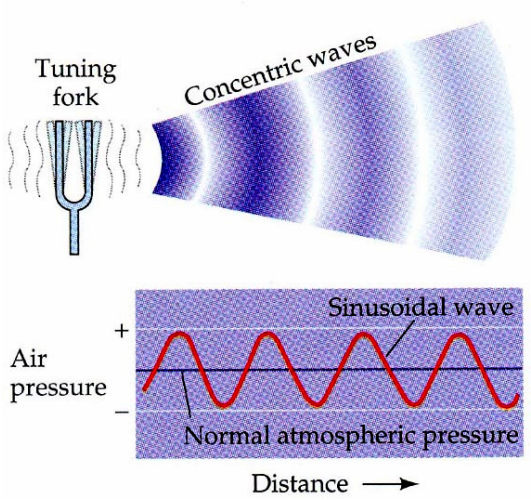
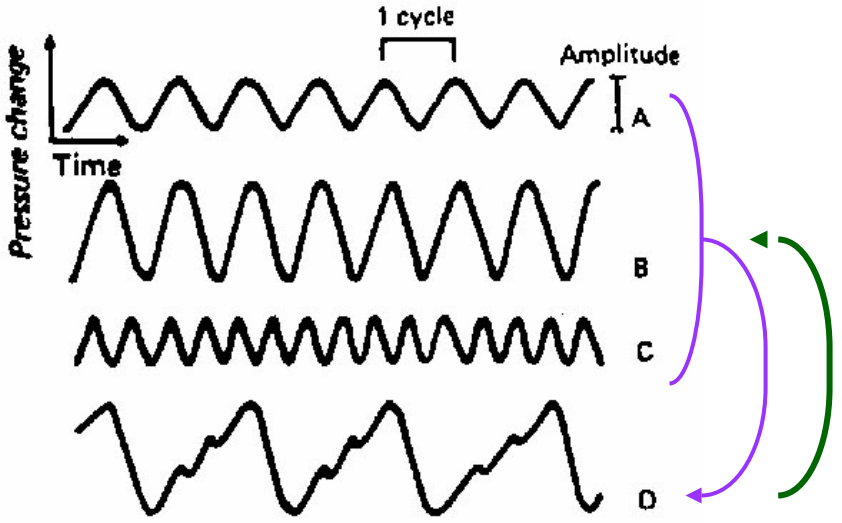
Auditory stimulus: Properties of the sound

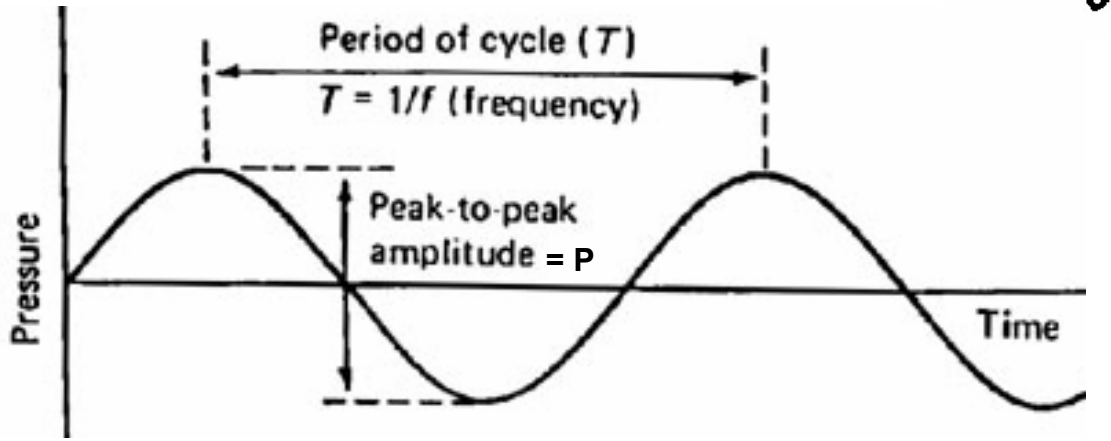


Complex sound waves: ***Timbre***



D = A+B+C

Fourier analysis



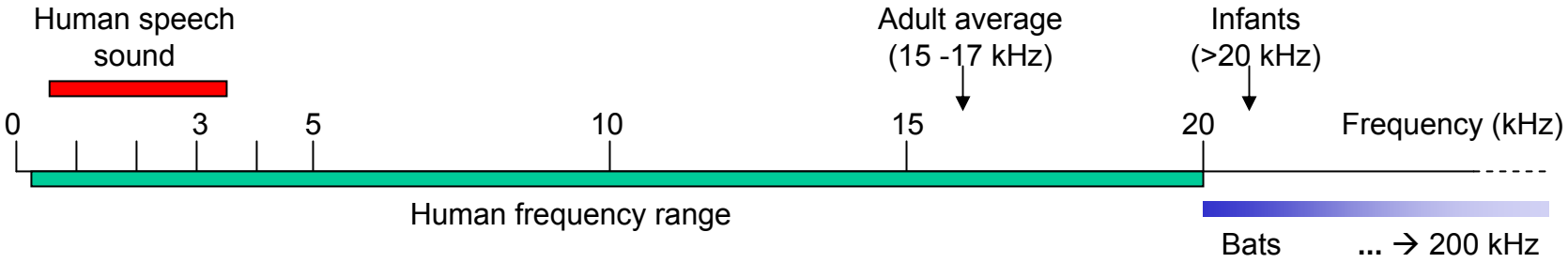
Frequency → cycles per second = Hertz

Amplitude → decibels
number of dB = 20 • log (P/P_0)

Modality ***Location*** ***Intensity*** ***Timing***

Auditory stimulus: The audible spectrum

Frequency spectrum



Amplitude range

Decibels

160 Jet plane

Pain

120 Discomfort

Subway, live rock music

80 Heavy traffic

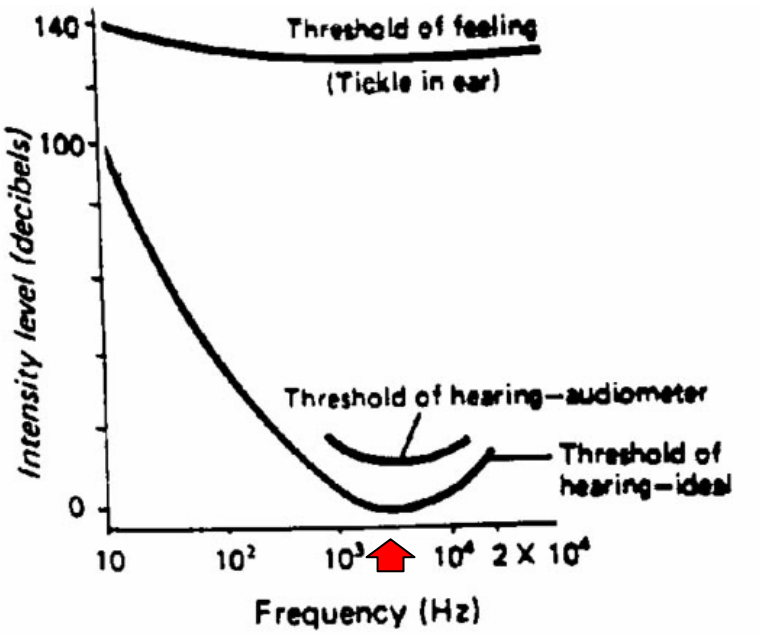
Normal conversation

40

Whisper

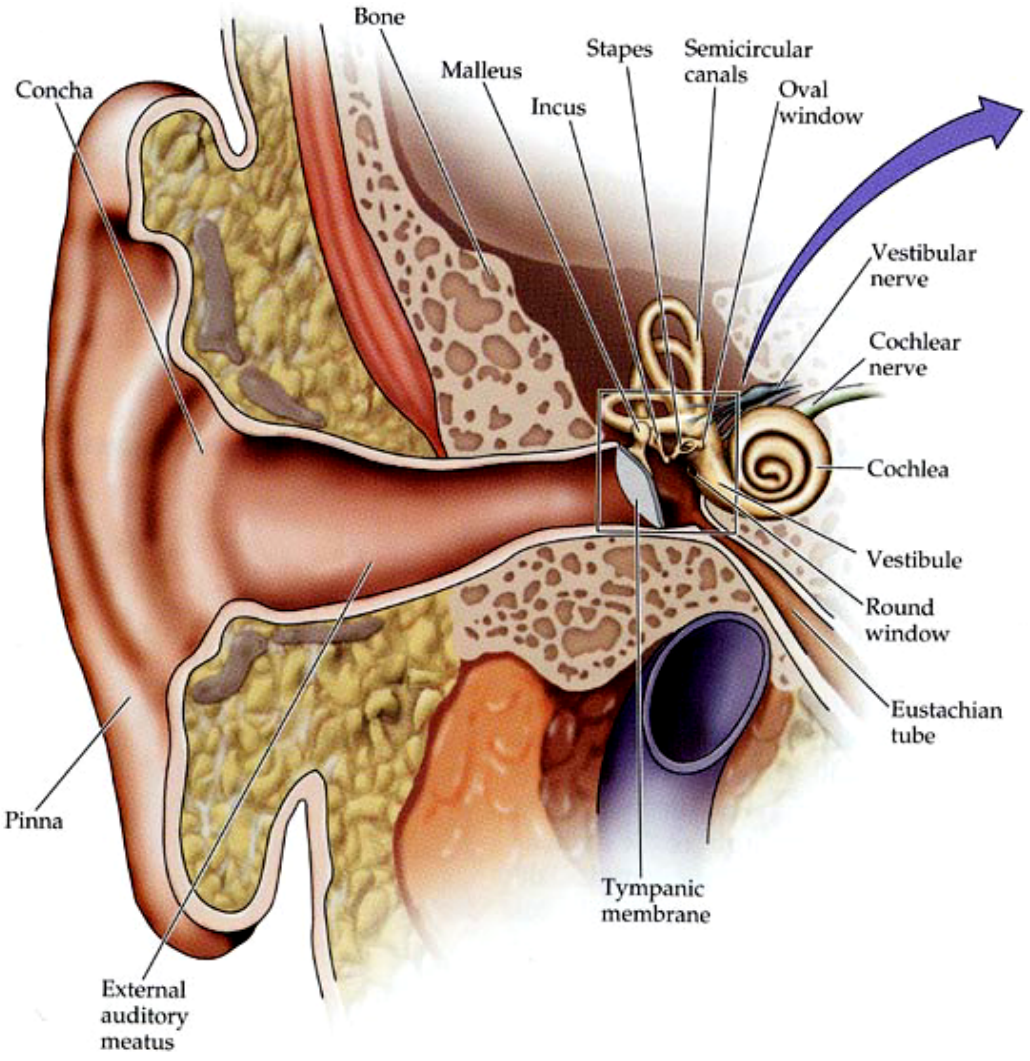
0 Threshold of hearing (0.0002 dyne/cm^2)

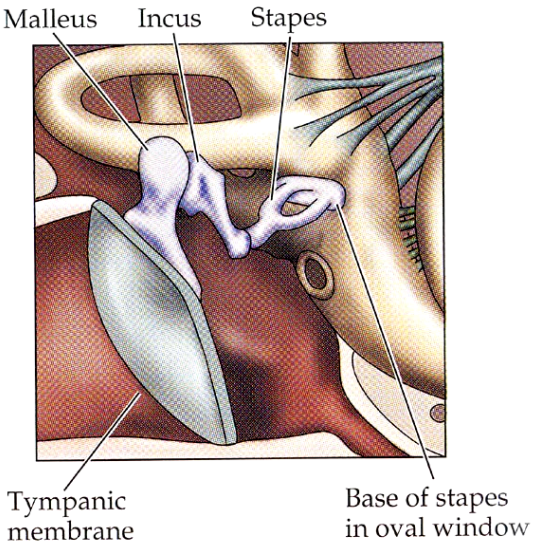
Audiogram



Modality **Location** **Intensity** **Timing**

Functional structure: External and middle ear





Middle ear: Impedance adjustment

1) Differences in membrane area:
   Tympanic membrane/Oval window = 17
   Pressure x 17

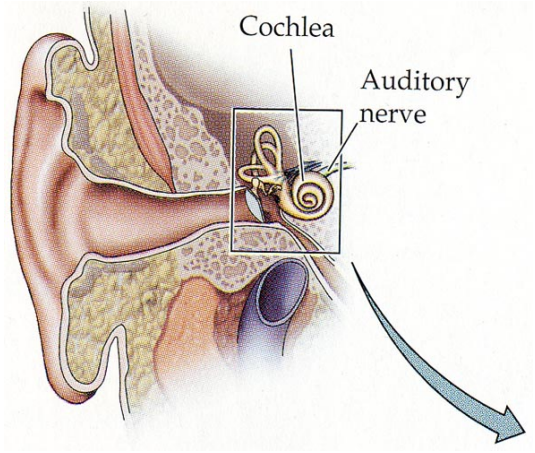
2) Lever action of ossicles:
   Force x 1.3

