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Title:
The Role of Resonance in Middle Ear Transmission

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Abstract:
The rodent middle ear transmits sound pressure to the inner ear with high fidelity: in the frequency domain middle ear transmission is broad-band with a delay-like phase-frequency relationship, and in the time domain the time waveform is preserved. High fidelity transmission occurs despite the presence of pronounced mechanical resonances in the tympanic membrane (TM) and acoustic resonances in the middle ear space. We present two studies that probe the role of these resonances in middle ear transmission, both performed in the gerbil ear. In one study, a click stimulus (acoustic duration ~ 40 microsecs) was applied open field to the ear canal and the motions at many locations on the TM, and the lateral process of the malleus were measured. The motion time-waveform of the lateral process was quite similar to the acoustic click. In contrast, the TM responded with prolonged oscillatory responses of various frequencies at different locations. However, the *average* of the TM response waveforms was quite click-like. This finding suggests that the "Discordant Eardrum" view of the TM proposed by Fay, Puria and Steele (PNAS, 2006), in which many discordant resonances produce high-fidelity and broad-band sound transmission, is a meaningful way to conceptualized TM operation. In the other study (reported in Bergevin and Olson, JASA 2014) pure tone stimuli were delivered open field to the ear canal and the pressure responses in the middle ear cavity were measured at several locations, via a small opening in the bony wall of the bulla. While a large pressure drop existed across the TM (~10-30 dB, varying in frequency), the motion of the TM produced significant pressure within the cavity, and subsequent reflections from the bony wall of the bulla gave rise to pressure maxima and minima. These reflections will modify the pressure difference across the TM that drives its motion, and in particular, will increase the pressure drive when a minima occurs at the TM. However, the multi-phasic motion of the TM (related to study 1), and the irregular shape of the bulla walls will reduce the effect of these reflections.