Cover illustration

Shedding light on the reflections

Arthropoda, as a phylum, includes the crustaceans, arachnids and insects. This is the largest phylum in terms of the number of species, as it includes perhaps three quarters of the million or so described species. These groups probably had their origin in the Cambrian period or before, and divergence began early—thus accounting for such a numerous and diverse phylum. These are segmented animals, much like the annelid worms, but the arthropods have evolved a harder outer shell, or cuticle, which serves as an external skeleton. Some of the larger crustaceans have taken this hard outer shell to an extreme—the crabs, shrimps and lobsters. But, this organic armour comes at a price. It is rigid, and must be shed for the animal to grow and mature during a process called apolysis (separation of the shell from the epidermis), followed by ecdysis (shedding of the old shell). During this process, the outer “cornea” of the eye will be shed and replaced with a new one. The cover images show a living lobster’s eye and a shed carapace, illustrating just how complete and delicate this process is. The process of ecdysis is relatively well understood, and is controlled by a gland in the animal’s eyestalk. The epidermal cells secrete the beginning of the entire shell as apolysis begins. Eventually, when ready, the lobster will pump in water to force the shell away from its newly formed, but still incomplete, shell, and will jettison the old chitinous carapace (upper left cover). Often, the lobster will consume the remnants of the old shell and expand further by ingesting seawater, allowing the new shell to complete itself with extra space to allow for growth. During its molt, a lobster will grow approximately 15% in length and 50% in volume. During the subsequent few days, the lobster must hide because it is soft, vulnerable and nearly blind. It must wait to move around until its shell hardens and the new corneae form completely (upper right cover).

Long-bodied decapods have interesting eyes beyond the eyestalk gland and reformed cornea. To understand the eye

Shrimp eye.

of these creatures, a brief review of compound eyes may be useful.

Compound eyes can be divided into two basic groups: apposition and superposition. Many of these compound eyes have been discussed previously, but the eyes of long-bodied decapods are truly unique. These are called reflecting superposition eyes. The optical principles are unusual, unlike any other eye, and have been understood only since the mid-1970s.

Apposition eyes, like those seen in bees (*BJO* March 2001 and May 2006), contain ommatidia that are optically isolated from each other, and each unit samples a different portion of the surrounding environment. The corneal lens is immediately adjacent to the cylindrical crystalline cone in each unit, called an ommatidium. Vision requires daylight, and these eyes are not particularly sensitive. Each point of light must be sent to the brain for the assembly of an image.

Most superposition eyes cannot be distinguished from apposition eyes externally as the external configuration is so similar. But, internally there is a great deal of difference. The corneal lens and contiguous crystalline cone are offset from the reticular cells, which are analogous to photoreceptors. A clear zone exists between the refracting elements and the receptive elements that could, in a way, be considered analogous to the vitreous cavity. This space

allows several ommatidia to direct an image to the same point on the reticular cells, providing an upright image that is already assembled at the reticular cell level. This results in a much more sensitive eye with the potential for better vision. Most of these eyes are refracting superposition eyes, as the two optical elements (cornea and crystalline cone) refract the image to a single point on the reticular cells (*BJO* September 2003). The external facets of the ommatidia are hexagonal, as they are for apposition eyes.

Eyes of the long-bodied decapods are distinctly different, as is illustrated in the lower left and right photographs on the cover. These external facets of the ommatidia are square cylinders. Internally, these eyes are different too—a difference which confused investigators for decades. No lens but rather a clear gelatinous substitute with no refracting power exists in this square cylinder. Then, how does it work? Conceptually, this is more difficult.

These square cylinders are lined with mirrors made of purines (lower left and right cover). These are mirror boxes. A point of light will be refracted somewhat by the cornea, before striking the mirrors. As it turns out, almost all rays will strike the two sides of the mirror box and will be focused to a single point on the reticular surface. It is the orthogonal nature (square and at right angles) of the mirrors that does the trick. These act much like two perpendicular mirrors at a haberdasher, with almost continual reflection no matter how you move. The pair of mirrors of different ommatidia struck by parallel incoming rays from a point will focus the image at a single point on the reticular surface much like the refracting superposition eye. Ingeniously simple.

Perhaps these creatures can shed some light on the reflections.

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