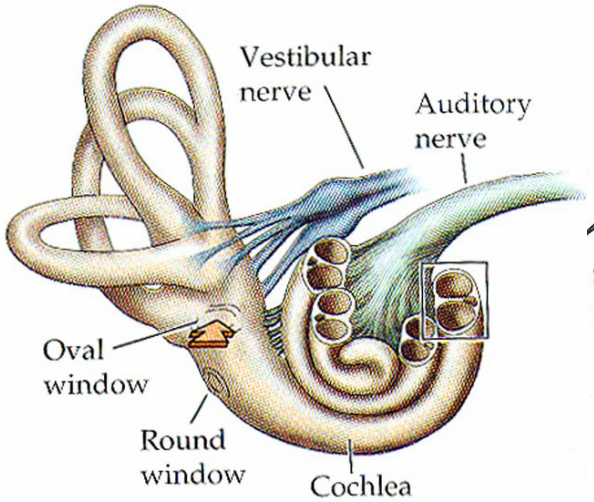
Transmission of sound energy across the air-fluid boundary

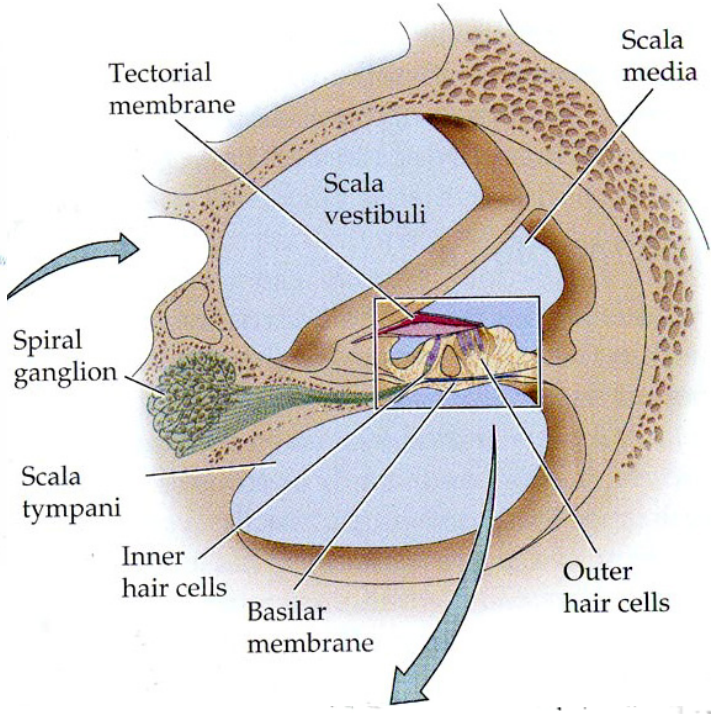
External ear: Amplification

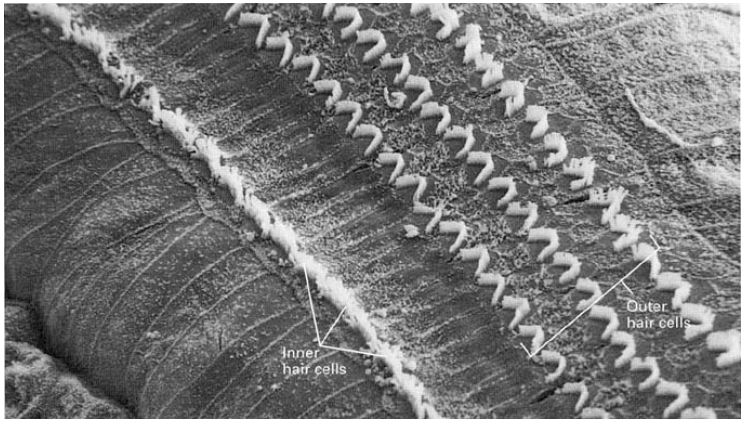
Sound pressure x30...x100 (around 3kHz)

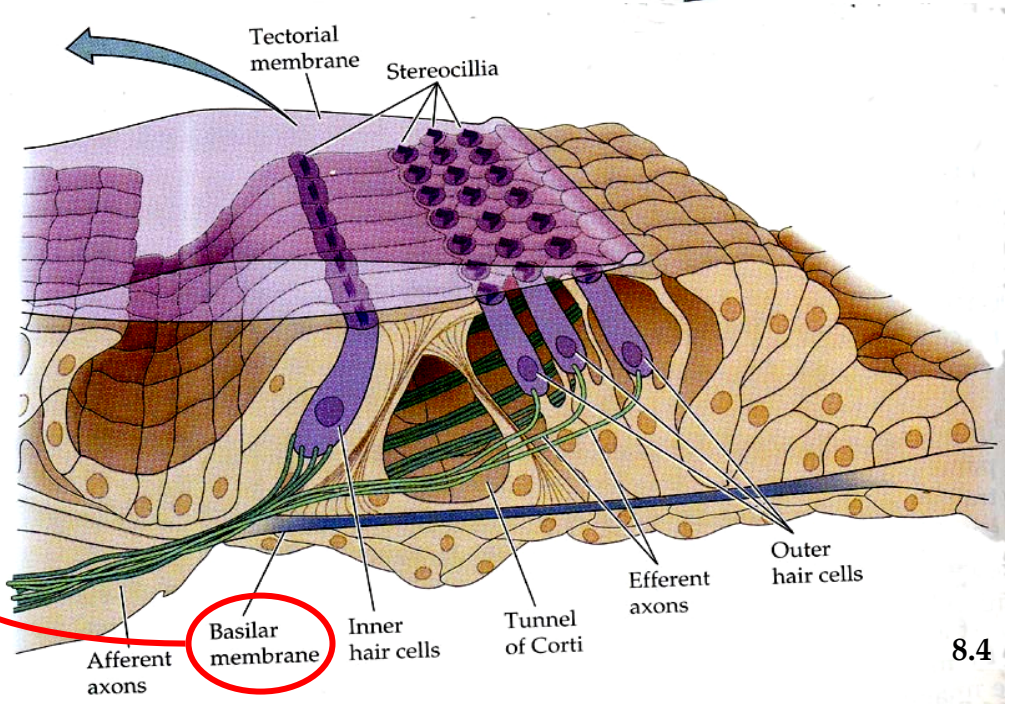
Functional structure: Inner ear







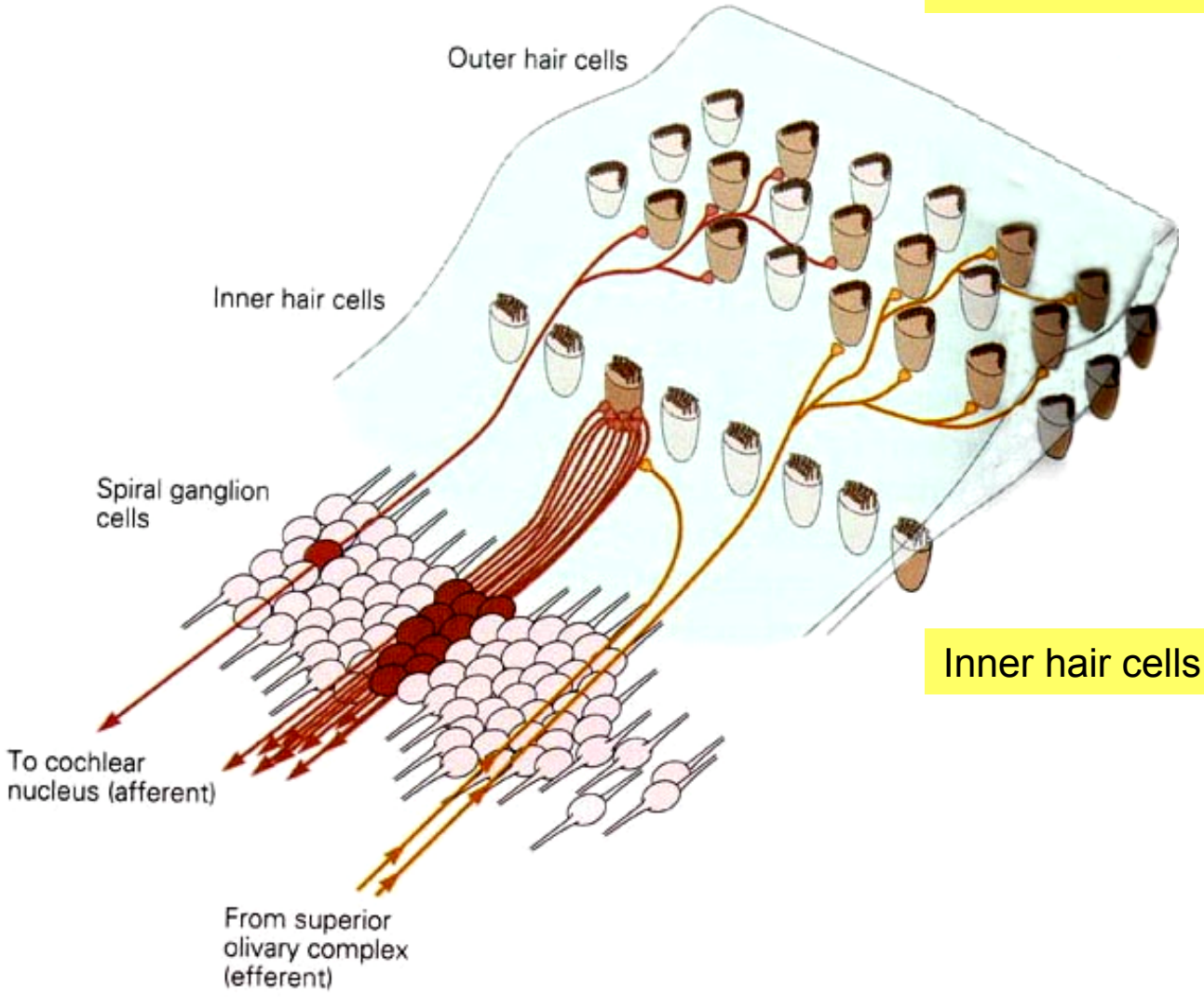




Topographic map of frequencies

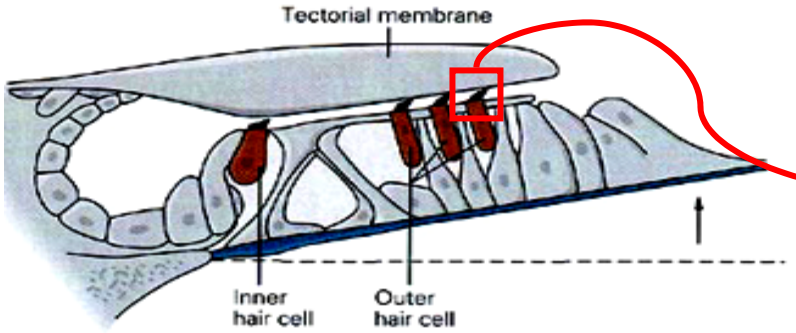
Functional structure: Innervation of hair cells

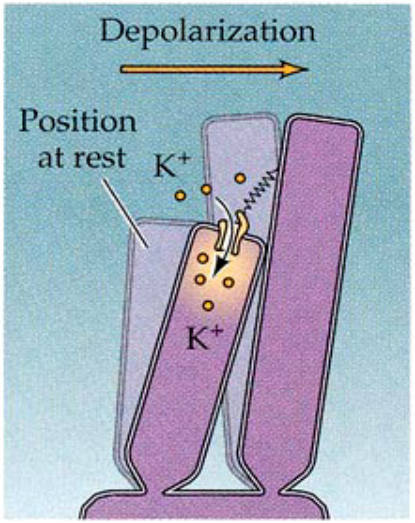
Outer hair cells → **electromotility: "cochlear amplifier"**

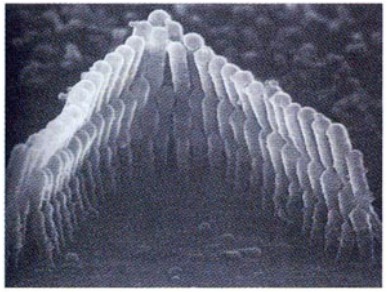


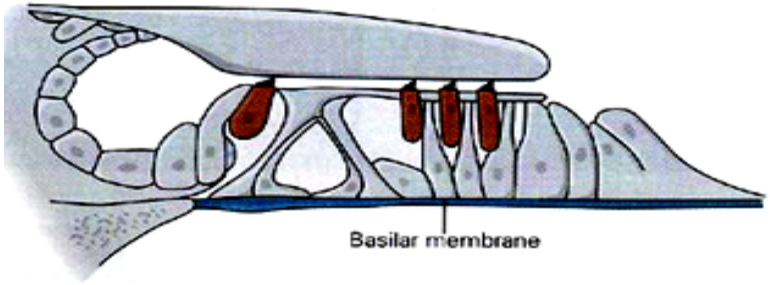
Inner hair cells → **sensory receptors**

