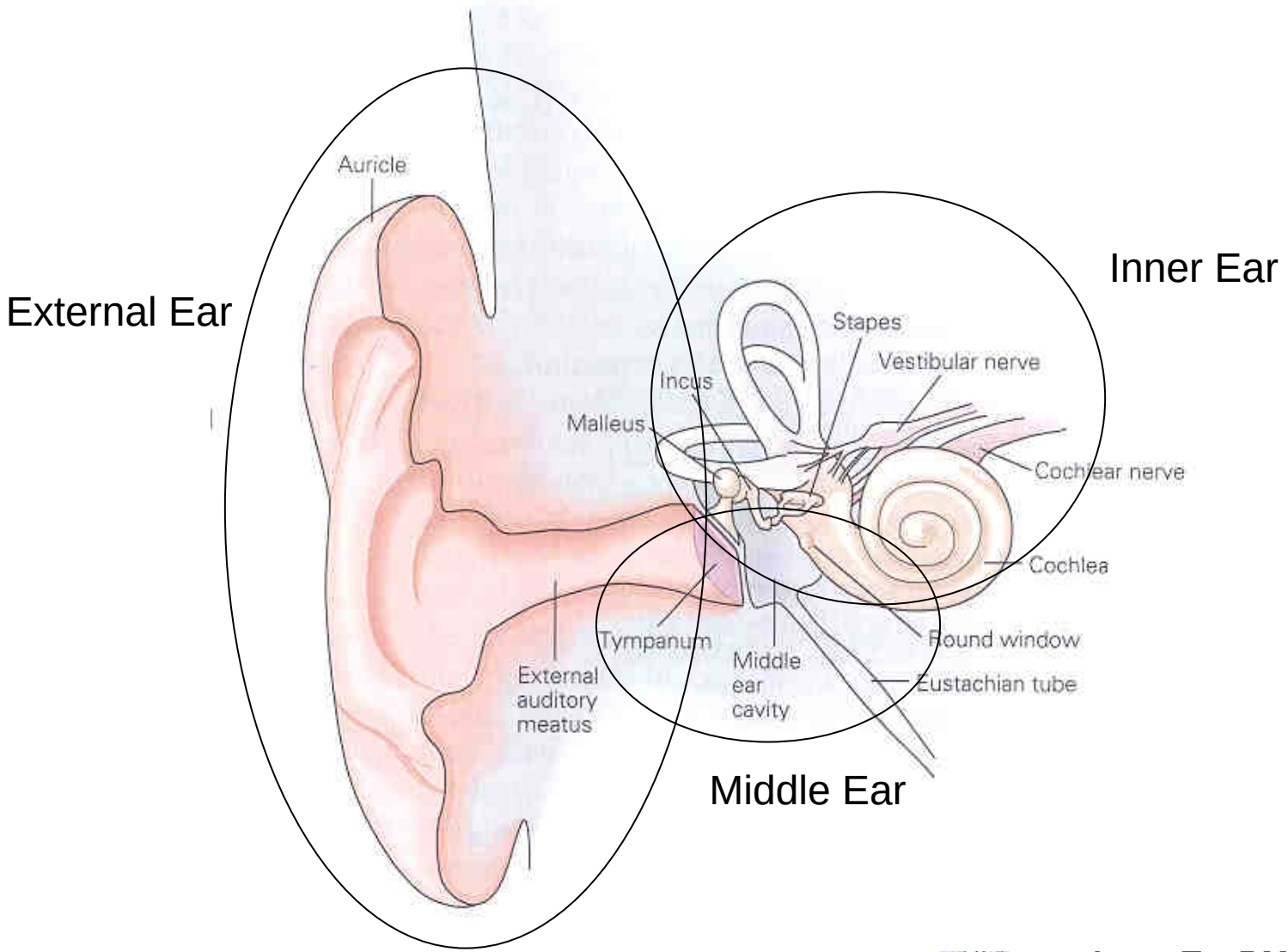
Biomedical Sensors appendix: Sensory Haircell as a natural transducer

Functional Anatomy of the Auditory System

•Reference :

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

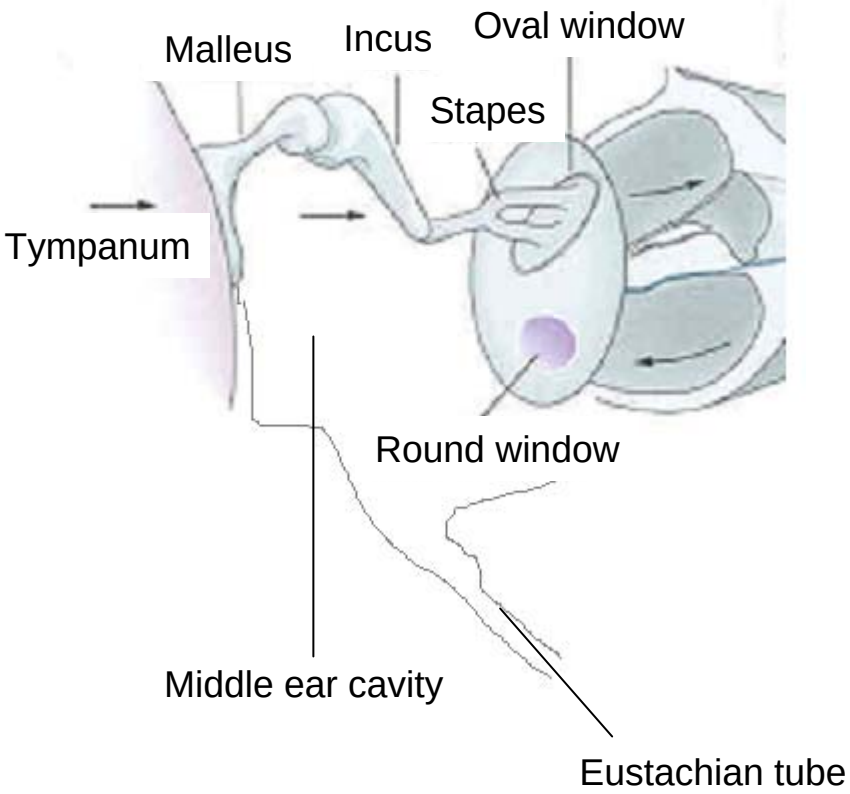
The Ear has Three Functional Parts



The Middle Ear

- The Middle Ear Cavity
- The Eustachian tube
- Ossicles
  - malleus(hammer)
  - incus(anvil)
  - stapes(stirrup)

The first two ossicles served as jaw in reptiles?

