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The effects of hair-cell polarity on the dynamics of two coupled hair-cell bundles of the inner ear

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Hair cells are the sensory receptors of the auditory and vestibular systems. A bundle of cilia situated atop each hair cell, termed the hair-cell bundle, is deflected upon an impinging of a mechanical force. This subsequently modulates the open probability of mechanically gated ion channels. Owing to the asymmetry in the geometry of the hair-cell bundle, individual hair cells are polarized and display the maximal response to a force applied in a certain direction. The auditory organs of most vertebrates comprise primarily hair cells with identical polarity, whereas hair cells of the vestibular system are organized in two opposite polarities. To understand the advantages of the bi-polarity arrangement of hair cells, we employ the theoretical framework of active nonlinear oscillators to investigate the dynamics of a system of two coupled hair-cell bundles with opposite polarity. Each hair-cell bundle is described by a nonlinear oscillator poised near a supercritical or subcritical Hopf bifurcation. Our results from numerical simulations reveal that a system of coupled hair-cell bundles with opposite polarity can undergo a limit-cycle oscillation, but with a significantly altered value of the critical control parameter. Predictions from the model further demonstrate that reversing the polarity of a hair-cell bundle can enhance the response of the system to a bi-directional constant force, as well as a periodic force, with respect to the displacement of a system of two identical hair-cell bundles.

Primary author: NGAMPATTRAPAN, Tanawat (Chulalongkorn University)

Co-author: Dr ROONGTHUMSKUL, Yuttana (Chulalongkorn University)

Presenter: NGAMPATTRAPAN, Tanawat (Chulalongkorn University)

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