Harvard-MIT Division of Health Sciences and Technology
HST.721: The Peripheral Auditory System, Fall 2005
Instructors: Professor M. Charles Liberman and Professor Joe Adams

HST 721 PROBLEM SET 1

Problem Set 1: Anatomy and Hair Cell Physiology
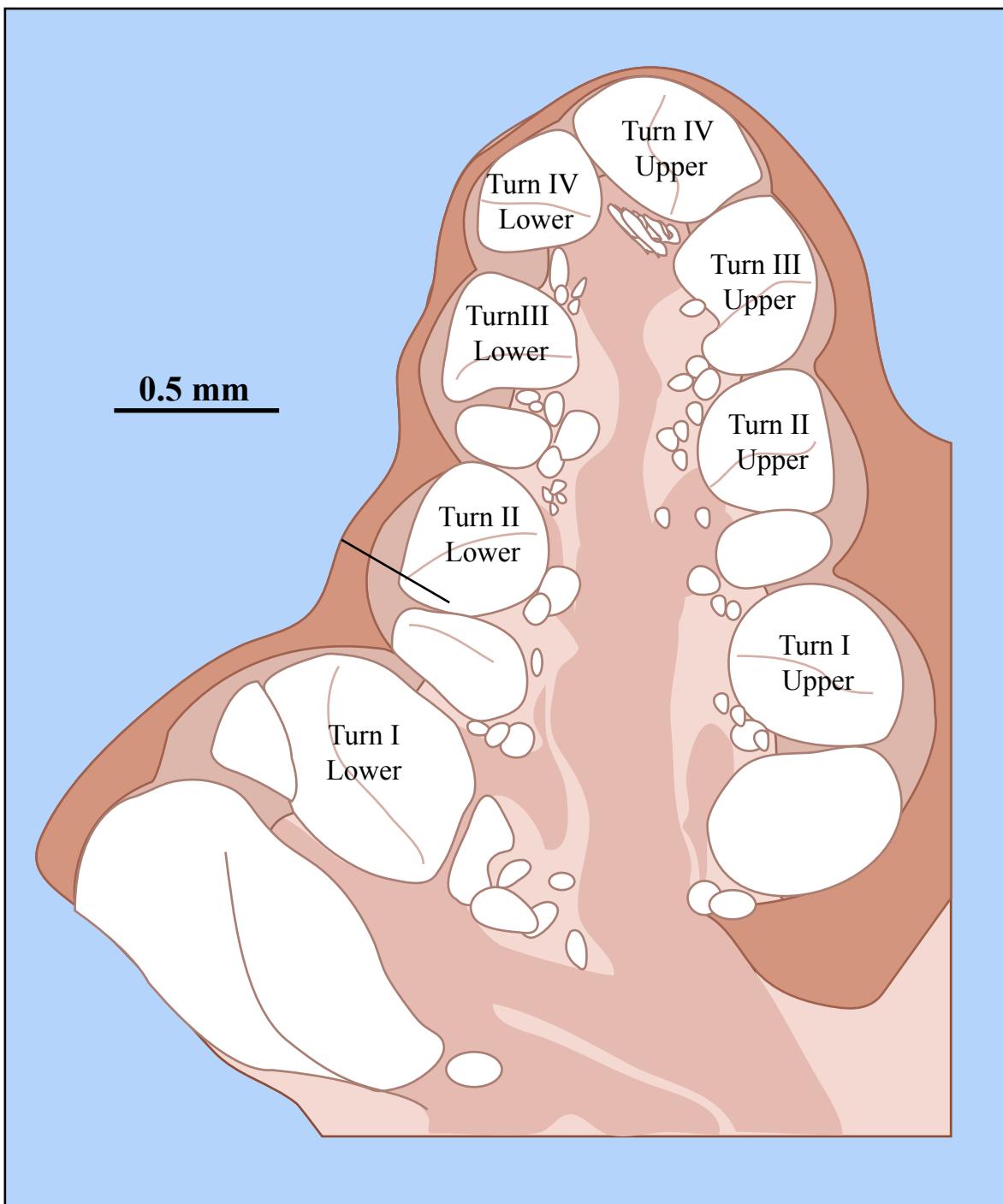
Due Date: 10-03-2005

These problems sets are intended to help you integrate the material learned in HST721. You are required to turn in individually written solutions sets. You are encouraged to work through the problems individually before discussing them in small groups. If you do work through the problems in small groups please include the names of your group members at the beginning of your write-up. Please include appropriate citations if you find your answers in the literature.

Problem 1

Use the accompanying image of a section through the middle of guinea pig cochlea to estimate the volume of scala media. Express your answer in mm^3 and show your work. Hint: Use the 3-D viewer of the human temporal bone to help you visualize how this single section must relate to the entire spiraling cochlear duct (remembering that the human cochlear spiral has three turns, whereas the guinea pig cochlear spiral has four turns.

