Evolutionary constraints revealed in diversity of fish skulls

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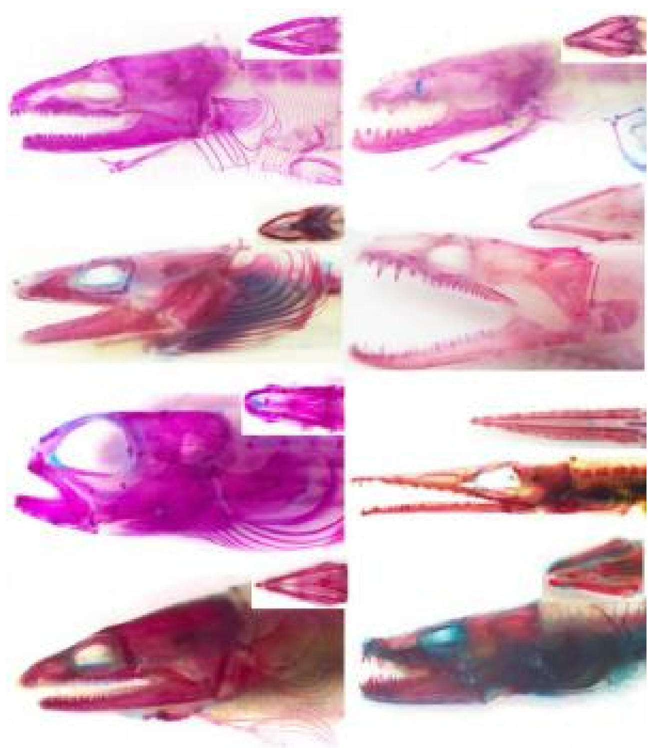

These images show the skulls of suction-feeding eels on the left and biting eels on the right. The insets show ventral views of the hyoid apparatus, one of the main skeletal elements used to produce suction. Credit: R. Mehta

In the aquatic environment, suction feeding is far more common than biting as a way to capture prey. A new study shows that the evolution of biting behavior in eels led to a remarkable diversification of skull shapes, indicating that the skull shapes of most fish are limited by the structural requirements for suction feeding.

"When you look at the skulls of biters, the diversity is astounding compared to suction feeders," said Rita Mehta, assistant professor of ecology and evolutionary biology at UC Santa Cruz.

With more than 800 species, including both suction feeders and biters, the eels are an ideal group for studying the evolution of feeding behaviors and skull shapes. Mehta's team mapped out the evolutionary relationships among the many species of eels and their close relatives in order to understand the factors that promote or constrain morphological diversity. They reported their findings in a paper published November 17 in *Nature Communications*.

Eels evolved from suction-feeding ancestors, but biting appeared early in their evolution, and the vast majority of eels are biters. In several eel lineages, however, suction feeding reappears, having evolved independently in separate lineages. This enabled Mehta's team to look at the evolution of biting and suction feeding and compare the morphological diversity of skulls in the different lineages.

"The biters are three times more diverse than the suction feeders. It's an incredible increase in diversity just from a shift in feeding strategy," Mehta said. "The suction feeders evolve the same traits over and over again, whereas the biters go in a lot of different directions."

Suction feeding requires tightly coordinated movements of several different bones in the skull to rapidly increase the size of the mouth cavity and create a flow of water strong enough to pull prey into the mouth. The shared features of suction feeders include short skulls, strong jaws, a well-developed hyoid bone on the floor of the mouth cavity, and large opercula (the bony flaps covering the gills).

"All these different parts of the anatomy have to work together to generate suction, so there are only a few ways you can evolve suction feeding," Mehta said. "Biters have hyoids of all different sizes, short and long skulls, all types of teeth in different places in the mouth cavity—it's a much more variable and flexible feeding strategy."

The moray eels, one of the largest families of eels, are all biters and have evolved some of the most extreme morphological features. In a 2007 paper in Nature, Mehta reported that after a moray eel captures its prey, a second set of jaws is launched from the back of the throat to grab the prey and pull it into the esophagus.

"Moray eels are the outliers, really pushing the envelope of morphological space to the extremes," Mehta said. "Biting and suction are not mutually exclusive—many biters still use suction to swallow their prey—but morays have lost suction altogether."

Somewhat surprisingly, the researchers found no difference in the rate at which morphological differences evolved in lineages with different feeding modes. In other words, suction feeders accumulated morphological changes at the same rate as biters, but those changes occurred within a much more limited "morphological space." The changes that occurred in biter lineages, in contrast, led to much greater diversity in skull morphology.

David Collar, a postdoctoral researcher in Mehta's lab, led the phylogenetic analyses and is the first author of the new paper. He is currently at the University of Massachusetts in Boston. The other coauthors of the paper are Peter Wainwright of UC Davis, Michael Alfaro of UCLA, and Liam Revell of University of Massachusetts Boston. This research was funded by the National Science Foundation.

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