

Sense of Hearing

Sense of Balance

Auditory system

Auditory system

- capturing and transmission of mechanical energy to the receptor organ, transduction into electrical signal (ear)
- transmission to CNS
- processing of the transmitted information
 - interpretation of the sound
 - interpretation of its importance for the organism

Auditory system

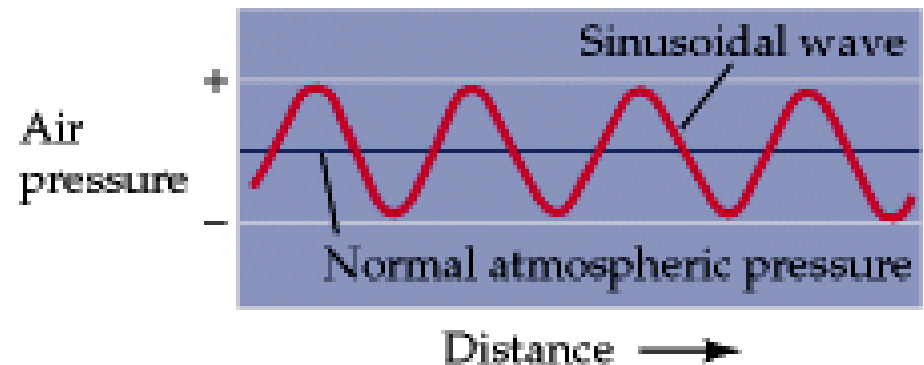
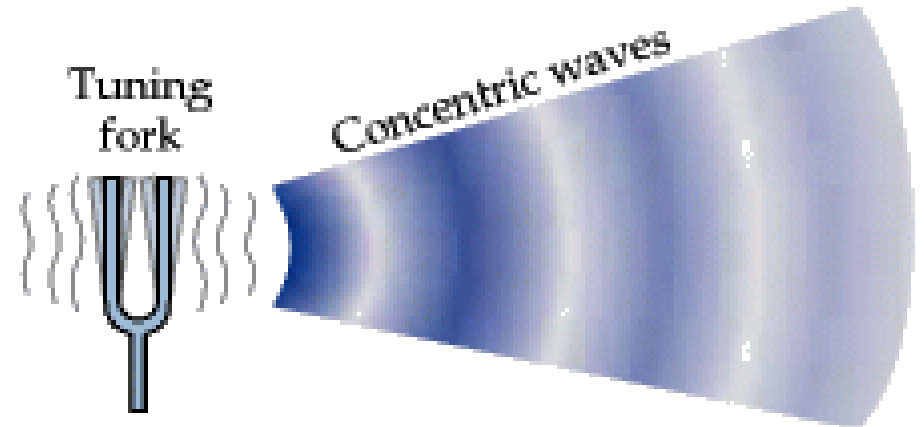
- capturing and transmission of mechanical energy to the receptor organ, transduction into electrical signal (ear)

Sound is a mechanical undulation of flexible environment with frequency in audible spectrum.

- transmission of transmitted information
 - interpretation of the sound
 - interpretation of its importance for the organism

Sound

- rises by vibration of a solid object in the air or water
- characteristics:
 - frequency – pitch of the tone
 - amplitude – intensity
 - timbre – given by representation of harmonic frequencies of the oscillation



Sound

- simple (clear)
- composite
 - harmonic
 - periodic
 - non-harmonic (noise)
 - non-periodic

Noise



Tone



<http://www.earmaster.com/music-theory-online/ch03/chapter-3-2.html>

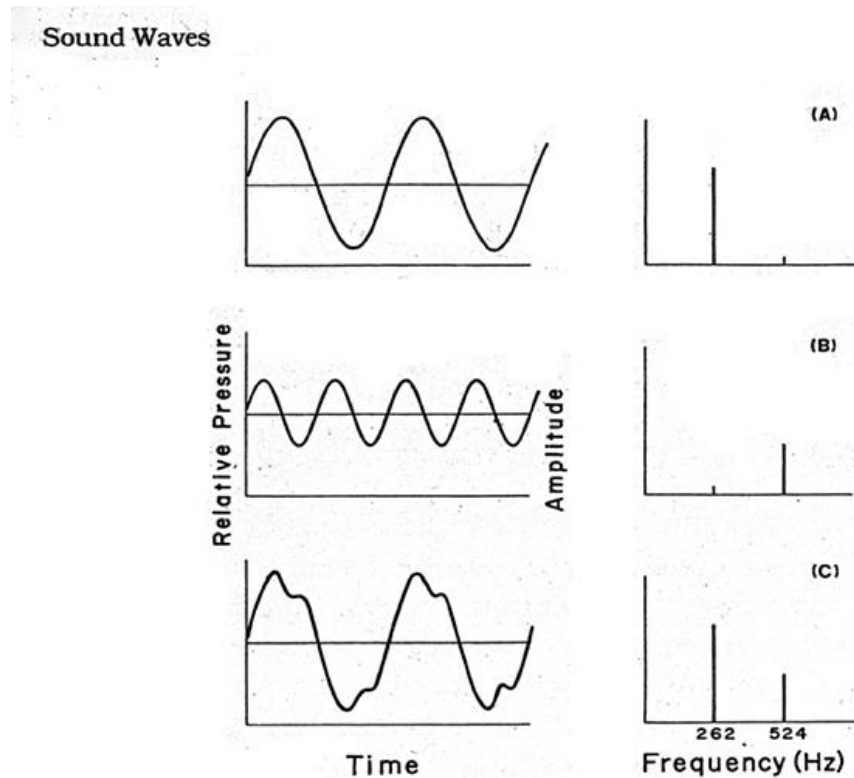
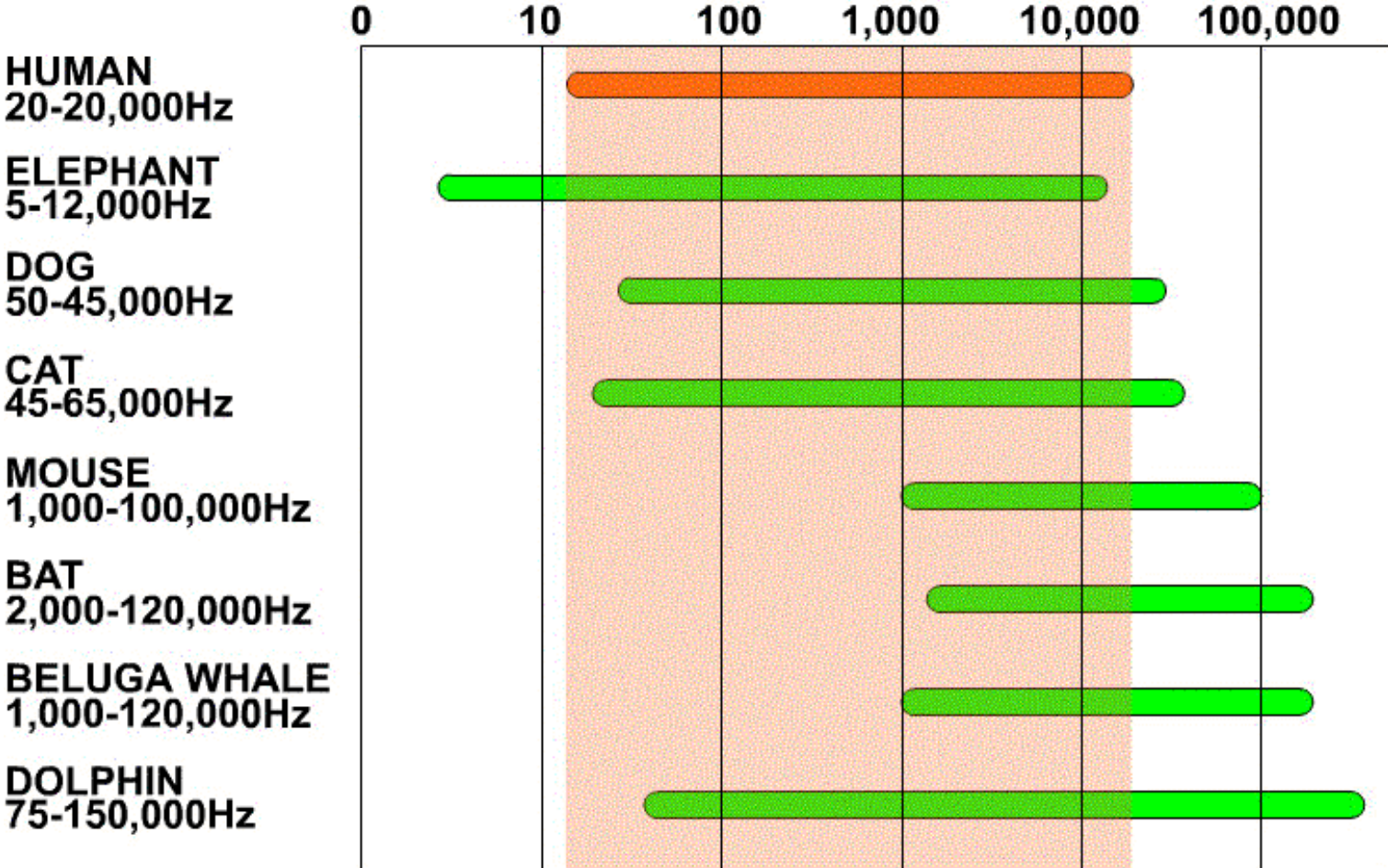


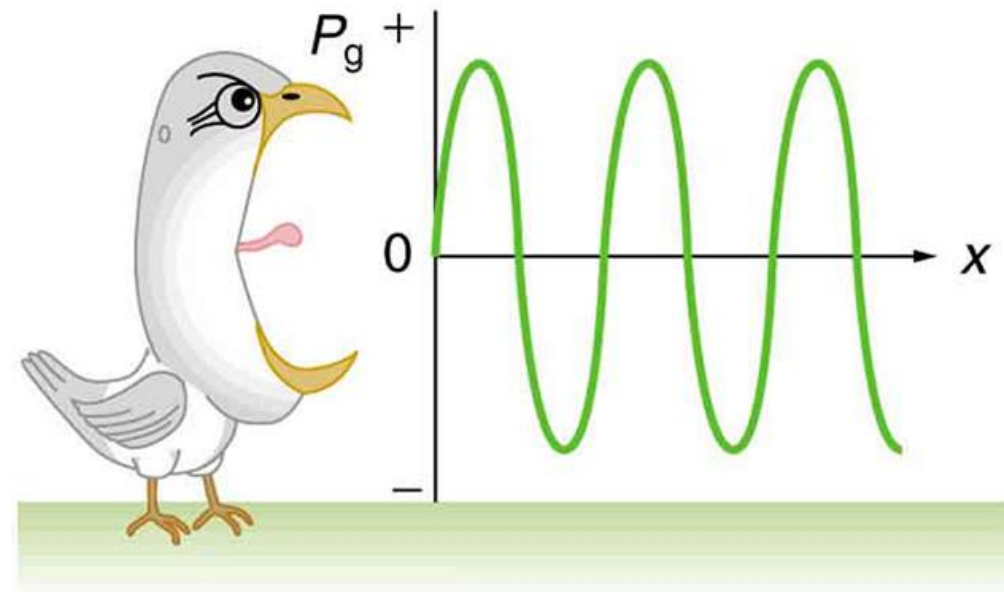
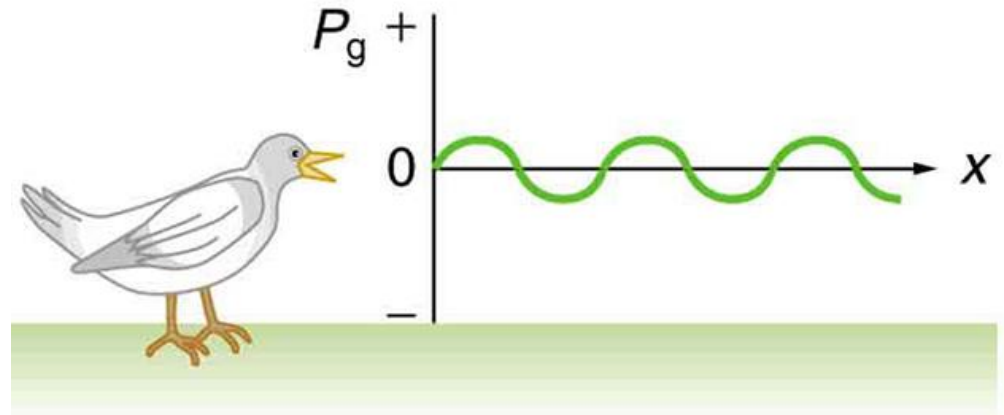
Figure 2.7 Waveform (left) and spectra (right) of two sine waves (A and B), combining into a complex wave (C).

