'Primitive' to 'Specialized': New Fossil Changes the Tune on Hagfish

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There is hardly anything under the sea as simultaneously simple and confusing as the hagfish[1]. The pinkish, tubular fish has four hearts but no eyes, stomach, or taste buds. Hagfish are one of the jawless fishes that comprise the superclass Cyclostomata. The only other jawless fish is the lamprey, another eel-like animal that distinguishes itself from the hagfish by having vertebrae. Despite having partial cranial skulls, hagfish lack backbones and therefore cannot be classified as true vertebrates. In fact, hagfish lack bones entirely; their skeletons are composed of cartilage.

The true claim to fame for the hagfish, however, is slime. When attacked or otherwise agitated, hagfish release roughly a teaspoon of concentrated slime from glands on the sides of their bodies. Upon contact with seawater, that teaspoon expands into liters. This is no ordinary mucus, either. It is reinforced by very fine fibers, allowing it to suffocate any creature attempting to attack the hagfish – even sharks, according to Massey University[2]. In just a few seconds, the assailant finds its mouth and gills brimming with goop and no other choice but to retreat.

An evolutionary conundrum

The strange anatomy of the hagfish makes it difficult to grasp in a phylogenetic sense as well. It is well-understood that all vertebrates comprise a clade, which is a group of organisms that descended from a common ancestor. Evolutionary biologists like Philip Donoghue of the University of Bristol in an interview with *Wired*[3] have struggled to fit the hagfish and the lamprey into this vertebrate history, since the two species share so many features except for the most important one: the backbone.

A group of researchers, including Donoghue, formulated two main phylogenetic hypotheses to tackle this issue in a paper published in *Development*.[4] The first hypothesis proposes a gradual accumulation of vertebrate features, with the hagfish serving as a precursor to the lamprey and more complex vertebrates. In this case, lampreys are considered to be part of the clade Vertebrata. The second scheme considers hagfish and lampreys to be more closely related in their own clade Cyclostomata, which precedes other vertebrates. While comparative morphology supports the first hypothesis, analyses of protein-coding sequences give weight to the second theory.

To complicate matters further, soft tissue and cartilage are especially prone to decay – that is, if scavengers do not consume them first. Without bones, shells, or teeth, the hagfish has been largely absent from the fossil record, making it exceptionally difficult for scientists to pinpoint how hagfish relate evolutionarily to vertebrates.

Pacific hagfish poking out from a sponge[7].
NOAA Okeanos Explorer Program (2011) A hagfish protruding from a sponge *[image], available: https://www.photolib.noaa.gov/htmls/expl2939.htm [accessed 25 March 2019].*

Long-awaited, rock-solid evidence

A new fossil recovered from a Lebanon quarry is shaking up preconceived notions of where the hagfish sits evolutionarily in relation to vertebrates. In their 2018 paper, Miyashita et al. confirm the identity of the Cretaceous era fossil as a hagfish, citing a distinctive cartilage plate in its mouth and slime glands containing chemicals that match those found in living hagfish[5].

This fossil is an important stepping stone in early vertebrate phylogeny because it reduces the gap in the cyclostome fossil record by 100 million years. Analysis revealed that hagfish and lampreys are in fact sister taxa that diverged during the Paleozoic era and comprise the clade Cyclostomata. This phylogeny indicates that the hagfish is indeed a vertebrate but one that lost several traits as it gained others, such as the ability to produce intense slime. Scientists suggest that the hagfish's missing eyes, stomach, bones, and spine are actually the result of many millions of years of specialization.

The logic behind a spineless vertebrate

Calling a fish with no spine a vertebrate certainly sounds oxymoronic. Suggesting that any organism would lose its spine, jaw, eyes, and stomach as an evolutionary advantage likewise appears nonsensical. Adding into consideration the environment in which the hagfish lives, however, the argument that the hagfish would forgo a spine and other common vertebrate body parts actually starts to make sense.

Hagfish are most commonly found on the deep-sea floor where they scavenge for food among dead and decaying sea life. Eyes are

of little use in those murky depths. Much more valuable senses are smell and touch, both of which are heightened in the hagfish. Aside from a round mouth and tooth-like appendages attached to a tongue, the hagfish has no means by which to eat. The animals solve this problem by being expert burrowers. As they burrow into the sea floor for protection, they frequently nestle into dead and decaying animals. Their porous skin absorbs dissolved organic matter from their surroundings while their mouth appendages consume flesh directly, allowing hagfish to capitalize on spontaneous and intermittent scavenging opportunities. In this way, the hagfish also serves as a deep-sea floor cleaner, aiding in the decomposition of detritus.

The hagfish's burrowing capabilities are made possible by its supple skeleton, which also comes in handy when the hagfish is under attack: the cartilage that composes its skeleton allows the fish to slither through spaces many times smaller than its width, making for convenient getaways according to the Museum of New Zealand Te Papa Tongarewa. The hagfish's exceptionally flaccid skin makes it difficult for any attackers to bite and latch on to it. If some creature does manage to get a bite and slime is secreted, the hagfish has its own clean-up mechanism: It is flexible enough to tie its body into knots and wring the slime right off.

Though the development of vertebrae has traditionally been considered a benchmark of evolutionary progress, the hagfish challenges that convention. Its slimy, spineless body lends itself well to the environment in which it dwells, enabling the hagfish to scavenge and avoid getting eaten. Apparently, less is more on the dark, treacherous sea floor. Unless, of course, it comes to slime. The hagfish is living proof that the more slime, the better.

SOURCES

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