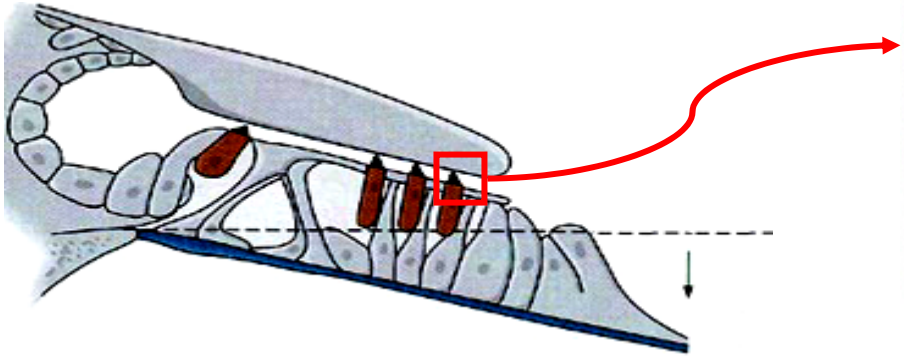
Mechanoelectrical transduction of sound waves in hair cells

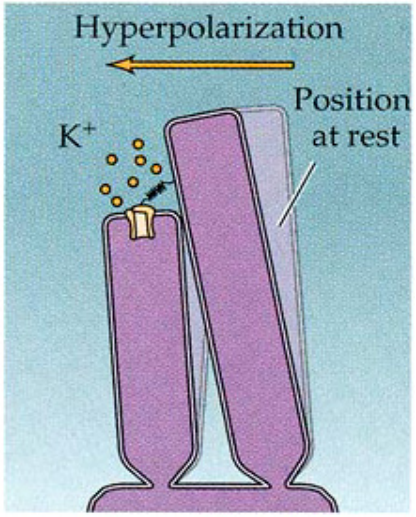




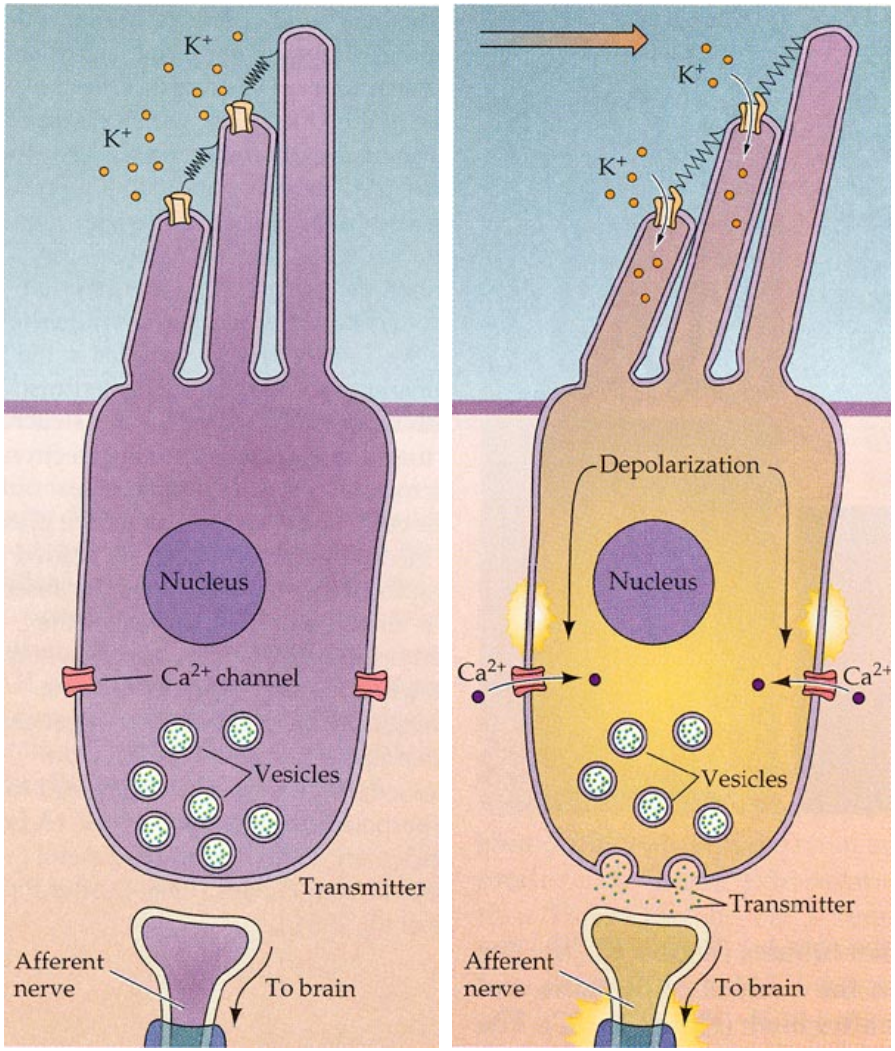


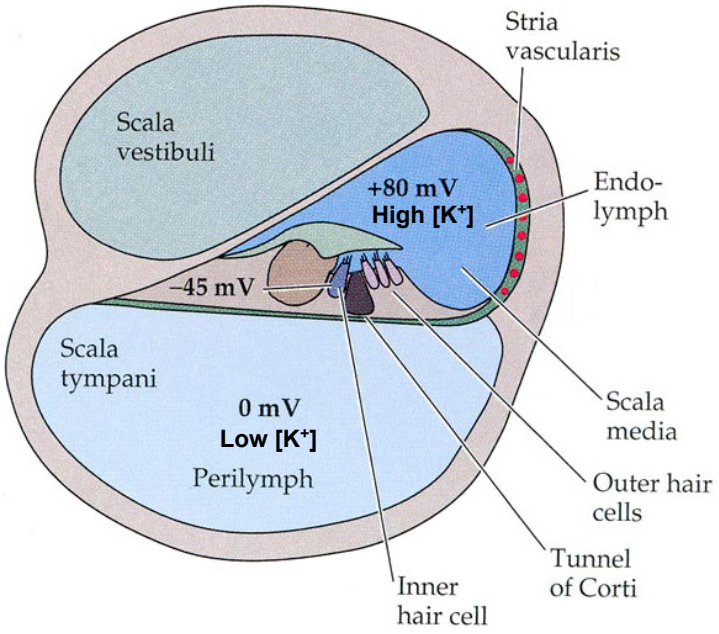






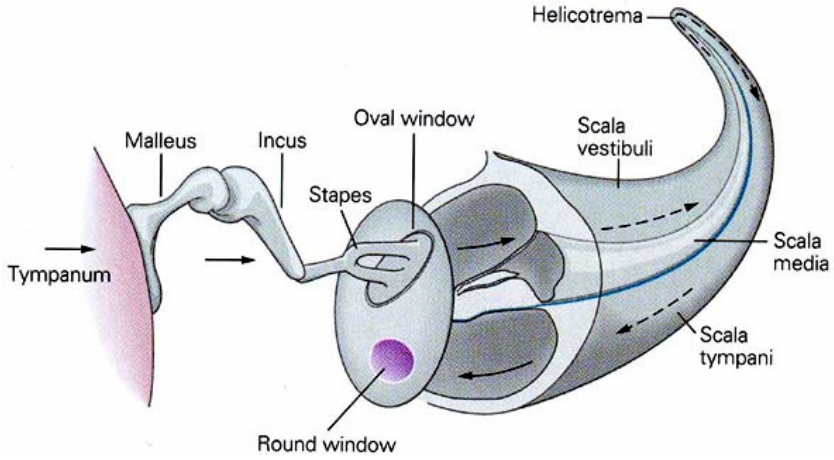
Mechanoelectrical transduction of sound waves in hair cells





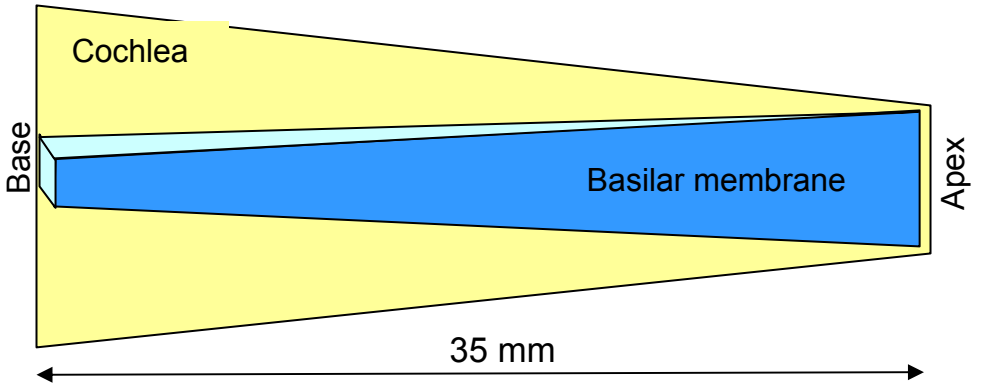
K^+ serves both to depolarize and repolarize the cell

Frequency discrimination mechanisms: Basilar membrane properties

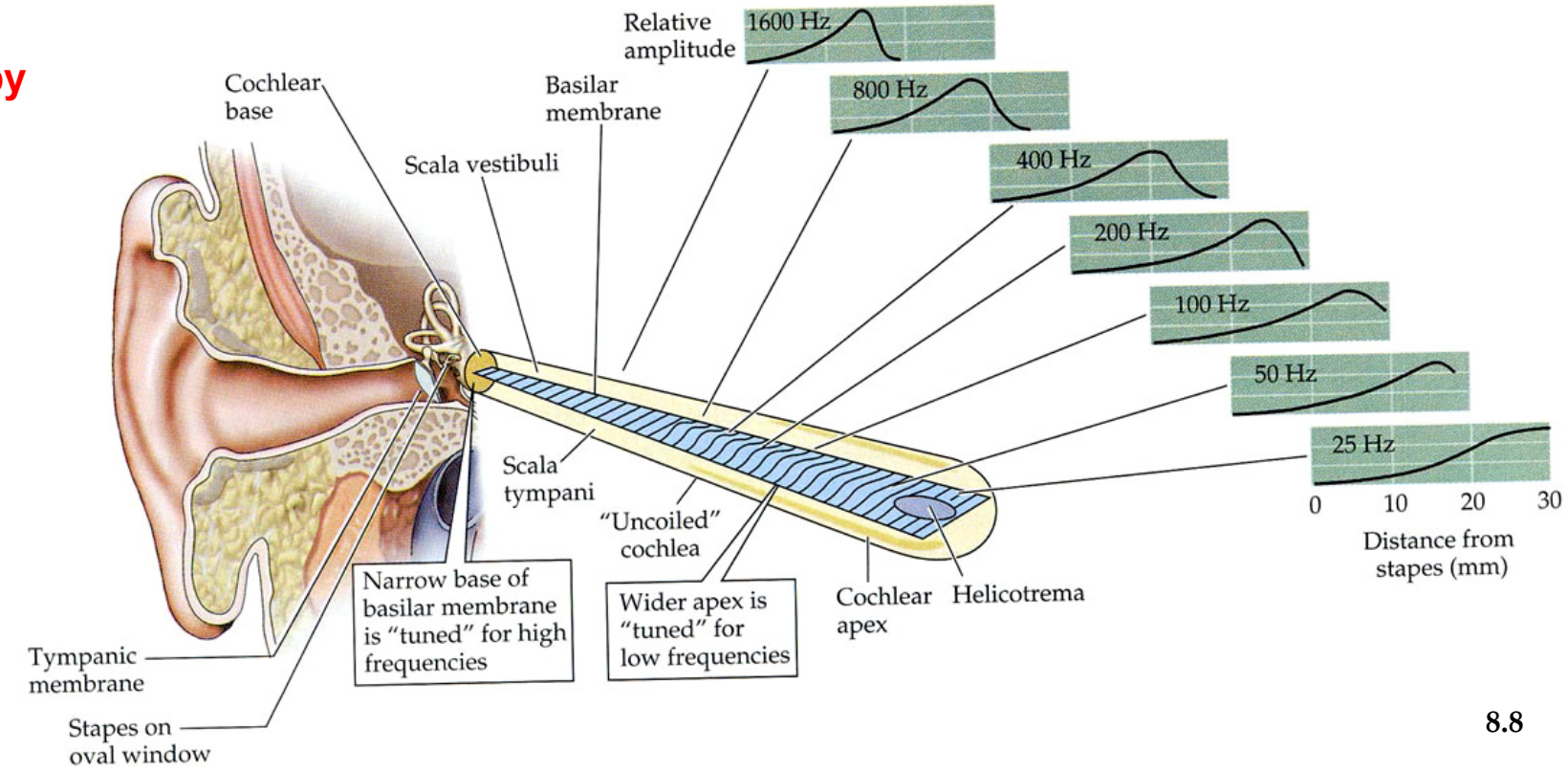


Geometry of basilar membrane

Mechanical resonance

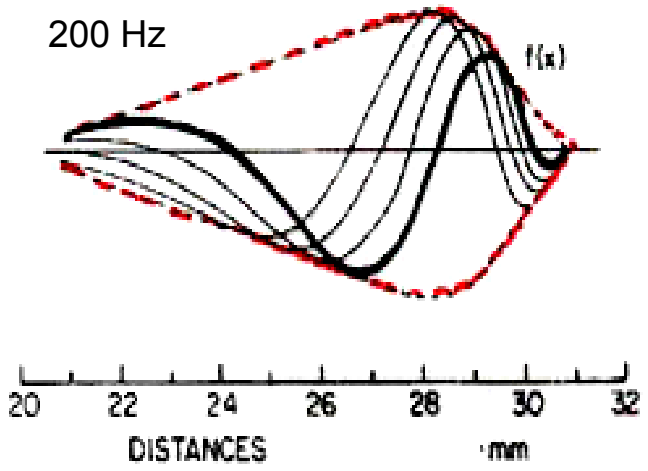


Tonotopy



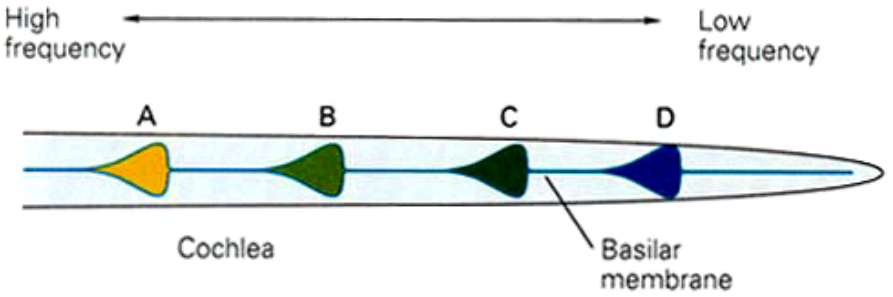
Frequency discrimination mechanisms: Basilar membrane properties

