

Aquatic adaptation and the evolution of olfaction in cetaceans

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Transition between the sea and land is one of the most striking types of evolutionary event in the history of life. Vertebrates originated in the sea, and a group of vertebrates became terrestrial during the Devonian period. This transition is well documented in the fossil record, and the land vertebrates that newly emerged are called tetrapods. Tetrapods include the modern amphibians, reptiles, birds and mammals. Amphibians still need a humid environment, while amniotes (reptiles, birds and mammals) have acquired keratin-covered waterproof skin and dehydration-protected embryos, allowing them to be independent of aquatic habitats.

Full terrestrial adaptation caused profound changes in the olfactory sensory modality in amniotes. Marine fish smells water-soluble molecules, whereas terrestrial amniotes need not smell underwater, but instead need to smell volatilized odorants in the air. The repertoires of the olfactory receptors (ORs) in amniotes differ greatly from those in marine fish. The ORs are encoded by intronless OR genes which constitute one of the largest multigene families in vertebrate genomes. It has been reported that the OR gene family in fish is much more diverse than that in amniotes, but two OR gene subfamilies have expanded explosively in the amniote genomes. These two OR subfamilies are called class I and class II, respectively. Interestingly, the OR gene repertoire in amphibians is as diverse as that in fish, but the class II OR gene subfamily expansion has also been confirmed in amphibian genomes. These findings suggest that the amniote class I and II OR subfamilies have been expanded to detect airborne molecules, and that large-scale degeneration of ORs that detect underwater odorants had occurred by the time when the transition to land was complete.

Amniotes have returned to the sea many times in their evolution, and a number of modern amniotes are living in the marine environment. Especially among such amniotes, cetaceans (whales, dolphins and porpoises) are one of the most perfectly adapted modern aquatic groups. Cetacea is an order of mammals that originated in the early Eocene epoch and that was derived from artiodactyls. Extant cetaceans are classified into two suborders -Mysticeti (baleen whales) and Odontoceti (toothed whales)- and both of them are fully aquatic. How did cetaceans re-adapt their olfactory systems to their underwater lives? Anatomical evidences strongly suggest that toothed whales have no sense of olfaction, whereas baleen whales have it but they can smell in air, not underwater. In my talk, I will provide my recent studies about the evolution of whale olfaction from the anatomical and genomic points of view.

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