Crab Crackers

Scientists take a harder look at stone crab shells

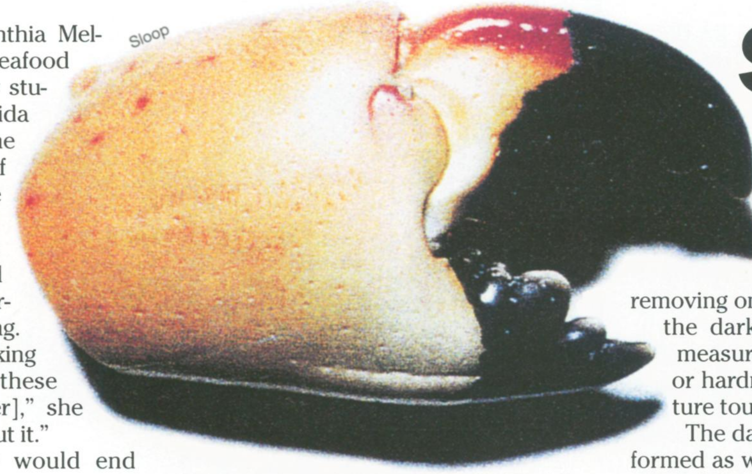
By CORINNA WU

Serendipity struck Cynthia Melnick Sloop in a seafood restaurant. A zoology student at the University of Florida in Gainesville at the time, she was feasting on a plate of stone crabs when she noticed that the black-tipped claws were much harder to crack than the light-colored parts of the shell. That observation set Sloop to wondering. "I tried not to be a geek talking about the engineering of these stone crab claws [at dinner]," she says, "but I was thinking about it."

Most people's curiosity would end there, but Sloop used her background in materials and mechanical engineering to learn more. She took some Florida stone crab claws into the university materials science lab to test their strength.

The black parts were indeed twice as robust as the light-colored parts. These results piqued her interest, because conventional wisdom says that animals developed coloration for camouflage or signaling. One study, however, showed that dark-colored feathers from wood warblers resist abrasion better than light-colored ones.

What connection, if any, could there be between mechanical strength and color? No clear answer has emerged, but Sloop's study gives some biologists a new way to look at animals they've studied for years.



Sixty percent of the weight of a Florida stone crab is concentrated in its stout claws.

Bert

Three species of stone crabs inhabit the coastal waters of the Gulf of Mexico and the Atlantic Ocean: the Florida stone crab (top), the Caribbean stone crab (lower left), and Gulf stone crab (lower right).

The Florida stone crab inhabits the coastal waters of the Gulf of Mexico and Atlantic Ocean from the Carolinas to southern Florida. Compared to most tropical crab species, stone crabs are large, with bodies measuring about 6 inches across and huge claws that form 60 percent of their body weight. Like Popeye's forearms, the pincer of one claw can dwarf a crab's body, says Theresa M. Bert, a biologist at the Florida Marine Research Institute in St. Petersburg, who has studied stone crabs for 20 years.

"They really are evolutionary anomalies. The claws are so huge and cumbersome, you wonder how they even walk around with those things."

The claws can apply a crushing pressure of 14,000 pounds per square inch. This enormous power enables the stone crab to munch on all sorts of hard-shelled mollusks, such as clams, scallops, and conch. The claws also equip them for fighting with each other, pinching and tussling in competition for food and mates. If a claw is lost, it regrows in about a year.

Stone crabs are "the lions of the invertebrate world," Bert says. "You don't even find them in the stomachs of the largest predatory fish, like groupers or sharks. Nothing eats them because their shells are thick, and you'd probably get pinched in the stomach [from inside]."

Sloop, a recreational scuba diver for nearly a decade, applied her familiarity with the sea to the process of gathering specimens for her research. She set traps for the crabs, emptying them once a week into a holding tank at the university. After removing one claw, she'd cut pieces from the dark and light parts. Then she measured their resistance to impact, or hardness, and to cracking, or fracture toughness.