Audible spectrum



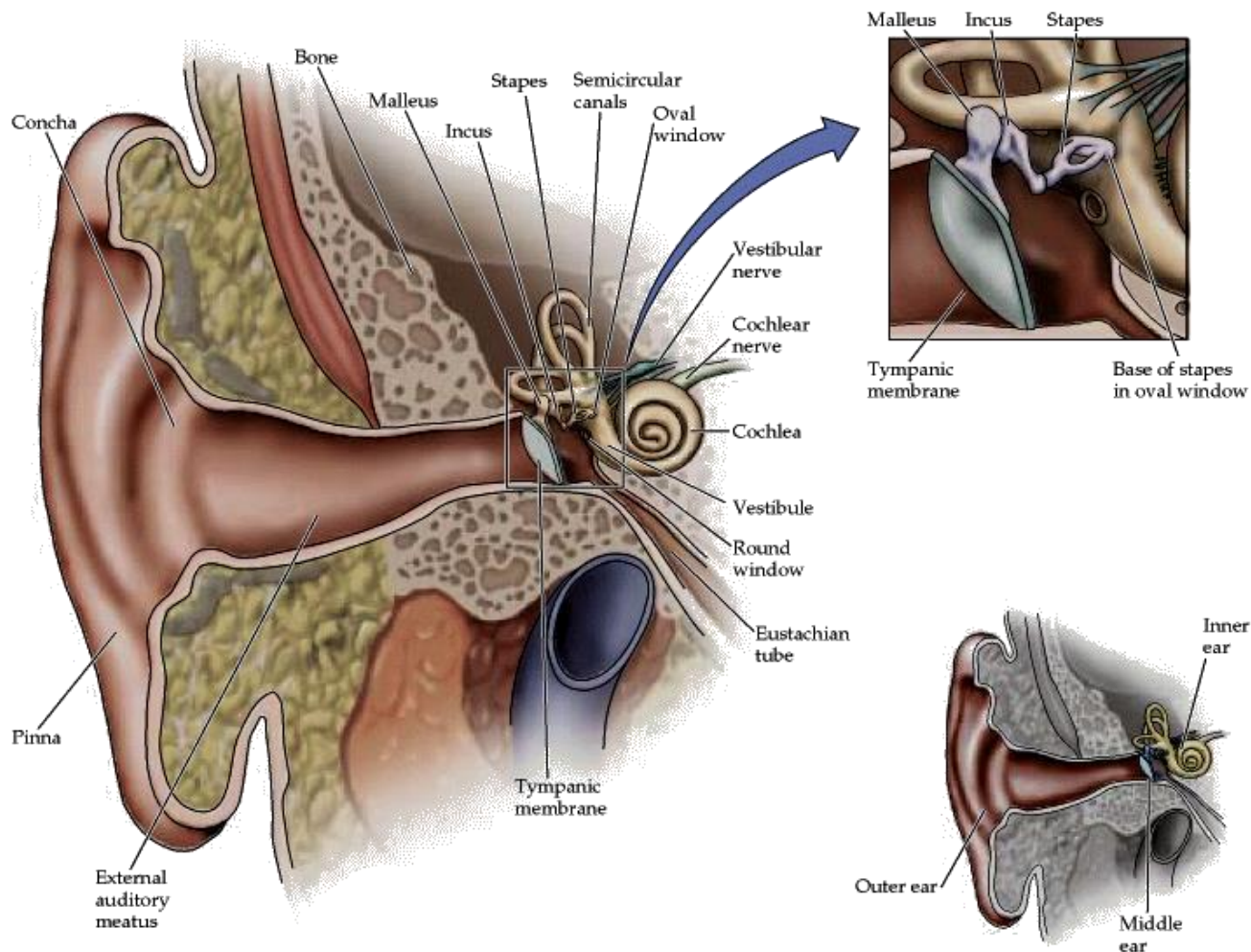
Intensity of the sound

- given by the amplitude of signal
 - whisper – 20 dB
 - common speech - 65 dB
 - jet engine – 100 dB
 - pain threshold – 120 dB
- volume (loudness) - subjectively perceived intensity of the sound



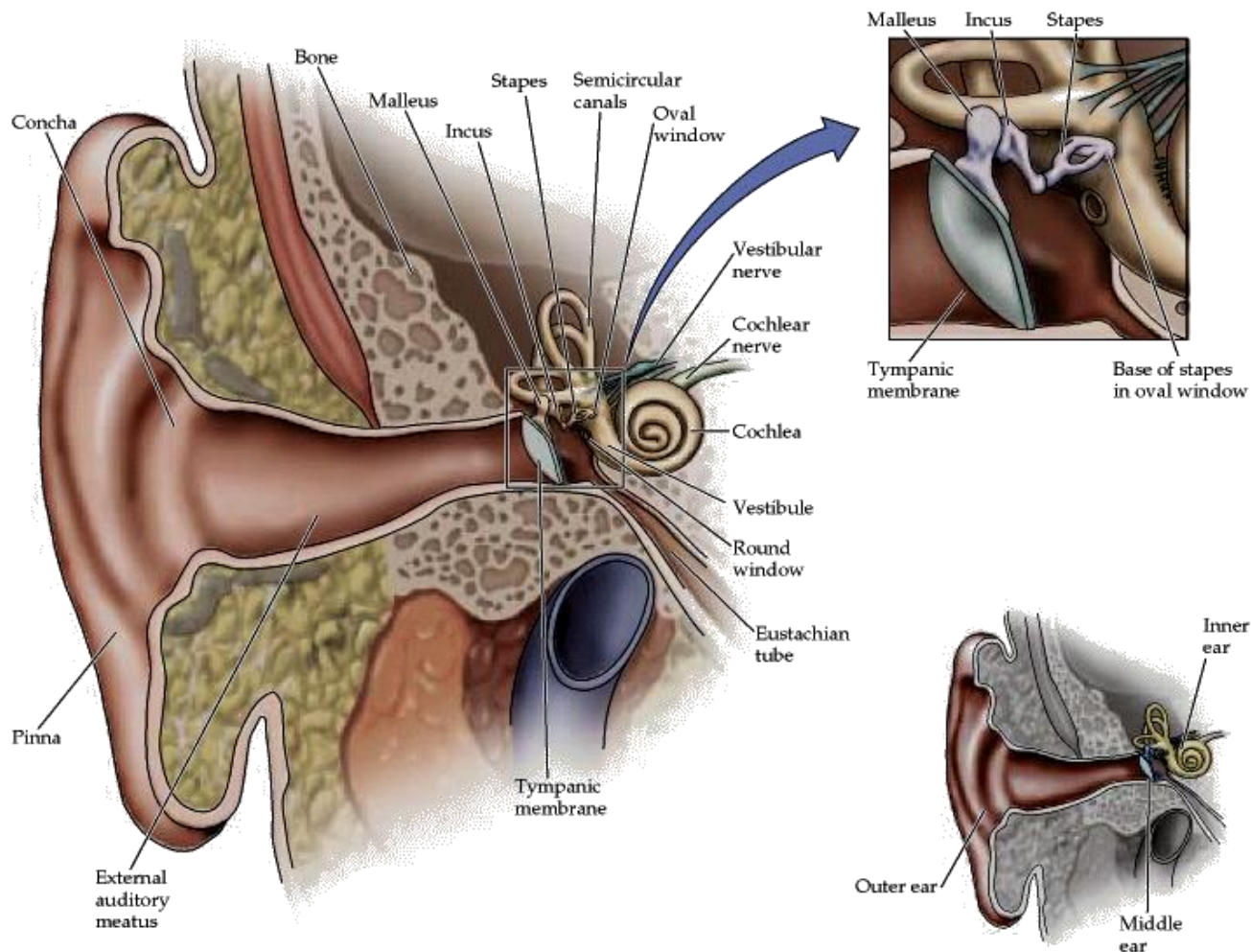
External ear

transmission of the acoustic signal from the external environment to the tympanic membrane



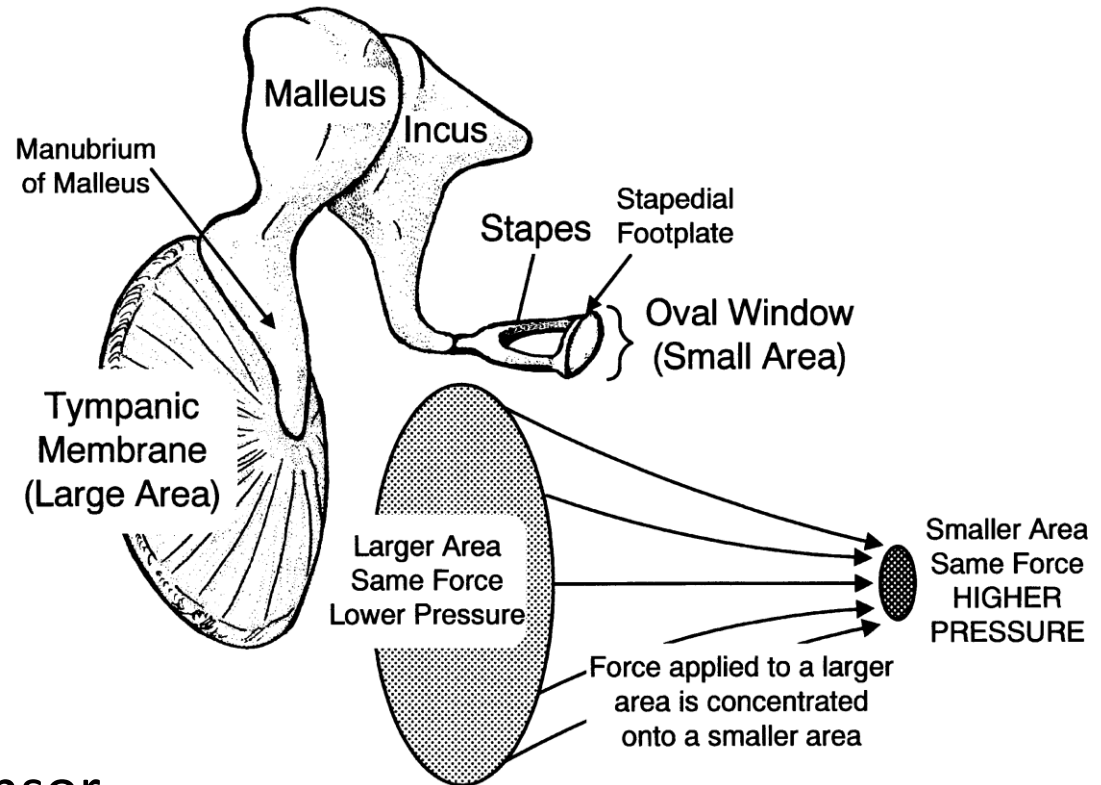
Middle ear

transmission of the signal from the tympanic membrane to the oval window and perilymph



