Phenotypic Plasticity in Mantis Shrimp Vision

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Cheroske AG, Barber PH, Cronin, TW. 2006. Evolutionary variation in the expression of phenotypically plastic color vision in Caribbean mantis shrimps, genus *Neogonodactylus*. Marine Biology, 150(2), 213-220.

Imagine that whenever you went outside into the glaring sunlight, you didn't need sunglasses – your eyes would simply alter their structure so you could see. Or when you walked into a dark room, you could still easily perceive shapes and colors without turning on the light.

Stomatopods, or mantis shrimp, have just this ability. This order of arthropods is known for the remarkable color vision capabilities of their compound eyes. What is less well known, however, is the degree to which stomatopods are able to modify their color vision depending on local light conditions, a process called spectral tuning. An organism that can spectrally tune is able to change the composition of the color receptors in their eyes for optimal color reception at a wide range of light intensities. Spectral tuning can be a huge advantage for hunting and predator avoidance.

Recent studies have shown that some stomatopod species are able to perform spectral tuning as juveniles when rapid physical changes are taking place. But the potential for adult organisms to do it too, when they have already been through their most drastic developmental changes, remains unclear. In 2006, Cheroske et al. performed an experiment attempting to determine if three different species of mantis shrimp are capable of modifying their color perception as adults in response to local environmental changes in light intensity. The researchers also collected molecular information from several mantis shrimp species by sequencing a specific mitochondrial membrane protein. That way, they could map out a molecular phylogeny, and trace the evolutionary history of the ability to spectrally tune.

The three species of mantis shrimp used in this experiment are all in the genus *Neogonodactylus. N. wennerae*, *N. oerstedii*, and *N. bredini*, are closely related, but live at different depths. *N. wennerae* is most common at depths ranging from 10-30 m, while *N. oerstedii* and *N. bredini* both live in much shallower habitats; *N. oerstedii* in water less than 5 m deep and *N. bredini* in the intertidal zone in 2 m or less of water.

Adult individuals from each of the three species were randomly put into small aquaria and assigned a light treatment - either white, as the control, or blue, to replicate the reduced light availability in deep water. All of the stomatopods were kept under their respective light treatments for 12 weeks before their visual systems were examined. After 12 weeks, the eyes of all of the mantis shrimp were cryosectioned and mounted on slides. A stomatopod eye is essentially six rows of ommatidia (the single units of a compound eye). In the 2nd and 3rd rows from the top, there are sets of two color filters each (represented by the black bands in the figure). The researchers collected data on the physical lengths as well as the absorbencies of those filters after the light treatments. By comparing the white-treated individuals to the blue-treated individuals of each species, they could gauge the change in color vision. To better understand how the eyes of a mantis shrimp are organized, refer to Figure 1.

The results were conclusive. Although the filter lengths in the 2nd row of ommatidia showed no change, there were notable differences in the lengths of the filters in row 3. *N. wennerae* blue-treated individuals had significant reduction in the lengths of both of the filters in their 3rd row ommatidia. *N. bredini* had a similar but weaker trend, with only one row 3 filter shortening by about 30%, and the other staying the same. A shortened filter would absorb less light, so that more and broader-spectrum light would reach the photoreceptors behind the filters. The shrimp were clearly responding to the blue light by adjusting their filter structures. In support of these results, the wavelength absorbencies were shifted downward in both of the row 3 filters in the *N. wennerae* blue-treatment group (proximal filter shift = 8 nm, distal filter shift = 15 nm). In *N. bredini*, only one of the row 3 filters in the blue-treatment individuals showed a significant downward shift in absorbency (distal filter shift = 16 nm). There were no significant differences in any filter lengths or spectral wavelength absorbencies in *N. oerstedii*, so it seemed not to be affected by the light conditions.

So what do these results tell us? Simply put, some mantis shrimp have the rare ability to change the color filters in their eyes as adults, depending on the amount of light available to them. The only other well-documented example of adult spectral tuning is in the cichlid fish, *Aequidens pulcher*, and even it takes at least 17-19 months to achieve any change, compared to 12 short weeks in the mantis shrimp. And fascinatingly, the ability to spectrally tune is not even present in all mantis shrimp species, but is rather a function of their typical depth range. *N. oerstedii* lives in very shallow water at a consistent depth and so has high, consistent light exposure. The researchers found little or no change in its color vision. On the other hand, *N. wennerae* lives in a very broad range, reaching into deep water. It likely experiences a wide range of light environments, and the results clearly showed a significant shift in color vision in this species. *N. bredini* was in the middle, showing limited but clear changes in filter length and absorbency. This is odd, since *N. bredini* lives in a narrow range of shallow water, even shallower than *N. oerstedii,* which showed no response to light changes. The inconsistency can be explained by the phylogeny mapped by the researchers from the mantis shrimp's genetic sequence data. In it, we see that *N. bredini* is a sister species of *N. wennerae*. The two species are immediately related, despite their very different habitats. If *N. bredini* recently speciated from *N. wennerae*, it may still hold in its genes a limited inducible ability to spectrally tune. Thus, it would seem that the ability of a species to express the phenotypically plastic color vision trait depends not only the photic characteristics of each species' particular habitat, but also on their evolutionary history.

This experiment had some fascinating results, but the conclusions also raise many more questions for study. For example, if mantis shrimp respond to lowered levels of light availability, do they spectrally tune at night? What would be a good experiment to test this? Why do they need such sophisticated vision systems? What are the possible implications of this experiment on our understanding of color vision? Perhaps you will be the one to find the answers.

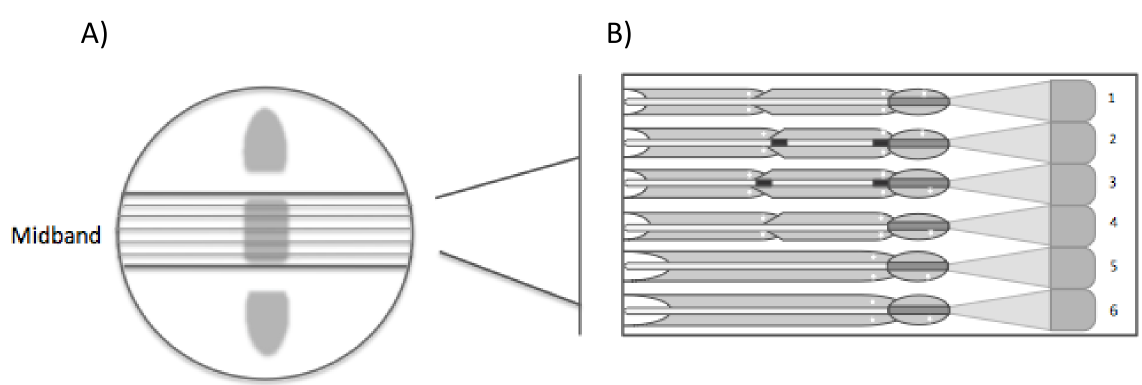

Fig. 1. Representation of the stomatopod eye. The midband shown in the center of (A) is divided into six rows of ommatidia. The 2nd and 3rd rows have the color filters being examined in this study, represented by the black bands in (B).