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Jaws of Clamworm Are Hardened by Zinc Say UCSB Scientists

Scientists often look to nature for inspiration in the search for ways to make new materials. A new study of the clamworm, an intertidal creature, shows that it has jaws made partly of zinc, making them strong, stiff and tough - fundamental properties by which all materials are evaluated.

The properties of the clamworm jaws are described in this week's online publication of the Proceedings of the National Academies of Sciences (PNAS). The research began with questions by scientists at the University of California, Santa Barbara and the Argonne National Laboratory, and evolved into an international project involving scientists from Austria and Finland.

"Zinc zips together proteins in a way that hardens the material," said Galen D. Stucky, a materials chemist and professor in UCSB's Department of Chemistry and Biochemistry. He noted that the study of how nature makes hard materials, their structure and function, may eventually yield information on how scientists can make lightweight, flexible materials ranging from more durable tires to protective coatings.

The scientists found that that this polychaete worm (a marine worm with bristle-tipped organs of locomotion) has the greatest amount of zinc concentrated toward the tip of its jaw, where it needs the most strength. In the PNAS article the authors compare this polychaete (scientifically named *Nereis limbata*) with another one

described last year in a paper in Science.

That worm, *Glycera dibranchiata*, a cousin of the clamworm and commonly known as a bloodworm, has copper-containing fangs which inject venom into its live prey. This discovery was a surprise since copper has never been found in such concentration in an organism. The copper fangs of the bloodworm were found to have a resistance to abrasion that is comparable to that of a human tooth, and greater than the clamworm jaws with zinc. But since the clamworm is a scavenger, it doesn't need quite as much strength as the bloodworm to catch its food.

Professor Herbert Waite, in UCSB's Department of Molecular, Cellular and Developmental Biology who originated this research, said that he was intrigued by finding metals in the mouths of the worms. "Usually the healthy cells in our bodies have pathways to deal with the toxicity of these metals," said Waite. "When zinc and copper imbalances occur, serious pathological disorders result. In the case of the jaws, however, the metals are intentionally concentrated to serve a function, and this highlights the exotic nature of these structures."

He explained that it is usually axiomatic that if (in materials science) you want something hard, stiff and wear-resistant, it needs to have mineral in it - minerals are the best materials for making something stiff. In nature's best cutting structure, vertebrate tooth enamel, the mineral content is 95 percent. Yet the clamworms do not use any mineral for hardening, thus revealing a new paradigm in nature and sparking new ideas for materials science.

"The jaws are much lighter than if they were calcified," said Waite. "If you want something lightweight then you reduce reliance on minerals. I'm not sure why, in their watery environment, the clamworms jaws need to be light." Yet the jaws are lightweight, wear-resistant biomaterials without mineral.

"It's not that technology will copy verbatim what the worm does," said Waite. "But we are interested in knowing concepts of how organics interface with transition metals to produce functional material." Waite has studied the way that mussels attach to rocks. Their attachment threads are another example of the use of copper and zinc in nature. "Their biochemistry is very similar to both worms. It's only natural that I would get into the jaws."

"A lot of science involved in exploring the relationship between metals and proteins is so interdisciplinary," he said. "A little lab like mine couldn't hope to handle it

independently. We pooled expertise in physics, inorganic chemistry, materials science and biology. UCSB is really good at interdisciplinary work."

For their study, the scientists also used labs outside of UCSB. For example, they used a nanoindentation device in the lab of Thomas Schöberl of the Austrian Academy of Sciences to test for mechanical properties - flexibility, hardness and elasticity. Besides nanoindentation, a number of state-of-the-art methods were used to study the jaws, including x-ray scattering using a synchrotron at Argonne National Laboratory in Illinois.

The first author on the paper, Helga C. Lichtenegger of the Vienna University of Technology in Austria, came to UCSB to collaborate with Waite and Stucky on the research. Other authors include Henrik Birkedal of UCSB, Thomas Schöberl of the Austrian Academy of Sciences, Jann T. Ruokolainen of the Helsinki University of Technology in Finland, and Julie O. Cross and Steve M. Heald from Argonne National Laboratory.

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