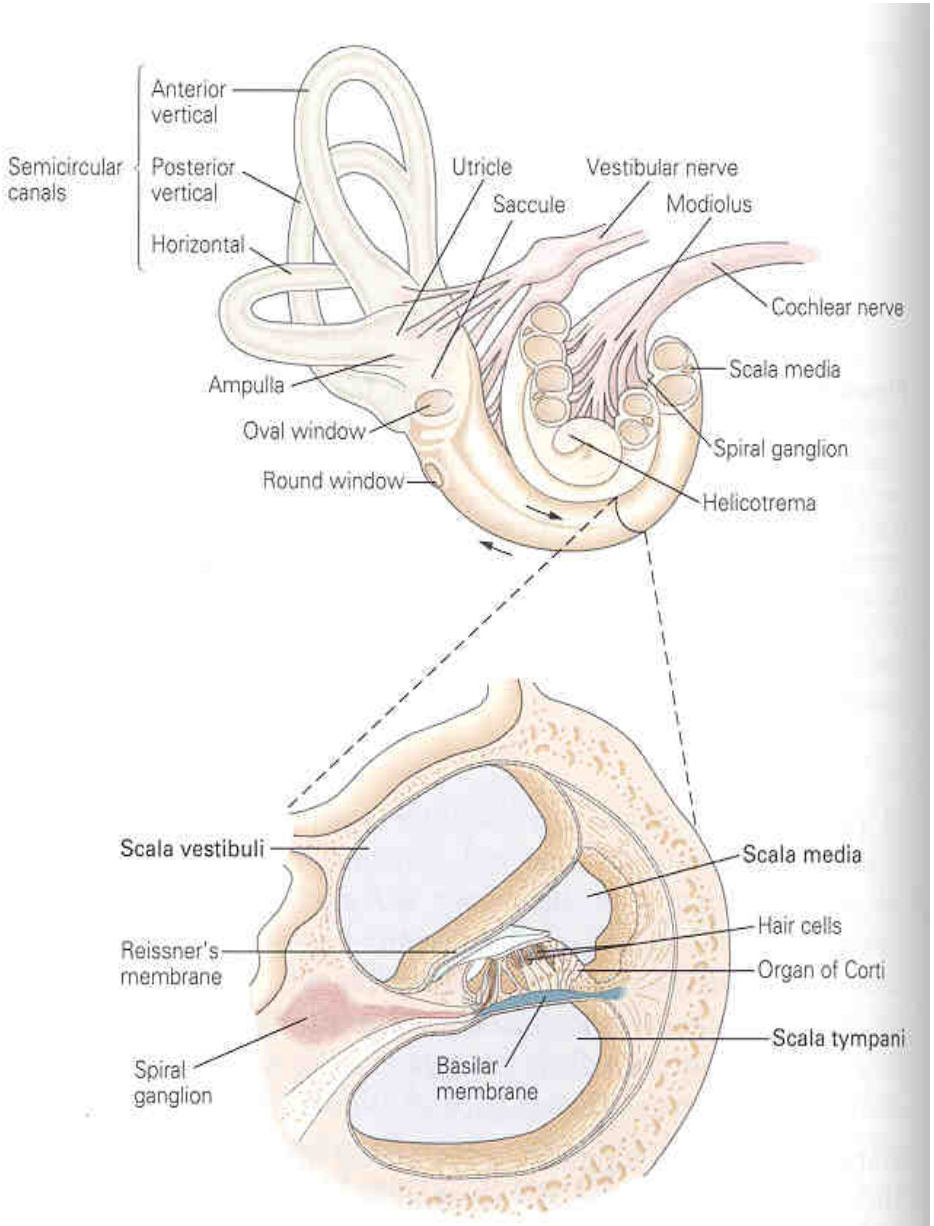


The Inner Ear

- 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

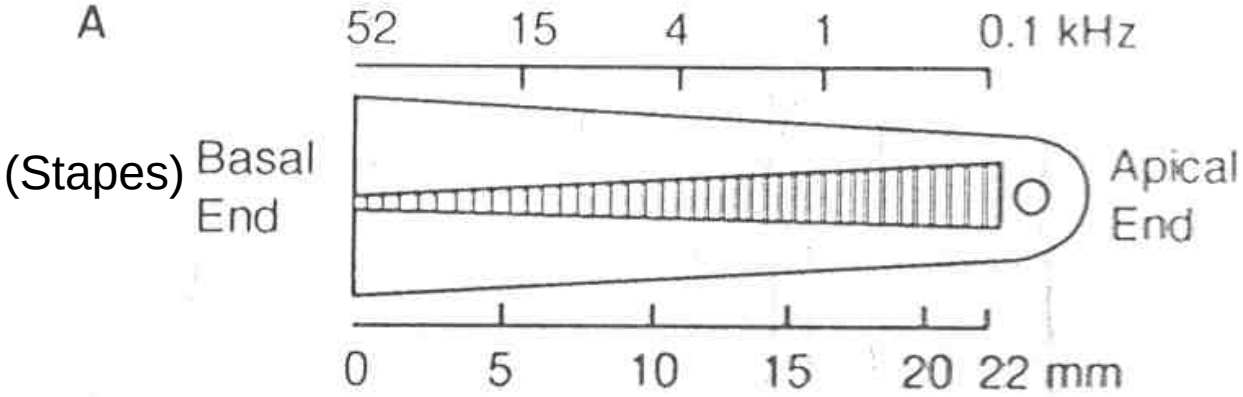
- Membranes - Basilar membrane
  - Reissner ‘s membrane
  - Tectorial membrane



