Whales have altered their development to be able to echolocate

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Credit: Pavel Danilyuk from Pexels

Researchers found that different groups of whales and dolphins take varying routes as they develop in a delicate balancing act between their evolutionary history and current environment.

Whales overwrite their own evolutionary history when they put their heads together.

A new study, published in *Proceedings of the Royal Society B: Biological Sciences*, has investigated how the skulls of whales and dolphins, collectively known as cetaceans, change during development to allow them to echolocate.

The researchers found that while all toothed whales begin development with symmetrical skulls, some species rapidly gain lopsided heads to focus on navigating underwater.

The study found that even distantly related whales can develop very similar structures in extreme examples of convergent evolution, where unrelated species develop in similar ways when exposed to the same evolutionary pressures.

Dr. Agnese Lanzetti, a researcher at the Museum and lead author on the paper published in Proceedings B, says, "This is the first study that has ever looked at the ontogeny, or the developmental process, in cetacean asymmetry."

"We found that while porpoises keep symmetrical skulls throughout their development, the skulls of other whales rapidly become asymmetric."

"Their evolutionary differences are completely lost as whales adapt to their environment and studying these changes may help us better understand how these marine mammals evolved."

How do cetaceans develop?

Cetaceans are among the animals with the longest gestation periods in

the world.

The blue whale, the largest animal on Earth, takes up to a year to produce a calf, while sperm whales can take up to 16 months. Size isn't everything, however, as killer whales can have gestation periods as long as 18 months. The differences between the different cetaceans are likely related to the environment they live in, and how developed their offspring are at birth.

Agnese and her co-authors wanted to look into how this process of development, from embryo to calf, leads to skull asymmetry and the ability of toothed whales, such as sperm whales, to echolocate using high-pitched sound.

"It is believed that the asymmetric skulls and fat bodies of toothed whales helps them to detect sound directionally," Agnese explains. "If their skulls were symmetrical, then sound would contact both sides of the head at the same time. With an asymmetric head, echoes contact the skull at different times, allowing a cetacean to work out the direction and distance of an object."

Using 3D models, the researchers measured the shape and size of skulls from five toothed whale groups, including oceanic dolphins, beluga whales and porpoises, at different stages of the cetaceans' development.

The smallest whales, the porpoises were found to be an outlier, showing very little change in skull shape between a fetus and a juvenile.

"We found that porpoises have very symmetric skulls in the womb, and this doesn't change," Agnese says. "Unlike all other toothed whales, they never become asymmetric. This may be because they use narrow-band high-frequency sounds (NBHF) to communicate which are higher than those used by other species."

"Other species which use NBHF, such as the pygmy sperm whale, have very asymmetric skulls, however, so it may be that a requirement to use NBHF sounds is to grow for a short period to a small body size."

How did turning points in whale evolution affect their development?

The researchers tracked the development of asymmetric skulls throughout history, with the earliest examples being found in early toothed whales known as Xenorophidae that lived over 30 million years ago.

Many groups during the early evolution of toothed whales still had symmetrical skulls, like Kentriodontidae, the ancestors of both beluga whales and porpoises. As beluga whale ancestors developed an asymmetric skull to adapt to their habitat, they lost the ability to hear NBHF sounds, which the porpoises retained.

The drastic changes in their prenatal development have caused modern beluga whale skulls to develop very asymmetrically. As a result, their skulls appear very similar to the skulls of pilot whales, despite both groups being separated by 20 million years of evolution.

"These evolutionary differences are completely lost because whales have adapted for their environment," Agnese says. "Even though beluga and pilot whales live in very different habitats, they tend to do things in similar ways. They are social animals, they feed on similar soft-bodied prey, and forage in complex environments."

"Over the course of evolution, they have evolved inner ear canals which are very similar shapes in adults of both groups, even though they start their development in very different places."

The scientists now hope to turn their attention to the baleen whales, which, unlike their toothed relatives, cannot echolocate

"There are 12 species of baleen whale in total, significantly fewer than toothed whales, and if you look at the skulls they all share the same main features," Agnese says. "I think there is something about how they develop to be learned there."

"Baleen whales in particular get especially big, while the only very large toothed whale is the sperm whale. I think there are interesting differences in their development which will help explain why they one group is much more diverse and adaptable than the other."

More information: Agnese Lanzetti et al, The ontogeny of asymmetry in echolocating whales, *Proceedings of the Royal Society B: Biological Sciences* (2022). DOI: 10.1098/rspb.2022.1090

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