Cover illustration

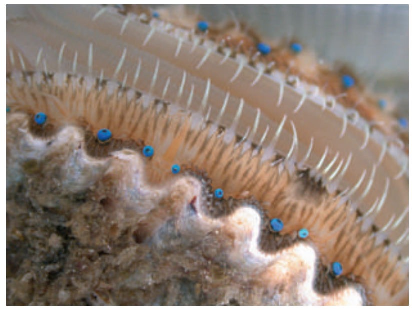
Mirrors at the birth of Aphrodite

The first reflecting telescope was invented in 1663 by James Gregory, but was never popularised because the mirrors were too difficult to manufacture at that time. A slight variation on the principle, the Newtonian telescope, was first recognised in 1672 by its namesake, and was a most dramatic step forward in the observation of the stars. Even today the Newtonian telescope is perhaps the most economical and popular instrument of amateur astronomers. The Schmidt catadioptric telescope was not devised until 1930, and is a variation on the Newtonian telescope. In a Schmidt telescope, light first strikes a corrector plate that is essentially a lens, and then strikes a concave mirror. The reflected light is focused upon a film plate within the column of the original light beam. One of the principal purposes of the initial lens in the Schmidt telescope is to eliminate spherical aberration, but a simple bivalve mollusc had this elegant design as much as 500 plus million years ago, and still uses this system.

When you envision scallops, you probably imagine the painting of Aphrodite's birth from the sea foam on a giant scallop before she walked ashore in Cyprus, or more simply you think of butter, garlic, and white wine, but this creature has several curious ocular features that are not found elsewhere on earth and are surprisingly elegant.

The eye of *Aequipecten irradians* (and other scallops of the genus Pecten) as seen among the tentacles in the picture on this month's cover, is quite colourful and is essentially the only Newtonian or Schmidt style telescope in the animal kingdom. The common scallop may have 40–60 pallial eyes around the edge of the mantle, and each one has a lens (acting as a corrector plate as in the Schmidt design), two separate, tiered retinas, and a biological mirror lining a pigment cup. There are two optic nerves that leave each eye in opposite directions and join behind the eye. Much like the jellyfish (*BJO* cover, May 2003), there is no central processing or brain and hence the animal does not "see" in the true sense of the word. There is no brain to do the interpretation.

The design of this Schmidt/Newtonian telescopic eye is so unusual



as to deserve the word "unique." The lens, as can be seen, is aspheric with what would appear to be a curved bow on either side of the central lens. Careful work by Land (*J Physiol* 1965;**179**:138–53) has illustrated that this design will eliminate spherical aberration, which is a problem that afflicts Newtonian telescopes to this day. That may be true, but with only 5000 photoreceptors in each retina, and only cerebral ganglia to process the image, one wonders why spherical aberration would be a problem for such a creature.

In this animal's elegant model, light strikes the aspheric lens and is refracted towards the convex mirrored surface proximal to the lens. The photons will pass through a layer of photoreceptor cells representing the proximal retina and strike the guanine lined posterior surface. Immediately proximal to this retina is a layer of pigment cells to restrict any light scatter. The partially focused light is then reflected by the concave mirror towards the posterior aspect of the lens. These reflected rays will come to point focus immediately behind the lens on the second or distal retina. Each photoreceptor of both retinas sends a single fibre to the optic nerve with no synapses. Each retina sends its fibres in a different direction around the mirror and through the pigment cup to join into a single nerve proximal to the eye. This optic nerve then travels to the viscero-parietal ganglion.

Curiously, the proximal retina lining the mirror will never receive a formed image as the aspheric lens does not focus on the mirror. Furthermore, this proximal retina (or most posterior from an anterior-posterior (AP) direction) responds to a cessation of illumination. These photoreceptors fire when light goes off! The distal retina (or anterior retina in an AP direction and immediately behind the lens) responds in a more typical fashion and fires when stimulated by light. Through elegant work, it has been suggested that scallops use the information from the proximal retina to determine orientation to or away from light. The information from the distal retina is sensitive to directional stimuli and responds to moving objects. There appears to be some utilisation of an image by using this distal retina with the more focused image. Predator avoidance would be highly likely as these species can "swim" by jet propulsion. Scallops accomplish this by using their adductor muscle (the portion served in fine restaurants) to rapidly close their shells and thus produce a jet stream of water.

From an evolutionary and phylogenetic approach, these animals become even more interesting. The distal retina contains photoreceptor cells that are ciliary, whereas the proximal retina photoreceptor cells are microvillous cells. Classically, vertebrate photoreceptors are ciliary cells and invertebrate photoreceptors are microvillous. This bivalve species has both. As these creatures probably developed shells during the Cambrian explosion and may have done so as a protective measure, it is interesting to speculate that the last common ancestor that preceded the scallops also contributed to those creatures that later became the protochordate—pikaia and later amphioxus. These protochordates were probably our ancestors and obtained their ciliary cells from a predecessor.

Hence, the scallop may stand evolutionarily close to the split between vertebrates and invertebrates, at least based on its photoreceptors. Its mirror optics, and beautiful appearance (as well as its delicious flavour!) would make Aphrodite proud.

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