Cover illustration

No end in sight

Vision includes the frontier of perception, and involves cortical interpretation; thus requiring an "eye" and the neurological machinery for processing. But photoreception is a far different matter and is much more common.

There are many creatures that have extraocular photoreception, even beyond the parietal eye, discussed in the *BJO* March 2005 essay. Most plants have photosynthesis and, in some sense, photoreception. But, there is more to it than that.

Living creatures are divided into three great domains, bacteria, Archaea (including the extremophiles), and eucarya or eucaryotes. The bacteria and Archaea are both prokaryotes, meaning they lack a nucleus. The eucaryotes include all single celled nucleated organisms, such as the protists, and all metazoa, or multicellular organisms. All three domains contain creatures that use photoreceptive compounds that include vitamin A aldehyde, or retinal. The opsins, however, are different. Bacteria and Archaea have opsins that resemble those in eucaryotes, but are not identical. All metazoan opsins, however, are very similar suggesting that these proteins must be very old.

The sun represents the ultimate source for most, but not all, of the earth's energy. This source is finitely renewable and the usable energy is concentrated in a narrow spectrum including the visible and nearly visible spectrum. Most living organisms have fashioned their lives around this spectrum.

Evolutionarily, photoreception occurred very early, suggesting that the critical molecules required for this process, including the opsins and retinal, may have preceded life. Opsins are part of a family of transmembrane proteins that may have begun as membrane transporters. Early life had some form of photoreception and the opsins are almost certainly the molecule used. Eyes came later, and essentially have been a way to organise that sensory input. Organisms within two of the domains, bacteria and Archaea, still retain these opsins within their cell membranes.

Eyes, then, are not the only way to perceive and utilise the visible spectrum, as plants bear witness. Most invertebrates, especially those without eyes, have some mechanism of extraocular photoreception. Coral, for example, is photoreceptive, and even has Pax-6-like gene, the so called master eye gene. Many invertebrates have novel anatomical placement of extraocular photoreceptors. For example, some butterflies have photoreceptors in their genitalia allowing the male to confirm penetration. Marine invertebrates as diverse as sea squirts, anemones, sea urchins, and annelids (worms) all have extraocular photoreception. But even vertebrates, further distanced from the prokaryotes, can have extraocular photoreception. Amphibians, lizards, and snakes, including the banded krait on this month's cover, have all been shown to have such abilities.

Snakes are believed to have evolved approximately150–95 million years ago, and arose from within the true lizard group. The first snake probably evolved from an aquatic or semi-aquatic species, although this remains controversial. Once the Serpentes evolved, however, they slithered onto a terrestrial lifestyle and became quite successful. But just as these reptiles had begun colonising the land, some of their own headed back to the sea.

Although the eye of the yellow lipped sea krait, *Laticauda colubrina*, has never been examined, the eye of a close relative, *Pelamis paturis*, has. These snakes have an all-cone retina that is thin and non-vascularised with a high concentration of horizontal cells and large degree of summation indicating excellent motion perception, at the sacrifice of visual acuity. Unfortunately, the cornea of *P paturis* was not examined, so we don't know if the cornea is flattened compared to its terrestrial relatives, but it is likely that it is, given that other aquatic animals such as fish have rather flat corneas. The cornea and water have approximately the same index of refraction so the cornea loses its refractive ability under water.

Laticauda colubrina

All sea snakes are predators with a neurotoxic venom that is remarkably efficient. Found in the Coral Sea, *L colubrina*, preys mainly on eels, although it will take fish. This rear fanged snake is not particularly aggressive, although it is highly venomous. Once the prey succumbs, the meal is swallowed whole.

In the ocean, one either eats or is eaten, and that is true for these snakes as they may be prey for sharks, and predatory birds such as the white bellied sea eagle. Avoidance of predators, then, is at least as important as prey capture.

An agile swimmer with a paddle-like tail, as seen on the cover, *L colubrina* and other sea snakes suffer from not knowing exactly where their tail is, and would benefit from a set of eyes behind them.

The sea snakes may have just that. They possess cutaneous photoreception in their tails so that they may pull their tails completely under rocks or into crevices to avoid detection and predation (Zimmerman *et al*, *Copeia* 1990:860–2). Although the exact mechanism is unknown, thermal recognition is not part of this process. Sea snakes' tails recognise light under water where the thermal difference would not be significant.

Photonic response probably preceded life. Photoreception, sight, and vision followed sequentially with further evolution as these sensory inputs became more organised. But, extraocular photoreception continues well into recent evolutionary changes and will continue to part of the lives of many creatures. There seems to be no end in sight.

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