Traveling wave



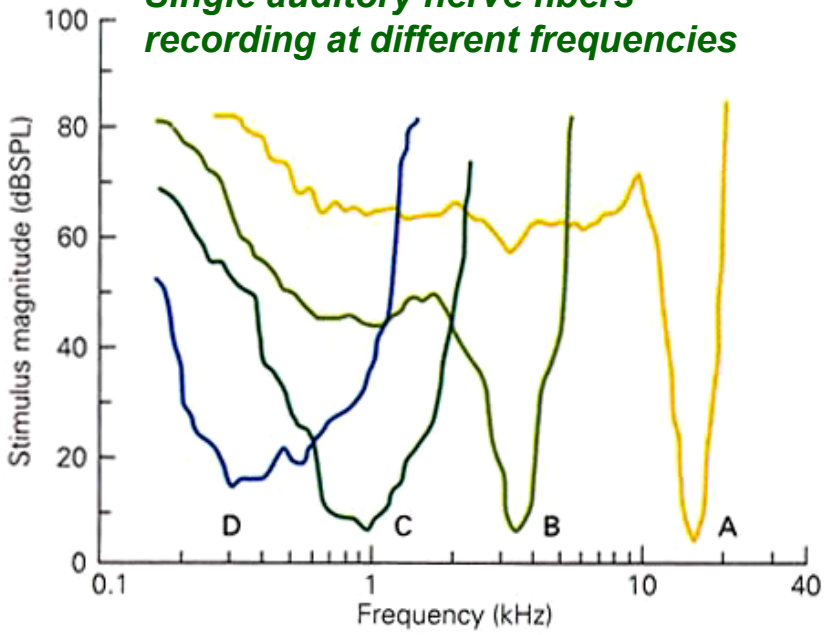
Maximal vibration at a particular position

Stimulation of particular receptor cells in the cochlea



Single auditory nerve fibers recording at different frequencies

Minimum sound level required to increase the fiber´s firing rate



Tonotopical organization → frequency code

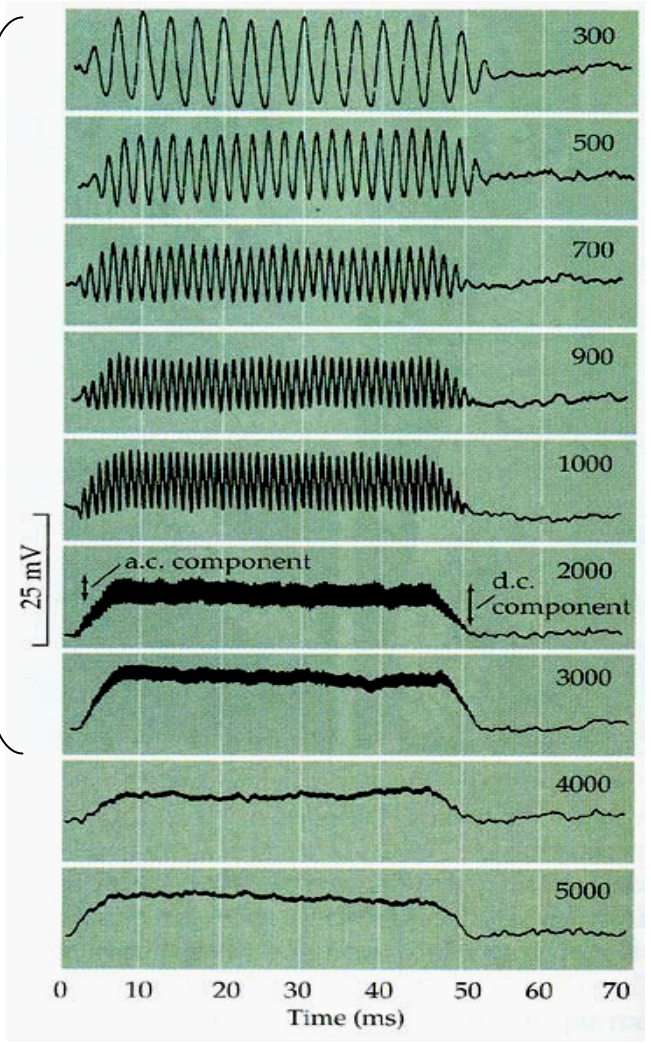
Frequency discrimination mechanisms: Electrical tuning of inner hair cells

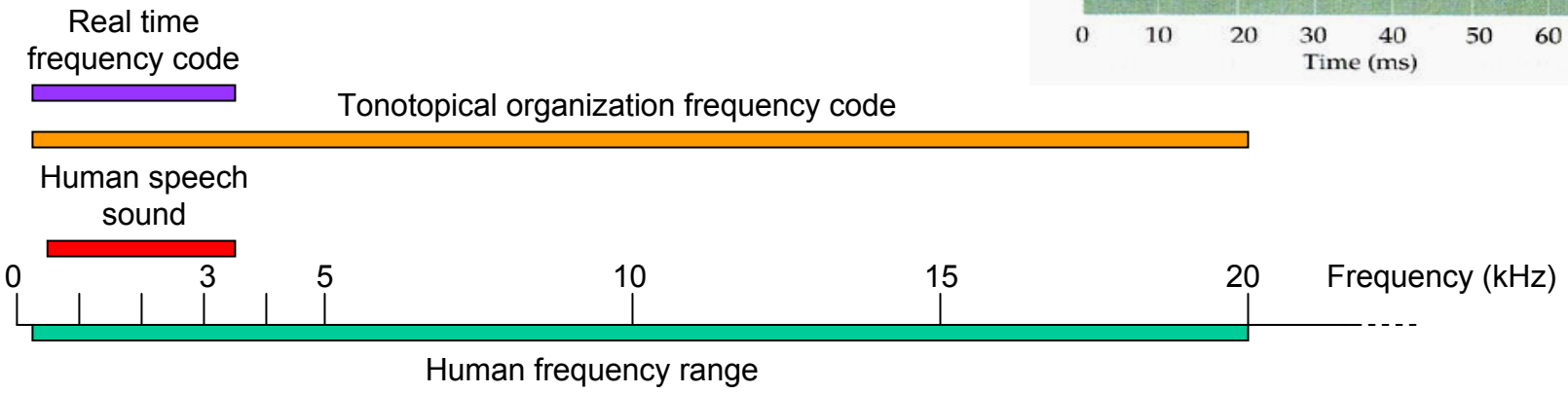
Receptor potential in hair cell :

Movement ↑ ⟶ Depolarization

Movement ↓ ⟶ Hyperpolarization

Sinusoidal receptor potential



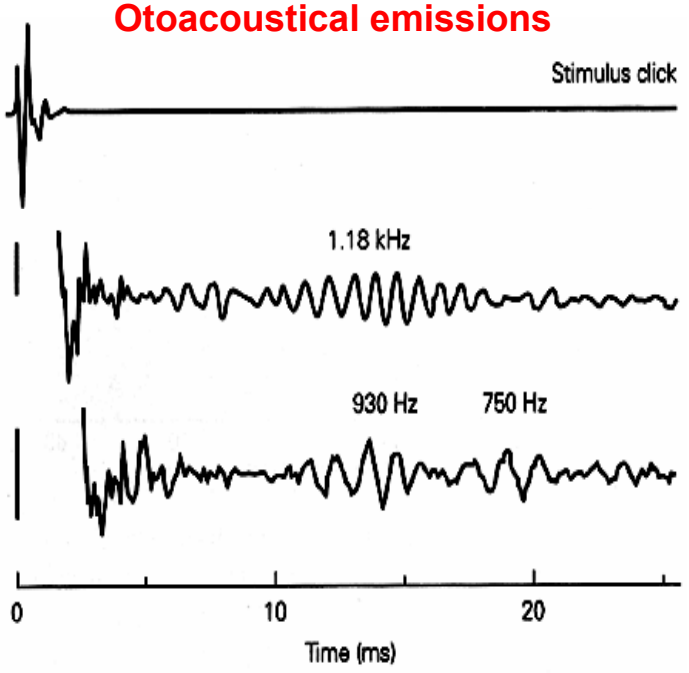


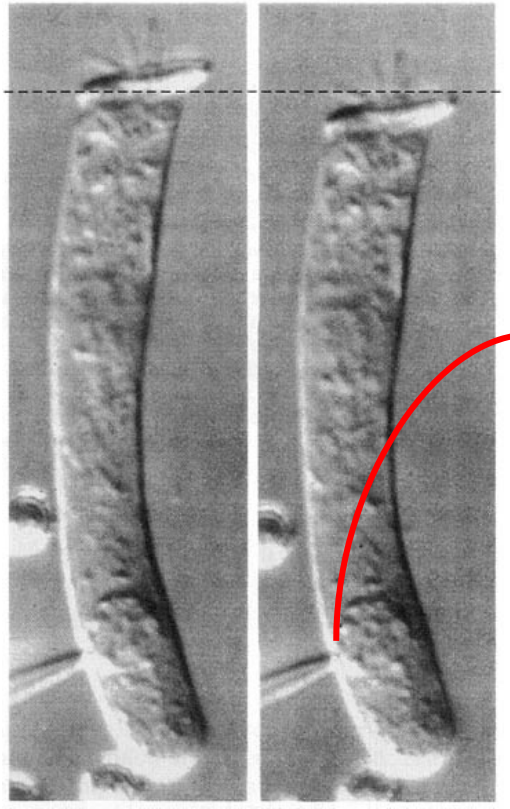
Frequency discrimination mechanisms: Role of outer hair cells and efferent innervation

Vibration of basilar membrane is not linear at low frequencies

→ ***Active amplification mechanism***

Otoacoustical emissions





Depolarization

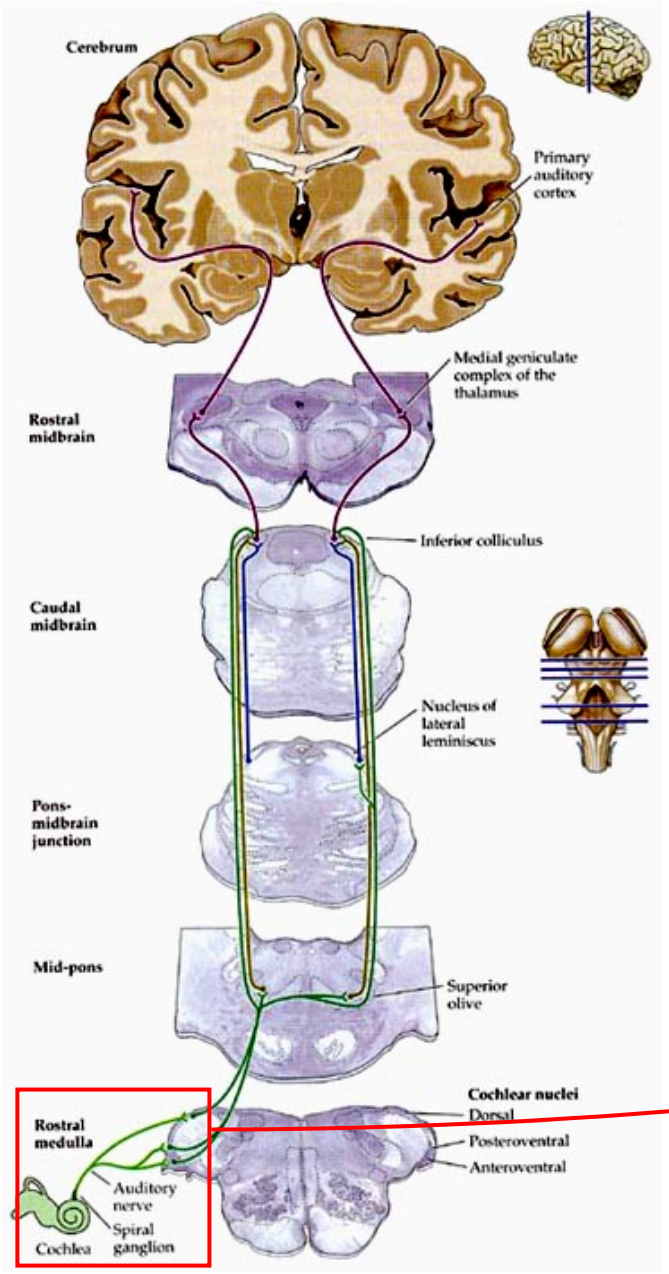
Cell body shortening

Cochlear amplification

- **is mediated by movement of outer hair cells**
- **is regulated by efferent innervation**

