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Auditory and vestibular system

Auditory system

- Transduction of sound waves to the receptor and the action potential
- Transmission to CNS
- Signal processing
 - Sound decoding
 - Interpretation

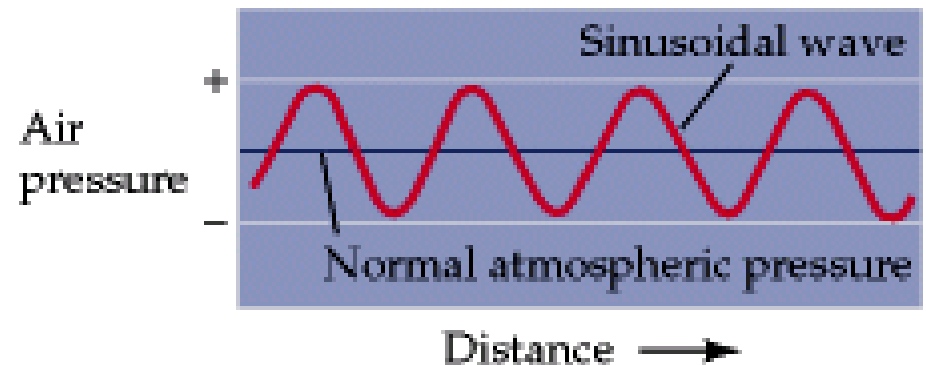
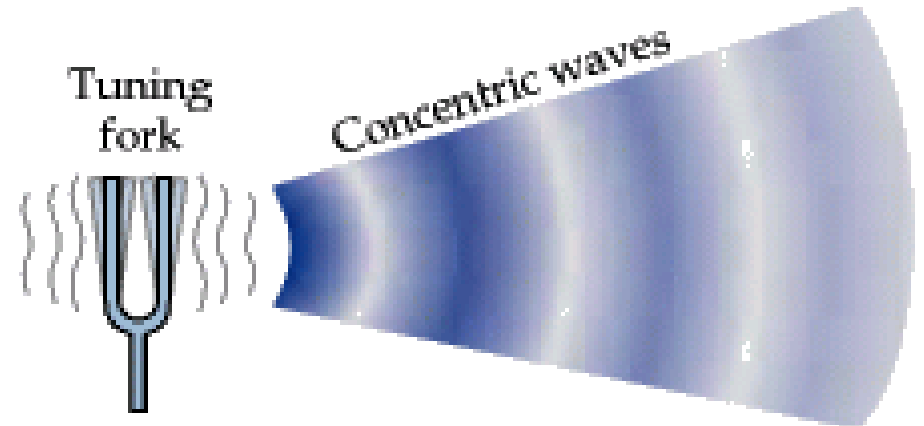
Auditory system

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Sound is audible mechanical vibration of an elastic medium such as air

Sound

- Produced by vibration of solid object in the air or water
- Sound characteristics
 - Frequency – pitch
 - Amplitude – intensity
 - Timbre – given by representation of harmonic frequencies of the oscillation
- Pure tone
- Complex sound



<http://www.slideshare.net/drpsdeb/presentations>

Sound

- Pure tone
- Complex sound
 - Harmonic (musical)
 - periodic
 - Disharmonic (noise)
 - aperiodic

