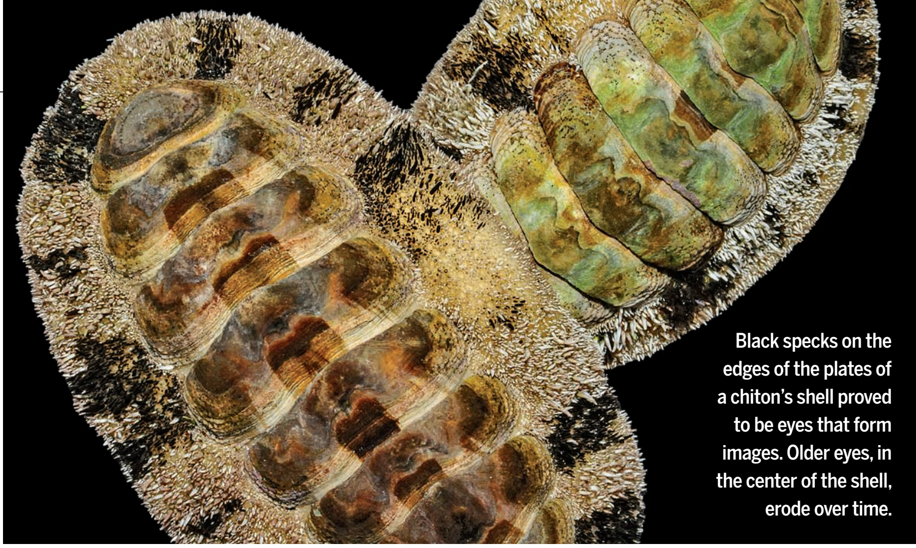


Black specks on the edges of the plates of a chiton's shell proved to be eyes that form images. Older eyes, in the center of the shell, erode over time.

BIOMATERIALS

Crystalline eyes of chitons inspire materials scientists

Mollusk makes hundreds of eyes from shell mineral

By **Elizabeth Pennisi**

Slow-moving and shaped like pebbles, most chitons are far from showy. But a close look at some of these marine mollusks reveals something remarkable: up to 1000 tiny eyes, each a bit smaller than the period at the end of this sentence, studding their plated shells. Now, on page 952, a team of materials scientists, engineers, and biologists describes how chitons build the lenses of their eyes from the same hard mineral that armors their shells. The work offers a striking example of how a single material can perform two jobs—seeing and protecting—at once. And it may offer insight to materials scientists seeking to design their own dual-use materials.

It's a "great paper," says materials scientist Peter Fratzl of the Max Planck Institute of Colloids and Interfaces in Potsdam, Germany. "What nature has perfected is to use comparatively simple, cheap starting materials and turn them into an exquisite, multifunctional material," he says. "We want to copy that approach."

Chitons move sluggishly up and down rocks or reefs in the intertidal zone, clamping tightly to the surface when threatened by fish, birds, or other predators. Yet they are quite successful, with a 500-million-year-long fossil record and a thousand species thriving today along wave-swept shores worldwide. "They are clearly doing something right," says Julia Sigwart, an evolutionary biologist at Queen's University Belfast in Ireland.

Only about 100 species have eyes, and until 10 years ago, researchers thought the eyes too small to be of much use, especially because all chitons have other light sensitive structures called megalaesthetes. But a few years ago, after hearing about the eyes from molecular systematist Douglas Eernisse of California State University, Fullerton, Daniel Speiser decided to give captive chitons a vision test. When he blocked light with black circles, the animals clamped down, suggesting they were detecting images. "The eyes … let the chiton distinguish an actual object, say a predator, from a passing shadow," says Speiser, now a visual ecologist at the University of South Carolina, Columbia.

Speiser, Eernisse, and others described chitons' visual system, reporting in 2011 that in contrast with the protein lenses found in most animals, including humans, chiton lenses are made of aragonite, the same calcium carbonate mineral that makes up their shells. Working in the lab of materials scientist Christine Ortiz at the Massachusetts Institute for Technology in Cambridge, graduate students Matthew Connors and Ling Li then explored how the eyes are made and how well they work.

Using high-resolution microscopy and x-ray techniques, as well as computer modeling, Li and Connors found that the oblong lens is made of large crystals, aligned to allow light through relatively unimpeded. Up to 100 photo-sensitive cells form a retina (see graphic, below). When the team suspended isolated lenses in water, they found that they could project recognizable images of a fish. "It actually forms a shockingly clear image," says sensory ecologist Sönke Johnsen of Duke University in Durham, North Carolina.

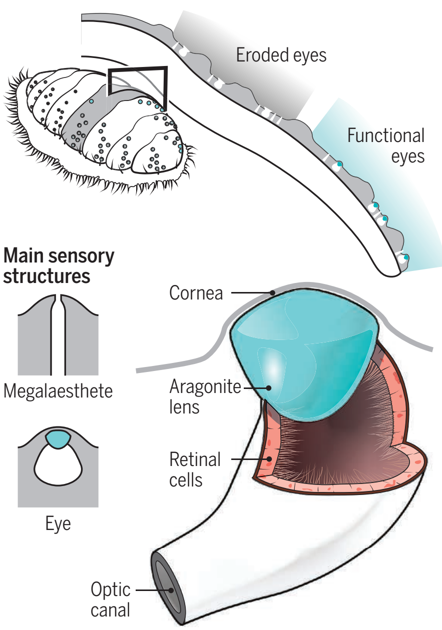
But chiton vision has a cost. Mechanical tests verified that the lenses create weak spots in the armor. "In order to see, they had to back off on mechanical protection," says Sheila Patek, a Duke evolutionary biomechanist. Protrusions in the shell partly compensate, so that the eyes nestle in protective grooves. But dual use does constrain how well the shell performs any single function.

For example, chitons could see better if their lenses were bigger or formed from just a single crystal. But that might compromise the shell's integrity too much. "Sometimes we assume nature is perfect," says biologist Andrew Parker from the Natural History Museum in London. "But more often than not it is a perfect compromise."

Co-author Joanna Aizenberg from Harvard University and others would like to come up with their own perfect compromises to create new dual-function materials that combine light-sensing and strength. The work on chitons hints at how that might be done—for example, by changing the shape or sizes of crystals. Johnsen also wonders whether the chiton visual system might inspire a network of multiple eyes in the skin of robots. "Nature has reached some very clever material solutions that we can harness," Fratzl says. "It allows you to dream about implementing similar kinds of ideas into technical systems." ■

A chiton's many eyes

A slice through a chiton's shell reveals an upper layer pitted with light-sensing megalaethetes and eyes.



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