A STUDY OF THE FUNCTIONAL EVOLUTION OF THE INNER EAR OF BALEEN WHALES

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This study focuses on the bony structures of the inner ear of fossil baleen-bearing whales. The two extant cetacean suborders, Mysticeti and Odontoceti, are distinct in their ear structure and hearing function. Mysticetes are sensitive to low frequency sounds and can hear well in the infrasonic range. By contrast, odontocetes can hear high frequency sound as a part of their ultrasonic echolocation. Two conflicting hypotheses have been proposed to explain the evolution of infrasonic hearing specializations in mysticetes. A traditional hypothesis suggests that the specializations for infrasonic hearing in modern baleen whales are a retention of the primitive condition. A more recent hypothesis suggests that infrasonic hearing in mysticetes is a reversal from an ancestral condition of high frequency hearing and that modern baleen whales have secondarily lost the ability to hear high-frequencies and echolocate.

High frequency hearing is known to be closely correlated with several bony structures of the inner ear, including: 1) a well developed secondary bony lamina for a more rigid suspension of the basilar membrane, 2) a narrow laminar gap in the basal cochlear turn indicating a narrow basilar membrane, 3) a high density of foramina for nerve fibers innervating the base of the cochlea where high frequencies are detected, 4) a large spiral ganglionic canal that could contain more ganglionic cells for better frequency resolution, and 5) wide separation between cochlear turns. These bony structures are well preserved in fossil whales and provide reliable evidence on the evolution of their hearing.

Using serial sectioning and 3-D computer graphic reconstruction, we examined the inner ear structures of two fossil members of the extant families Balaenopteridae and Eschrichtiidae of the mysticete crown group. In addition, we examined the inner ears of Pelocetus and Herpetocetus, two distantly related archaic baleen whales. Morphological specializations for high frequency hearing are much less developed in these specimens than in any odontocetes. Secondary laminae are limited to the basal 3/4 turn of the cochlea, and are thin and poorly developed, indicating a less rigid suspension for the basilar membrane. The laminar gap in the basal cochlea is comparatively wide, indicating a basilar membrane less sensitive to high frequency sounds. The density of foramina for cochlear nerve fibers is less in the basal than the second turn of the cochlea, very unlike odontocetes in which cochlear fiber foramina are denser in the basal turn than apical turns. Spiral ganglionic canals are smaller, and the separation between cochlear turns is narrower than in early odontocetes. These fossil baleen whales and basilosaurid archaeocetes are more similar to the outgroup artiodactyl (Sus) that lacks high-frequency hearing, than they are to odontocetes. These data contradict the hypothesis that high frequency hearing was present in archaic mysticetes (or ancestor to mysticetes), but subsequently lost in extant baleen whales.

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