors will be highly sensitive to IR radiation but won't have to be cooled to freezing temperatures to work.