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Wrap Your Mind Around a Whale

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The facts of a blue whale seem improbable; it is hard to wrap your mind around an animal with jaws the height of a football goal post. Those jaws are not just the ocean's utmost bones (to borrow from Melville) but the utmost bones in the history of life on Earth.

And yet these superlative whales haven't been huge that long. In fact, they emerged just about 4.5 million years ago, coinciding almost perfectly with the human era.

We are living right now in the age of giants. Blue whales, fin whales, right whales and bowhead whales are the largest animals, by weight, ever to have evolved. How did this happen? And what does this tell us about how evolution works?

Fossils show that the earliest whales were more obviously mammalian — they had four legs, a nose, maybe even fur. They had bladelike teeth and lived in habitats that ranged from woodlands with streams to river deltas, occasionally feeding in the brackish waters of shallow equatorial coasts. And they were the size of a large dog.

If you were somehow able to return to an ancient shoreline and happened upon the entire assemblage of early whales, you wouldn't be able to guess which four-legged creature would beget the whales we know. In their own times and habitats, each was as well adapted as any sea lion or otter living today. But it was the whales that completely severed their ties to land that eventually won the evolutionary sweepstakes.

Still, it took these whales most of their 50-million-year history to become giants. It was not the parade of evolutionary transformations and innovations to their bodies (the refashioning of forelegs into flippers or the appearance in some species of baleen, for feeding, for example) that made them big. Instead, my colleagues and I argued in a 2017 study that the onset of ice ages, a few million years ago, affected the distribution of their prey, making it hyperabundant in warmer seasons along the coasts. This set the stage for long-range migration, while enhancing advantages that baleen whales already had for living large.

This brings up a theoretical question: Can whales continue to get bigger?

A lot about an animal's biology — how quickly its heart races, how many young it produces, how long it lives — can be predicted from its size alone, whether it is enormous or microscopic. The mathematics that describes how biology changes across these scales is called allometry (the same math is used to explain economies and traffic jams). Applying allometry to the study of whales is the key to understanding not just what it takes to be a giant, but also the limits of living things on Earth.

There are disadvantages to being enormous. The largest whales are so big and thick with blubber that overheating in warmer waters is a risk.

Whale lungs are so large and specialized that they present their own quandaries. They must be able to collapse quickly enough to avoid rupturing when the whales dive deep (as some toothed whales do), but also to reinflate rapidly at the surface after two hours underwater. Blue whales don't dive anywhere close to the depths you'd expect for their body size. In part it's because their prey live near the light, but it also seems that it takes too much energy to breathe all the oxygen necessary for a deeper plunge.

As organisms scale up, physics dictates what's possible for any kind of movement and function, be it blood flow, digestion or locomotion. Sauropod dinosaurs, for example, had limbs like columns to support their massive weight, yet their load was most likely lightened by an avian-like respiration system, which permeated their skeleton with air sacs.

Whales obviously haven't had to deal with the force of gravity since they became fully aquatic; underwater, they are essentially weightless. Instead, forces such as drag have shaped their bodies, especially when feeding. When scientists used allometry to calculate drag on mathematical models of different-size whales, they found that beyond lengths of 110 feet a blue whale would not be able to close its mouth fast enough around quickly escaping prey. Others have found that a whale that big wouldn't gain enough calories from the mouthful to make up for the energy lost from the act.

In other words, the largest whales ever measured, at 109 feet, are theoretically the largest whales that can exist.

Of course, physics isn't the only factor imposing limits on these leviathans. Whaling is estimated to have killed nearly three million whales in the 20th century alone.

Human hands have imperiled other cetaceans. Not a whistle or splash of the Yangtze River dolphin has been recorded since the first decade of the 21st century. Responsibility for the extinction of this species can be placed squarely on our shoulders: We dammed the only river in which it lived. Other species such as the vaquita, a small porpoise that has never been spotted outside the Gulf of California, remain on the extinction watch list; there are only one or two dozen left.

The news isn't all dire: Some whale species, such as humpbacks, have rebounded from the brink; gray whales, icons of the West Coast, are even expanding to new habitats as climate and oceans change.

But on today's planet, large body size is correlated with a higher extinction risk. Almost all of the largest whale species today, including blue whales and right whales, are navigating an increasingly urbanized ocean, full of larger and faster ships, noise and detritus. The extreme size of the largest whales puts them at risk of entanglement in fishing gear and trauma from ship strikes.

Their size can also be a liability if the environment changes rapidly, which we know is happening now, thanks to the behavior of our own species. Features of past whale worlds, such as sea-level rise and the acidification of ocean water, will return in the near future as a result of widespread burning of fossil fuels driving climate change.

How successfully whales and humans can share this evolutionary moment is a high-stakes story that's still being written. The more we learn about these giants that can live more than twice as long as we do, and whose migrations take them across entire oceans, the better their chances of survival on Earth in the age of humans.

I think we have reason to hope that these largest creatures on the planet will continue to awe us for centuries to come, living, as they do, on the knife-edge between perfect and perilous adaptation.

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