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An Interview with Professor Roy Caldwell

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Envision the underwater world: vibrant coral, swaying seaweed, and lively creatures abound. However, the postcards and National Geographic covers that try to capture the beauty of this picturesque habitat can only represent it at one moment in time -- in reality, the landscape is hardly static, since many of its animals are capable of body modifications to change their shape and color. To understand the coloration and color vision of sea creatures, UC Berkeley Professor Roy L. Caldwell researches various marine animals such as stomatopods and cephalopods. In an interview with Professor Caldwell on December 13, 2012 BSJ had an opportunity to discuss different aspects of color vision and color change in sea animals with respect to behavioral ecology.

Our discussion began with the basics. What is the physiology behind color vision in stomatopods? Stomatopods, commonly known as mantis shrimp, have very complex and highly developed structures for eyesight. Whereas humans only have three types of color photoreceptors (red, blue and green cones), stomatopods have 16 different types of photoreceptors responsible for a unique color vision that ranges from far-red into the ultraviolet. The stomatopod eye is a compound eye composed of up to 10,000 ommatidia – optical units containing photoreceptor cells, a cornea, and axons to transmit information to the brain. The ommatidia are further divided into three regions. The upper and lower hemispheres of the eye are responsible for motion and shape recognition. The middle portion of the eye, known as the midband, is responsible for color vision. The midband is comprised of six parallel rows of ommatidia. The first four rows are used for color vision ranging from red to ultraviolet. Row five and six are specialized for seeing polarized light.

After an overview of the stomatopod eye structure, we ventured further into the mechanism of vision. The eye contains several pigments responsible for converting the electromagnetic energy of light into chemical energy, which can stimulate an impulse in nerves to detect various colors in the environment. Stomatopods have a common compound in crustacean cuticle known as astaxanthin, a red-colored dichroic ketocarotenoid, which produces polarized light. As mentioned above, stomatopods are capable of detecting and analyzing colored light as well as polarization signals, through the function of the midband. Furthermore, stomatopods are capable of generating polarized light. Polarized reflections from the antennal scales of stomatopods are produced by the dichroic properties of astaxanthin molecules, oriented vertically within the antennal scale. The detection and transmission of polarized light provides a private method of communication for stomatopods. The polarized light signals mediate various events such as mate choice and territoriality.

Whereas stomatopods have specialized organs to confer color vision, other creatures are capable of changing their appearance in a matter of seconds for predatory advantages. Professor Caldwell also researches behavior, specifically aggression and predation of cephalopods influenced by their change in bodily coloration and appearance. Cephalopods, which include well known animals such as the octopus and the squid, can easily change their body coloration depending on the background color, texture and pattern at which they are hunting. Various techniques used by cephalopods include transparency, silvering, counter-illumination and red coloration. In the relatively well-lit environments, cephalopods often appear transparent or have highly reflective silvered sides to minimize their silhouette to prevent predation by other animals, as well as to confer a predatory advantage. Below 30 meters depth, they often display red, purple, brown, or black body coloration. Red wavelengths are mostly absent at these depths due to the filtering of the water. As a result, cephalopods appear black in the absence of red light. Using camouflage tactics, cephalopods have honed their skills to hunt in various depths of the ocean.

Professor Caldwell's research on the color vision of stomatopods and the changing coloration of cephalopods offer several broader implications. For example, scientists can use features of circularly polarized light reflectors and sensors found in stomatopods to create man-made equipment based on the same principles. Circular polarized light filters and imaging have been used in photography and object-detection systems, especially in turbid environments. BSJ thanks Professor Caldwell for his time.