→ **enhances cochlear sensitivity and frequency selectivity**

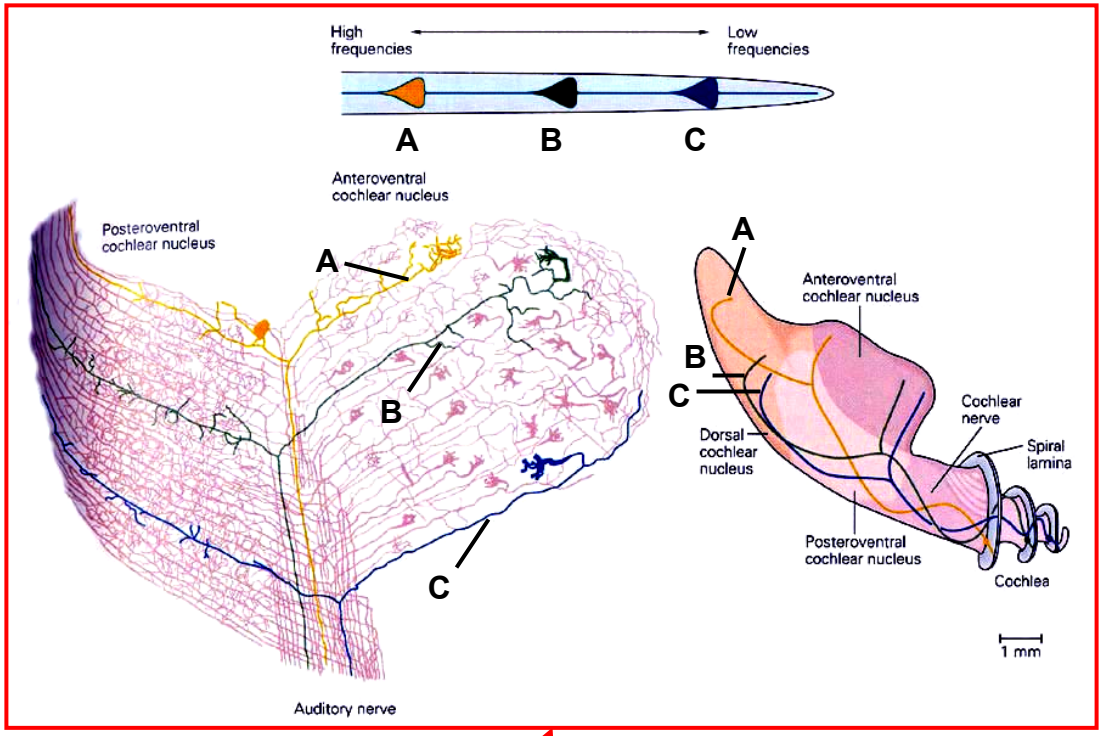
Central processing of auditory information



Properties:

1) Several **parallel pathways**

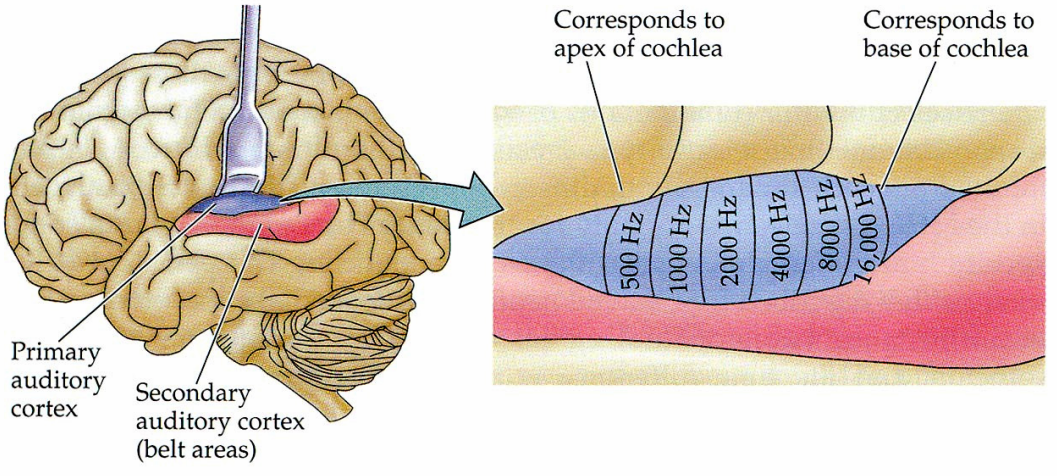
2) Each ear → Both sides of the system → **Divergence**



3) Preserved topographic map of frequencies.
From the cochlear nucleus... → **Tonotopy**

Properties (cont.):

4) ... to the auditory cortex. → **Tonotopy**



5) Both ears → One side of the system → **Convergence**

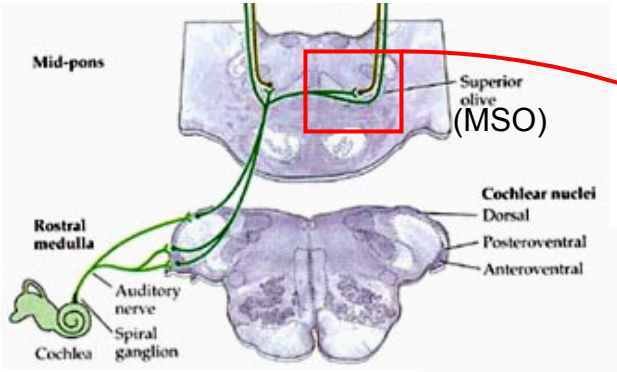
↓

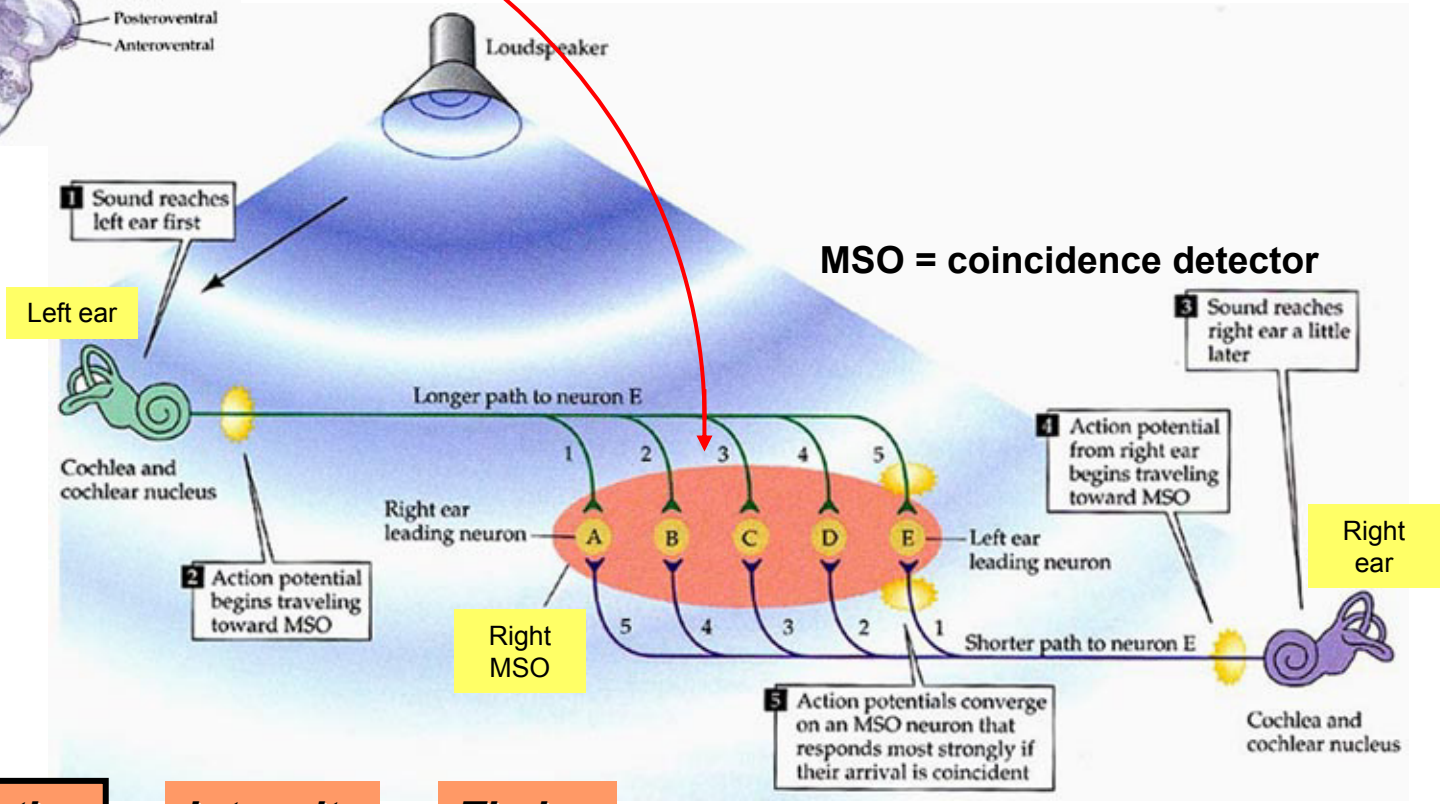
Localization of sound source

Central processing of auditory information

Best understood function of brainstem nuclei: ***Sound localization.***

1) Low frequencies (up to 3 kHz) → use interaural **time differences**

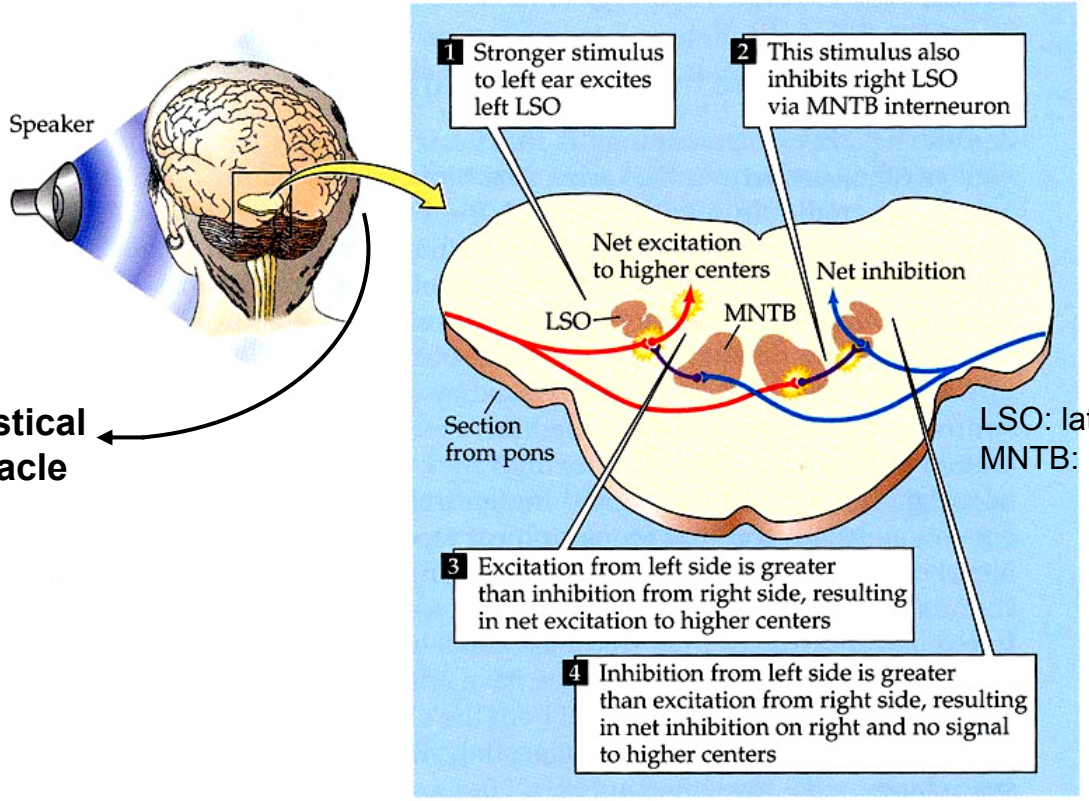


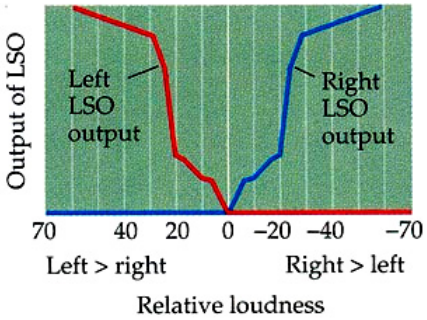


Modality ***Location*** ***Intensity*** ***Timing***

Sound localization (cont.)