Fluidic motion in cochlea

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

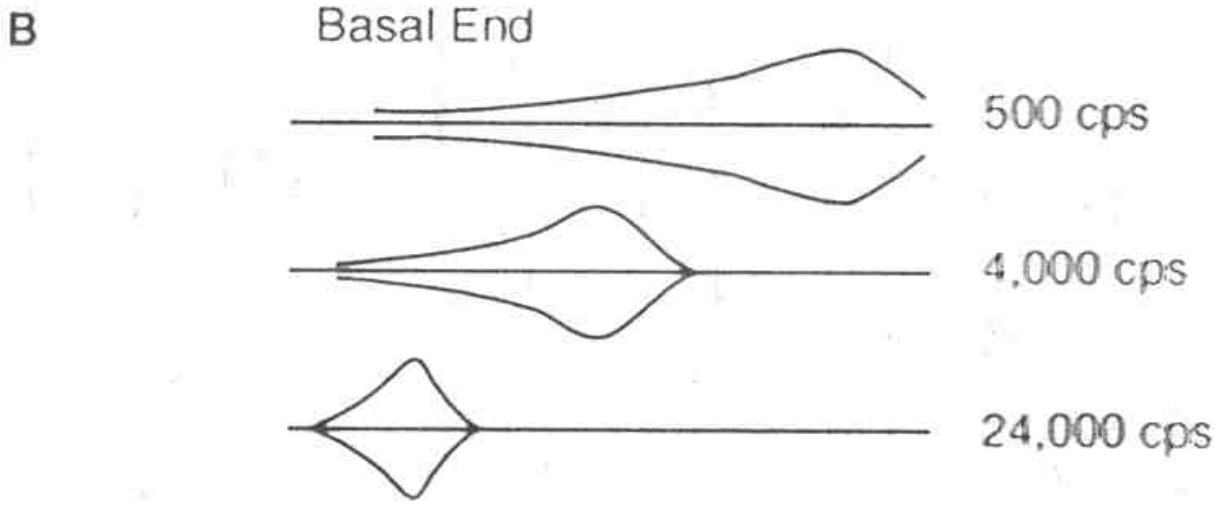
The Basilar Membrane



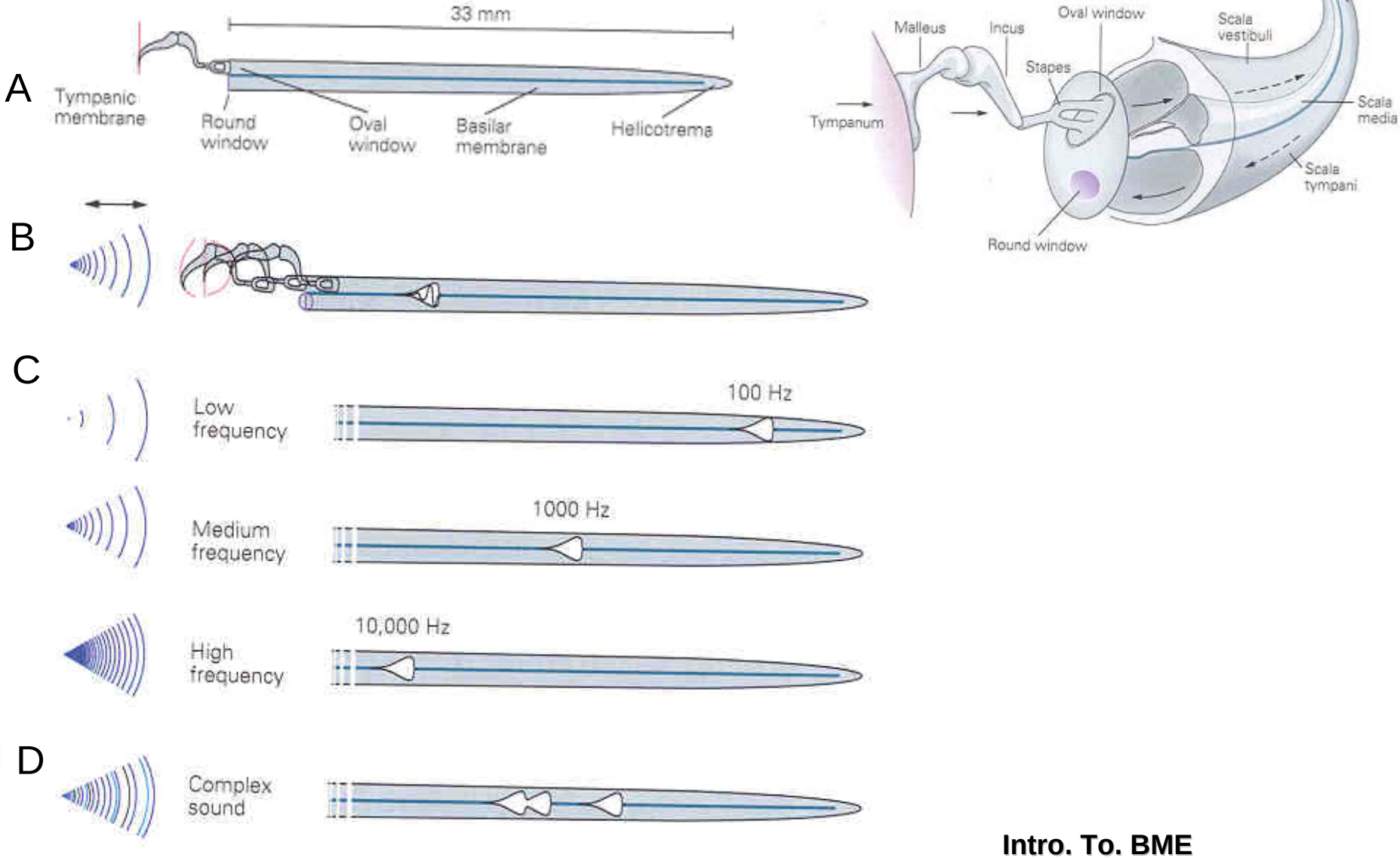
Thin, floppy apical end

Thick, tat basal end

5x breadth at base



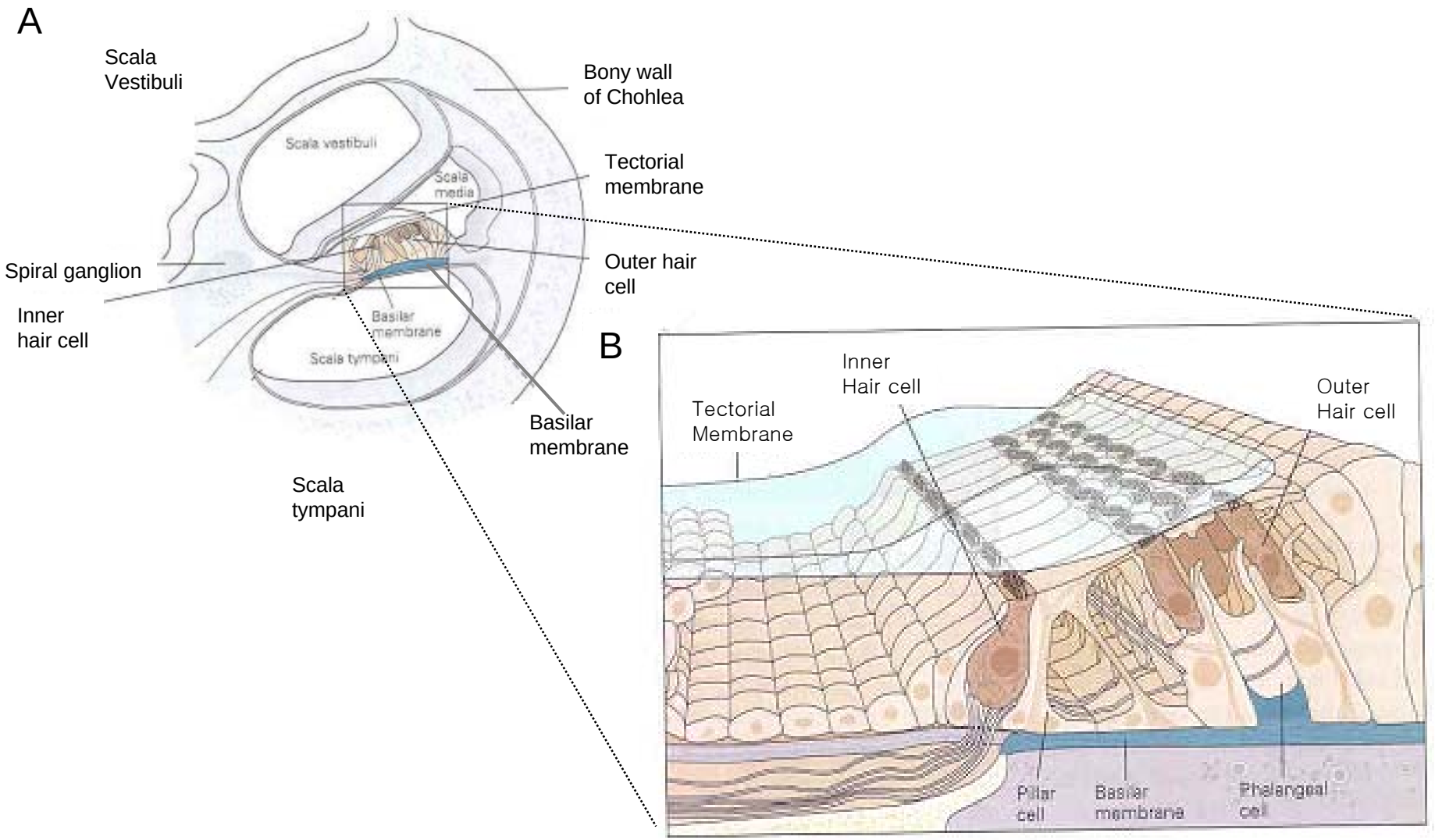
Motion of the Basilar Membrane



Place Code

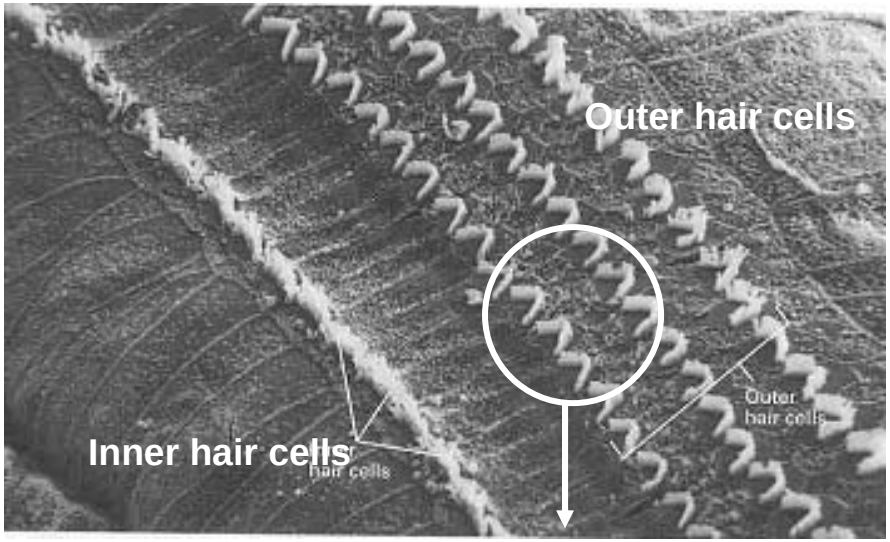
- Demonstrated by Georg von Bekesy under stroboscopic illumination.
- Certain place of the membrane responds to certain frequency
