Hearing:
Functional Anatomy of the Auditory System

•**References :**

– Eric R. Kandel et. al, "Principal of Neural Science", 4th edition, p590-624, 2000, McGraw Hill

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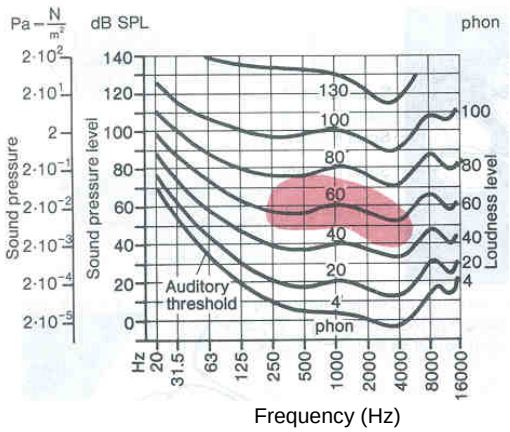
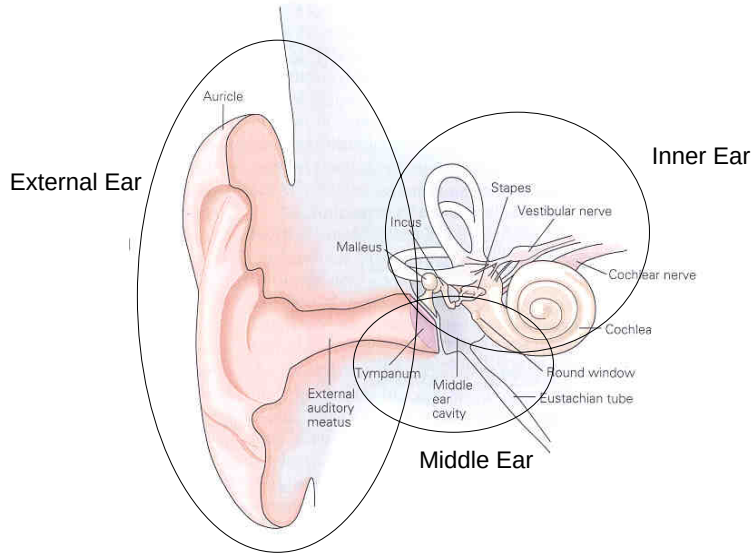
The Physical Properties of the Sound Stimulus

• Sound Pressure Level (SPL)

SPL = 20 x $\log_{10}$ (Px / Pref)
, Pref = 2.5 x 10^{-5} N/m^2
(approx.threshold of human hearing at 4KHz)



