Cover illustration

Jewels of the jungle

Giant metallic Ceiba borers are forest jewels that begin their lives as eggs in rotting stumps or logs. They hatch into a larval form, and remain in the rotting vegetation for a year or more without exposure to light. There they feed on wood, digesting cellulose with the help of bacteria in their gut, and, as a result, are important recyclers of the forest floor as they turn the fallen trees in compost. The larvae pass through various stages, known as instars, to maturity. As they mature, these metallic looking wood boring beetles or scarab beetles exit the stump as adults and are capable of flight.

Beetles are the largest order of insects, with more than 350 000 known species, although this probably represents only a small fraction of the total extant today. Those estimates may even be off by an order (or two) of magnitude. Beetles, in general, have been successful because of two characteristics—body shape and their ability to adapt and evolve with plants. This diverse and adaptive group represents a fifth of all living organisms and a fourth of all animals! As you might suspect, their eyes and visual mechanisms are no less diverse, as we are just beginning to learn.

Beetles are defined as having two pairs of wings with the outer pair hardened into a shell-like covering when retracted. These outer front wings, called elytra, meet in a straight line on the back and cover the hind wings like a sheath. They are responsible for the name of the order—*Coleoptera*. Aristotle named this order from the Greek words, “koleos” meaning sheath, and “ptera” meaning wing (incidentally, this is the same root for the word “pterygium”).

Jewel scarab beetles, such as *Euchroma gigantea* illustrated on the left of this month's cover and on this page, have been used on or in jewelry and as decorations at least since the time of the pharaohs. Carapaces of *E gigantea* have been used as body ornaments and in necklaces by Amazonian tribes, and have been cherished as decorations for shrunken heads by tribes in eastern Ecuador. The structural colour of this 5-6 cm long beetle gives a glistening metallic appearance and may function in camouflage and communication.

Dorsal carapace of giant Ceiba beetle.

Beetles have a variety of interesting eyes worthy of review. The most common and basic design of the compound eyes within the order *Coleoptera*, is that of the apposition eye.

The apposition eye is perhaps the oldest of the extant compound eyes, and consists of multiple facets, called ommatidia. Each ommatidium is a tiny individual eye with a cornea and a more proximal crystalline cone for focusing. Immediately proximal to the crystalline cone is the receptor cell, or rhabdom, and it is the most proximal element in the cylinder of each ommatidium. The rhabdom, which is often surrounded by pigment, conducts signals to the receptor axons that then lead away from the eye.

The rhabdom consists of inner portions of eight different cells arranged in a circle around the centre of the cylinder. Each cell contributes its inner portion fused to the other seven cells along the longitudinal axis. These cells come together like triangular slices of pie with nearly all of the tips touching. This fused element of parts of all eight cells contains microvilli, from each cell, covered with photoreceptive visual pigment. The rhabdom performs like a fibreoptic cable, and in optical parlance is called a light guide. The individual cells of the rhabdom, however, cannot discriminate individually. Hence, the visual acuity is determined by the inter-ommatidial distance, since each unit presents a single spot, or pixel in computer terms. It might seem, then, that the individual cells of the rhabdom do not have a purpose, but the truth is otherwise. Each of the cells has photopigment in the microvilli, but the visual

pigment of each separate cell is sensitive to different wavelengths. So, this apposition eye has a mosaic pattern tessellated in the predominant colour received by each rhabdom. *E gigantea*, a diurnal beetle, probably has such an apposition compound eye although no one has examined the eyes of this particular beetle.

Nocturnal beetles, as represented by the click beetle on the right side of the cover, have an entirely different compound eye, as different as, well, night and day. Don't be fooled by the yellow spots on the carapace—these are the not the eyes, although predators may assume so. The real eyes are the small black structures at the front of the beetle. The yellow spots are bioluminescent organs used for communication and subterfuge.

Nocturnal beetles usually have a refracting superposition compound eye with significant differences when compared to the apposition eyes of diurnal beetles. Although externally similar, the internal optics are completely and surprisingly different. The crystalline cones acting as lenses are set above the rhabdom layer with a clear region analogous to our vitreous. These superposition compound eyes act as simple inverting telescopes and create a single erect image on the rhabdom layer similar to our retina. Superposition eyes are much more sensitive to light than apposition eyes, and not surprisingly are found in most nocturnal beetles among other arthropods.

The bioluminescent organs on the thorax of *Pyrophorus* produce light with a combination of luciferin and luciferinase much like fireflies do. This bioluminescent beetle generally uses the light to signal a potential mate, and each species has its own pattern and style of presentation. When active at night, these charming creatures provide an ethereal, comfortable feel to the warm moist equatorial forests. Jewels indeed!

I R Schwab

University of California, Davis, Sacramento, CA, USA; irschwab@ucdavis.edu

Photographs by the author.