Sparkly Spiders and Photonic Fish

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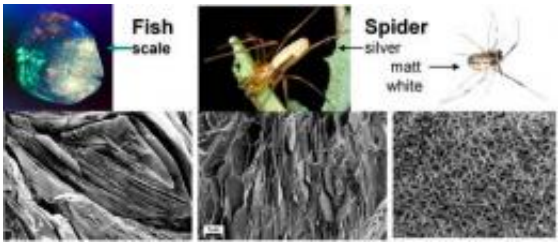

(PhysOrg.com) -- Scientists in Israel and the UK have uncovered the details of how certain fish and spiders create their iridescent scales and silvery skins.

Applying new techniques Levy-Lior and colleagues at the Weizmann Institute of Science and York University showed that similar readily available biological materials are made and arranged with great precision in the creatures' coatings. Intriguingly, although the patterns of arrangement are quite different for the fish and spiders, both result in highly reflective systems of similar effectiveness, indicating that modern-day scientists still have much to learn from nature.

"It is astonishing how through evolution, fish and silver-colored spiders have independently succeeded in achieving light-reflecting structures with similar efficiencies, although differences in mechanism is apparent," according to Lia Addadi, the leader of the Israeli group.

The creatures use photonic systems, periodic physical structures that control the interaction of light with matter, either by scattering it or reflecting it. Such phenomena are familiar to us in cosmetics, iridescent paints and inks, and reflective coatings on mirrors and lenses. Nature brings us photonic systems in opals, some butterfly wings, and beetles. The Koi fish studied in this work is well known for its "extraordinary iridescent colors", while the silvery spiders of the study usually lie in the province of experts.

Both fish and spider photonic camouflage systems are composed of layers of guanine crystals. Guanine is a common molecule in biological systems; it is most widely known as one of the components of DNA. These fish and spiders are able to make guanine crystals of very specific size and orientation to achieve the reflectivity they require. While this was known previously, there was no evidence of exactly how the systems were assembled and how they worked to reflect light. One major obstacle was the difficulty involved in studying skins and scales intact, without damaging their delicate structure. "A major breakthrough," according to Addadi, "was in the use of a high pressure freezing and freeze-fracture techniques followed by observation with cryo-scanning electron microscopy. Nobody had used these techniques before in this system."

Their observations showed that "in the fish, single crystalline [guanine] plates alternate with layers of cytoplasm layers. [Cytoplasm is the major component of living cells.] In contrast to fish, in the spider the thin layers are crystal doublets, held together by amorphous guanine layers. We have calculated the predicted reflectivity of these arrays and determined that both systems, although they show differences in crystals arrangement, finally reach similar efficiencies in light reflectivity."

Prof. Peter Fratzl works in the Department of Biomaterials at the Max Planck Institute of Colloids and Interfaces and is not related to the

research. According to him, “It is very surprising that fish and spiders, pertaining to completely different taxonomic groups, independently acquired through evolution the ability to generate mirror-like reflections on their skin by depositing guanine crystals. This suggests that the solution must be quite efficient and it is, therefore, extremely promising for the materials scientists to try and understand the structural principles of these photonic crystals working as (colored) mirrors.”

He notes that the structural details of the photonic systems used by fish and spiders are “quite different” and points out that “the spider, in particular, uses a physical trick to enhance the reflectivity by separating the guanine crystals by layers of amorphous guanine…This new understanding will increase the pool of ideas which nourish the emerging research field of bio-inspired materials science where one attempts to transfer clever solutions which emerged in the course of evolution into concepts for new materials.”

More information: A. Levy-Lior, E. Shimoni, O. Schwartz, E. Gavish-Regev, D. Oron, G. Oxford, S. Weiner, L. Addadi, “Guanine Based Biogenic Photonic Crystal Arrays in Fish and Spiders”, *Advanced Functional Materials*, 2009, DOI: 10.1002/adfm.200901437

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