Cell

Seeing the Light through Borrowed Lenses

Detecting light is arguably one of the most coveted abilities in the living world. Eyes, or their anatomical equivalents, have independently evolved many times among animals, and the consistency of their organization, featuring a cornea or lens that focuses photons onto a sensory surface, is often brought to the fore as an example of convergent evolution. Light sensing is also a constant in prokaryotic organisms, where single molecules with light-detecting capabilities inform metabolic and mechanical functions of cells. Understanding how different kingdoms catch light has been a focus of several recent studies that showcase ingenious solutions to this perennial problem.

One example comes from the dim world of eukaryotic microorganisms. Clasped between the high-end eye of multicellular organisms and the minimalist bacterial photodetectors, ''eyespots'' found in unicellular algae and fungi, consisting of pigments and light-detecting rhodopsins, allow local absorption of light and direct behaviors. Among such structures, the ocelloid of dinoflagellates stands out for its baffling similarity to the eyes of vertebrates. Now, taking advantage of techniques allowing the imaging and sequencing of subcellular structures, Brian Leander and colleagues tackled the origins of this cytoplasmic ''eye,'' demonstrating that the ocelloid structure arises from an unpreceded degree of cooperation among organelles (Gavelis et al., 2015). Electron microscopy analysis uncovers a ''cornea'' created by a layer of mitochondria, perpendicular to a ''lens'' consisting of dense membranous structures, and a ''retina'' derived from a network of plastids. Sequencing of nucleic acids found in these structures demonstrates their endosymbiotic origins, further showcasing how repurposing of organisms into organelles, and finally into intracellular ''organs'' allows the rise of complex structures when the building elements are limited.

Light micrograph of the dinoflagellate *Nematodinium* showing the ocelloid in focus. Image courtesy of Brian Leander.

Another twist on reusing of nature's building blocks comes from studies of regulators of light-responses in bacteria. The ubiquitous CarH-type photoreceptors bind to DNA and activate transcription upon exposure to light (Ortiz-Guerrero et al., 2011). CarH uses a vitamin B12 derivative as the light-sensing chromophore, and Catherine Drennan, S. Padmanabhan, Montserrat Elias-Arnanz, and colleagues (Jost et al., 2015a) now characterize the crystal structures of CarH under different light conditions, demonstrating the key role of the chromophore in driving the large-scale conformational changes that activate transcription. Indeed, they find that the B12 derivative stabilizes a tetrameric repressor form of the photoreceptor, and that its photolysis leads to collapse of the repressor form and transcription initiation. This study, together with the recent analysis of the derivative's photochemistry by Alex Jones and Roger Kutta (Kutta et al., 2015) and the photolysis products (Jost et al., 2015b), thus demonstrates how the clever harnessing of the B12 derivative's instability can be used to drive robust changes in the shape of a molecule.

These are just a few examples of the myriad molecular and anatomical adaptations that fuel life; however, they clearly showcase nature's ability to solve complex problems by repurposing elements and exploiting their side properties. Where there is need, there is a way, especially when it comes to finding a place under the sun.

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