- Traveling wave motion.
- Tonotopic Map
- Logalithmic relation

The Organ of the Corti

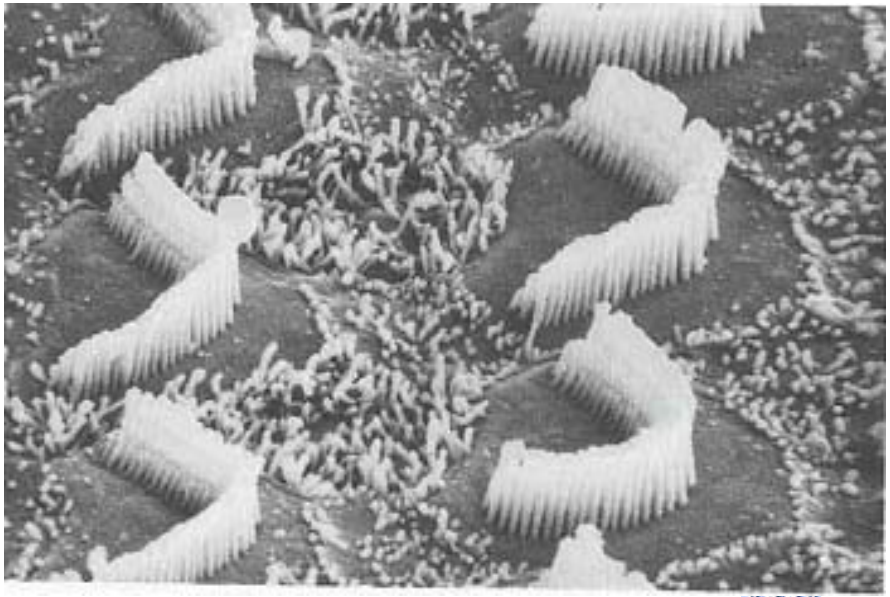


The Hair Cells

A



B

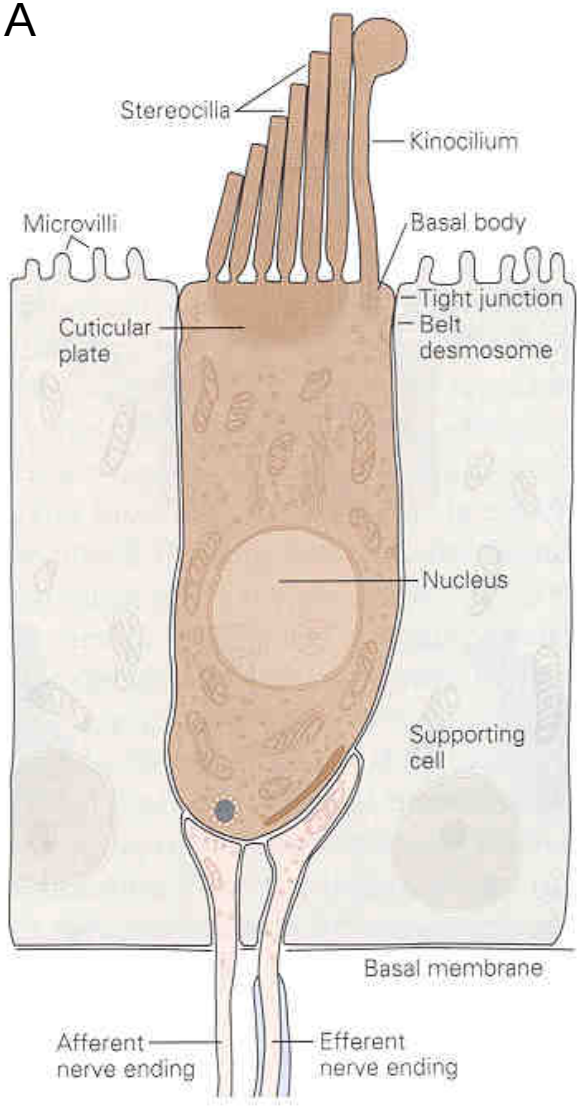


Hair cell as mechanoelectrical transducer

- 16000 hair cells and 30000 afferent fibers each side.
- Hair cells are also tonotopically mapped .
- This seemingly 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 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.

