# Neural Beginnings For the Turtle's Shell

Exoskeletons are usually reserved for insects, crustaceans, or other arthropods. But the turtle breaks that mold. Its body is surrounded on top by the carapace, a fusion of about 50 bones, and on the bottom by the nine-bone plastron. Neither has any counterpart among other vertebrate species.

Paleontologists have long sought clues to the shell's beginnings, but without much luck. They have found no fossils representing intermediate stages of the shell's evolution. Evolutionary developmental biologists thought they had largely solved this mystery in the last few years, however: The shell isn't as novel as it might seem. From a molecular perspective, the carapace develops much like a typical vertebrate skeleton. Thus, a minor detour during development could produce an exoskeleton fairly suddenly, evolutionarily speaking. But the turtle refuses to shed its mysteries.

Judy Cebra-Thomas of Swarthmore College in Pennsylvania reported at the meeting that the plastron is probably formed from embryonic cells that make up the neural crest. The finding has developmental biologists stumped: Most of the neural crest is destined to become the muscles, blood vessels, and bones of the face, and no one expected it to be involved with the turtle's shell. "The results will promote a reexamination of what we thought we knew and understood about the neural crest," says Eduardo Rosa-Molinar of the University of Puerto Rico in San Juan.

The turtle's skeleton is basically inside out. In most vertebrates, the ribs are enveloped in muscle as they develop; in turtles, the ribs grow straight out, punching through the surrounding muscle. The ribs then become trapped in dorsal tissue called the carapacial ridge.

In the past 3 years, Cebra-Thomas, Scott Gilbert of Swarthmore, and others have begun to figure out the cascade of proteins that guide this process. By studying snapping turtles and red-eared sliders, they showed that fibroblast growth factors cause certain cells to form ridges. These ridges produce a signal that lures cells destined to become ribs. As the ribs harden, they release yet another set of signals, bone morphogenic proteins (BMPs) and hedgehog proteins, which cause nearby tissue to turn to bone. These hardening cells secrete more BMPs, eventually completing the carapace. Even though it's a unique skeleton, the carapace is built by means of "a developmental program that uses bits and pieces of what's already there," Cebra-Thomas says.

The same cannot be said about the plastron. There are no ribs to initiate ossification of the surrounding tissue. Instead, there are nine places where bone begins to form spontaneously. "It's reminiscent of the skull," Cebra-Thomas notes, and that led her and Gilbert to test whether the same set of cells—the neural crest—might build the plastron. She and Gilbert labeled neural crest cells to see if they were present in the turtle's shell. "All the bones of the plastron seem to be of neural crest origin," Cebra-Thomas reported.

**Head starts.** Skulls and turtle shells may come from the same stock of cells, the neural crest.

Some researchers are skeptical. Brian Hall, an evolutionary developmental biologist at Dalhousie University in Halifax, Nova Scotia, points out that the cell markers are not specific enough to prove that the plastron's cells are neural crest ones. That's been a problem for many researchers trying to track the fate of these cells in other organisms. But other scientists, including William Bemis, a zoologist at the University of Massachusetts, Amherst, are convinced. "I totally believe it," Bemis says.

# Bird in Bush Aids Snake in Grass

Cottonmouth snakes and pelicans seem to have established an unlikely alliance on a tiny island off Florida's Gulf Coast. By all indications, birds feed fish to the snakes. In return, the snakes may keep rodents and other predators at bay. "It's an interesting potential relationship that people hadn't thought about," says Steven Beaupre, a physiological ecologist at the University of Arkansas, Fayetteville. "Part of the conservation of nesting birds may lie in the lowly cottonmouth. Who would have ever thought that?"

**Chick sitter.** Pelican nests may be safer because cottonmouths stay close to rookeries, where food is plentiful.

Researchers have known for about 70 years that Seahorse Key has an unusually high population of cottonmouths—so many that many people refuse to set foot on its shores—and that these snakes subsist on fish. What's more, 90% of the birds—pelicans, herons, ibises, cormorants, and egrets—that set up nests in the Cedar Keys island chain pick Seahorse Key.

Harvey Lillywhite and postdoctoral fellow Frederic Zaidan III of the University of Florida in Gainesville decided to find out what made this key such an attractive spot. They censused cottonmouths, tracked them using radio tags, and observed the animals' activities. The snakes "tend to remain in areas that are very close to nesting trees," Lillywhite reported at the meeting. Snakes spent so much time there that they were white from bird droppings. At night, the snakes gobbled up fish morsels and regurgitated fish that birds had dropped from the trees above.

Lillywhite's analysis of the ratios of carbon and nitrogen in the cottonmouths confirms that "the snakes are depending on the rookery almost completely for food," comments Thomas Wolcott, a behavioral and physiological ecologist at North Carolina State University in Raleigh. This is in contrast to snakes from the mainland, where rodents and other small animals are typical fare.

"I've never seen anything like that," says E. Eugene Williams, a cellular physiologist at Salisbury University in Maryland. The fish-eating snakes' population is booming, and they "look like tires lying on the ground," says Beaupre, who adds that these snakes are the biggest pit vipers he's ever seen. Lillywhite proposes that the cottonmouths have deterred or eradicated nest predators such as raccoons or arboreal snakes, making Seahorse Key more hospitable for the birds.

–ELIZABETH PENNISI

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