2) High frequencies (> 2 kHz) → use interaural **intensity differences**





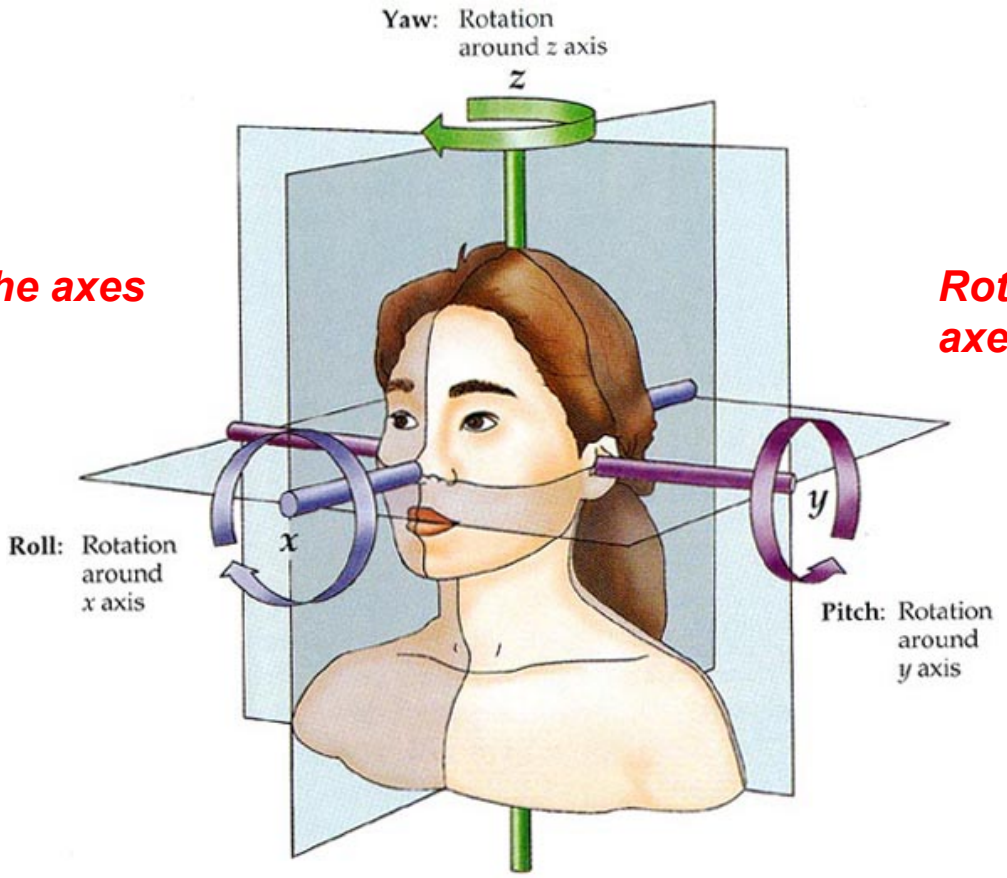
LSO: lateral superior olive.
MNTB: medial nucleus of the trapezoid body.

Vestibular stimulus: Head position and motion

Movement along the axes
→ Linear acceleration

Utricle
Saccule

Head position



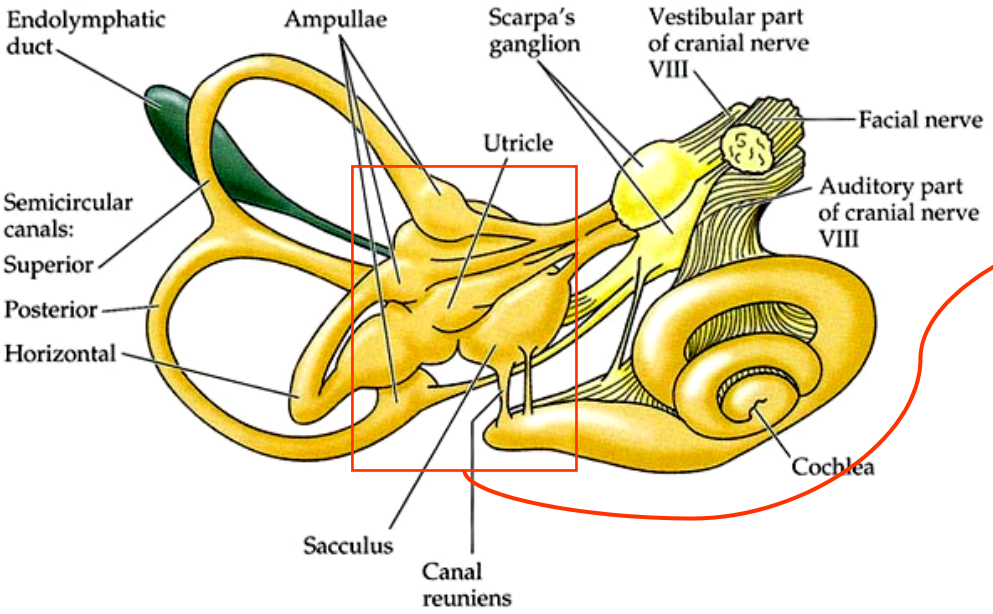
Vestibular navigation

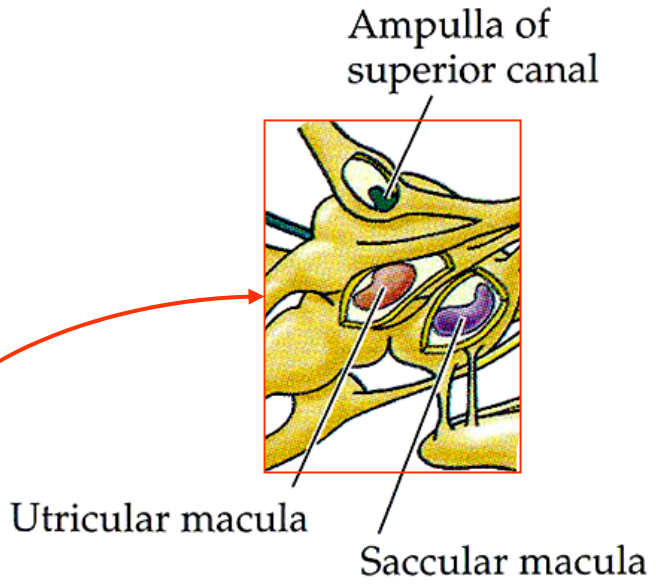
Rotation relative to the axes → Angular acceleration

Semicircular canals

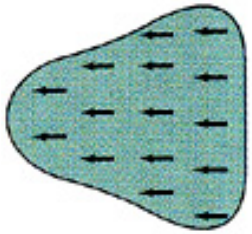
Modality ***Location*** ***Intensity*** ***Timing***

