Iron-plated snail could inspire new armor

Analysis of unique deep-sea mollusk offers insights into design of armor for soldiers and vehicles.

Anne Trafton, MIT News Office

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Image: Anders Warén, Swedish Museum of Natural History

Tiny snails sitting on the ocean floor might seem defenseless against a large, determined predator such as a crab. But evolution has provided one species of sea snail with a unique iron-plated armored shell that resists such attacks, new research from MIT shows.

By copying aspects of that shell structure, scientists could design better armor for military use, says Christine Ortiz, MIT associate professor of materials science and engineering, who led the study. “Such fundamental knowledge holds great potential for the development of improved biologically inspired structural materials, for example soldier, first-responder and military vehicle armor applications,” says Ortiz.

The study of the sea snail’s shell was partly funded by the Army and the Department of Defense and appears this week in the Proceedings of the National Academy of Sciences.

Ortiz became interested in the gastropod, known informally as the scaly-foot snail, when its discovery was reported in 2003. The snail lives in a relatively harsh environment on the floor of the Indian Ocean, near hydrothermal vents that spew hot water. Therefore it is exposed to fluctuations in temperature as well as high acidity, and also faces attack from predators such as crabs and other snail species.

“Life in nature is not idyllic; it is an ongoing fight for survival,” says Anders Waren, a biologist at the Swedish Museum of Natural History, who described the snail in a 2003 paper in the journal *Science*. “Predators evolve to being more efficient hunters and specialize in their capacity to catch and kill their prey. At the same time the prey responds by developing new methods of defense, like escaping by swimming or running faster, producing toxins that make them less desirable, or by evolving different kinds of armor.”

In this case, the snail has evolved a tri-layered shell structure consisting of an outer layer embedded with iron sulfide granules, a thick organic middle layer, and a calcified inner layer. This creates a configuration in which the inner compliant layer is sandwiched between two rigid layers.

Ortiz and her colleagues, including MIT Dean of Engineering Subra Suresh, used nanoscale experiments and computer modeling to determine the shell’s structure and mechanical properties. They found that the unique three-layer structure dissipates mechanical energy, which helps the snails fend off attacks from crabs that squeeze the

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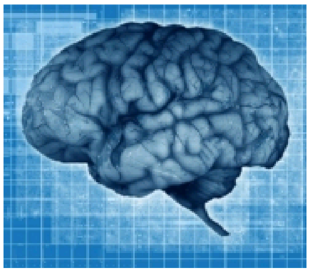

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shell with their claws in an attempt to fracture it. The shell of the scaly-foot snail possesses a number of additional energy dissipation mechanisms compared to typical mollusk shells that are primarily composed of calcium carbonate.

The scaly-foot snail gets is name from the scaly plates protecting its foot, a unique feature that Waren believes evolved to allow them to defend against other snails that attack by injecting venom into the soft bodies of their prey. If their feet were unprotected, an attack would force the snails to give up their grip on favorable feeding spots. “If the scaly-foot snails were to retract into their protective shell when attacked, they are very likely to fall down from the often vertical rocks and lose the food source,” says Waren, who was not part of the research team.

Ortiz, who has done similar analyses of other natural armor including that of a primitive armored fish, measured the mechanical properties of the snail shell using a machine called a nanoindenter, which has a diamond tip. By measuring the force applied to the shell, and the shell’s resulting displacement, her team can calculate its mechanical properties.

Engineers who wanted to mimic the snail’s unique stability and penetration resistance — valuable traits for armor — could copy the tri-layer structure but replace the organic components with manmade components such as bulletproof materials.

Robert Ritchie, professor of materials science and engineering at the University of California at Berkeley, says he admires Ortiz’ work but believes it may take a while for the principles she has uncovered to translate into practicable new manufacturing techniques.

“The first thing to do is to understand different organisms and how they’re put together,” says Ritchie. “There is tremendous potential in this field, but few people have actually made these kinds of biomimetic materials because it’s so difficult.” For example, naturally occurring materials are often intricately assembled on many different scales, from nanoscale to macroscopic scale, and that kind of structure is very difficult reproduce artificially, he says.

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More complexity means more tremendous potential. It's worthy of a biomimetic try.