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Boost of transmission at the pedicle of the incus in the chinchilla middle ear

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We are re-examining ossicular vibrations in the middle ear of the living chinchilla, a species with a relatively narrow hearing bandwidth, similar to that of humans. This study was motivated by a review that disputed the commonly held notion that middle-ear vibrations restrict the bandwidth of hearing (Ruggero and Temchin, P.N.A.S. USA 99: 13206-13210, 2002). The new measurements are facilitated by better stimulus and recording methodologies than were available when we conducted our initial study of the chinchilla middle ear (Ruggero et al., JASA 87: 1612-1629, 1990). The vibratory responses to tones of the long process of the incus just peripheral to the pedicle, the lenticular plate of the incus, and the head of the stapes were measured using a laser velocimeter and a wide-band acoustic-stimulus system. The velocity magnitude of stapes vibrations was relatively constant (~0.1 mm/s/Pa) up to 32 kHz and decreased at a rate of ~-20dB/oct at higher frequencies. Phase lag relative to pressure in the external ear canal increased approximately linearly, with a slope equivalent to a pure delay of 76 μs. Both the large bandwidth and the delay of the middle-ear responses appear to originate principally at the tympanic membrane, since they are present in the vibrations of the incus peripheral to its pedicle. These features, however, are refined by a wide peak in the magnitude of the transfer function across the incus pedicle, i.e., between the long process and the lenticular plate, which is accompanied by a large phase lag. The magnitude peak boosts vibrations by about 16 dB at 25 kHz, further flattening the magnitude middle-ear transfer function. The phase lag extends the range of constant delay to about 20 kHz. The vibration of the head of the stapes is similar to that of the incus lenticular plate. This implies that the pedicle of the incus provides more flexibility to the ossicular chain than the incudo-stapedial joint, as previously suggested (Funnell et al., JARO 6: 9-18, 2005). The present results support the contention that the chinchilla middle ear behaves as a wide-band pressure transformer which transmits acoustic signals into the cochlea even at frequencies exceeding the cut-off of hearing (Ruggero and Temchin, op. cit.).