Middle ear

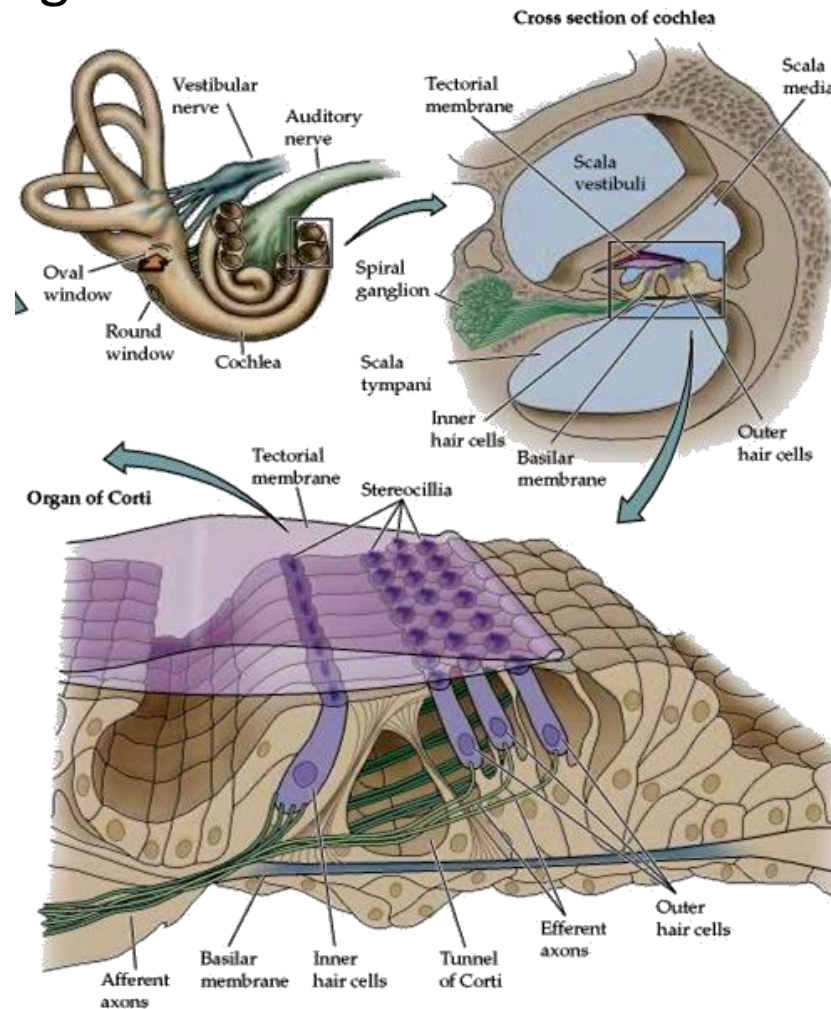
- Reinforcement of the signal
 - area of the tympanic membrane/ area of the oval window
 - leverage mechanism of the middle ear ossicles



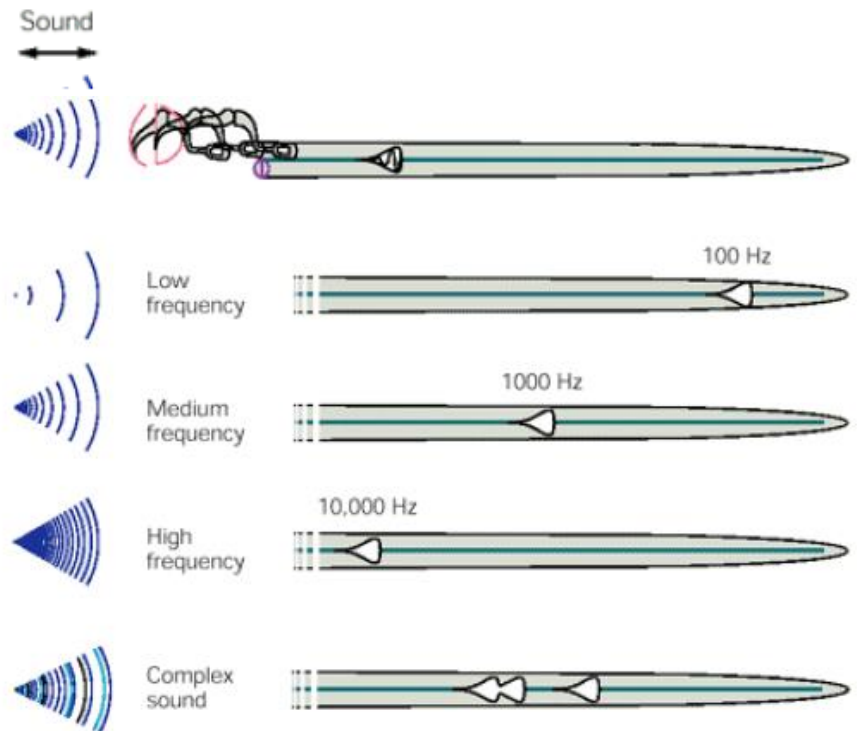
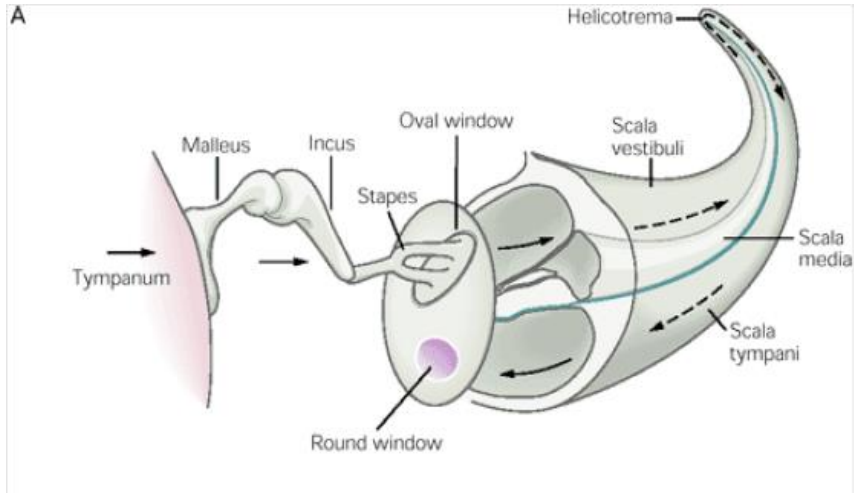
- Protective function
 - m. stapedius, m. tensor tympani
 - Eustachian tube

Inner ear

transmission of mechanical undulations of the perilymph to the neural (electric) signal

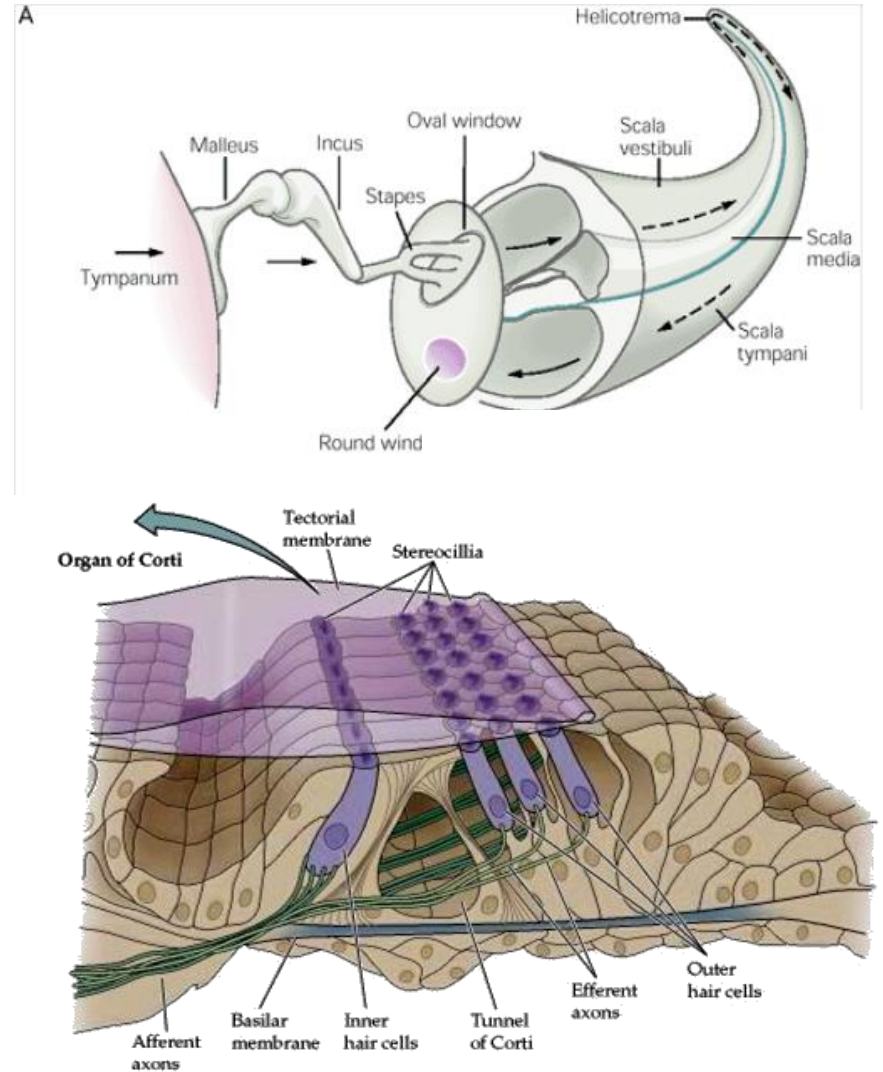


Tonotopic arrangement



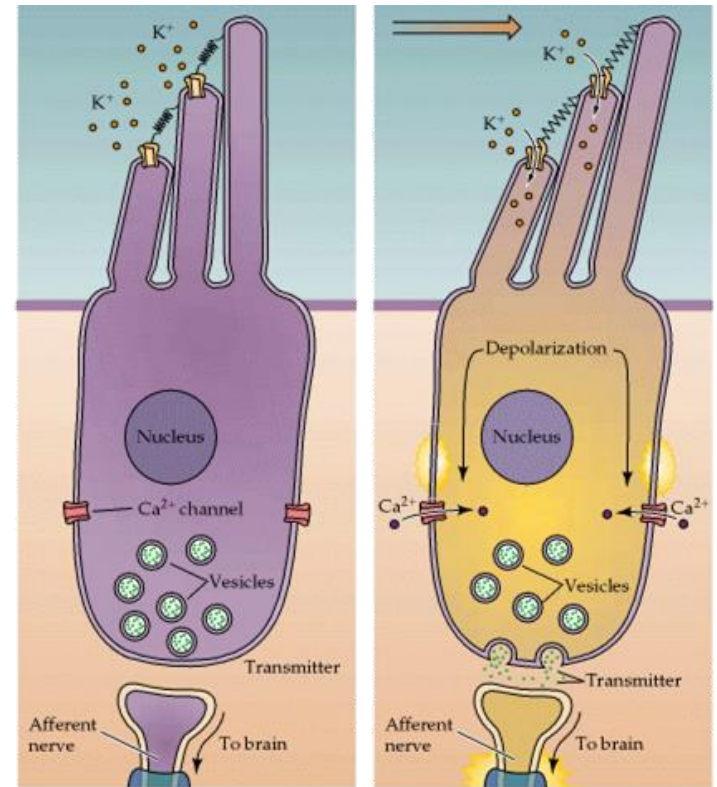
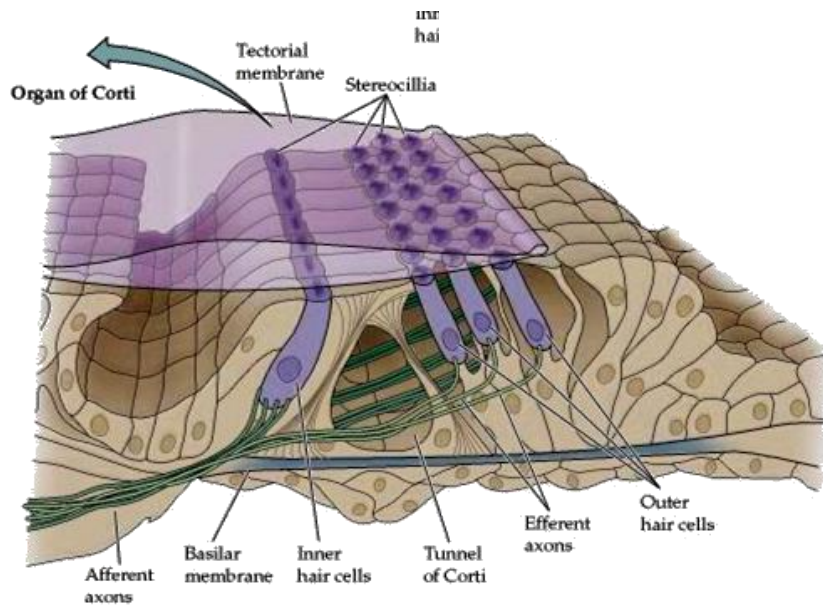
Organ of Corti

