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Supplemental Information

Energy Output from a Single Outer Hair Cell

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Supporting material to: Energy output from a single outer hair cell

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Internal drag of a hair bundle

Here internal drag of a hair bundle is estimated assuming it is due to the shear between stereocilia in a hair bundle.

Shear between stereocilia

To provide an estimate, the shear between two stereocilia is approximated by the shear between two plates, assuming the separation is the same as the rootlet separation s, and the widths of the plates is given by the diameter d of the stereocilia, ignoring end effects. This model overestimates the separation because the nearest distance between the stereocilia is less than s, resulting in an underestimate of the drag. At the same time the planar model overestimates the drag because end effects are not considered.

If the angle θ of bending and the separation s between the stereocilia are small, viscous drag F_p between a pair of stereocilia can be expressed,

$$F_p/v_s \approx \eta(hd)/s,$$

where v_s is the speed of the relative motion of the stereocilia, s root separation, h height of the gap, d stereocila diameter, and h_0 tip height (Fig. A1). Since $v_s \approx s \cdot d\theta/dt$ and the tip velocity is expressed by $v_t \approx h_0 \cdot d\theta/dt$, the drag coefficient F_p/v_t with respect to tip velocity does not depend on the separation s. If the bundle has N sliding pairs, the drag coefficient F_b/v_t of the bundle is,

$$F_b/v_t \approx N\eta d \cdot (h/h_0).$$

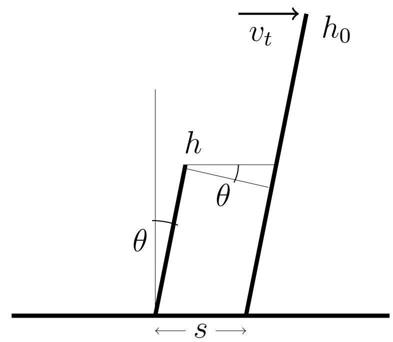

Figure A1: Shear between two stereocilia

Frog saccular hair bundle

Frog saccular hair bundle is modeled by a hexagonally packed hexagonal array that consists of 62 stereocilia [1]. Let a displacement applied through the kinocilium at a vertex toward the center of the bundle. The number of sliding pairs in this direction is 53. The number of pairs away from this direction by 60 degree is 106. Those pairs are subjected a half as large shear as those in the direction of stimulation. Thus the effective number N of sliding pairs is 106. The mean height h of these pairs is $\sim 0.75 h_0$. Hence $N \cdot (h/h_0) \approx 75$.

If we choose a value 0.4 μm for the radius d of stereocilia, we obtain $F_b/v_t = 30 \times 10^{-9}$ Ns/m, which is about 1/3 of the total drag coefficient [1], consistent with the significance of end effects. If we choose d$\leq$0.1 μm, $F_b/v_t \leq 7.5 \times 10^{-9}$ Ns/m, $\leq$1/10 of the total drag coefficient. It is compatible with the calculation of Kozlov et al. [1]

OHC hair bundle

In the cochlea of rats, 4 kHz location is at 80% from the base [2], which is in the apical turn. The ratio h/h_0 is typically 0.5 [3]. If we assume the total number of stereocilia is about 60, similar to chinchilla hair bundles [4], the number of sliding pairs is 40. If we can use d$\leq$0.1μm for the effective radius of stereocilia, we obtain $F_b/v_t \leq 2 \times 10^{-9}$ Ns/m.

Supporting References

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3. Furness, D. N., S. Mahendrasingam, M. Ohashi, R. Fettiplace, and C. M. Hackney, 2008. The dimensions and composition of stereociliary rootlets in mammalian cochlear hair cells: comparison between high- and low-frequency cells and evidence for a connection to the lateral membrane. *J. Neurosci.* 28:6342–6353.

4. Lim, D. J., 1986. Functional structure of the organ of Corti: a review. *Hear. Res.* 22:117–146.