Structure of the Hair Cells

A



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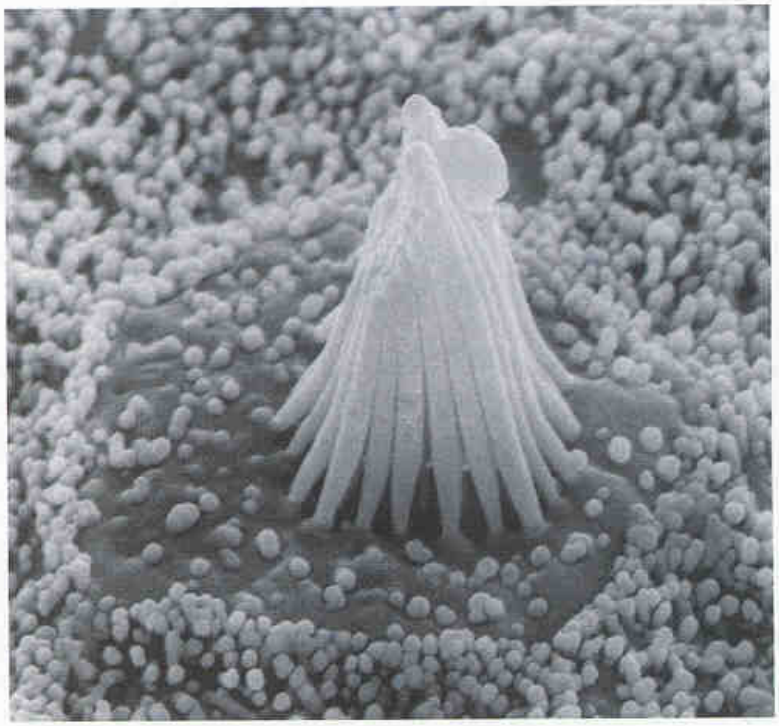
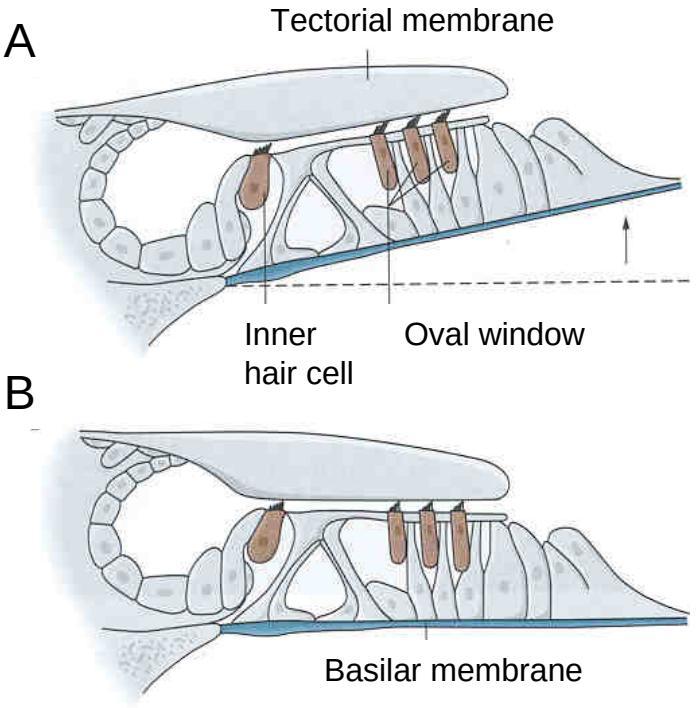


