

Seeing how evolutionary mechanisms yield biological diversity

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An international team of scientists has discovered how changes in both gene expression and gene sequence led to the diversity of visual systems in African cichlid fish.

In research published in the December 21, 2009 issue of the journal [PLoS Biology](#), Assistant Professor Karen Carleton, together with post-doctoral associate Chris Hofmann and graduate student Kelly O'Quin, in the University of Maryland Department of Biology, and collaborators Justin Marshall, University of Queensland; Tom Cronin, University of Maryland, Baltimore County (UMBC); and Ole Seehausen, University of Bern; describe how over 60 species of cichlid fish from Lake Malawi and Lake Victoria have adapted their [visual sensitivity](#) in response to specific ecological factors, including what they eat and the clarity of the water in which they swim.

Evolutionary biologists seek to understand the mechanisms behind genetic changes that have led to the vast diversity of life on Earth. There are two important molecular mechanisms that contribute to organismal diversity - changes to the sequence of genes, and changes in the way genes are expressed, including when, where, and how much of a gene is made. This study was one of the first to look at how both [gene sequence](#) and gene expression can contribute to the same trait, and showed that they contribute in complementary ways.

"African cichlid fishes are some of the most diverse animals on the planet. Their visual systems differ dramatically in their sensitivity and

represent some of the largest differences known in vertebrates," explains Hofmann. "Yet there has been little understanding as to why such diversity exists. Our findings have important implications for understanding both the factors and the mechanisms responsible for generating biodiversity."

Cichlids have several different cone opsin genes that enable them to detect light across the visible and ultraviolet regions of the spectrum. Different species express different subsets of these opsins to create alternate visual systems. The research team found that cichlid fish in the clear waters of Lake Malawi expressed a wide range of opsins, with closely related species differing in whether they used the shorter wavelength or longer wavelength gene combinations.

The method of foraging for food was a key factor influencing fish vision. Fish whose diets consist primarily of zooplankton were more likely to have UV sensitivity, which enables them to detect the presence of these small transparent aquatic organisms that absorb ultraviolet light. In contrast, cichlids in the murky waters of Lake Victoria expressed longer wavelength combination of opsin genes, regardless of what they ate.

This long wavelength combination matches the light that is best transmitted through the murky water. A few Lake Victoria fish at clearer sites turned on shorter wavelength genes, suggesting that opsin expression matches the light environment. Therefore opsin gene expression in both lakes is adaptively determined based on important ecological variables.

The authors also examined changes in the genetic sequence of these opsins that fine-tuned visual pigment sensitivity at the short and long-wavelength ends of the spectral range.

"When you get to the extremes of the light spectrum, there is no other gene that can be turned on or off, so the only way to extend the sensitivity is to change the gene structure itself," says O'Quin. Therefore, this study presents a model of sensory evolution in which both molecular genetic mechanisms work in concert.

Previous work by Ole Seehausen, Karen Carleton, Nori Okada and colleagues (*Nature*, 455, 620-626, 2 October 2008) has demonstrated that color vision plays a key role in how cichlids recognize different species and choose mates. (Read more about this work here: www.physorg.com/news142615133.html)

"Previously, we showed that changes in opsin gene sequence contributed to generating new species," says Carleton. "The speed with which opsin [gene expression](#) changes suggests that it might also contribute to creating the incredible diversity of cichlid fishes."

The authors are extending their work to other African Great Lakes and even to coral reef fishes, to better understand how biodiversity is formed.

More information:

<http://www.plosbiology.org/article/info%3Adoi%2F10.1371%2Fjournal.pbio.1000266>

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