Functional structure of the vestibular labyrinth

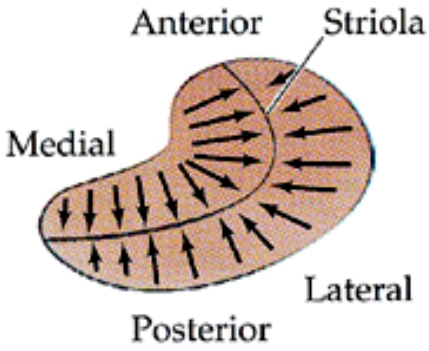




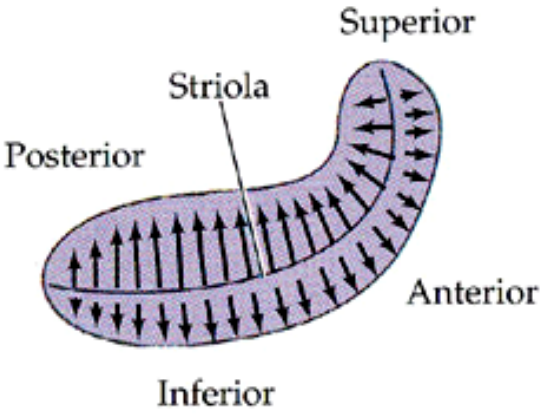
Polarization of hair cells



Ampulla



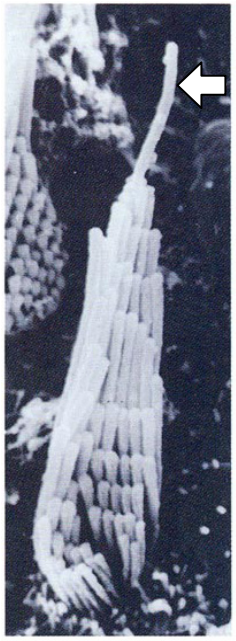
Utricle

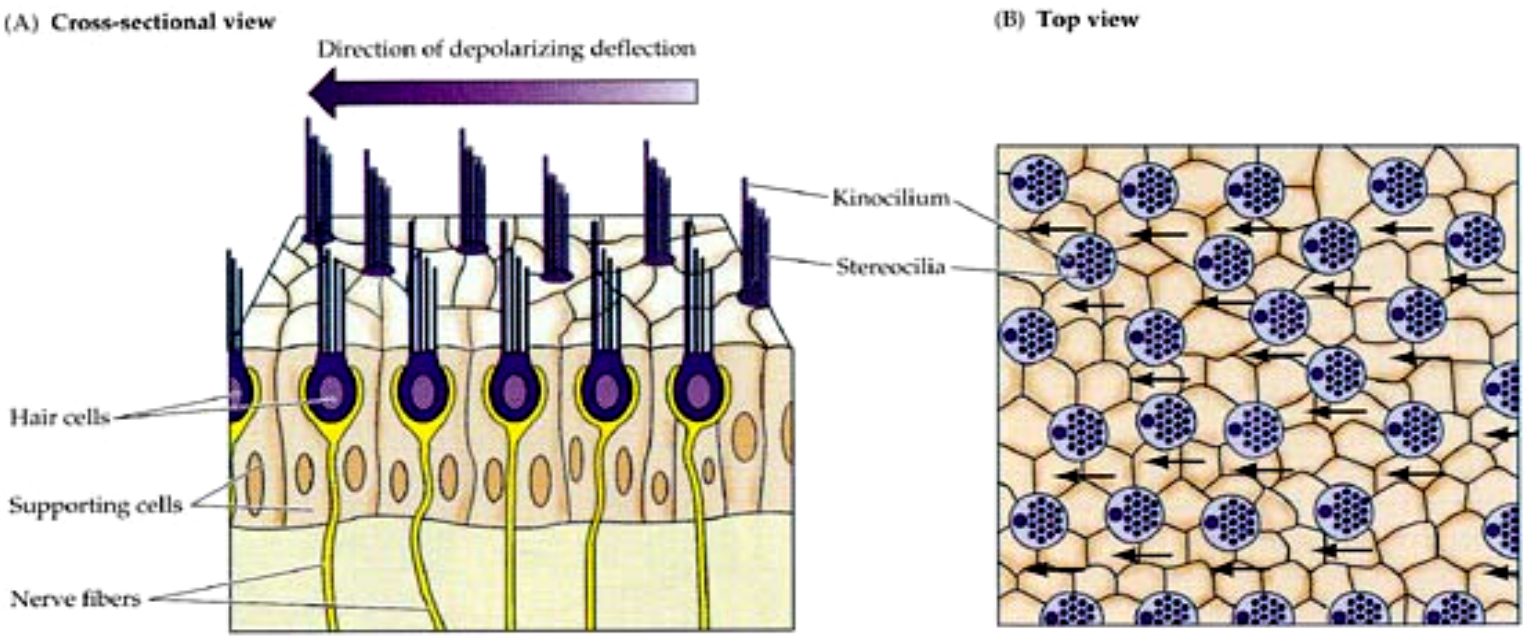


Sacculus

Functional structure of the vestibular labyrinth

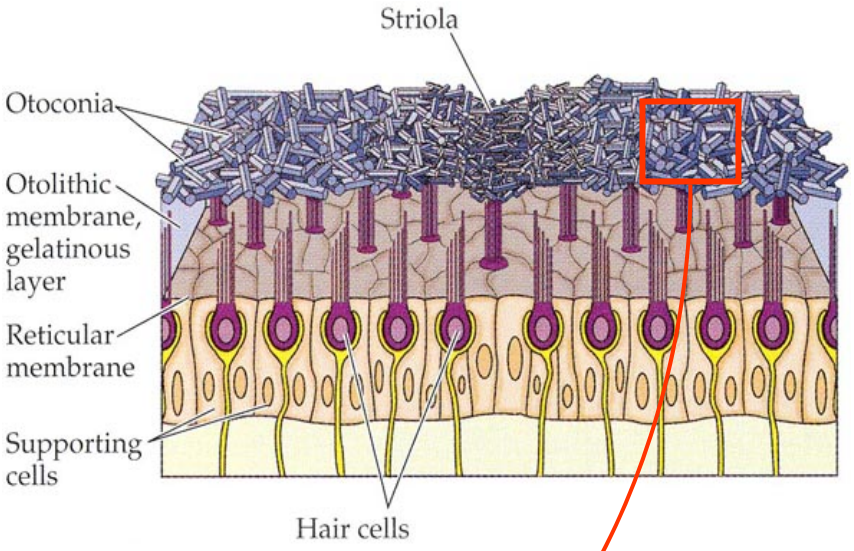
Polarization of hair cells

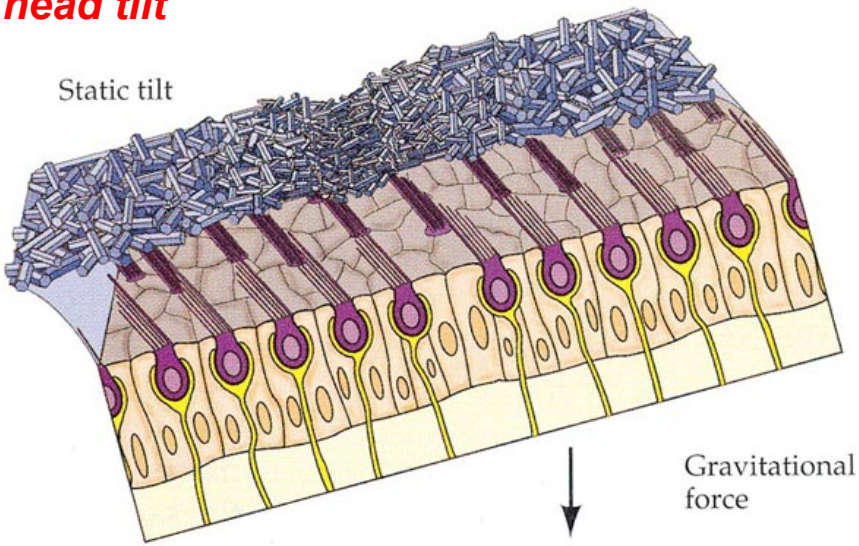


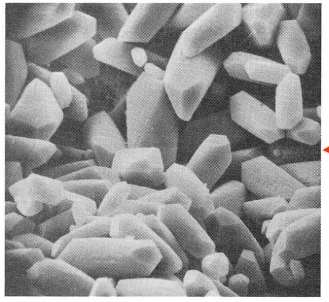


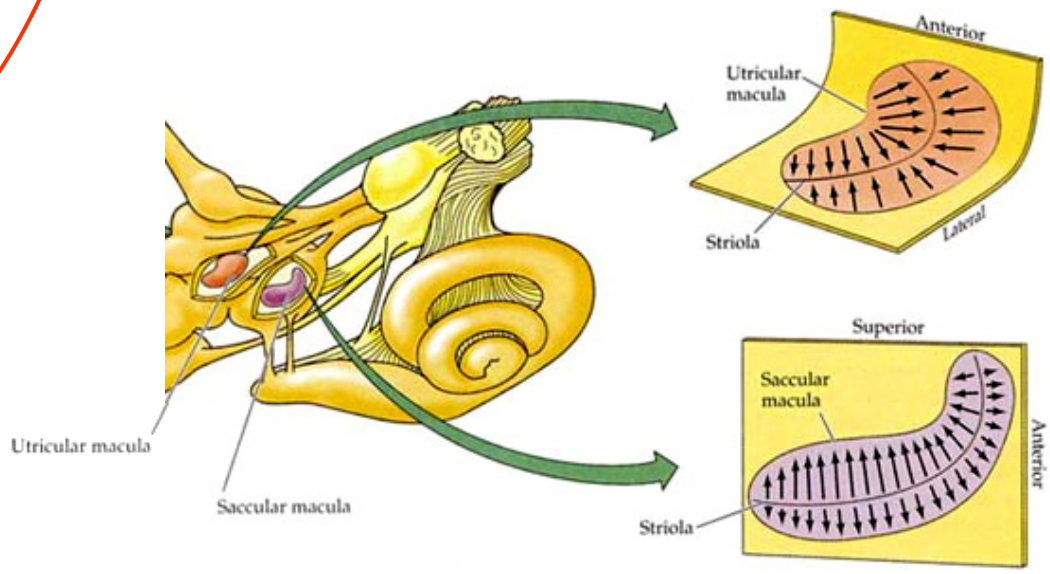
The otolith organs: Head position

Transduction of a static head tilt



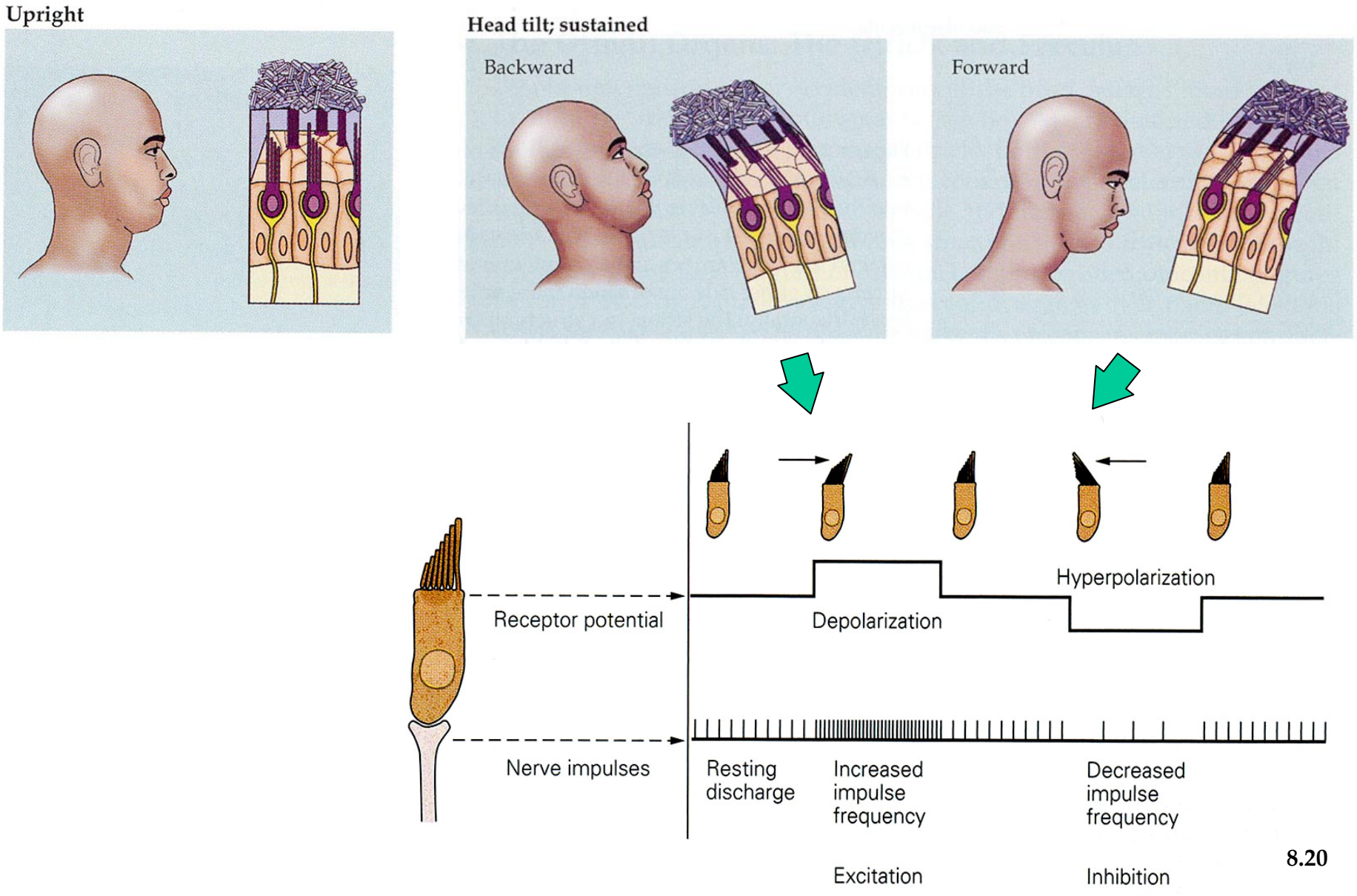




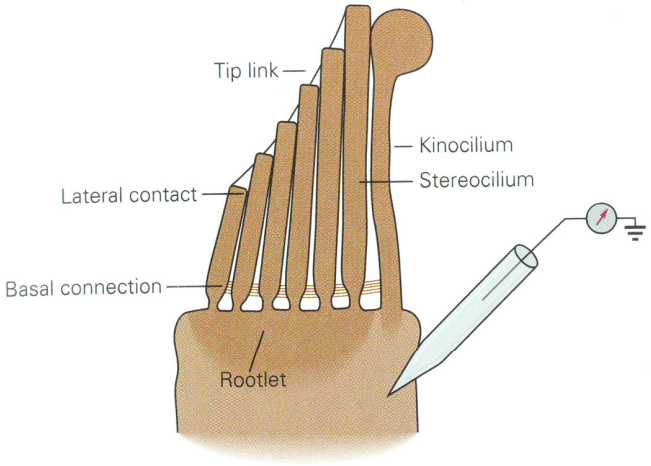


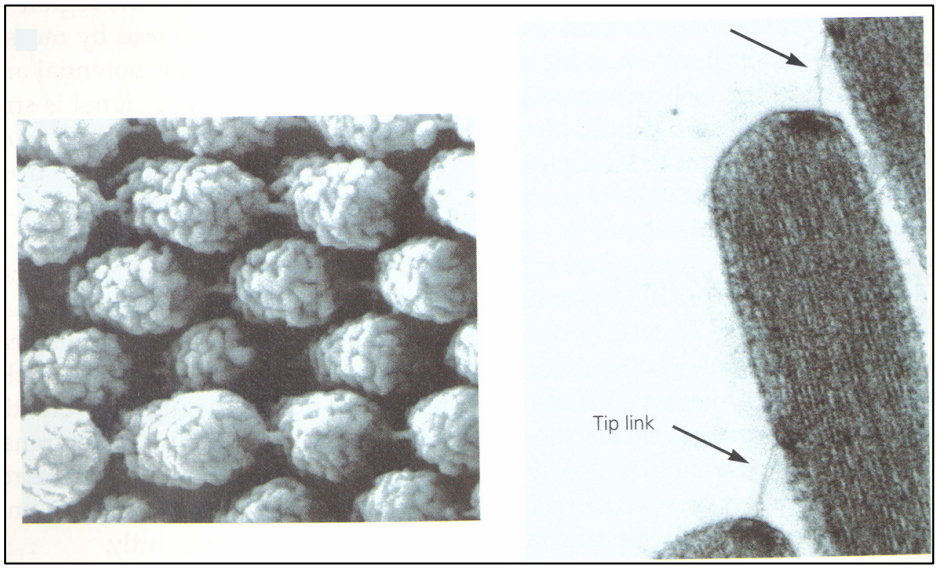
The otolith organs: Head position

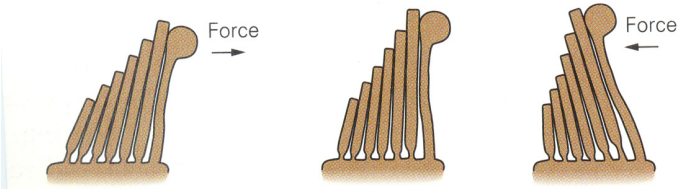
Transduction of a static head tilt

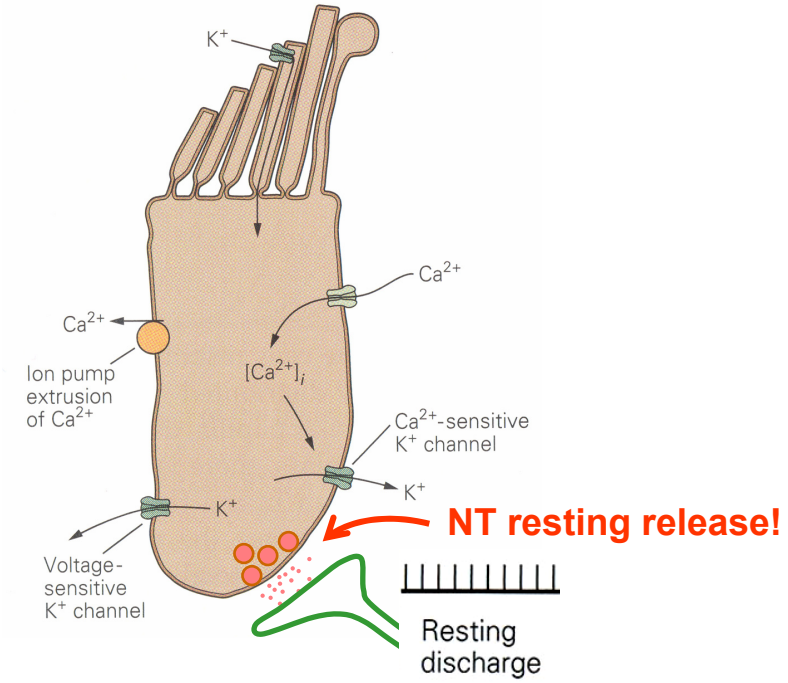


Images to respond to your questions:
Some properties of hair cells in auditory and vestibular system.



