

The Curious Tale of Whales

Whales and dolphins are spectacular creatures.

Their ancestors climbed out of the ocean 360 million years ago, developed lungs and legs, and evolved into mammals. Then, 50 million years ago, they walked back into the sea.

To survive there, they developed specialized behaviors, which require even more special biology.

Perhaps most famous is echolocation. They move air between sinus cavities to emit sound. When it bounces back to them, they don't hear it with their ears, but feel it in a fatty fluid in their lower jaw.

Only toothed whales, like sperm whales, orcas, and dolphins, can echolocate—a skill we think they developed to hunt prey, especially squid, in the darkness of the deep ocean.

Baleen whales focused on other prey, floating shrimplike creatures, and for this they developed comblike plates in place of teeth.

They can't echolocate but are known for their elaborate songs. We *think* they use these for communication. But we're not sure how they produce them, since they don't have vocal chords.

Both types of whales can hold their breath for 45 minutes or longer. To do this, they reduce their heart rate and cut blood flow to some organs, like the stomach, while providing it to others, like the brain.

Even their blood is specialized. It can carry far more oxygen than land-dwelling mammals, and they have much more of it.

Whales are an amazing example of what evolution can do, given enough time.



Faroe Islands postage stamp art featuring the blue whale (*Balaenoptera musculus*).

Credit: Postverk Føroya (Philatelic Office) (public domain), via Wikimedia Commons

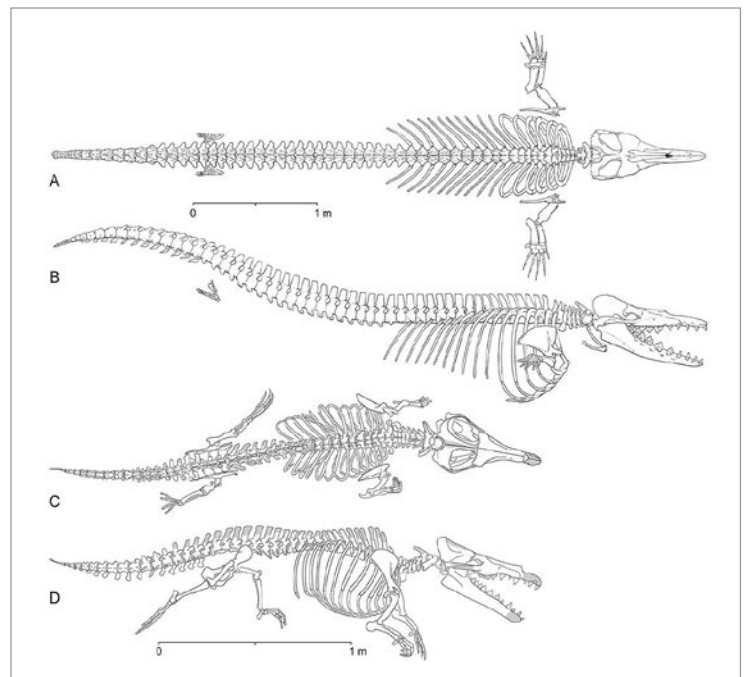


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Background: The Curious Tale of Whales

Synopsis: Blue whales are the largest animals that ever lived on Earth. They are almost as long as a 130-passenger Boeing 737 and more than twice as heavy. Their ancestors left the sea over 360 million years ago and slowly evolved into carnivorous mammals. But about 55–50 million years ago, the predecessors of the cetaceans—whales, dolphins, and porpoises—abruptly changed their evolutionary direction and returned to rule the sea.