- Inner hair cells
- Outer hair cells



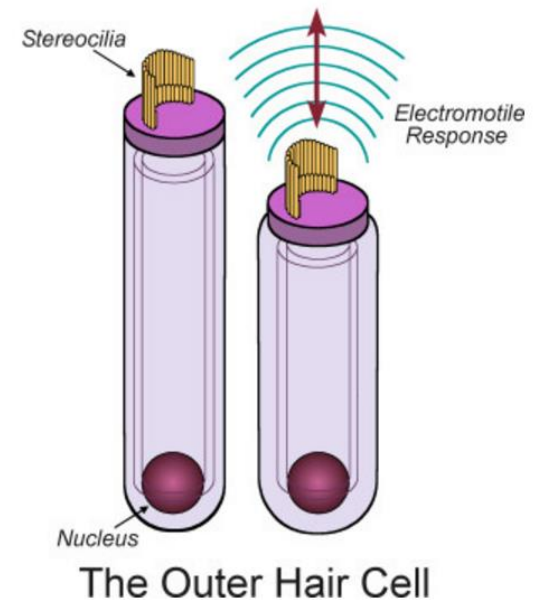
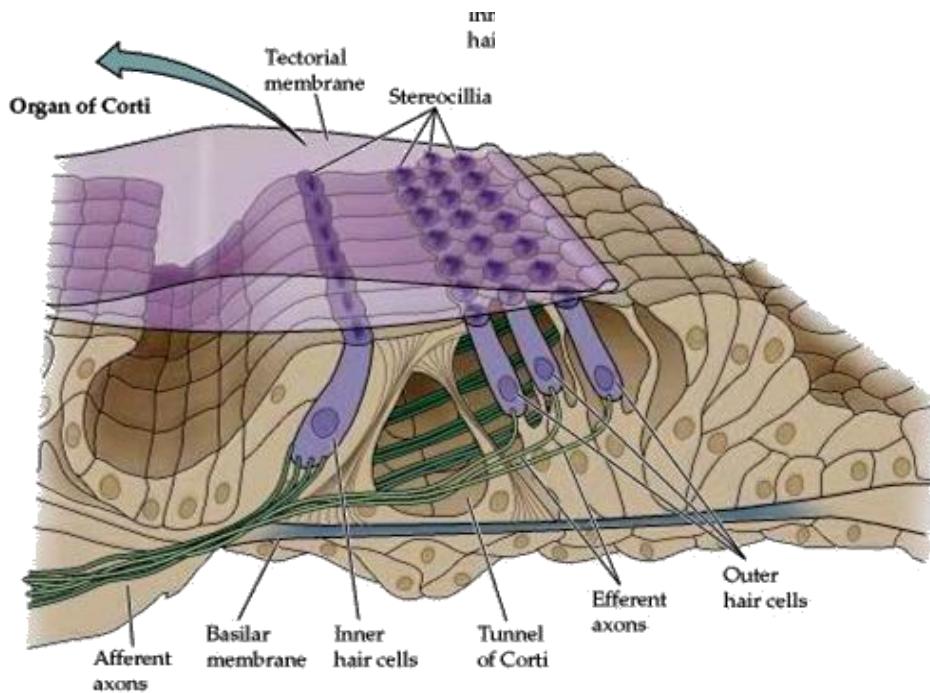
Inner hair cells

- sensory cells



Outer hair cells

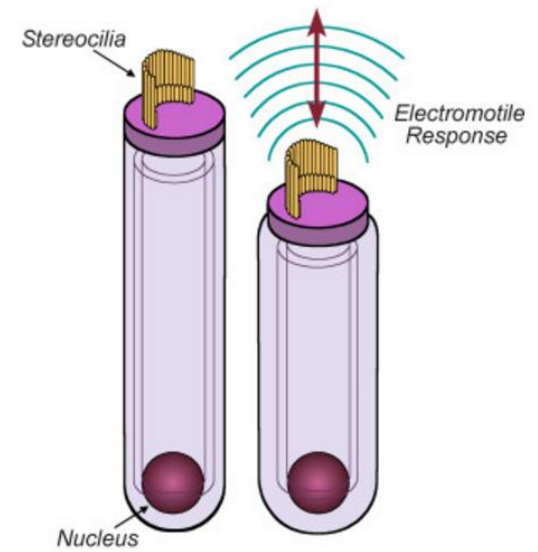
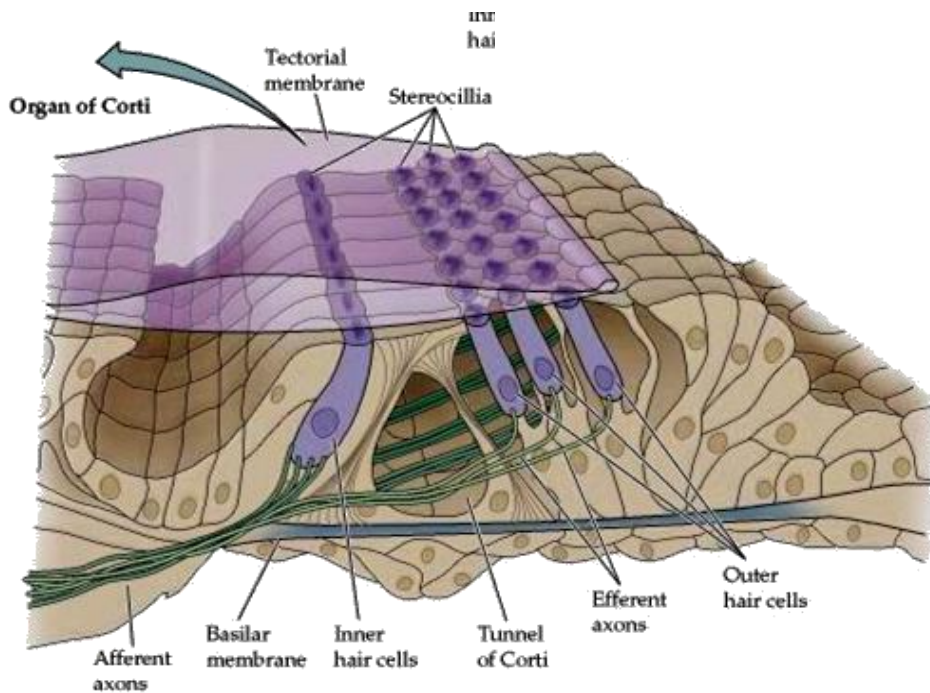
- modulation of the signal
 - ✓ amplification of the signal of required frequencies
- their number increases in the direction to the apex (low frequencies)



Outer hair cells

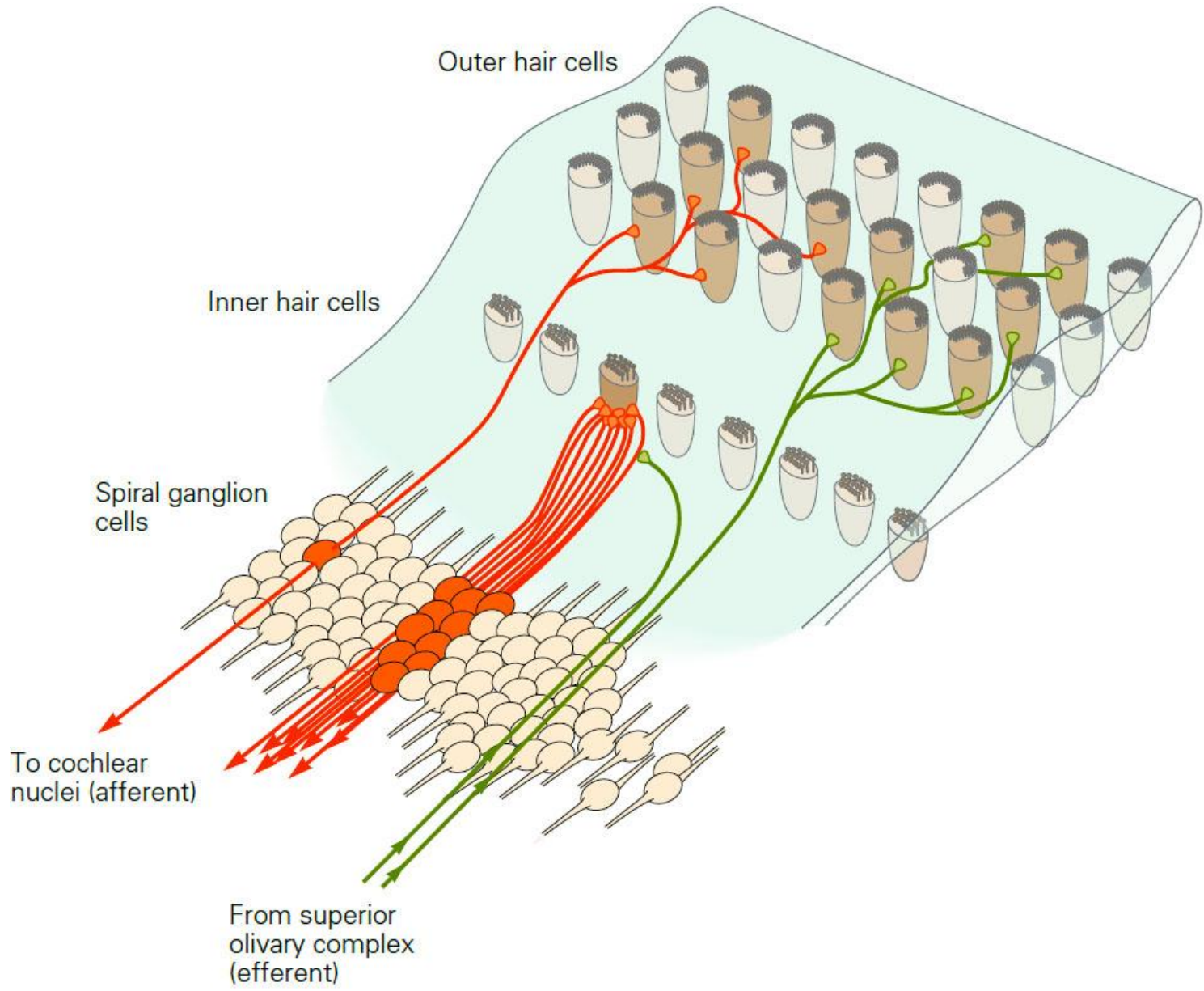
- modulation of the signal
 - ✓ amplification of the signal of required frequency
- their number increases in the direction of the apex (low frequencies)

Their action may be detected (otoacoustic emissions)