The Mechanical Deflection of the Hair Bundle

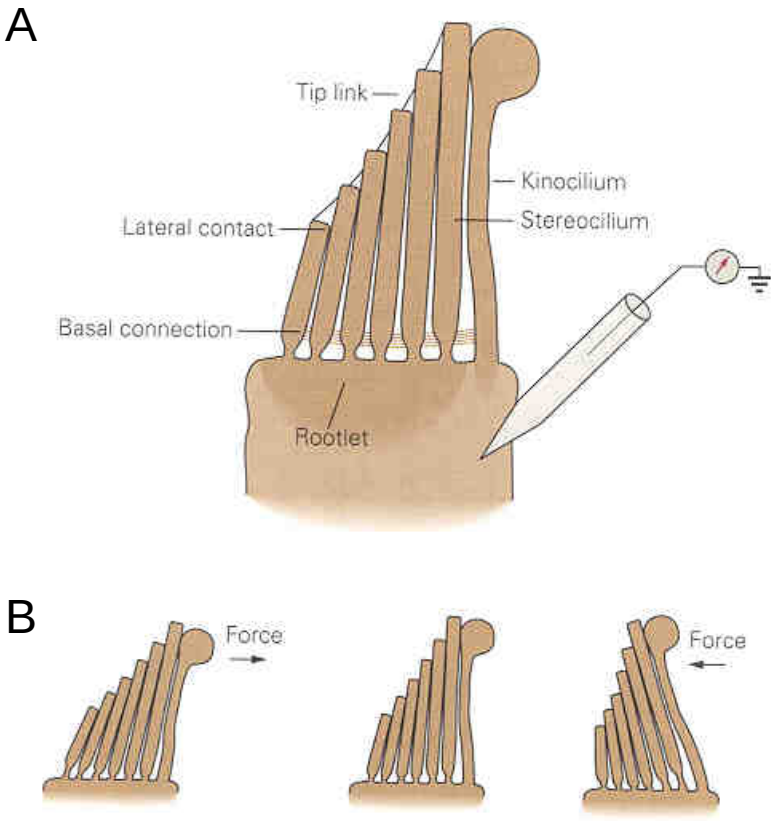


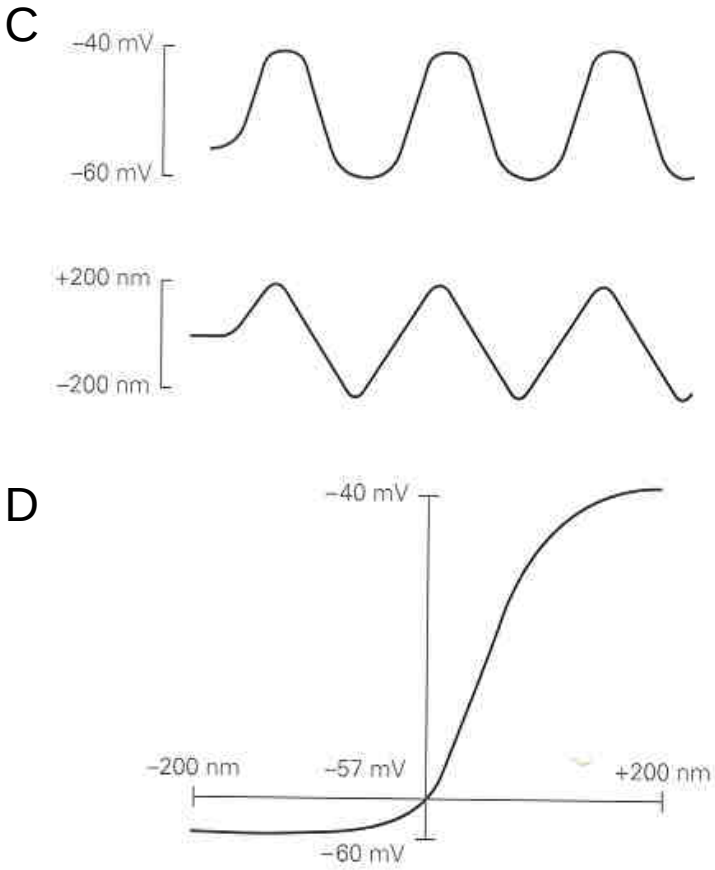
Excitation

Resting

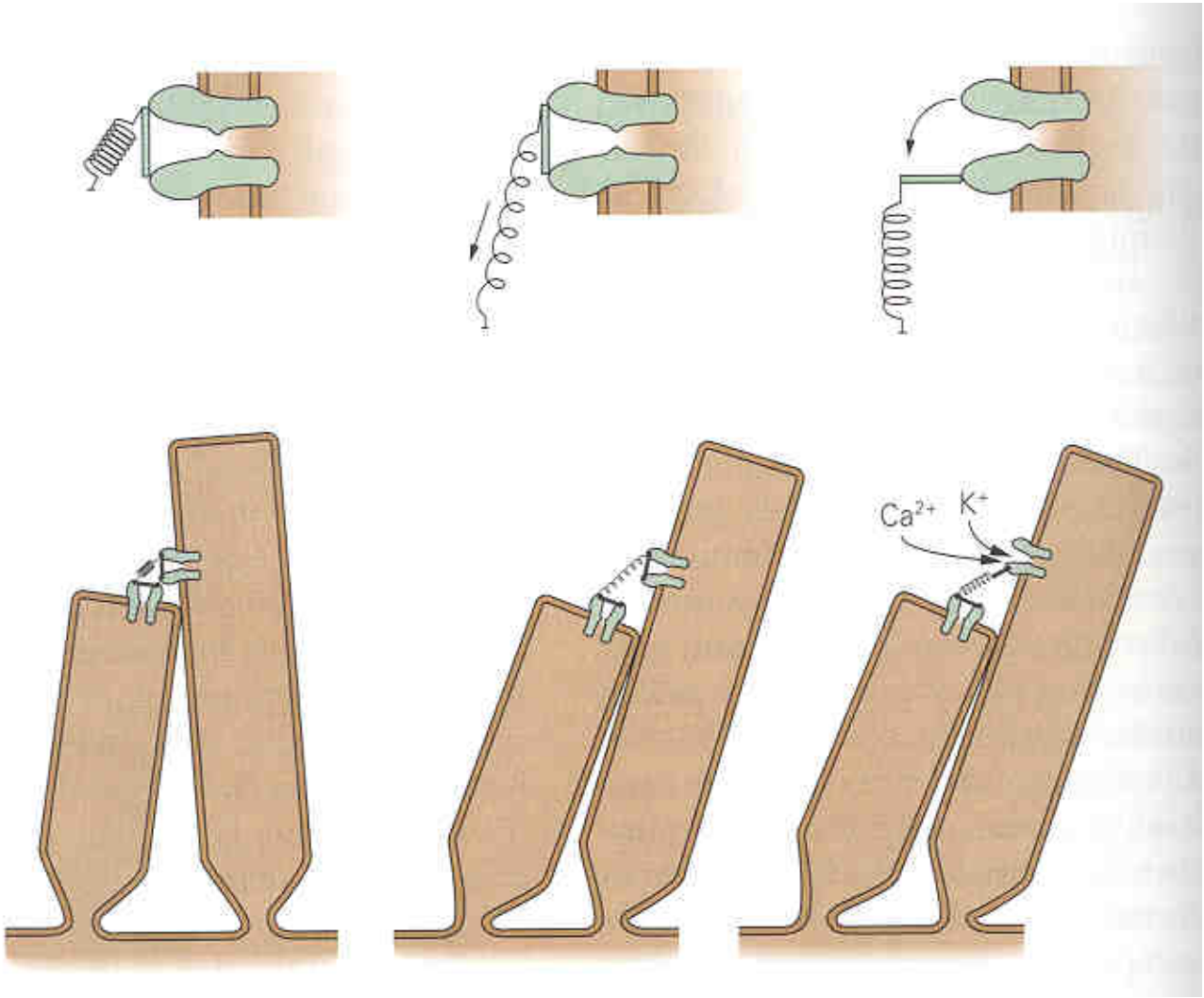
Inhibition

Mechanical Sensitivity of a Hair Cell

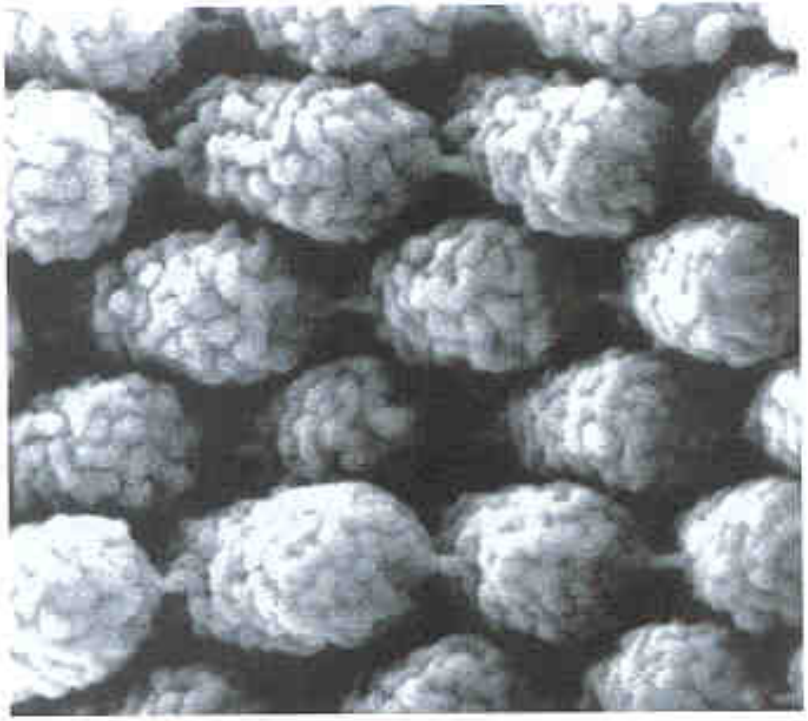


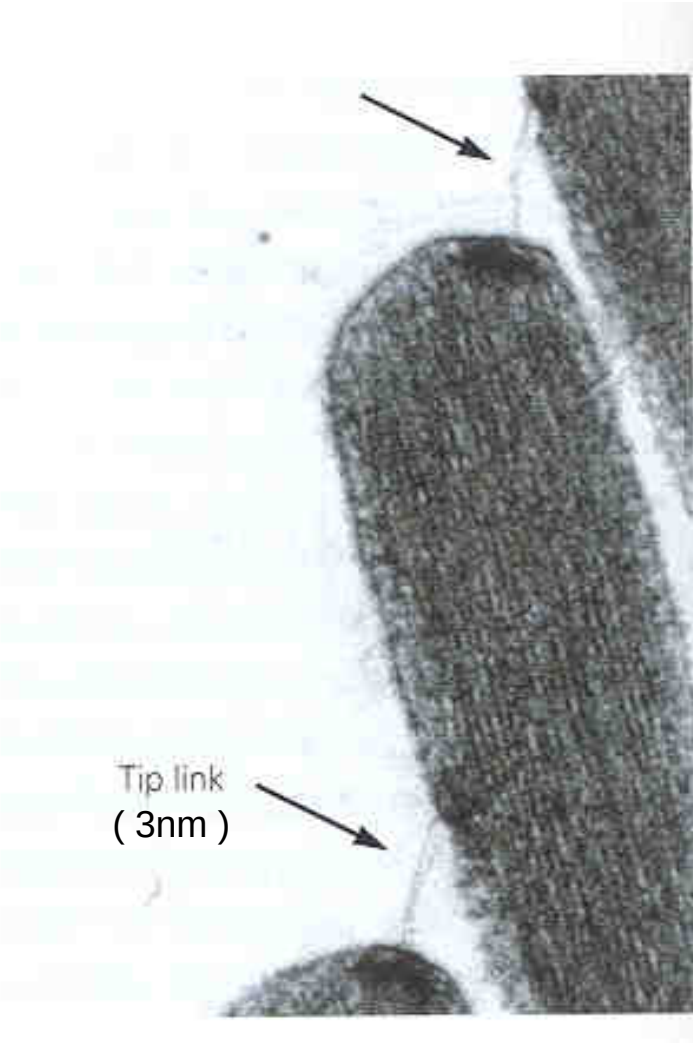


The Mechanism of Mechanoelectrical Transduction by Hair Cel



A Scanning Electron Micrograph of the Stereocilia





Outer Hair cell as Mechanical Amplifer

- The above operation seems too simple to explain the sensitivity and freq. Selectivity of sound perception.