- Cetaceans are marine mammals. They live their lives entirely in the water but, like other mammals, are warm-blooded, have lungs, and give birth rather than lay eggs.
 - Cetaceans live in pods and are very social.
 - Some superpods may include more than 1,000 animals.
 - The pods have complex social structure and provide safety in numbers as well as group feeding and migration.
 - Older cetaceans care for younger ones in nurseries.
 - Groups have been known to stay with injured or sick individuals, helping them to the surface for air as needed.
- Cetaceans include about 90 species of whales, dolphins, and porpoises. The two categories of whales are *baleen* and *toothed*.
 - There are about 15 species of baleen whales, including blue whales and humpback whales.
 - Baleen whales have hundreds of plates in their mouths that are like huge combs made of fingernail-like keratin that hangs from their upper jaws.
 - After enormous gulps of seawater, they use the baleen plates to filter the water, then swallow the marine life that remains in their mouths.
 - Most cetaceans are toothed, and they eat their prey like most carnivores. The sperm whale is the largest of the toothed whales.
- Scientists have long pondered why air-breathing mammals ended up as water dwellers.
 - More than 360 million years ago, in the Devonian period, vertebrates developed lungs and appendages that could support their weight in air and left the competitive environment of the sea for new environmental niches on land.
 - Reptiles, dinosaurs, and birds diversified from these original tetrapods, which were characterized by their four appendages. Some tetrapods evolved into warm-blooded, air-breathing mammals that were fairly small, about 50 lbs or less.
 - When the asteroid wiped out the dinosaurs, about 65 million years ago, many of these smaller mammals survived and expanded into environmental niches left open by the dinosaurs.



Skeletons of 34–56 million year old (Eocene) ancestors of whales showed progressive changes to their limbs. A and B are from the *Dorudon* genus, and C and D from the *Maiacetus*.

Credit: Doug Boyer (A, B) and Bonnie Miljour (C, D) (CC BY 2.5 [<http://creativecommons.org/licenses/by/2.5>]), via Wikimedia Commons

References: The Curious Tale of Whales

- How Did Whales Evolve? | Smithsonian
- How Whales Made the Dramatic Evolutionary Shift from Land to the Sea | Gizmodo
- The Evolution of Whales | Berkeley.edu
- Evolution of Cetaceans | Wikipedia
- Cetacea | Wikipedia
- Welcome to the World of Whales and Dolphins | Whale and Dolphin Conservation

Contributors: Juli Hennings, Harry Lynch

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- About 10 million years later, one group of mammals that lived in coastal swamps re-entered the aquatic realm. These ancestors of the cetaceans evolved to be able to swim and live full-time in this unchallenged niche.
 - ✦ Fossils show vestiges of rear limbs that shrank as they became increasingly useless.
- The closest living relatives of cetaceans are hippos, which descended separately from the same mammals that lived on the water's edge.
- To live in the water, the earliest cetaceans had to make amazing adaptations.
 - Cetaceans can drink seawater. The salt concentration in their blood is lower than that in seawater, and their long, flat kidneys have evolved to be able to secrete salt.
 - Hearing underwater is a challenge for land mammals, but cetaceans have developed spongy parts in their auditory system that are encased in dense, bony structures that enable hearing deep below the water.
 - Some cetaceans are capable of echolocation; they can figure out the size and shape of an object, how far away it is, and how fast it is moving, making it possible for them to catch prey in total darkness.
 - Cetaceans have developed a wide array of sounds that they use for communication, from songs to clicks and grunts.
- The most amazing adaptation is the ability to stay underwater for long periods of time. Whales can dive to more than 6,000 ft; humpbacks can stay underwater for about 45 minutes, and sperm whales have been known to stay underwater for up to 2 hours. How do they do it?
 - Whales can cut their heart rate in half to conserve oxygen. Oxygen to certain organs, like the stomach, can be placed on hold, while other organs, like the brain, get a constant supply of crucial oxygen while underwater.
 - Whales have to think about every breath they take and must be awake to inhale and exhale—they replace 80–90 percent of the air in their lungs each time they take a breath. (Humans breathe involuntarily and exchange only 10–15 percent of the air in our lungs each time we inhale and exhale, which is comparatively inefficient.)
 - When cetaceans surface after a dive, they forcibly exhale all their air first—forming their famous spouts—then take a fresh, clean breath. (After holding our breath, humans inhale first, then exhale and finally take a fresh breath, delaying access to oxygen.)
 - Whale lungs take up 3 percent of their body size (compared to 7 percent for humans); it's not just relative lung size that provides their breathing capability, it's how the oxygen is stored within their bodies.
 - Hemoglobin stores and transports oxygen in the body. Whale blood has twice the hemoglobin (60 percent) of human blood (30 percent), and whales have a larger volume of blood (10–20 percent) in their bodies compared to humans (7 percent).
 - Human muscles store oxygen in myoglobin so it can be released when we need it. Whales have 30 percent more myoglobin than humans in their muscles; the myoglobin stores 35 percent of a whale's oxygen supply.
 - In most mammals, high concentrations of myoglobin clump together, rendering the oxygen supply they carry useless. Whale myoglobin, however, evolved to be positively charged—each of the myoglobin proteins repels the others, which keeps it ready to provide oxygen when needed.
 - For most mammals, water pressure deeper than 300 ft generates reactive oxygen species that can damage DNA, but cetaceans have evolved to produce extra amounts of an antioxidant known as *glutathione* that prevents this cellular damage.