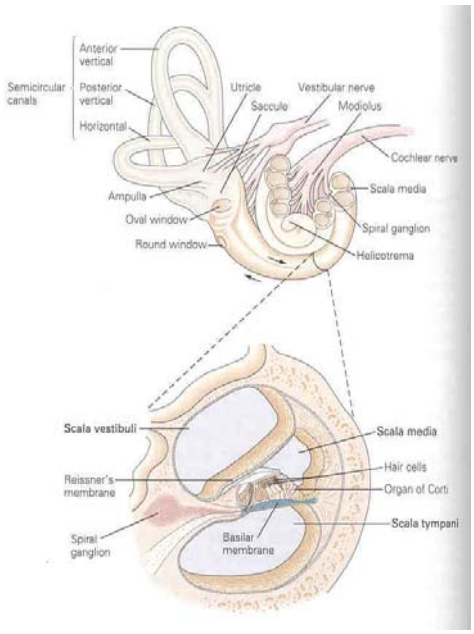
The Ear has Three Functional Parts



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

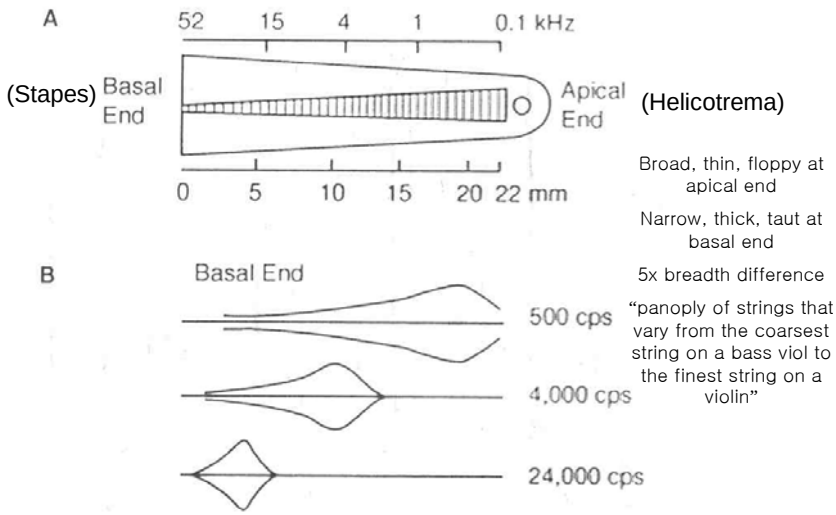


NeuralProsthesis

Fluidic motion in cochlea

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

The Basilar Membrane



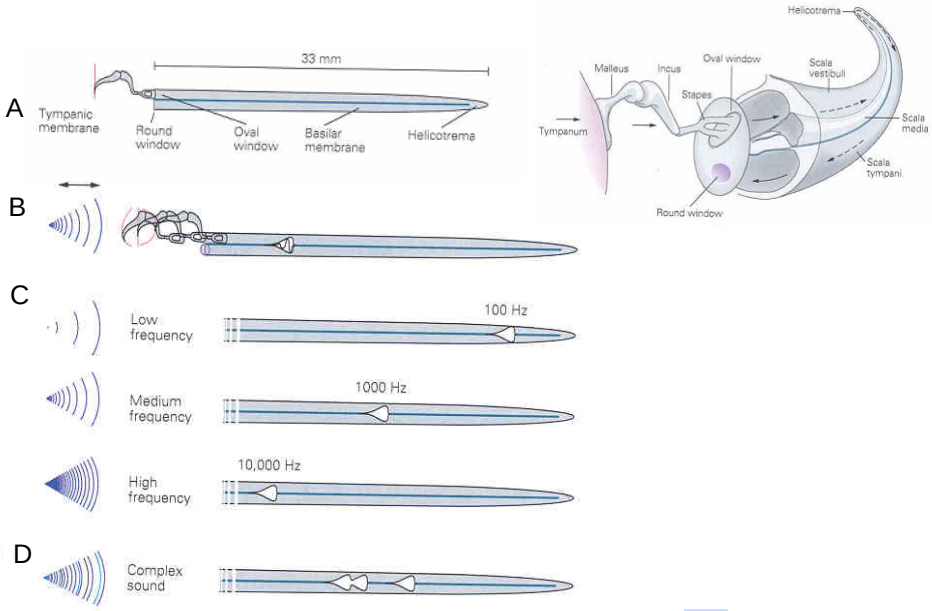
Broad, thin, floppy at apical end

Narrow, thick, taut at basal end

5x breadth difference

"panoply of strings that vary from the coarsest string on a bass viol to the finest string on a violin"

