The iron jaws of the bristle worm

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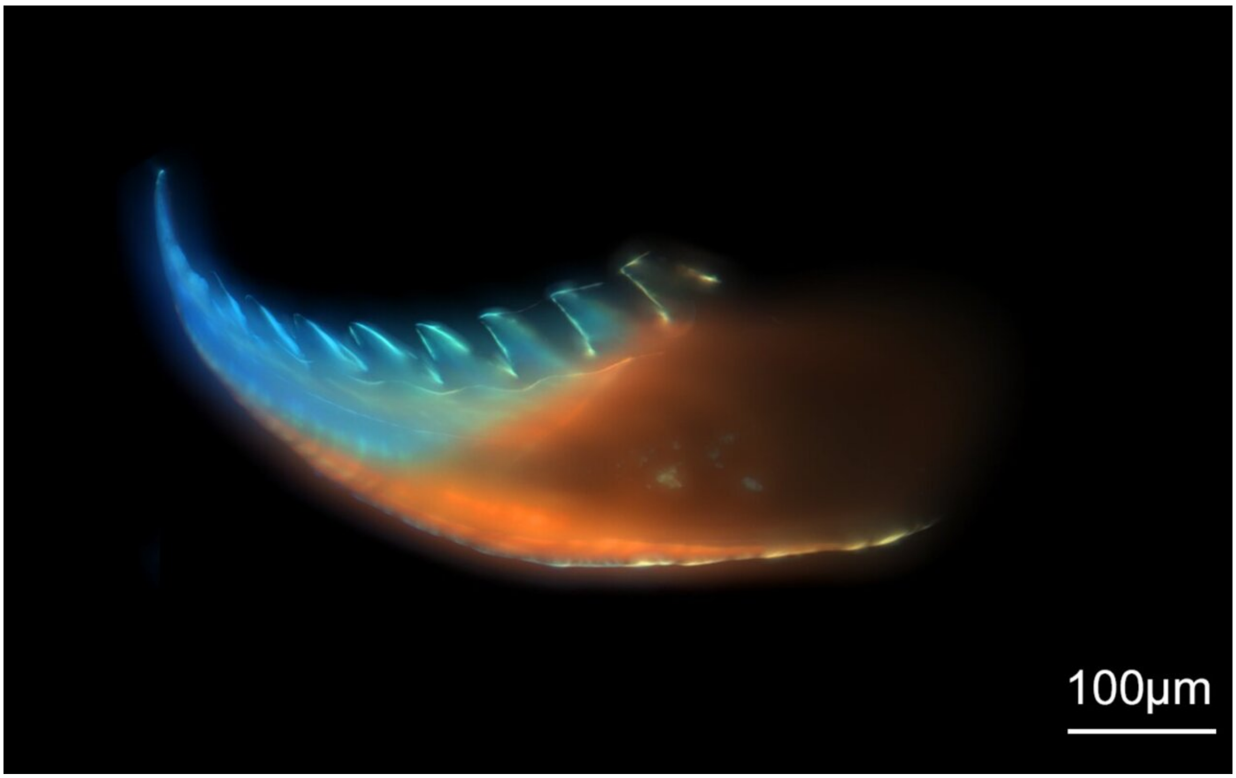

Credit: Dr. Kyojiro Ikeda/Universität Wien

Bristle worms are found almost everywhere in seawater, they have populated the oceans for hundreds of millions of years. Nevertheless, some of their special features have only now been deciphered: Their jaws are made of remarkably stable material, and the secret of this stability can now be explained by experiments at TU Wien in cooperation with Max Perutz Labs.

Metal atoms, which are incorporated into the protein structure of the material, play a decisive role. They make the material hard and flexible at the same time—very similar to ordinary metals. Further research on this class of materials aims at producing novel, industrially usable materials in a natural way.

Individual metal atoms

"The materials that vertebrates are made of are well researched," says Prof. Christian Hellmich from the Institute of Mechanics of Materials and Structures at TU Wien. "Bones, for example, are very hierarchically structured: There are organic and mineral parts, tiny structures are combined to form larger structures, which in turn form even larger structures."

It's different with bristle worms. Their jaws are extremely strong and unbreakable, but they do not contain mineral granules like vertebrate bones do. Instead, they contain metals. Of course, this has nothing to do with pure metal objects such as gold teeth or artificial hips made of titanium: The bristle worm uses metals such as magnesium or zinc in the form of individual atoms that are incorporated into a protein structure.

"On its own, the fact that there are metal atoms in the bristleworm jaw does not explain its excellent material properties," says Hellmich. The typical properties known from everyday metals—apart from their hardness and elasticity, above all their toughness—are ultimately only created through the interaction of many atoms. Sliding surfaces are created along which the atoms move against each other. This can be investigated with so-called nanoindentation tests: A force is exerted on the material in a precisely defined way and then the resulting deformations are studied. Surprisingly, it turned out that the material of the bristleworm jaw behaves very similarly to metal.

An ancient high-performance material

"The construction principle that has made bristle worm jaws so successful apparently originated about 500 million years ago," says Florian Raible of the Max Perutz Labs, a joint venture of the University of Vienna and the Medical University of Vienna. "The metal ions are incorporated directly into the protein chains and then ensure that different protein chains are held together." In this way, the bristle worm can produce three-dimensional shapes from a particularly stable protein matrix.

At the same time, this structure also allows for deformation: When an external force is exerted on the material, the protein chains can slide past each other. The material allows elastoplastic deformations, rather than being brittle and fragile.

"It is precisely this combination of high strength and deformability that is normally characteristic of metals," says Luis Zelaya-Lainez, the study's lead author, who used materials science techniques to examine the tiny jaws. "Here we are dealing with a completely different material, but interestingly, the metal atoms still provide strength and deformability there, just like in a piece of metal."

Whereas industrially manufactured metals can only be produced using a large amount of energy, the bristle worm achieves a similar feat in a much more efficient way. "Biology could serve as inspiration here, for completely new kinds of materials," Hellmich hopes. "Perhaps it is even possible to produce high-performance materials in a biological way—much more efficiently and environmentally friendly than we manage today."

More information: Luis Zelaya-Lainez et al, Jaws of Platynereis dumerilii: Miniature Biogenic Structures with Hardness Properties

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