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New insights into hearing of early synapsids

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The ability to hear air-borne sound has evolved independently in at least five vertebrate groups such as frogs, lizards, turtles, crocodiles and mammals (Müller & Tsuji 2007). Among these groups mammals are unique because they are able to hear high frequencies of air-borne sound. This might be a consequence of the very efficient impedance matching mechanism of the mammalian middle ear apparatus. This leverage system amplifies low pressure air-borne sound into higher pressure water-borne sound to the inner ear (Kemp 2005). However, this was not the ancestral condition, because the earliest land-living vertebrates were direct descendants of water-living vertebrates and, thus, were unable to hear air-borne sound. Nevertheless, the first land-living vertebrates were not completely deaf and could detect vibrations of the ground mainly via the mandible and probably by the air-filled thorax cavity.

The origin of tympanic hearing in the synapsid lineage is far from clear. It has been assumed that some advanced therapsids - the ancestors of mammals - had an eardrum at the caudal part of the mandible and were probably able to hear low-frequency air-borne sound. The bones of the jaw articulation in these animals transmitted sound vibrations from the eardrum to the inner ear. Consequently, the ancestors of mammals utilized the lower jaw not only for feeding, but also for hearing. In modern mammals this jaw articulation is reduced to the ear ossicles, but still functions for hearing in the same way. In the transition from therapsids to mammals this sound conducting apparatus was further optimized, whereby the auditory ossicles were functionally decoupled from the mandible and were miniaturized (Allin 1975). Although this evolutionary process is well documented in the fossil record, the hearing capabilities of non-mammalian synapsids, the presence or absence of an eardrum and a middle ear cavity are still subjects to debate, because soft tissue structures are not preserved. Moreover, the internal cranial anatomy of most therapsids is almost completely unexplored.

Our first examinations of skulls of non-mammalian synapsids by neutron tomography shed new light on the origin of tympanic hearing and the auditory capabilities of non-mammalian synapsids. 3D reconstructions of cephalic structures provided fundamental new insights into the anatomy of the inner ear, the middle ear apparatus and the otic region.

References:

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