The dark part of the crab claws performed as well as a tough synthetic polymer, while the light parts behaved more like a brittle ceramic. Moreover, the properties changed abruptly at the interface between light and dark areas. Sloop and her colleagues reported these results in the November 1996 JOURNAL OF MATERIALS RESEARCH.

The microstructure of the shell provides some clues to explain these differences. Crustacean shells are composed of proteins, calcium carbonate, and chitin—a long polymer of sugar molecules (SN: 7/31/93, p. 72). Scanning electron micrographs showed that the shell is less porous in the dark areas, Sloop says.

Sloop's hypothesis is that a process called tanning—more like the chemical tanning of leather than the tanning of skin exposed to the sun—accounts for this higher density. In leather tanning, substances called phenols react with the long protein fibers and link the fibers, imparting strength. A darkening accompanies the tanning process, but "no one has really pinned it down biochemically," Sloop says. "I think this tanning process is a different process than pigmentation."

Bert finds Sloop's results "interesting" but disputes the connection between color and strength. "I have a feeling that regardless of the color, the claw would be denser" than other parts of the shell, she says. "It may just be fortuitous that the dark part is stronger than the lighter part." She remains convinced that strength and color evolve separately.

A further clue to coloration comes from stone crabs that have had holes punched in their shells during fights. In parts that would normally be light-colored, the shell bordering the holes is dark, says Jack Mecholsky Jr., a materials scientist at the University of Florida who worked with Sloop on the project. One theory is that in response to trauma, the crab's repair mechanisms send more protein to that damaged area for reinforcement, darkening the shell at the same time. An uninjured crab normally has dark bands around the places where it may need extra reinforcement, such as the legs, joints, and mandibles, Sloop says.

Sloop also suggests that perhaps the color sends a signal about a claw's mechanical strength. Stone crabs show off their awesome claws to opponents before a fight. "They just hold their claws out as far and wide as they can to make themselves big," Bert says. So far, no one has assessed whether color variations actually affect one crab's behavior toward another.

Without more experiments to test the point, it's hard to know whether color is truly functional, says Darryl L. Felder, a biologist at the University of Southern Louisiana in Lafayette who has also studied stone crabs extensively. "We're anthropomorphic when we look at color because it's so difficult to tell what those animals perceive," he says. Something that looks black at the water's surface could look very different when it's deep underwater.

Felder says that since becoming aware of Sloop's work, he has begun to think about color as a cue for potential mechanical advantage. "It's one of the things we're now going to look at. It's really odd that these two fields [mechanical engineering and biology] cross over. Perhaps there's a lot more room for [interdisciplinary] things like this to be done."

Julian Vincent, director of the Centre for Biomimetics at the University of Cambridge in England, says that to get a true understanding of the shell material, the researchers must analyze it chemically and morphologically. "Otherwise, just saying that it's harder where it's darker isn't entirely useful." Sloop and her colleagues did some preliminary chemical analysis, but before they could complete it, Sloop graduated and took a job with a civil engineering firm.

In the past, not much research has been done on crustacean shells, but it is an interesting material, Mecholsky says. "The shell itself is an amazing structure." It's laminated like a fiber composite material, with every layer rotated 5° with respect to the one underneath. A crab shell, of course, is also self-healing, a property that scientists are interested in imitating. "We'd love to know how to send in polymers to fill holes and cracks" in manufactured products, he says.

Knowledge about insect and crustacean shells could also be used to make plastics strong and scratch-resistant on the surface, yet integrated with the pliable material underneath, Vincent says.

One of the most satisfying things about the project, Sloop says, was taking the unusual approach of using engineering to understand biology. She sees a parallel between the fields. Through natural selection, she says, nature keeps the designs that work well and gets rid of the ones that don't. An engineer does the same thing in an iterative design process.

Another good thing about the study, says Mecholsky, was that each week, a bounty of blue crabs found its way into the stone-crab traps and formed the basis of a regular Friday night feast. The stone crabs, however, were spared and returned to the sea—one claw poorer but alive to fight another day. □