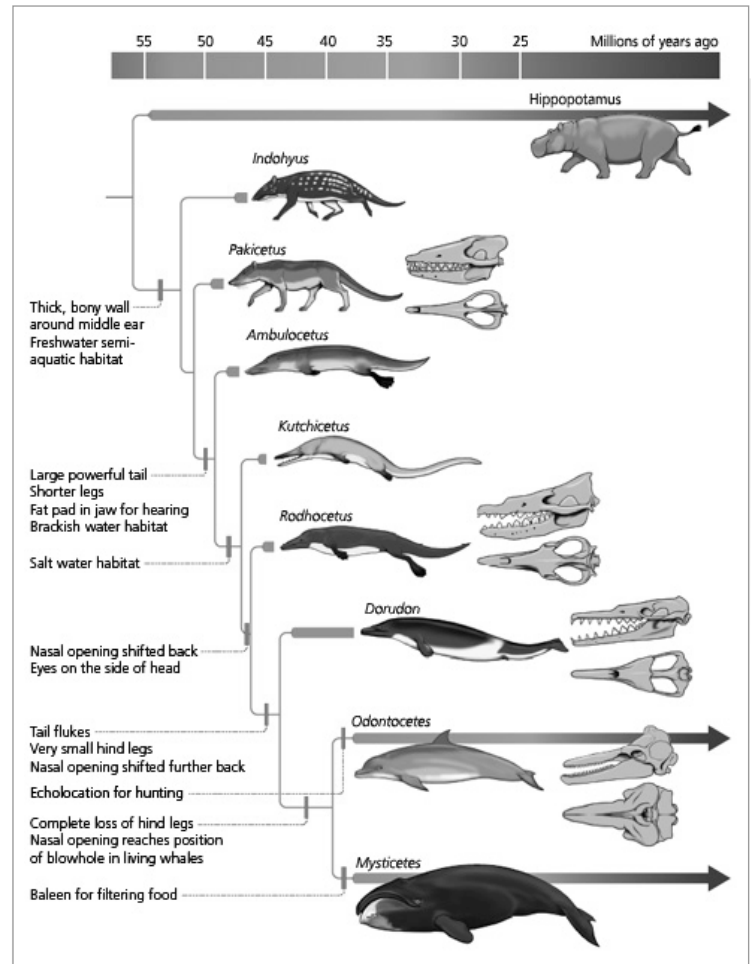
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Background: The Curious Tale of Whales

- The largest of the cetaceans is the incredible blue whale.
 - Blue whales are filter-feeding baleen whales that spend their summers in polar waters but migrate southward during the winters.
 - They are the size of the fuselage of a 130-passenger Boeing 737; the larger females grow to as much as 110 ft long.
 - They can weigh 200 tons, equivalent to the weight of 33 African elephants.
 - Their tongues alone can weigh as much as an entire elephant!
 - Their hearts weigh as much as a small automobile, and their heartbeat can be detected 2 miles away.
 - Blue whale calls can be louder than a jet engine, and their songs are audible up to 1,000 miles away.
 - They have 300–400 baleen plates made of black keratin on each side of their mouths. The plates filter out seawater, leaving a “bite” that contains about a ton of shrimplike krill and small fish. They need to eat up to 4 tons per day.
 - When born, their calves weigh 3 tons and are 25 ft long. The first year, the babies gain about 200 lb a day by drinking their mothers’ milk.
 - Blue whales may live 80–90 years. After whales die, researchers can count layers on their waxy earplugs to determine their age. The oldest known blue whale was 110.
 - Whalers hunted these giants of the sea since the 1800s. More than 360,000 were slaughtered from 1900 to 1960 so their fat could be rendered into whale oil. The International Whaling Commission finally protected them in 1966, but their population recovery has been very slow.



This Evogram shows the sequence of whale evolution; their closest cousin, the hippo, evolved separately.

Credit: The Evolution of Whales | Berkeley

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