Noise



Tone



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

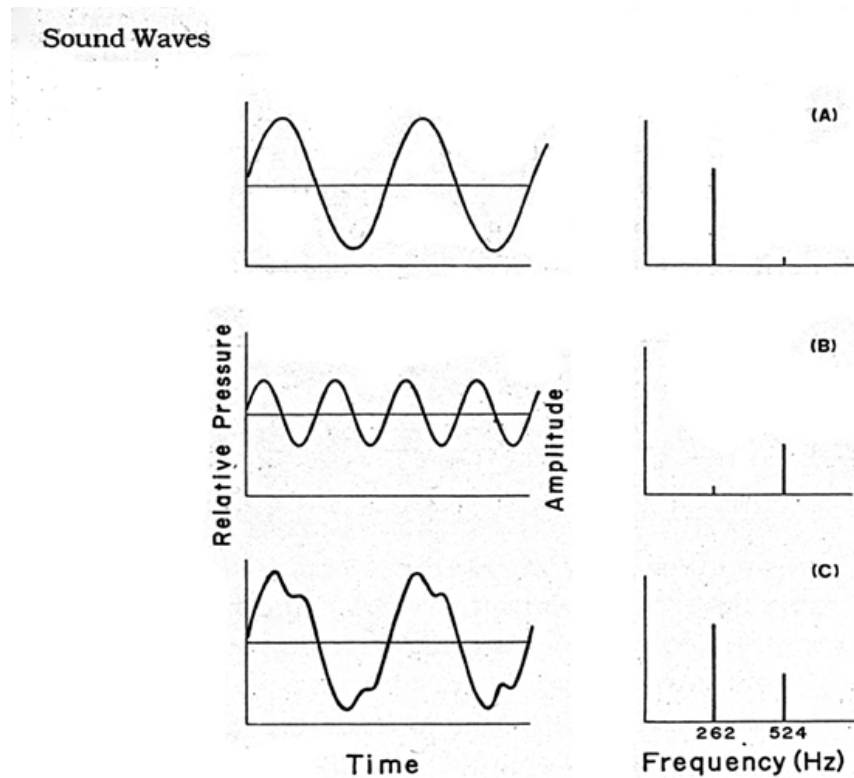
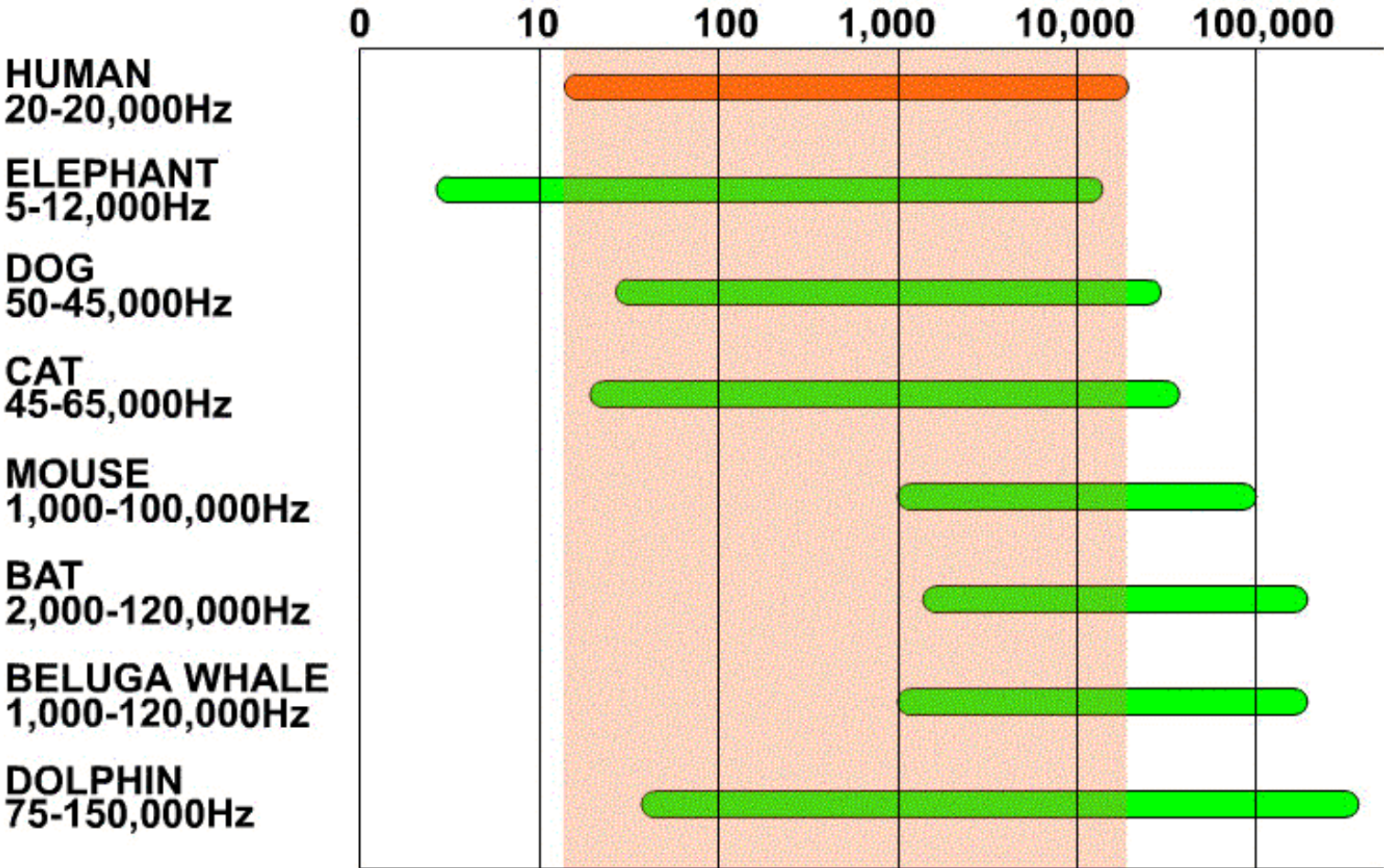