- Being active is evidenced by non-linear membrane sensitivity to the input magnitude, evoked otoacoustical emissions, and spontaneous otoacoustical emission.
- Large population of efferent fibers at OHC.
- Motility of OHC gives mechanical amplification.

Innervation of Nerve Fibers

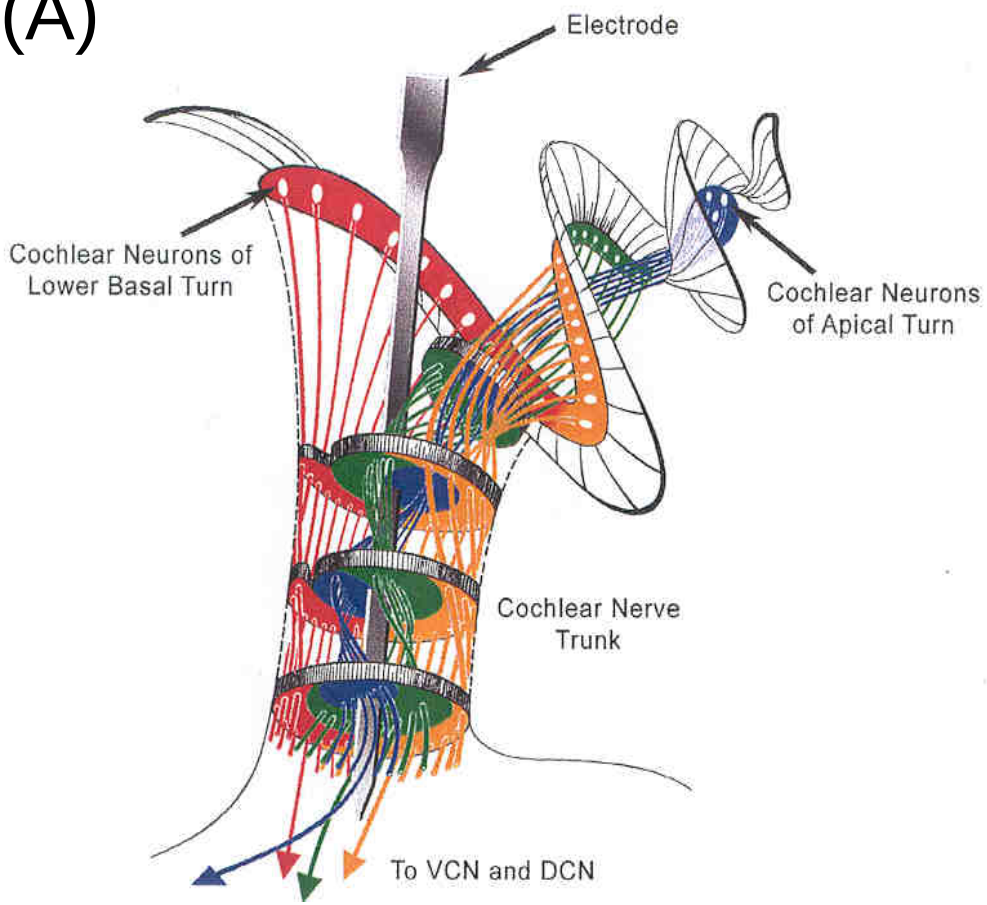
- Afferent: 90 % in IHC.
- Each IHC has an avg of 10 axons while one axon innervates several OHC’s.
- Efferent: Most in the OHC’s. very sparse in IHC.

Sound Processing

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

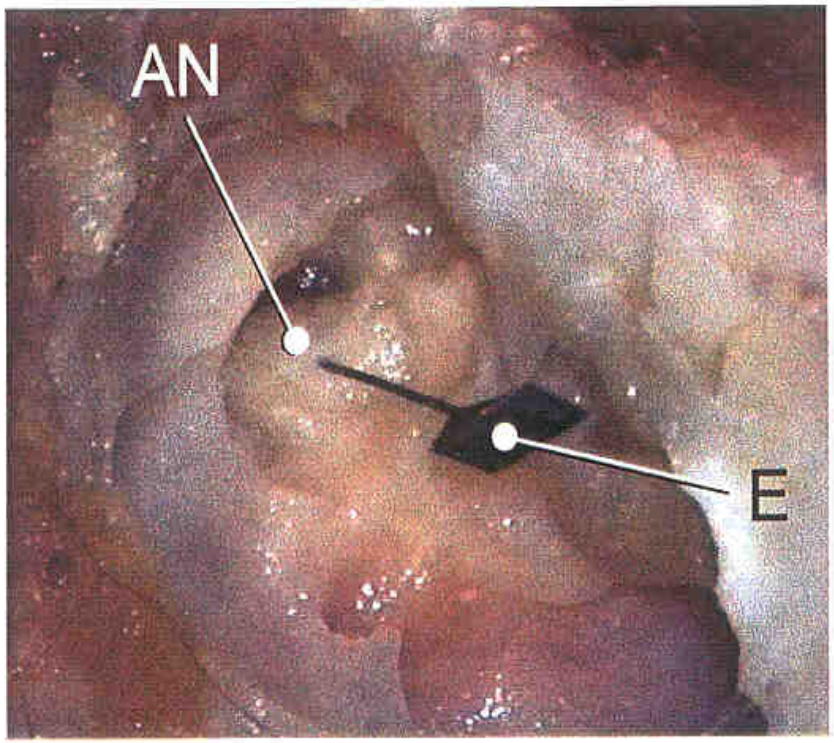
SNU Stimulating Electrode for Auditory Prosthesis

