The Hair-Cell Bundle as a Sensory Antenna and Nonlinear Mechanical Amplifier for Hearing

by

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Abstract:

Hearing can operate over six orders of magnitudes of sound-pressure levels, with exquisite sensitivity and sharp frequency selectivity to weak sound stimuli. Curiously, these remarkable technical specifications are associated with conspicuous nonlinear interferences, indicating that the ear does not work as a high-fidelity sound receiver. A person listening simultaneously to two pure tones can indeed perceive not only those two frequencies but also additional "phantom" tones that are not present in the sound input. In addition, the perceived loudness of a tone diminishes when a second tone is added. Mechanical correlates of these psychophysical phenomena have been observed in the sound-evoked vibrations of the mammalian cochlea and are thought to originate in sensory hair cells from the intrinsic nonlinearity associated with mechanoelectrical transduction by ion channels. Nonlinearity of the transducer, however, is not sufficient to explain the rich phenomenology of two-tone interferences in hearing. In this talk I will show that active oscillatory movements by the hair-cell bundle can produce two-tone suppression and distortions with properties that are characteristic of hearing. Our results promote a general principle of sound detection that is based on nonlinear amplification by self-sustained "critical" oscillators in the inner ear. Although thermal fluctuations seriously limit amplification by a single oscillatory hair-cell bundle, elastic coupling of to neighbors effectively reduces noise and enhances amplification to a level that can accord with in vivo measurements.

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