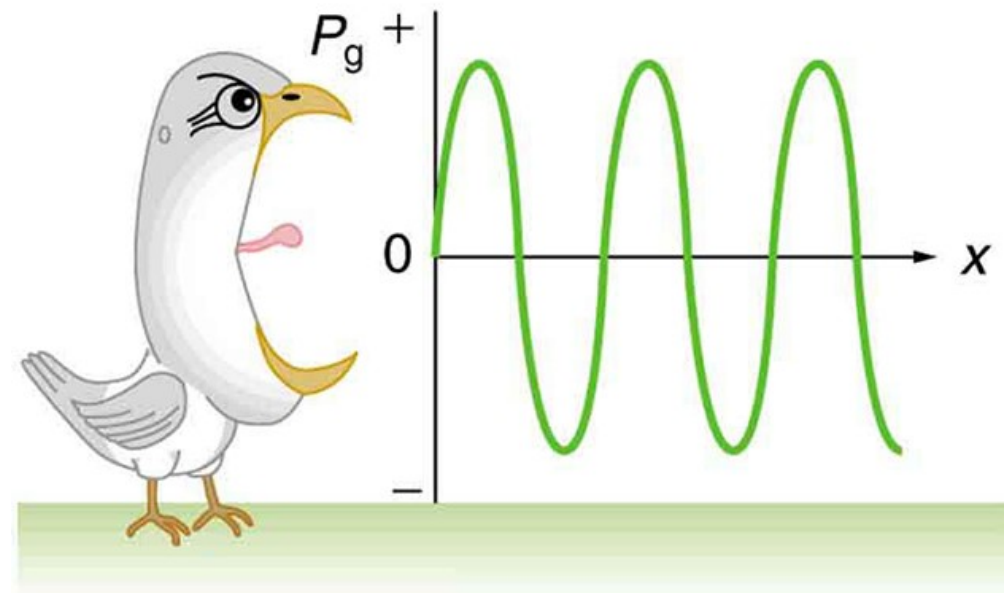
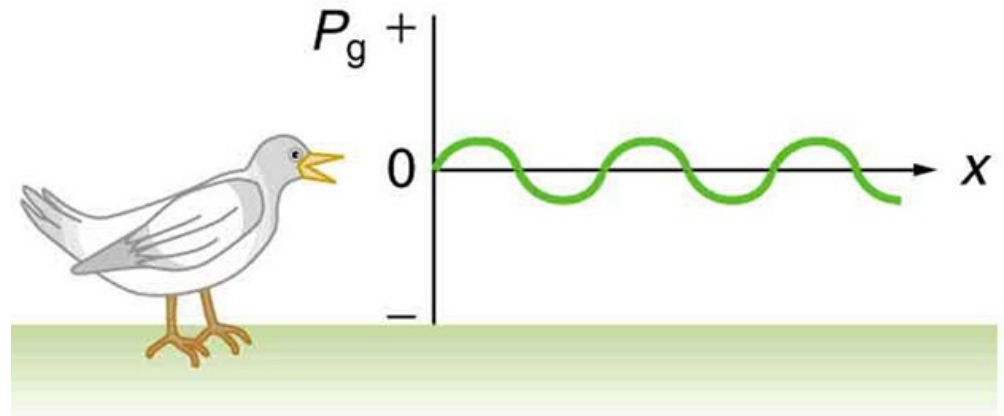
Figure 2.7 Waveform (left) and spectra (right) of two sine waves (A and B), combining into a complex wave (C).