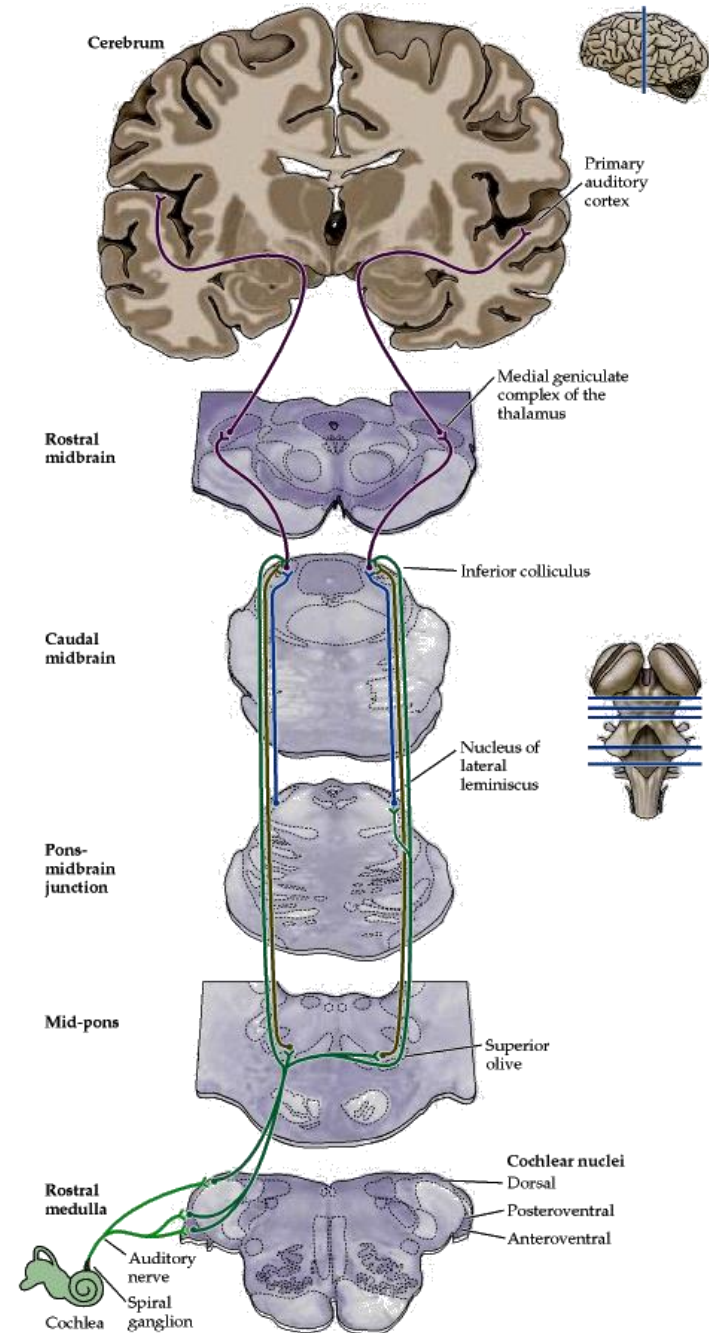


The Outer Hair Cell

Innervation of the organ of Corti

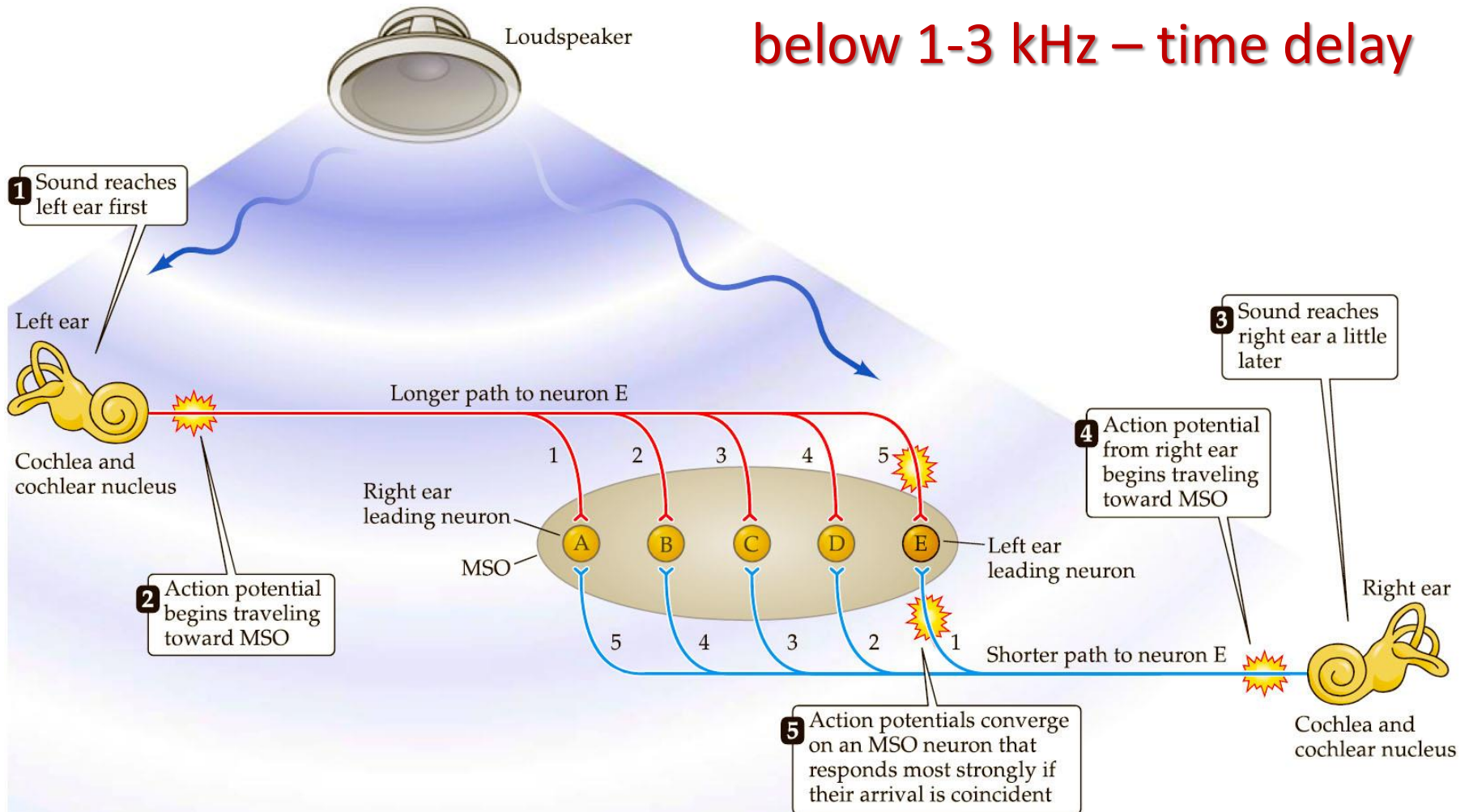


- Nucleus spiralis cochleae
- Nucleus cochlearis ventralis
 - information about the intensity
 - time delay - the sound direction
- Nucleus cochlearis dorsalis
 - information about the frequency
- Olivary nuclei
 - analysis of the direction
 - modulation (increase) of sensitivity of the outer hair cells



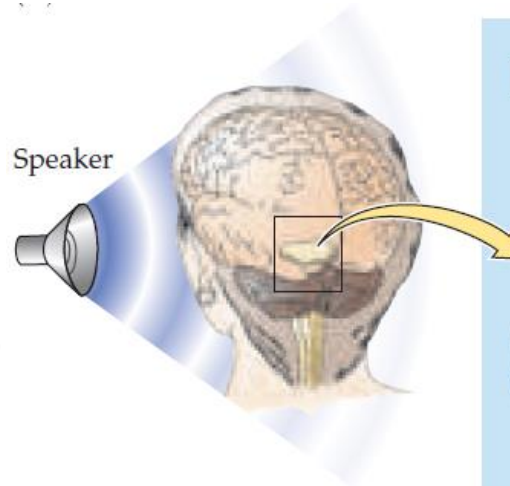
Nucleus olivaris superior medialis

localization of the sound based on analysis of the time delay

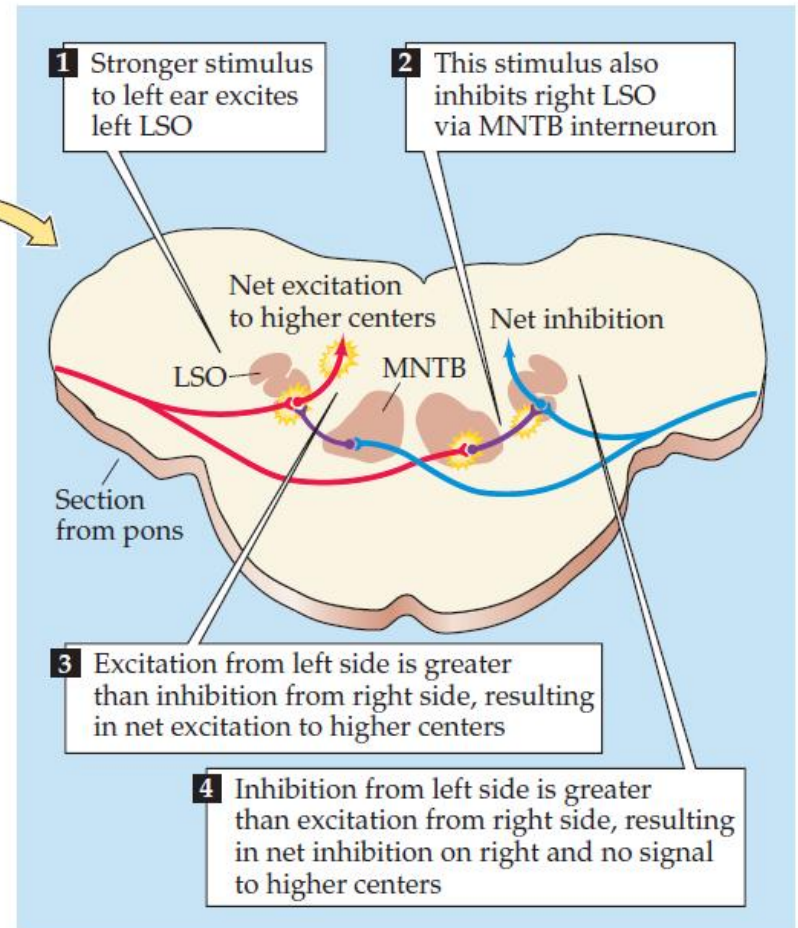
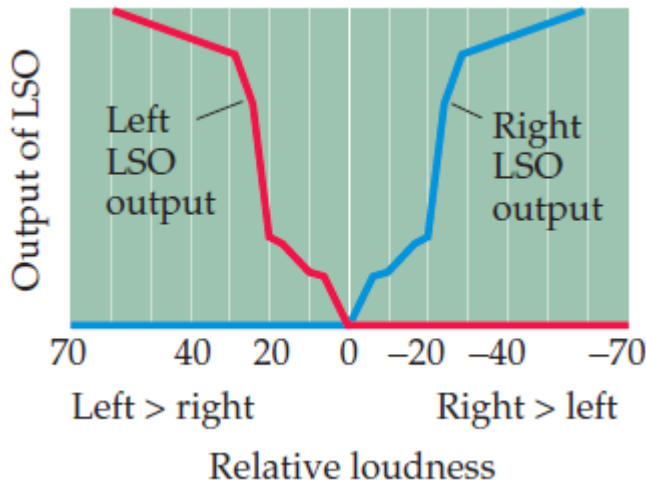