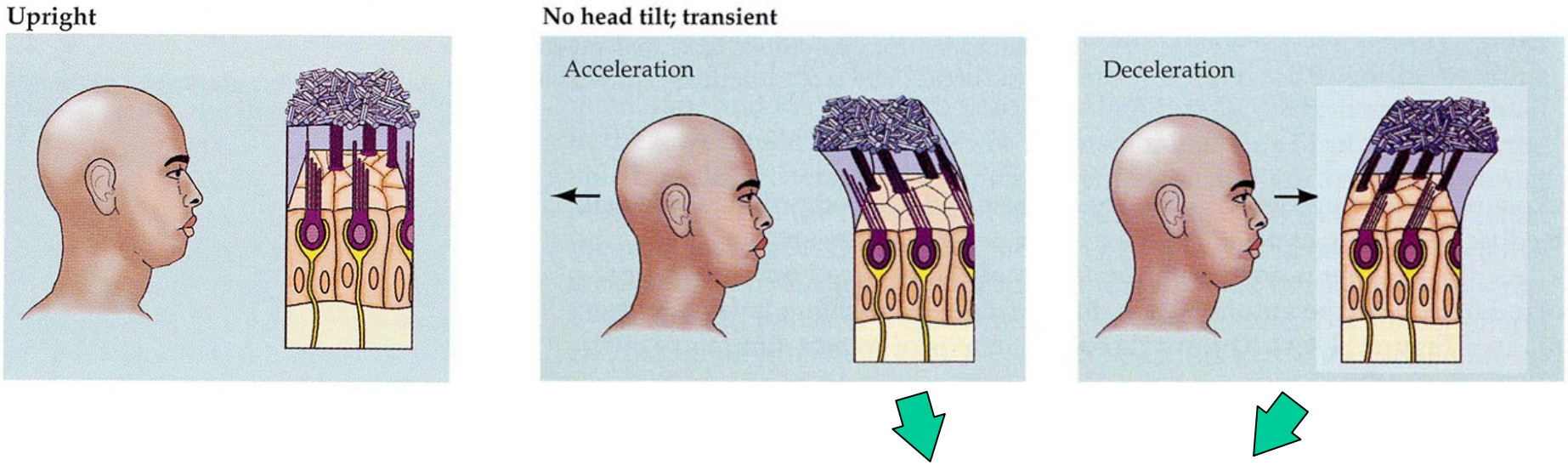






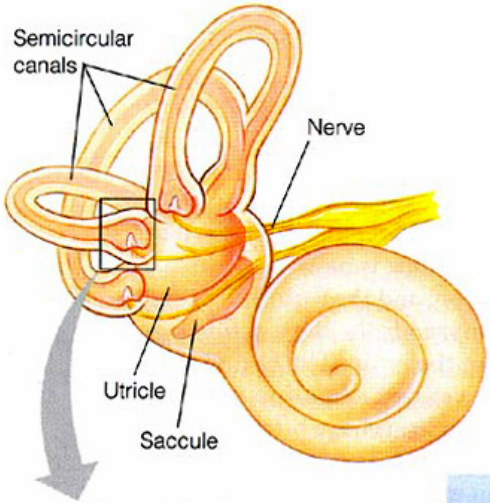
The otolith organs: Linear movement

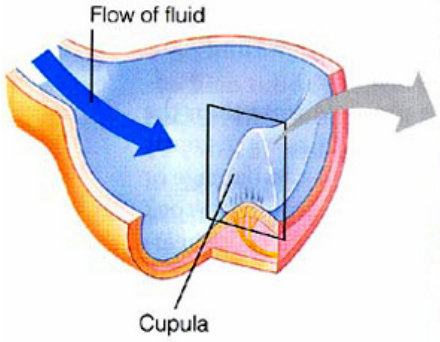
Transduction of linear acceleration

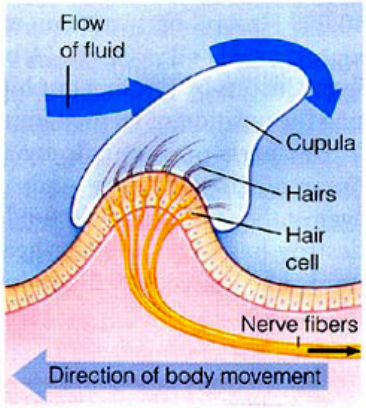


Make your own scheme:

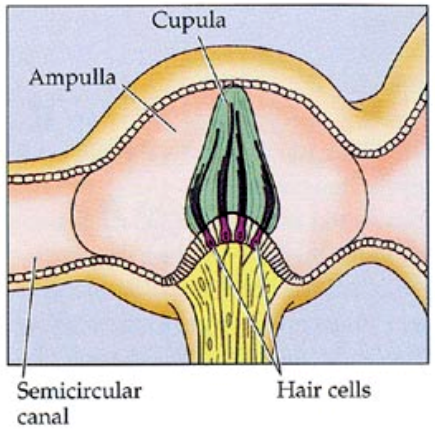
Functional structure of the semicircular canals

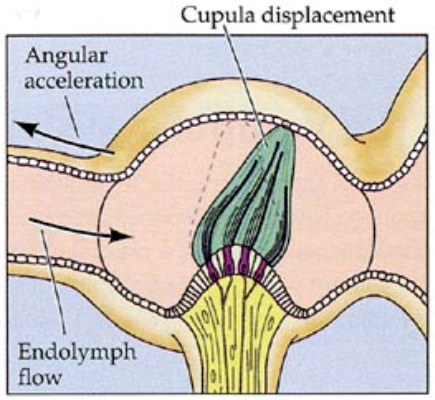


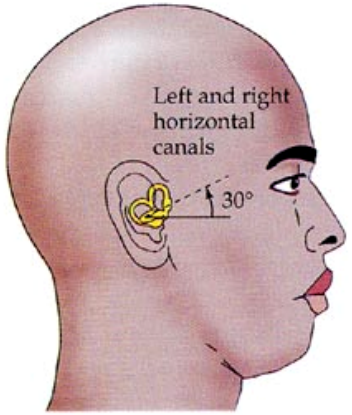


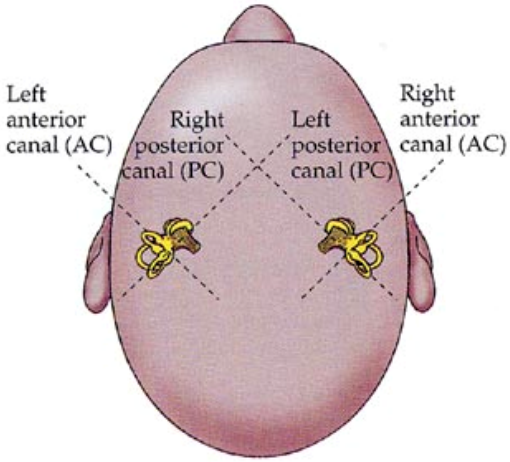


Transduction of angular acceleration

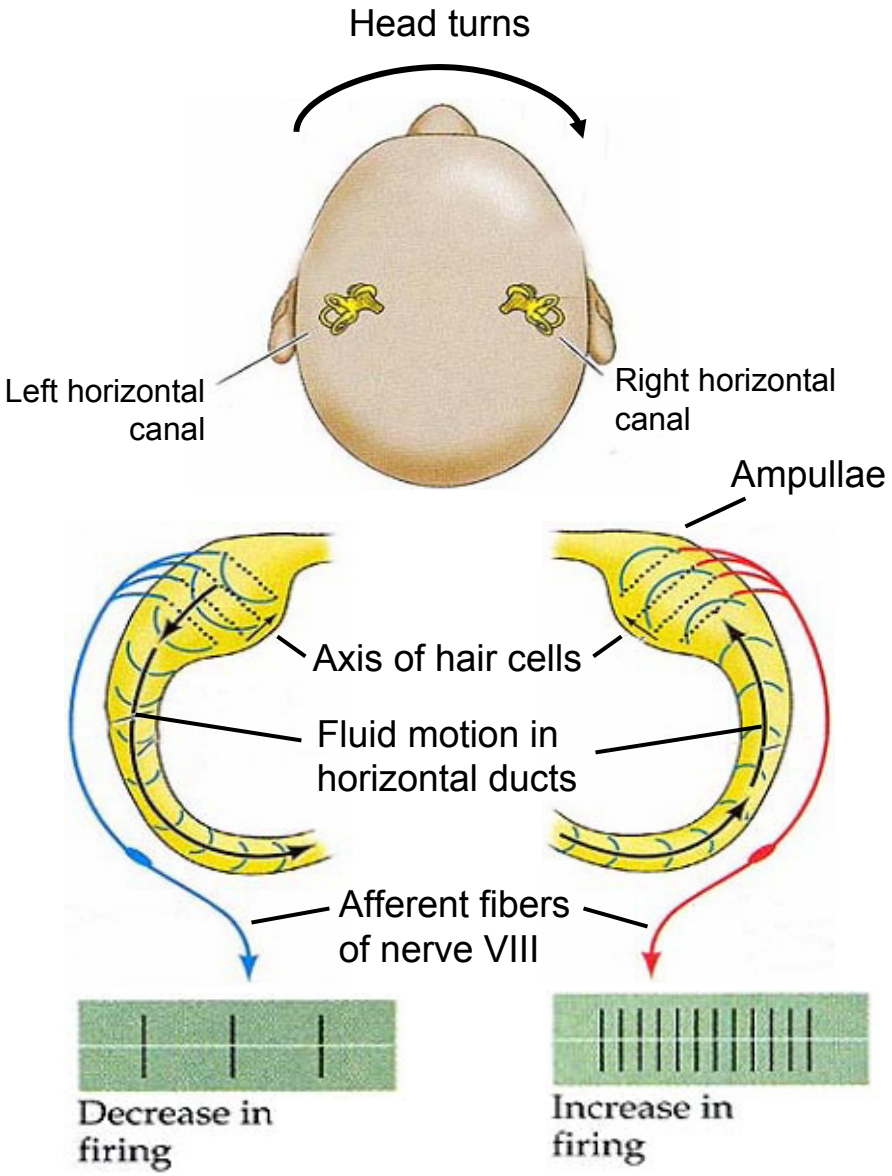






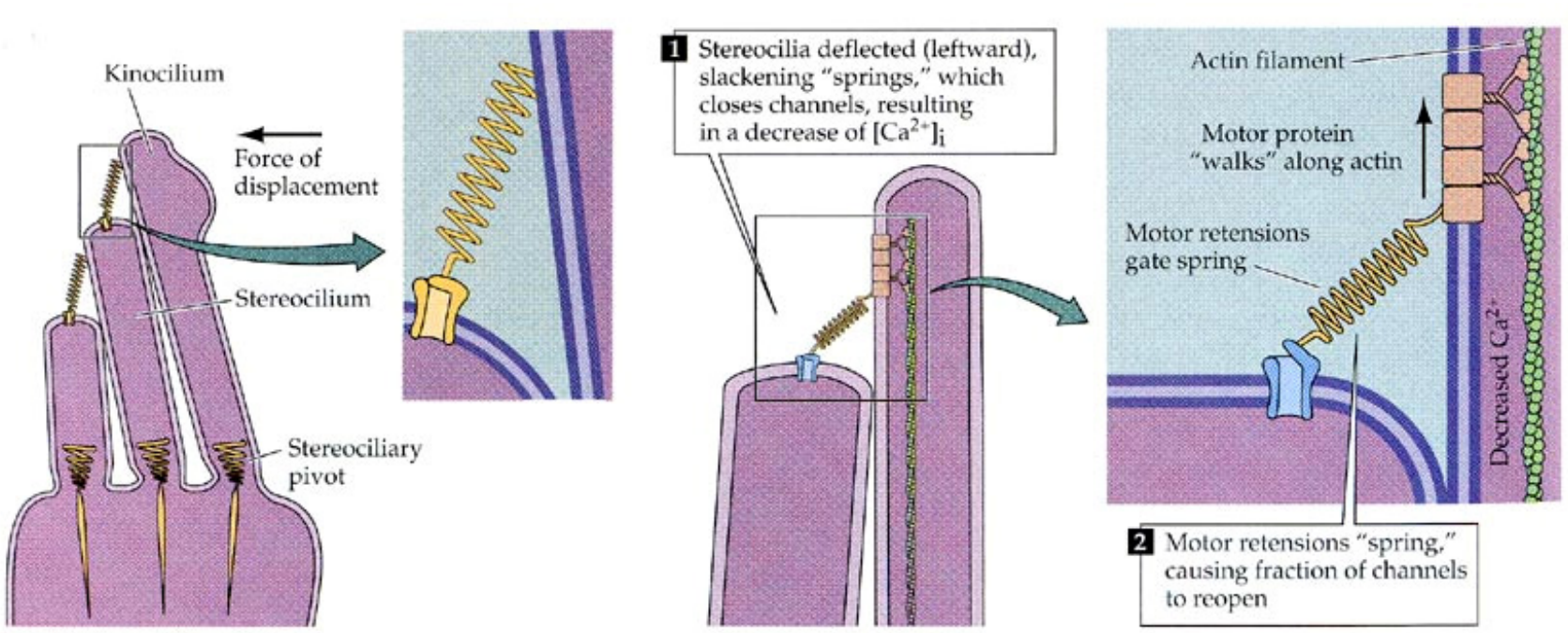


The semicircular canals: Rotational movement



Mechanoelectrical transduction of movement in vestibular hair cells: Special properties

Adaptation



Maintains high sensitivity under sustained static displacements → e.g. constant input from gravity

Also present in cochlear hair cells → e.g. sustained sound

Modality ***Location*** ***Intensity*** ***Timing***