Audible spectrum



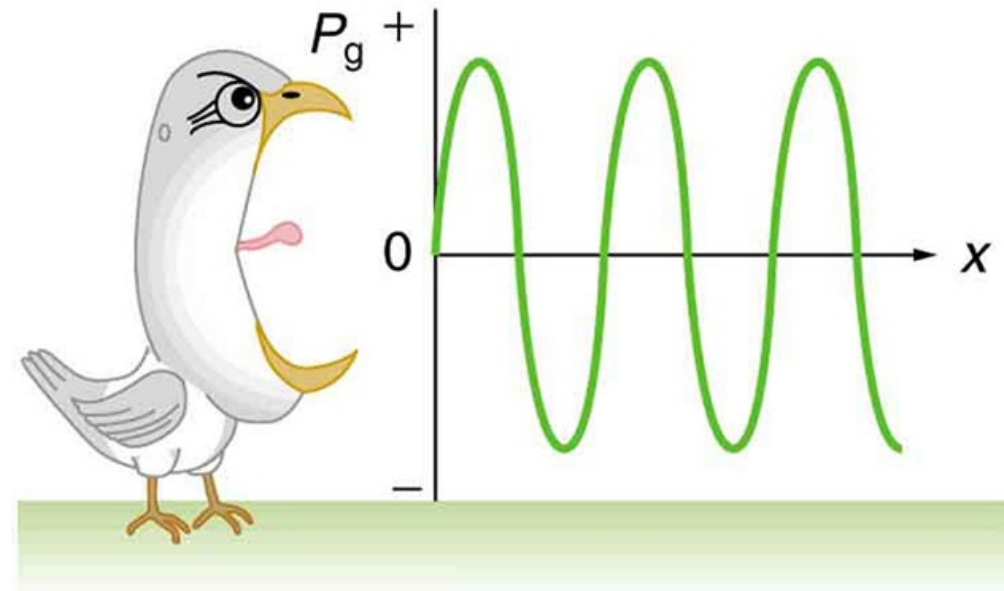
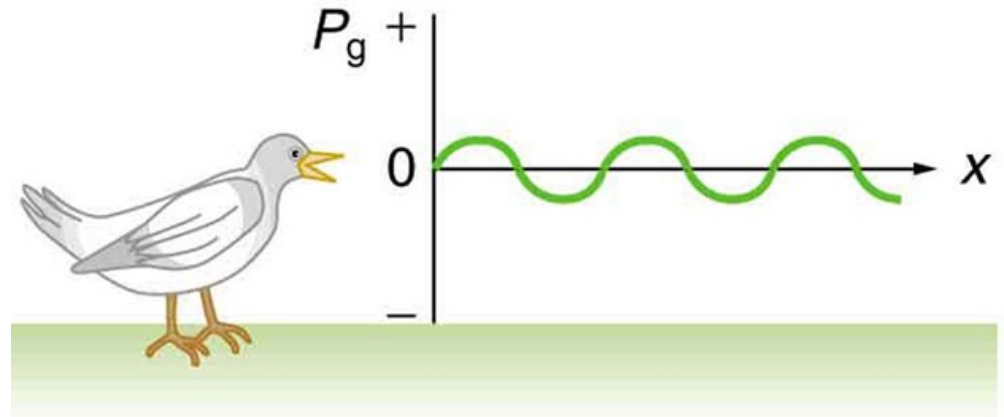
The intensity and volume of sound

- Intensity of sound
 - Amplitude
 - Whisper – 20 dB
 - Speaking - 65 dB
 - Jet engine – 100 dB
 - Pain treshold – 120 dB