Nucleus olivaris superior lateralis

localization of the sound based on analysis of the intensity

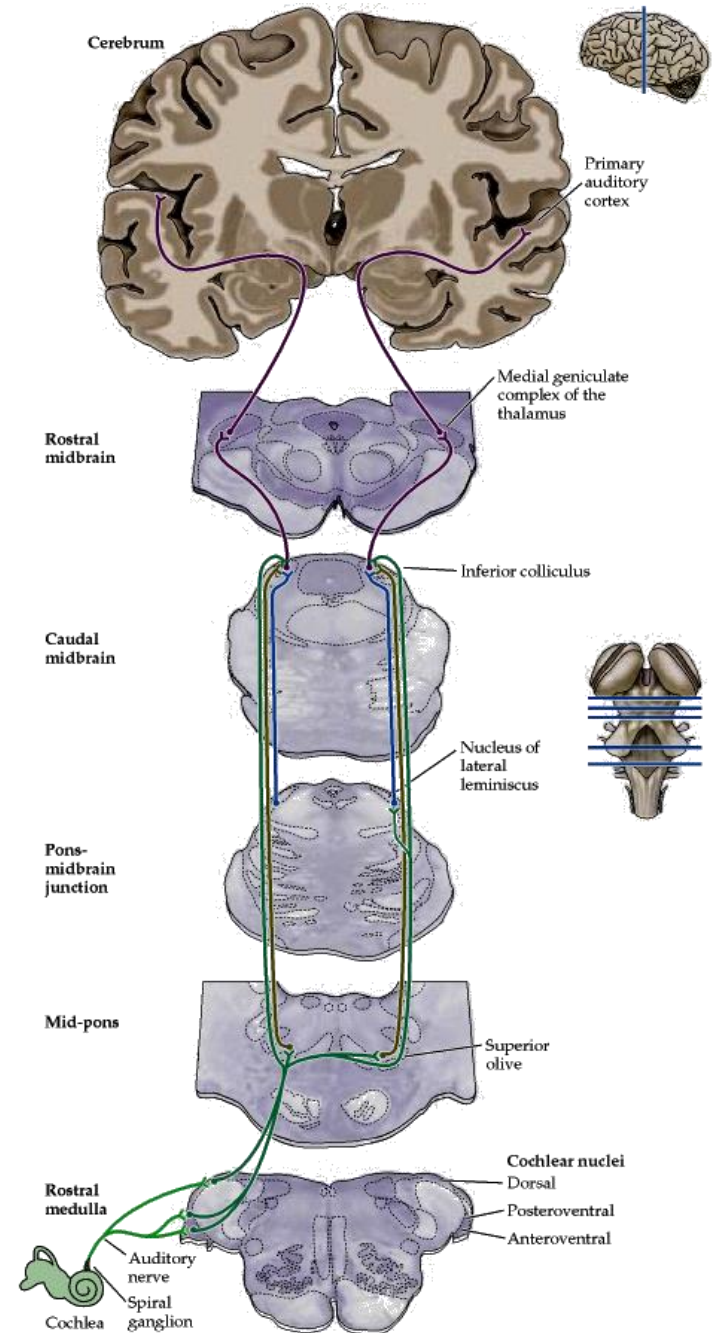


from 1-2 kHz –
intensity

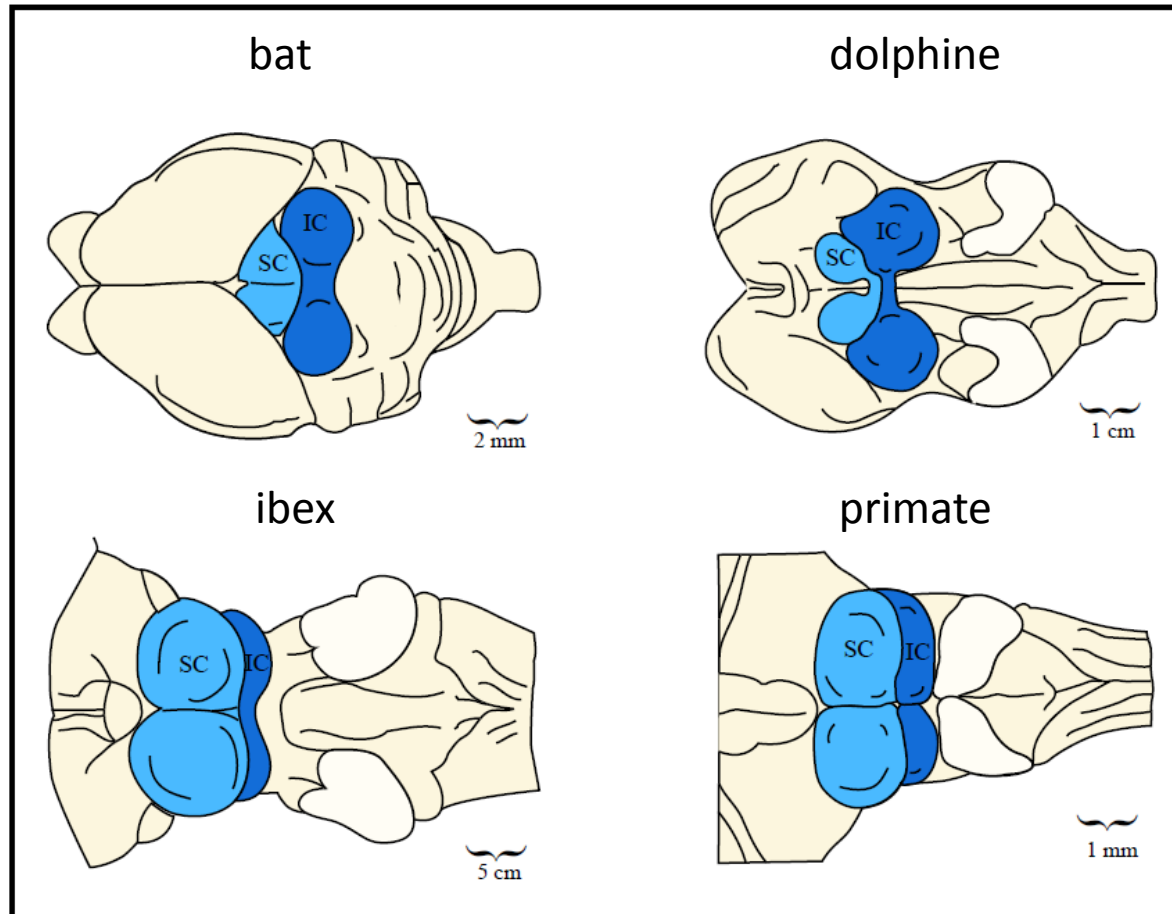


MNTB – medial nucleus of the trapezoid body

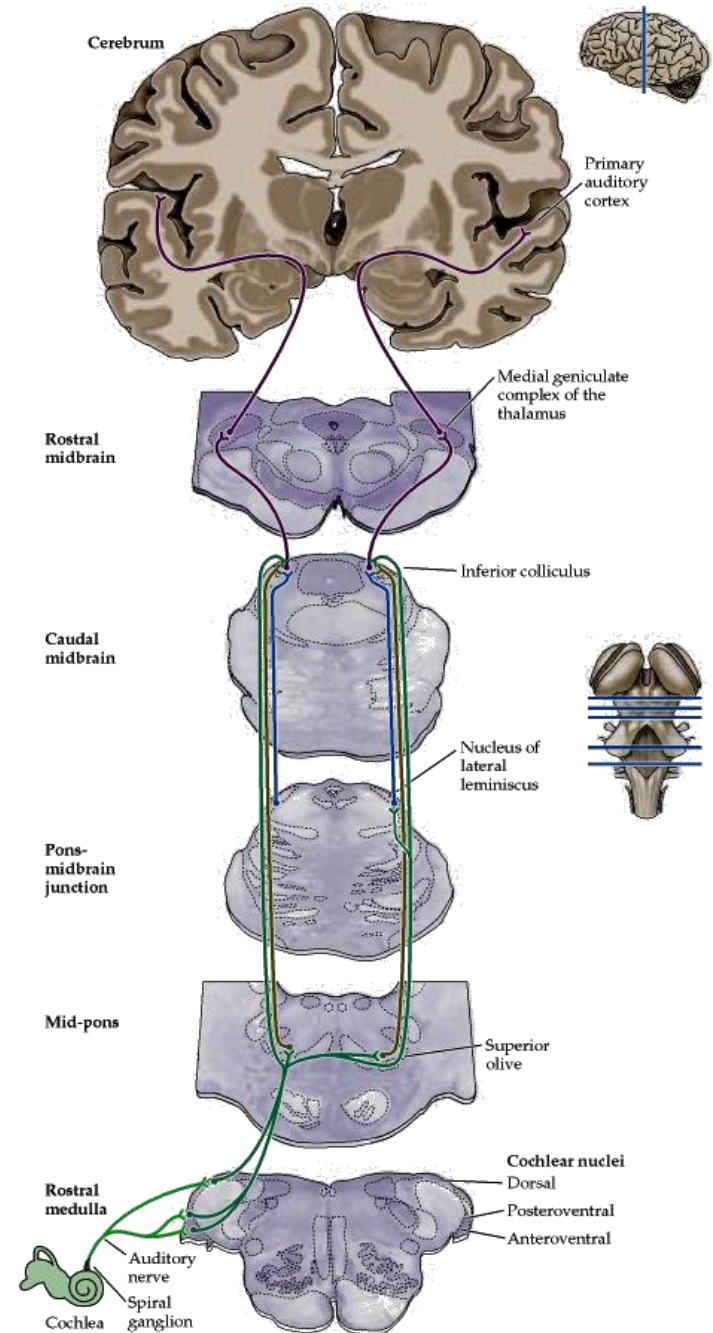
- Nucleus spiralis cochleae
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 - information about the intensity
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- Nucleus cochlearis dorsalis
 - information about the frequency
- Olivary nuclei
 - analysis of the direction
 - modulation (increase) of sensitivity of the outer hair cells
- Colliculi inferiores
 - integration of information from the lower structures
 - centre of the acoustic reflexes



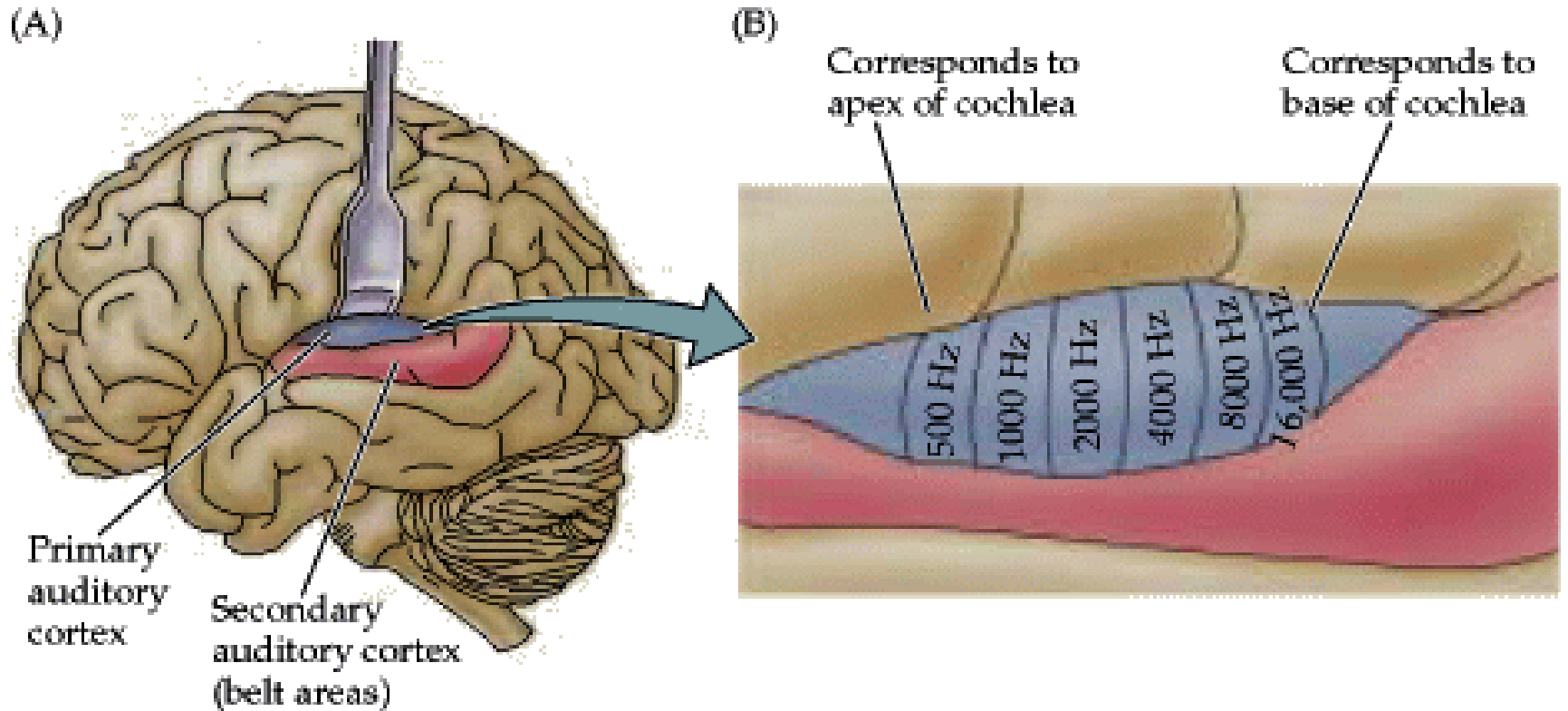
Colliculi inferiores in various animal species