(A)



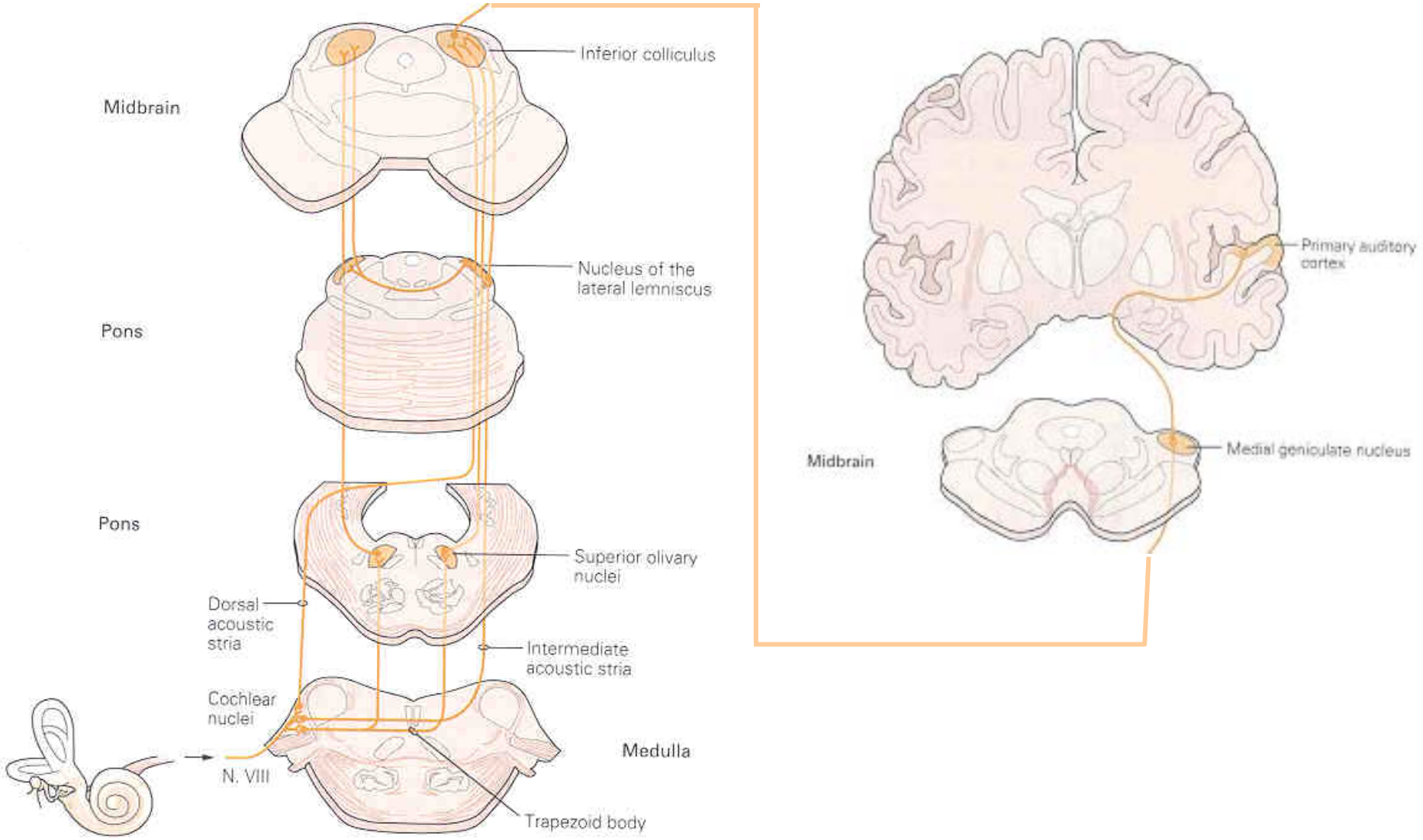
(A) A diagram of the spiralling of the auditory nerve fibers with an electrode array passing along the length of the nerve. The data based on the finding of Sando(1965).

(B)



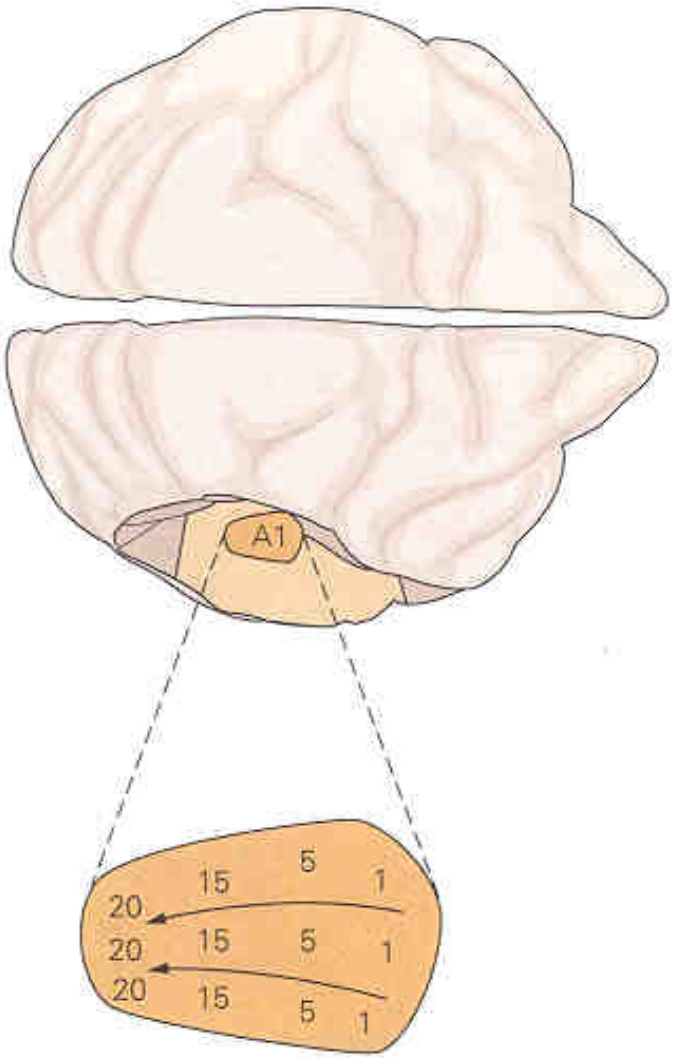
(B) The silicon electrode inserted into the cat cochlear nerve, but illustrating the need for adequate fixation and closure of the opening into the subarachnoid space. AN-auditory nerve ; E-depth type SNU silicon electrode

The Central Auditory Pathway



The Auditory Areas of the Temporal Cortex

Front



Information pathway

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