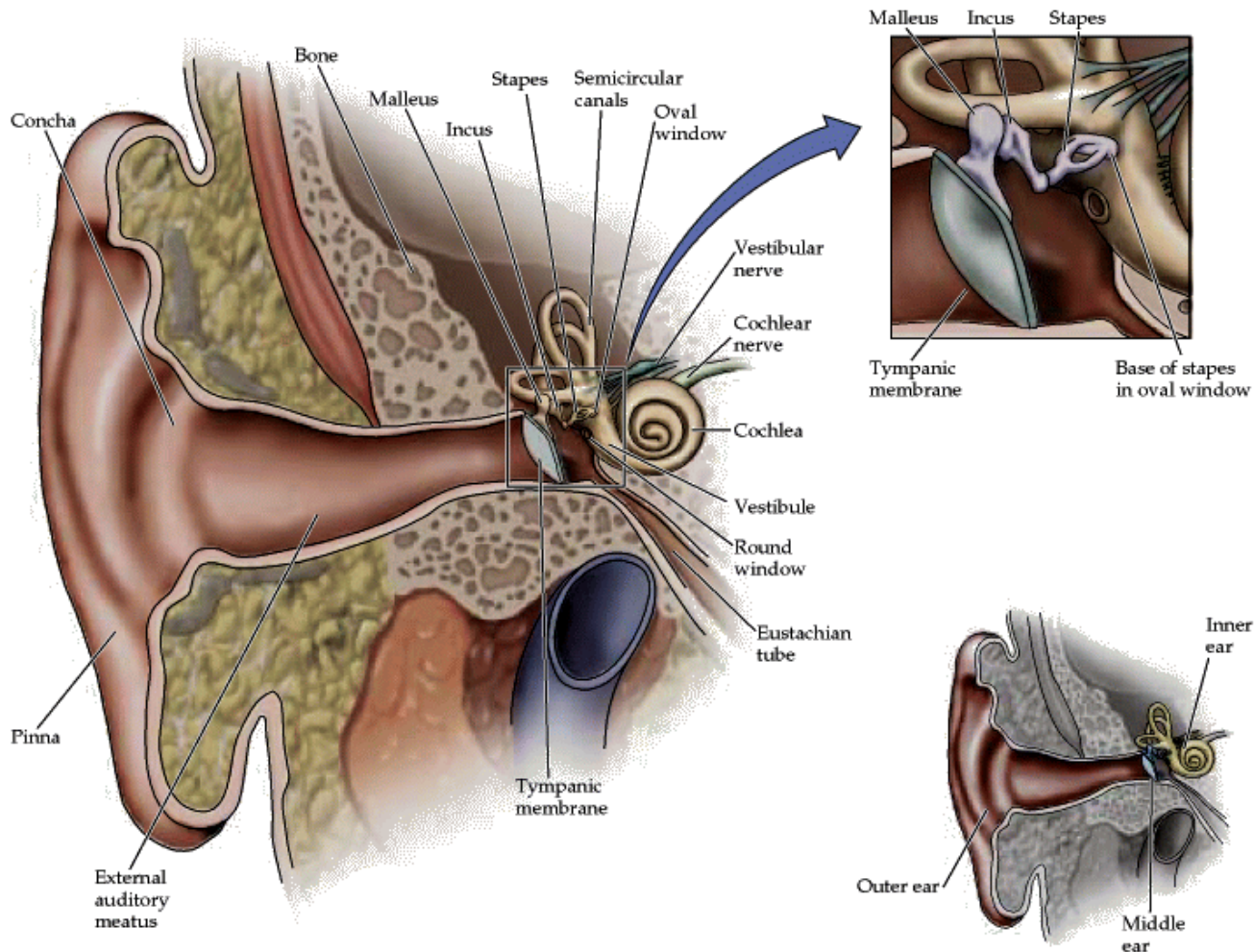
The intensity and volume of sound

- Intensity of sound
 - Amplitude
 - Whisper – 20 dB
 - Speaking - 65 dB
 - Jet engine – 100 dB
 - Pain treshold – 120 dB
- Volume – subjectively perceived intensity