- Nucleus spiralis cochleae
- Nucleus cochlearis ventralis
 - information about the intensity
 - time delay - the sound direction
- Nucleus cochlearis dorsalis
 - information about the frequency
- Olivary nuclei
 - analysis of the direction
 - modulation (increase) of sensitivity of the outer hair cells
- Colliculi inferiores
 - integration of information from the lower structures
 - centre of the acoustic reflexes
- Nucleus corporis geniculati medialis (thalamus)
- Auditory cortex



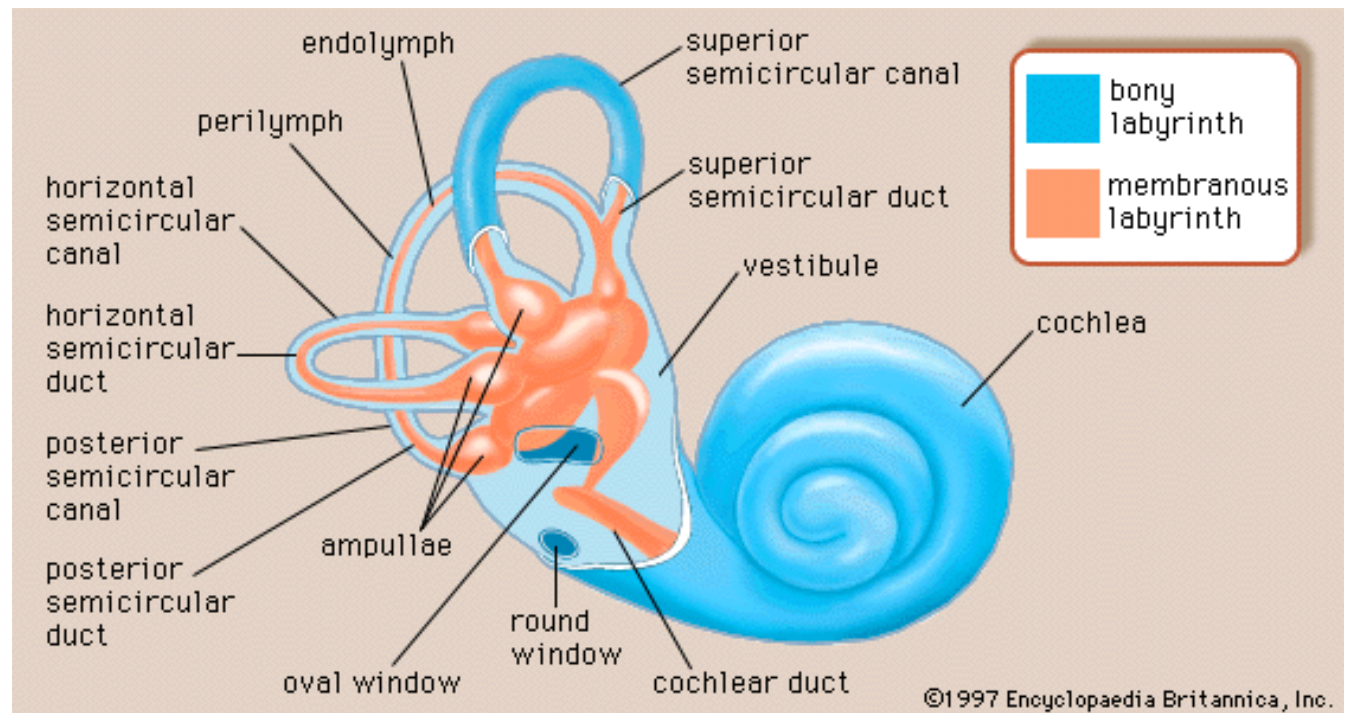
Auditory cortex



Vestibular system

Vestibular system

- anatomic localization, hair cells
- information about the position
- information about the acceleration
 - Linear
 - Angular



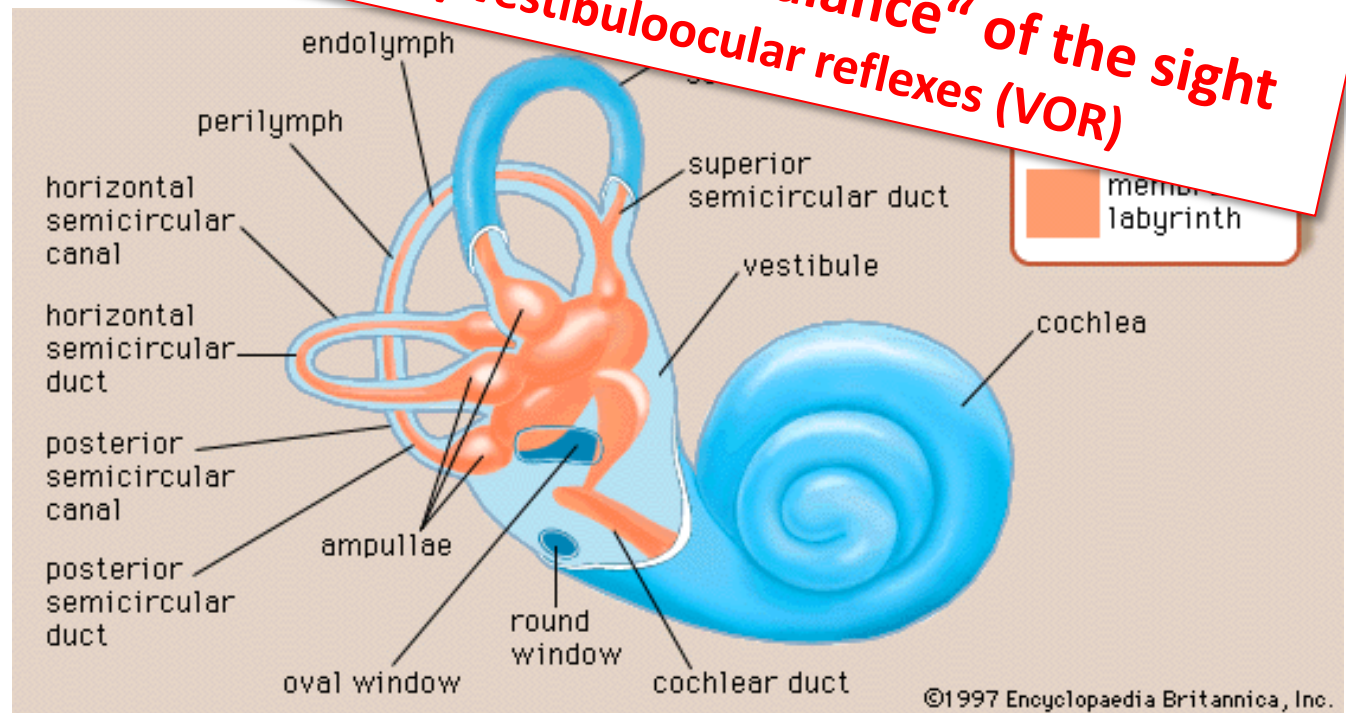
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Vestibular system

- anatomic localization
- information about
- information about
 - Linear
 - Angular

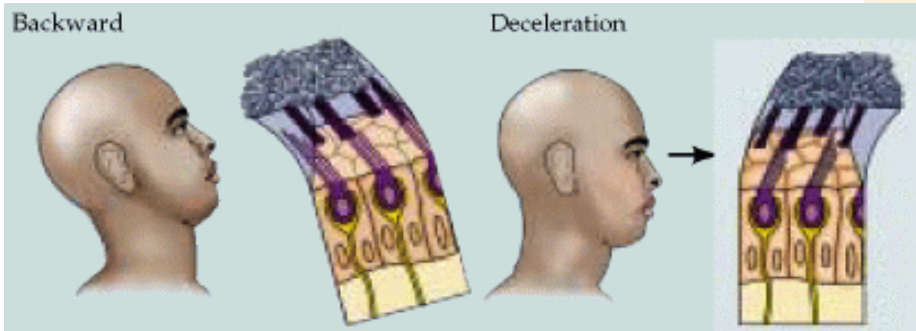
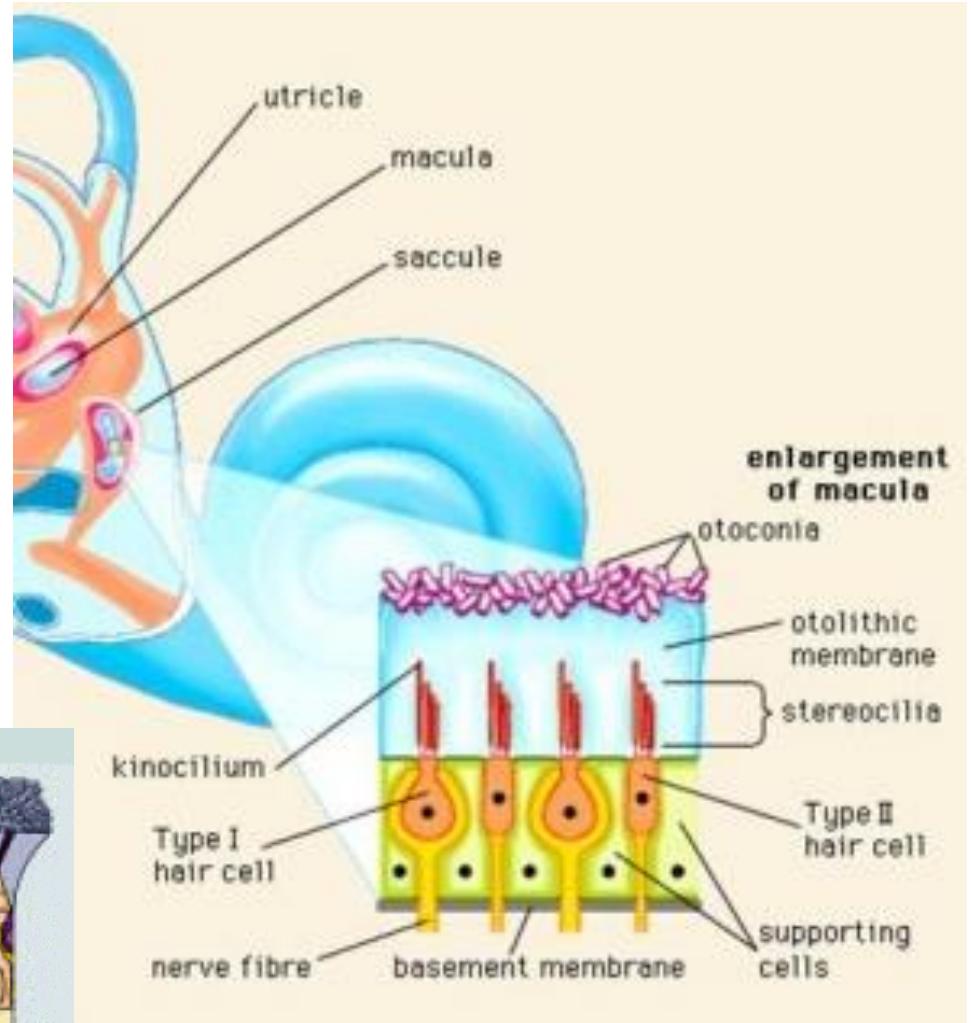
Maintenance of the balance
by modification of the muscle tone

