

Active hair-bundle motility in hair cells from the vertebrate ear

Pascal Martin *

Institute Curie, Paris

* Electronic Address: pascal.martin@curie.fr

The vertebrate ear produces active mechanical work to boost the ear's sensitivity, sharpen its frequency discrimination and extend its dynamical range of responsiveness. Perhaps the most arresting demonstration of mechanical activity comes from oto-acoustic emissions, the unprovoked emanation of sound from the internal ear. The hair bundle, the mechanical antenna of the sensory hair cells, displays correlates of all four properties of the aural active process and could thus embody at least part of the amplifier. The dynamical behaviour of a hair bundle is rich. A hair bundle can oscillate spontaneously, "twitch" or simply relax in response to a force step. Using iontophoresis to affect the Ca^{2+} concentration near a hair bundle from the bullfrog's sacculus and displacement-clamp measurements of the bundle's force-displacement relations, we were able to reconcile these contrasting manifestations of active hair-bundle motility. We used Ca^{2+} and offsets of the bundle's mean position to control the fraction of open transduction channels at steady state and thus the bundle's operating point. In the case of non oscillatory hair bundles, we found that the polarity and kinetics of active hair-bundle movement evoked by a step stimulus depended on the bundle's operating point in the nonlinear force-displacement relation. When the force-displacement relation displayed a region of negative stiffness, spontaneous hair-bundle oscillations arose when the hair bundle was required to operate within this unstable region. Only three ingredients are necessary to account for the various incarnations of active hair-bundle motility: non-linear gating compliance of the transduction apparatus, myosin-based adaptation and Ca^{2+} feedback on the force that the adaptation motor can produce. Simulations successfully reproduced a wide range of observations from different groups and animal species.