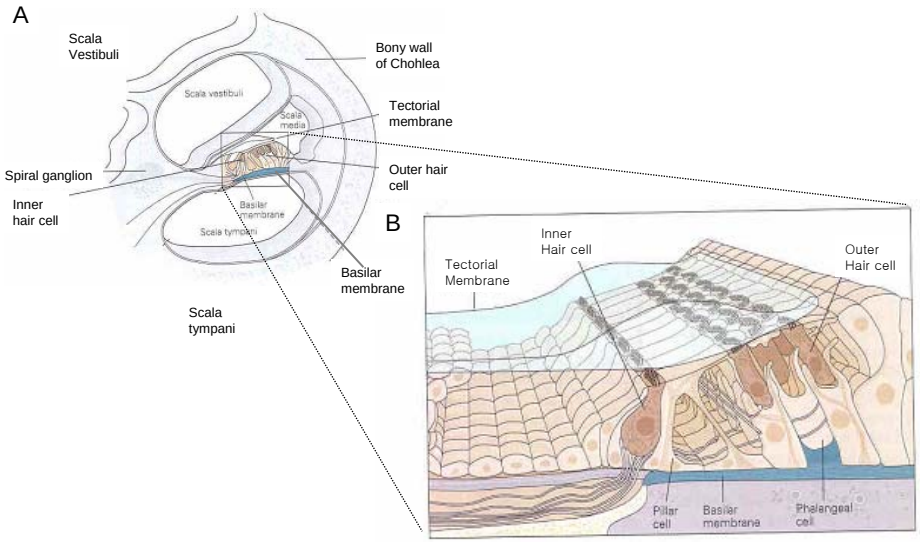
Motion of the Basilar Membrane



Place Code

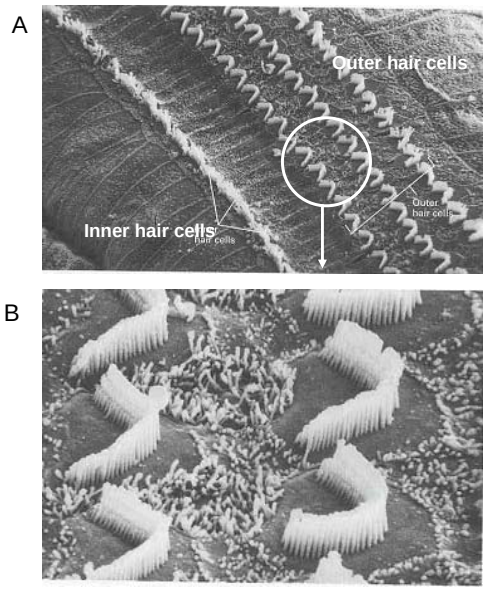
- Demonstrated by Georg von Bekesy under stroboscopic illumination.
- Certain place of the membrane responds to certain frequency
- Traveling wave motion.
- Tonotopic Map
- Logalithmic relation

The Organ of the Corti



NeuralProsthesis

The Hair Cells

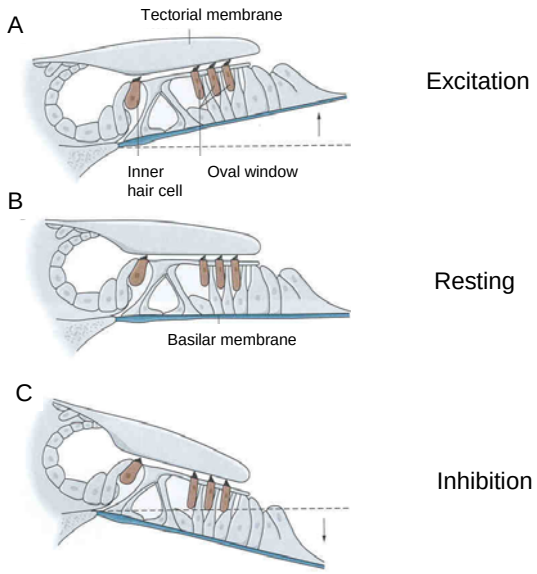


NeuralProsthesis

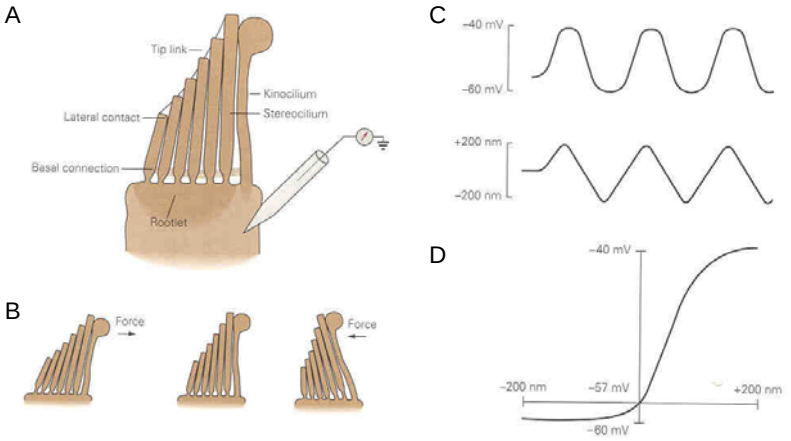
Hair cell as mechanoelectrical transducer

- 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.

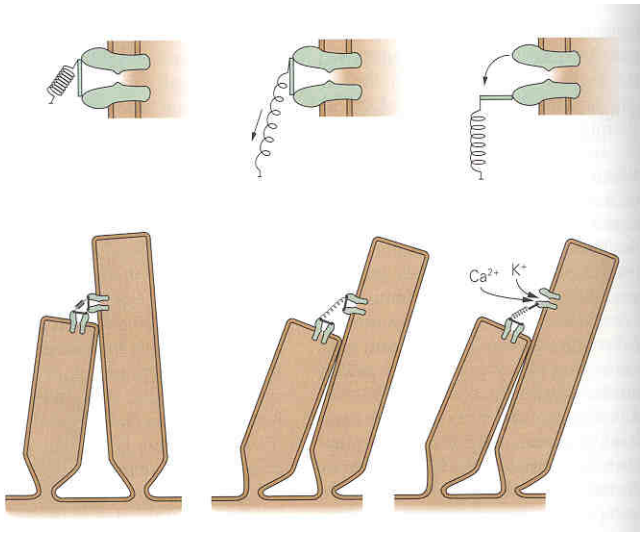
The Mechanical Deflection of the Hair Bundle



