Organisms manipulate light: Guanine crystal multilayer arrays

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Strikingly brilliant structural colors were independently evolved by organisms to fulfill a variety of functions, using 2D or 3D arrays of chitin or cellulose fibers, calcite or guanine crystals. Optical systems based on intra-cellular arrays of thin guanine crystal platelets are found in a variety of marine and terrestrial animals, such as fish, copepods, crabs, chameleons and spiders. The colors are produced by constructive interference of light reflected from stacks of guanine crystals alternating with layers of cytoplasm.

The silvery lustre observed from the skin and scales of many types of fish is generated by broadband reflectance over the entire spectrum of visible light. The lustre is produced by crystal/cytoplasm stacks in slightly disordered arrangements and spacings, which modulate the iridescence and reflectance intensity.

Certain families of small marine planktonic crustacean copepods are found in different colors covering the whole visible spectrum, and each color is characterized by well-defined spectral characteristics, forming true photonic crystal arrays. Each color is created by specific and precise spacings between uniformly thick guanine crystals within the stacks.

The fresh water fish Neon Tetra has the ability to change the structural color of its lateral stripe in response to a change in the light conditions, from blue-green to indigo, forming truly tunable photonic crystal arrays. Reversible variations in crystal tilt within individual arrays are responsible for the light-induced color variations.

The insights gained from the understanding of how biology modulates reflectivity can provide inspiration for the design of artificial optical systems with properties yet hardly achievable, if at all, in artificial materials.