The unique position of monotremes in the evolution of hearing … Rob Shepherd

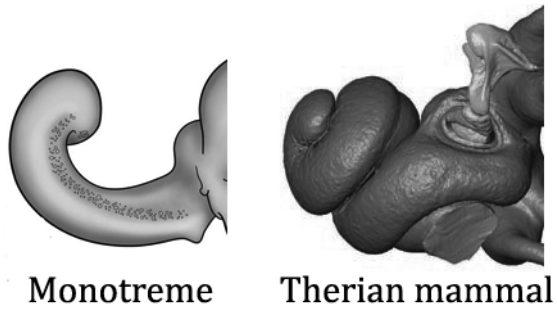
Hearing is one of seven senses[1] that provide input to an individual about the status of their own body and their environment. This can, for example, mean the difference between evading or falling prey, detecting food, and communicating with other members of the species (conspecifics). Our senses are the difference between life and death and are therefore under significant selective pressure. The development of hearing provides a fascinating example of this process. Unlike most sensors in the body, key aspects of the auditory system are encased in bone (the middle and inner ears), and are therefore well preserved in fossils.

The Short-beaked Echidna, Tachyglossus aculeatus, (shown at left) is commonly found in the Anglesea and Aireys Inlet area. Together with the Platypus, Ornithorhynchus anatinus, they are two examples of the order monotreme. Monotremes are egg-laying mammals; any mammal that does not lay eggs is a therian mammal (i.e. marsupials and placentals) (Image: Deakin University).

The hearing range of a species covers the vocalisations of conspecifics, predators and prey, and environmental sounds, most of which are associated with low- to mid-frequencies (100 – 4,000 cycles per second or Hertz (Hz)). There are, however, distinct advantages for both hunters and prey to detect high frequencies; e.g. the recognition of movement including the wing movement of birds and insects, rustling etc. Particularly useful is ultrasonic hearing — frequencies above ~20 kHz —as the detection of the source of the sound significantly improves at these high frequencies. This is epitomised in micro bats that have evolved to perceive upper frequencies in the order of 100 kHz enabling them to catch insects on the wing via echolocation.

Modifications to the hearing organ or inner ear have driven much of these evolutionary changes. The inner ear of modern birds and reptiles is straight and short (<4.5 mm long) with a maximum hearing sensitivity <6 kHz. The owl, a specialist nocturnal hunter, is an exception among birds, hearing to ~10 kHz via the development of a longer inner ear (~10 mm); increasing the length of the inner ear leads to improved higher frequency hearing.

Mammalian evolution diverged from birds and reptiles ~325 million years ago while monotreme and therian (marsupial and placental) mammal lines diverged ~ 250 million years ago. Over the following 150 million years the therian inner ear evolved to perceive very high frequencies through the coiling of the inner ear (see figure); an effective way of increasing the length of the hearing organ within the confines of the skull. High frequency hearing in therian mammals continued to evolve as mammals expanded into new niche habitats. In contrast, the monotreme inner ear only marginally increased in length (~7 mm) and did not coil. While monotreme high frequency hearing evolved to be greater than birds (~13 kHz) it is considerably less than therian mammals.



This figure illustrates the typical monotreme (left) and therian mammal (right) hearing organ. The monotreme inner ear is short and not spiralled, while marsupial and placental mammals evolved a spiral hearing organ that helped give rise to their ability to detect very high frequencies (20 kHz and above).

With a combination of both modern and relatively primitive components to their auditory system, monotremes provide a unique window into the evolution of hearing in vertebrates. This does not mean, however, that these beautiful creatures should be considered 'primitive'. They are superbly adapted to the environments in which they live, and the prey they hunt. While their hearing ability (and for that matter their vision) is not 'finely developed', all monotremes possess highly sophisticated electro- and mechano- receptors in their snout that are ideal for prey detection. Their continual presence on earth for over 100 million years attests to the success of this unique group of mammals.

Reference: Manley G. (2012). J *Assoc Res Otolaryngol* 13:733-743.

[1] Hearing, Sight, Smell, Taste, Touch, Balance & Proprioception.