„Maintenance of the balance“ of the sight
by vestibuloocular reflexes (VOR)



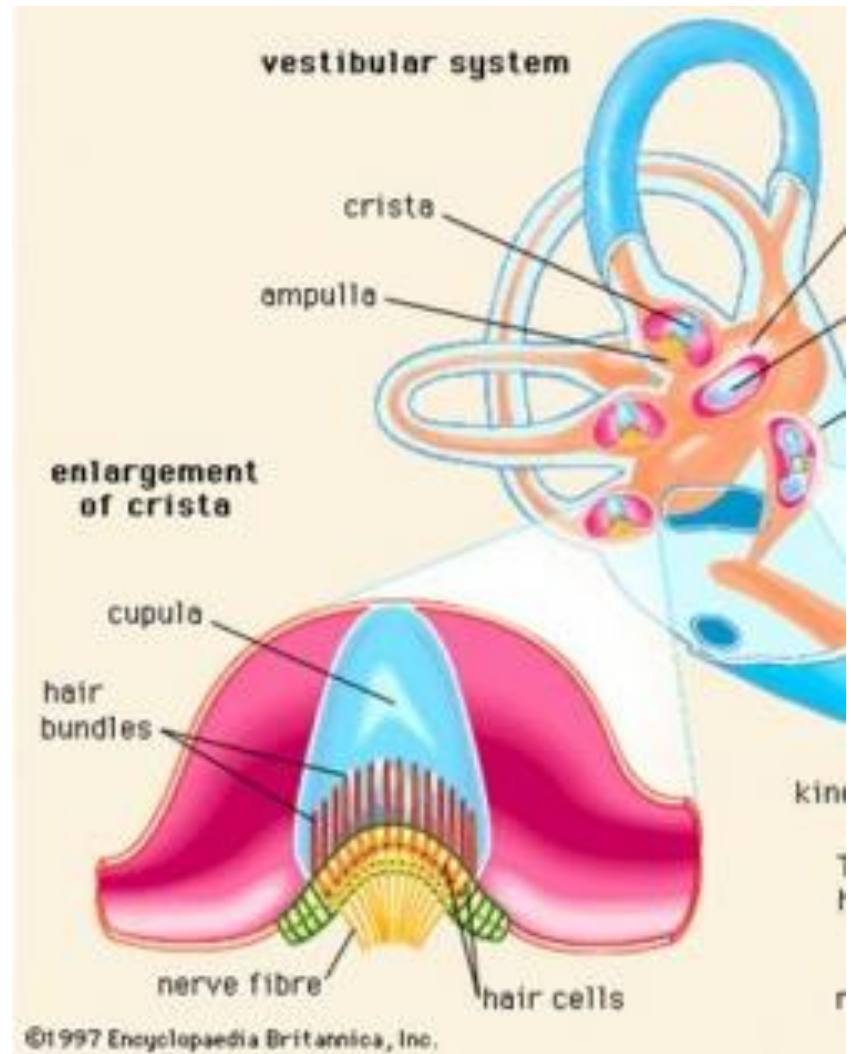
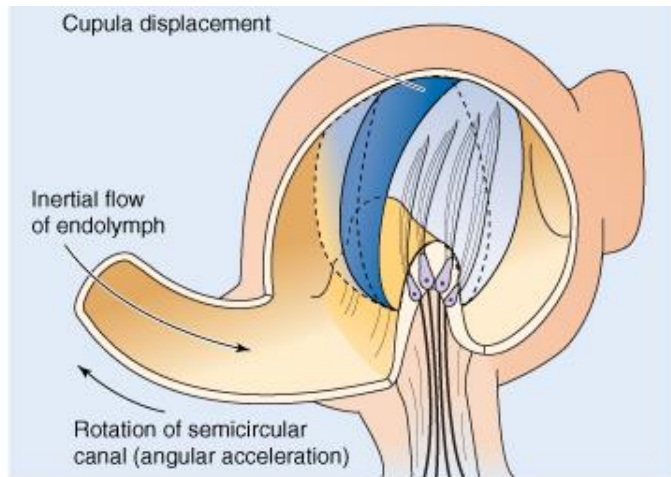
Information about position and linear acceleration

- Macula
 - Crystals of CaCO_3
- Utriculus
 - Macula horizontally
- Sacculus
 - Macula vertically



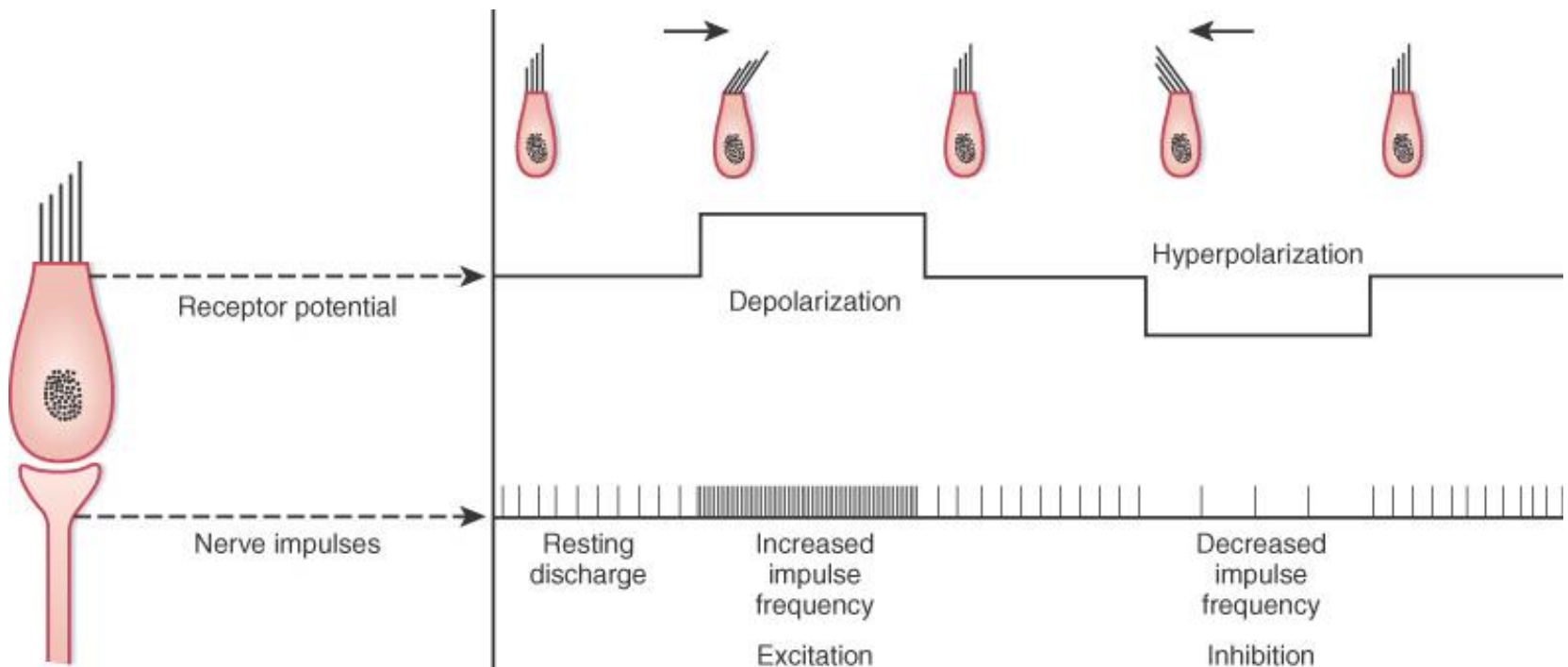
Information about angular acceleration

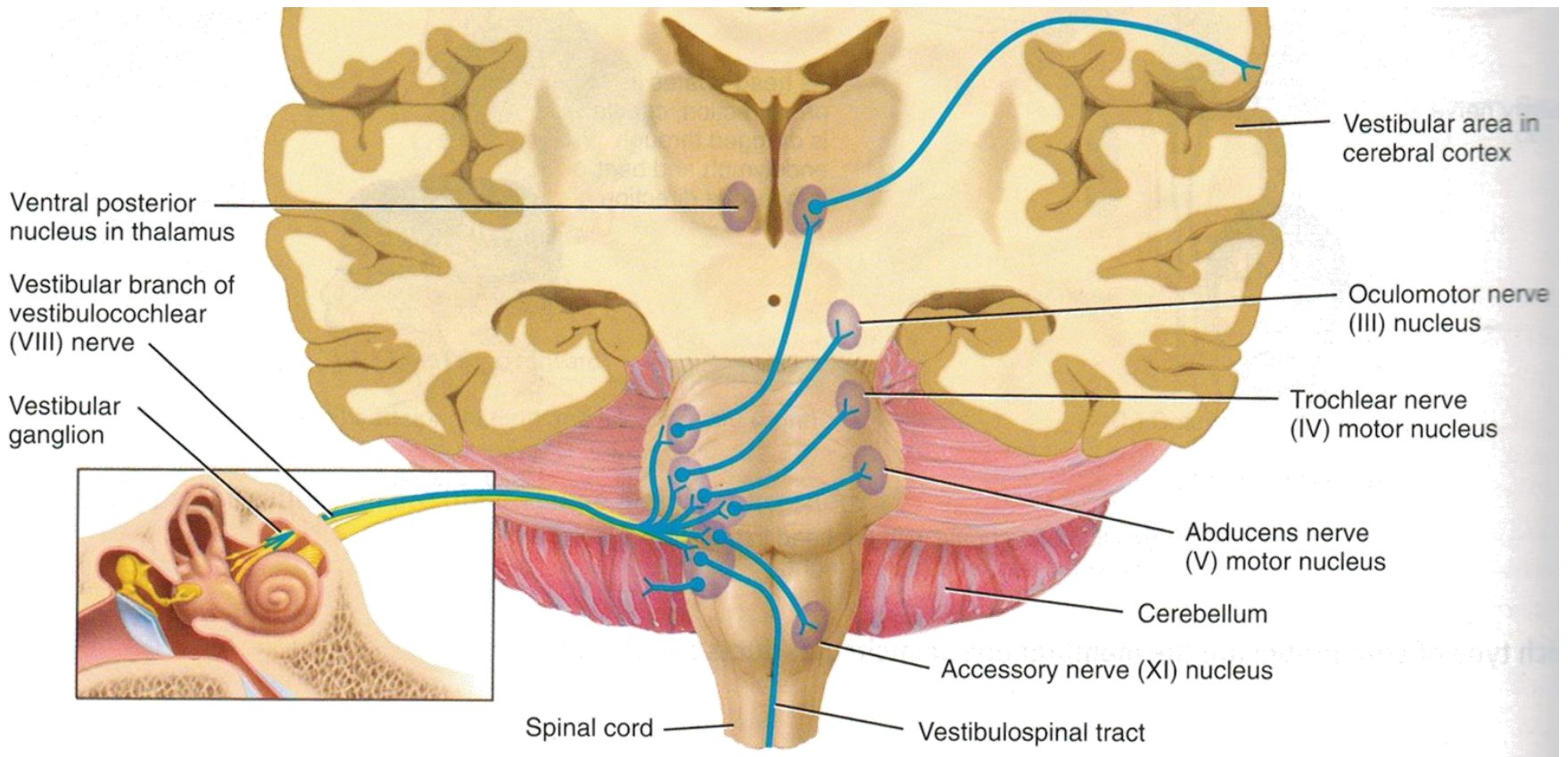
- Ampullae
- Semicircular canals
 - upper
 - horizontal
 - posterior



Mechanism

- Flexion towards stereocilia
 - opening of mechanically activated K^+ channels – depolarization
- Flexion away from stereocilia
 - closing of the channels - hyperpolarization





Vestibular nuclei

- integration of vestibular, visual and somatosensory information
- projections:
 - cerebellum
 - oculomotoric nuclei
 - nucleus of n. accessorius (neck muscles)
 - thalamus - cortex