To simplify the process, you may:
- consider each cross-section through the scala media to be a right triangle
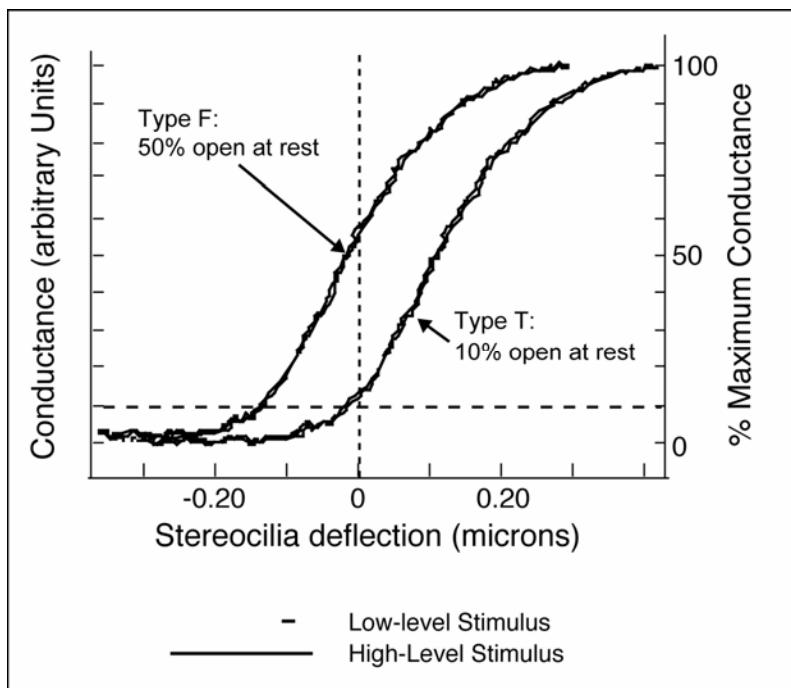- consider that each half turn (e.g. lower turn I to upper turn I) is a perfect semicircle

0.5 mm

Turn IV Upper

Turn IV Lower

Turn III Upper

TurnIII Lower

Turn II Upper

Turn II Lower

Turn I Upper

Turn I Lower

Image by MIT OCW.

Problem 2

a) Draw a schematic representation of a hair cell and its stereocilia bundle, indicating the hair cell type. Include all structures important for transduction.

b) Note on your drawing 1) the direction of stereocilia motion that produces a depolarization of the hair cell and 2) the location(s) of the transduction channels.

c) Provide estimates of the following: 1) hair-cell length, 2) height of the tallest stereocilia, 3) resting potential inside the cell, outside the cell near its apical (stereociliary) end and outside the cell near the synaptic end, and 4) Na^+ and K^+ concentrations inside the cell, outside the cell near its apical (stereociliary) end and outside the cell near the synaptic end.

d) Using the Nernst equation, compute the equilibrium potentials for K^+ and Na^+ across the basolateral hair cell membrane. What is an equilibrium potential? Explain the significance of any differences you find between the equilibrium potentials for Na^+ and K^+, and the value of resting membrane potential for this cell you cited in part c).

e) Graph the relationship between stereocilia deflection and the "open probability" of the transduction channels. Label the axes, indicating clearly the rest position for the hair bundle and the magnitude of the deflections eliciting maximal response.

f) When the transduction channels open, which ions carry the bulk of the transduction current? Why?

Problem 3

The instantaneous relations between transduction-channel conductance (summed over all transduction channels) and displacement of stereocilia tips have been determined in two types of hair cells. The shape of the relation and the maximum summed conductance is identical in both, but the situation at rest differs as indicated. For one, type "T," 10% of the transduction channels are open at rest; for the other, type "F," 50% are open at rest. All other electrophysiological characteristics of the two cell types are identical. Assume that both are present in an inner-ear organ facing the same fluid compositions and presented with the same electrical potential difference between endolymph and perilymph.

The figure shows conductance plotted against stereocilia deflection:

Type F: 50% open at rest

Type T: 10% open at rest

X-axis: Stereocilia deflection (microns), ranging from -0.20 to 0.20

Y-axis (left): Conductance (arbitrary Units)

Y-axis (right): % Maximum Conductance, 0 to 100 (with 50 marked)

Legend:
- Low-level Stimulus (short dash)
- High-Level Stimulus (solid line)

a) What differences in cellular or molecular processes or structures might account for the difference in the proportion of transduction channels open at rest?

b) How would you expect the two cell types to differ in their resting intracellular potentials with respect to perilymph?

c) How would you expect their AC and DC intracellular electrical responses to low-level stimuli (magnitude indicated by short horizontal bar) to differ for 300-Hz stimuli? For 5000-Hz stimuli?

d) How would you expect their AC and DC intracellular electrical responses to high-level stimuli (magnitude indicated by long horizontal bar) to differ for 300-Hz stimuli? For 5000-Hz stimuli?

e) One of the these transducer types more closely approximates the situation in inner hair cells and the other in outer hair cells. Which is which, and why might these characteristics be well suited to the differing functional roles of these two cell types?