Adaptations to unusual environments: spines of sea urchins with cryptic morphologies

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Sea urchins have evolved unique skeletal features. Among them, their spines are surely one of the most studied biogenic matrices. These spines are highly porous materials with a precise 3D organization in terms of structure, morphology, and composition. These mechanically resistant materials with highly exposed surfaces have encouraged the development of biomimetic and bioinspired materials with applications in batteries [1], catalysis [2], and other fields.[3]

In this study, we investigated the spines of different sea urchin species with a peculiar interest in two of them. The first, *C. atratus*, a species living in the intertidal zone on fully exposed rock surfaces, has spines evolved in an almost horizontal shield-like structure [4]. This species was sampled in Hawaii along with *Echinometra oblonga*, *E. mathaei*, and *Heterocentrotus mamillatus*. *E. oblonga* is a species sharing the same intertidal zone of *C. atratus* but living in rock niches and not on exposed rocks. *E. mathaei* has analogue habits to *E. oblonga*, but also lives below the intertidal zone. *H. mamillatus* is a species living only below the intertidal zone. The comparative study performed highlighted differences in morphology, composition, and mechanics between *C. atratus* and these other species. As an example, *C. atratus* has no vertical development of its medulla. This is replaced with a vertical pillar organization of its radiating layer, with strong influences in the final compression resistance of the spine.

C. maillardi, instead, is a deep-water species with very little literature knowledge about its living habits [5]. Its spines, about 1 mm thick and 10 cm long, have the unicity of being flexible, being able to bend of about 30°. Such a feature has never been observed before for species with analogue spine thickness. Our study showed how this property arises from a combination of morphology, composition, and a strategically located organic matrix.

This study could represent a breakthrough in material science to develop mechanically robust, or flexible porous inorganic materials for advanced mechanical applications.

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