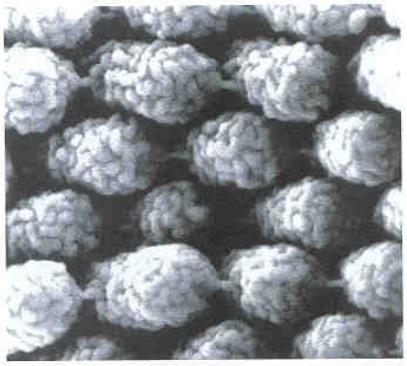
Mechanical Sensitivity of a Hair Cell

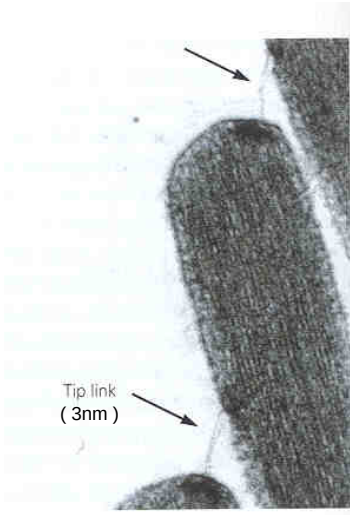


The Mechanism of Mechanoelectrical Transduction by Hair Cel



A Scanning Electron Micrograph of the Stereocilia





Innervation of Nerve Fibers

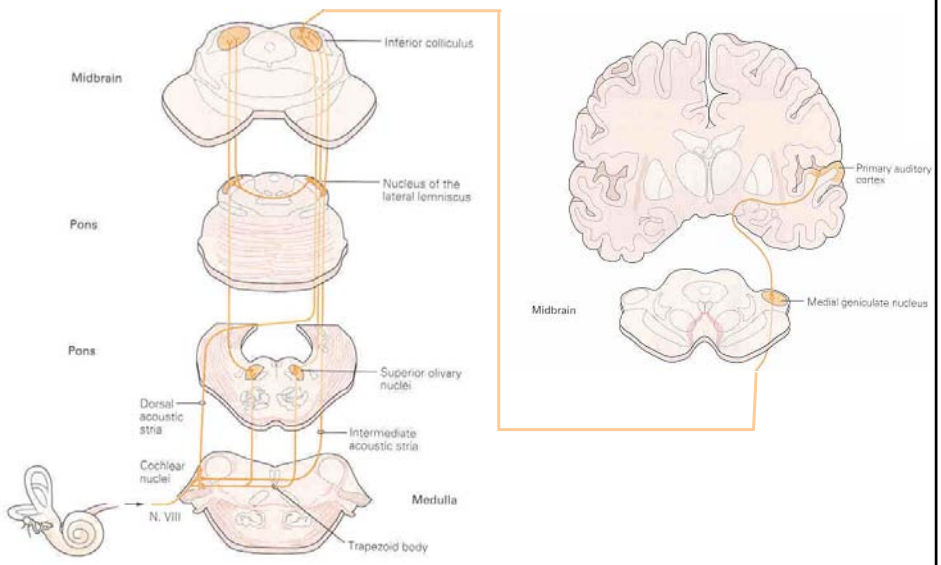
- Afferent: 90 % in IHC.
- Each IHC has an avg of 10 axons while one axon innervates several OHC's.
- Efferent: Most in the OHC's. very sparse in IHC.

Responses

- Logalithmic relation of firing rate to sound pressure. (linear to sound pressure level in dB)

NeuralProsthesis

The Central Auditory Pathway

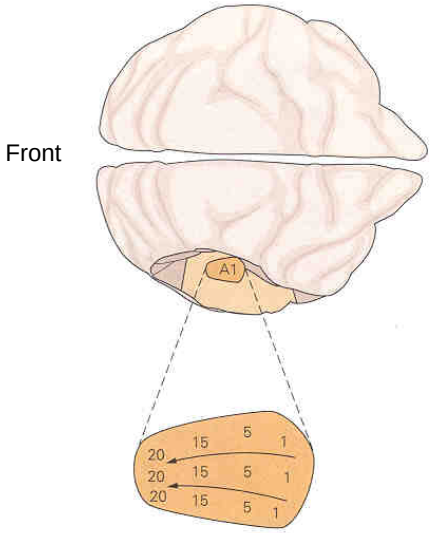


NeuralProsthesis

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