Hearing: Functional Anatomy of the Auditory System

• References:

The Physical Properties of the Sound Stimulus

• Sound Pressure Level (SPL)

\[
SPL = 20 \times \log_{10} \left( \frac{P_x}{P_{ref}} \right)
\]

, \( P_{ref} = 2.5 \times 10^{-5} \text{ N/m}^2 \) (approx. threshold of human hearing at 4KHz)
The Ear has Three Functional Parts

External Ear

Inner Ear

Middle Ear

NeuralProsthesis

The Inner Ear

• Cochlear consisting of Semicircular Canals
  • Slightly less than 3 turns
  • About 9 mm across
  • Embedded in temporal bone
• Canals - Scala Vestibuli
  - Scala Media
  - Scala Tympani
• Perilymph(s.t.and s.v.) and endolymph(s.m.)
• The Organ of Corti
  - Hair Cells
  - Supporting cells
• Membranes - Basilar membrane
  - Reissner ‘s membrane
  - Tectorial membrane
**Fluidic motion in cochlea**

- Acqueous perilymph is not compressible—stapes’ motion is to displace the s.v. fluid toward elastic cochlear partition.—this up-down motion increases pressure in s.t.

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**The Basilar Membrane**

- **A** (Stapes) (Helicotrema)
  - Broad, thin, floppy at apical end
  - Narrow, thick, taut at basal end
  - 5x breadth difference

- **B**
  - “panoply of strings that vary from the coarsest string on a bass viol to the finest string on a violin”
Motion of the Basilar Membrane

A

B

C

D

Place Code

• Demonstrated by Georg von Bekesy under stroboscopic illumination.
• Certain place of the membrane responds to certain frequency
• Traveling wave motion.
• Tonotopic Map
• Logarithmic relation
The Organ of the Corti

The Hair Cells
Hair cell as mechanoelectrical transducer

- 16000 hair cells and 30000 afferent fibers each side.
- Hair cells are also tonotopically mapped.
- This seeming redundancy is necessary for the traveling wave nature of the membrane selectivity.
- IHC 3500 cells in one row
- OHC 12000 cells in three rows
- Shearing motion is between the basal and tectorial membranes.
- Deflection is magnitude sensitive: Receptor potential as large as 25mV.
- Also direction sensitive: upward movement of basilar membrane leads to depolarization, while the opposite leads to hyperpolarization.
- Figure 30-7: V-shape tuning curves are obtained by measuring minimum acoustic stimulus for a receptor potential at 1mV.

The Mechanical Deflection of the Hair Bundle

A
B
C

Excitation

Resting

Inhibition
Mechanical Sensitivity of a Hair Cell

A

B

C

D

The Mechanism of Mechanoelectrical Transduction by Hair Cell
Innervation of Nerve Fibers

- Afferent: 90% in IHC.
- Each IHC has an avg of 10 axons while one axon innervates several OHC’s.
- Efferent: Most in the OHC’s. very sparse in IHC.
Responses

• Logarithmic relation of firing rate to sound pressure.
  (linear to sound pressure level in dB)
Sound Processing

- tonotopicity in cochlear nucleus.
- Spiral pattern is sustained in the 8th nerve, then is preserved in different pattern in the cochlear nucleus.

The Auditory Areas of the Temporal Cortex
Information pathway

- Sounds -> Tympanum -> Middle Ear -> Ossicles -> Basilar membrane -> Hair Cells -> Afferent Nerve -> Eighth cranial nerve -> Central Auditory Pathway -> Auditory Cortex -> Analyze -> Speech