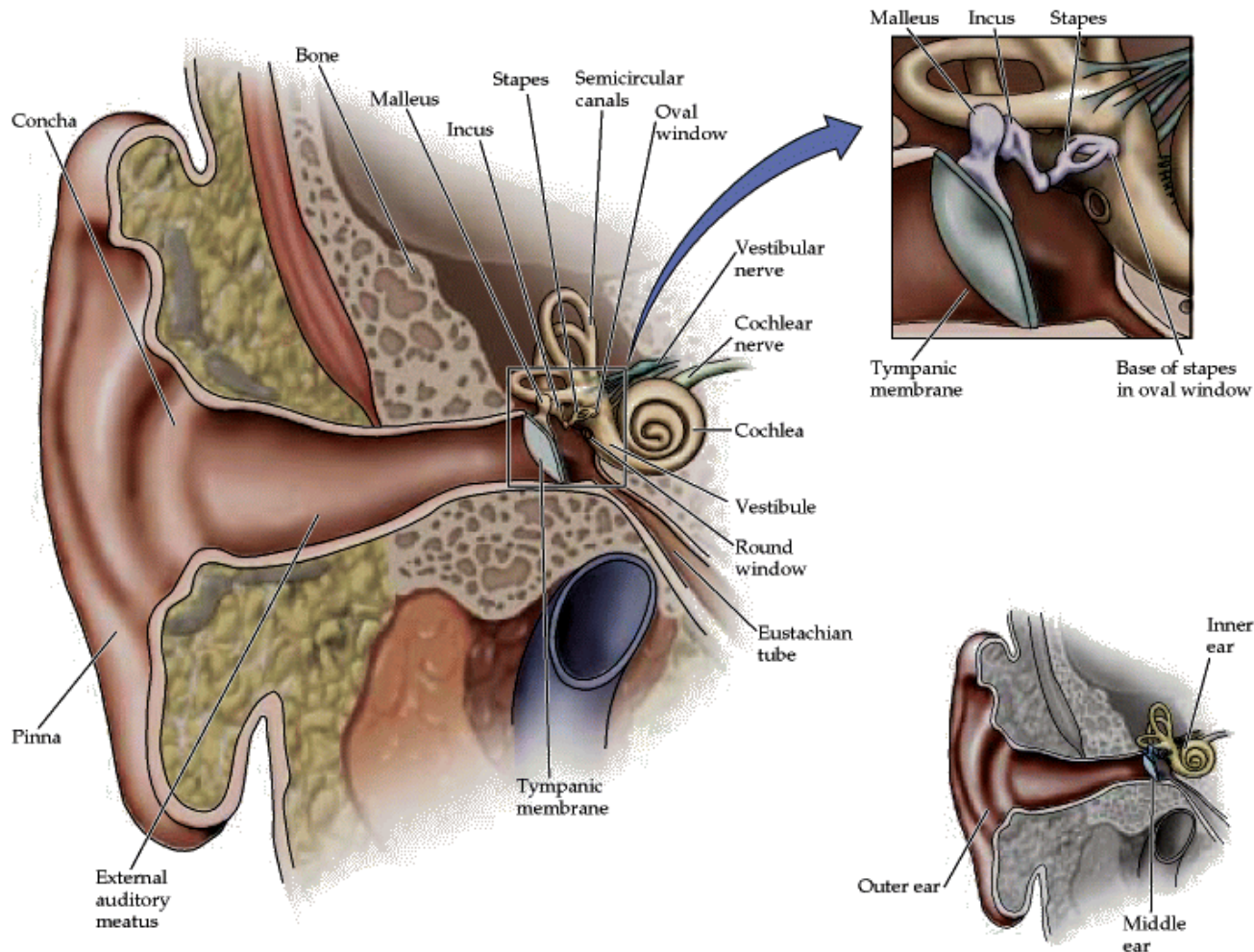
External ear

Transmission of acoustic signal from environment to the tympanic membrane



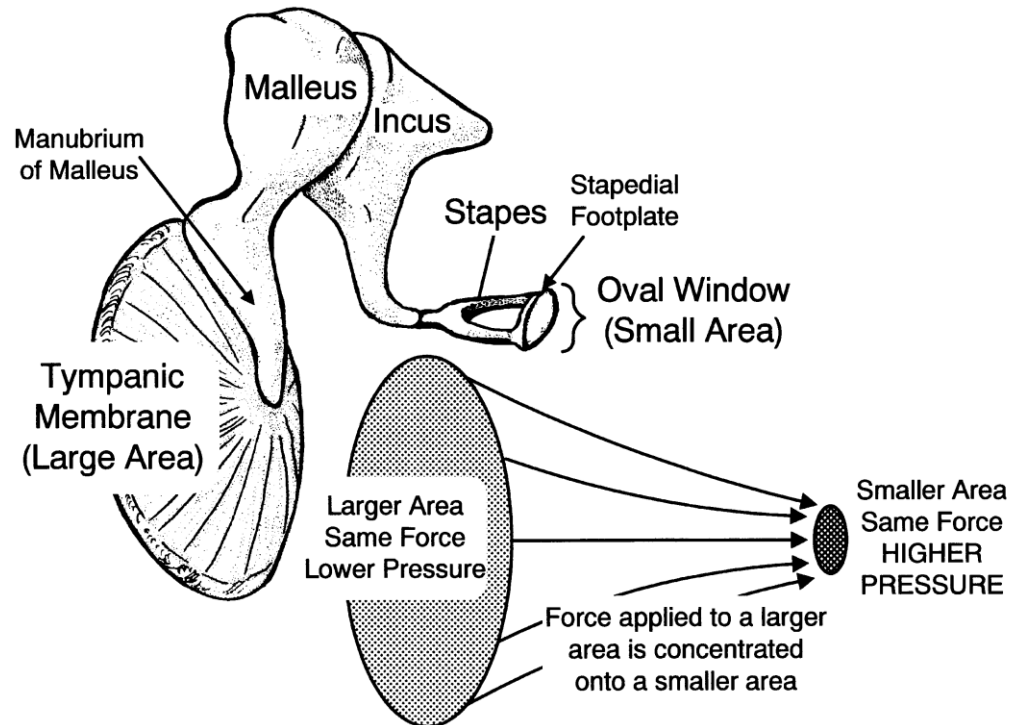
Middle ear

Transmission of acoustic signal from the tympanic membrane to the oval window and perilymph



Middle ear

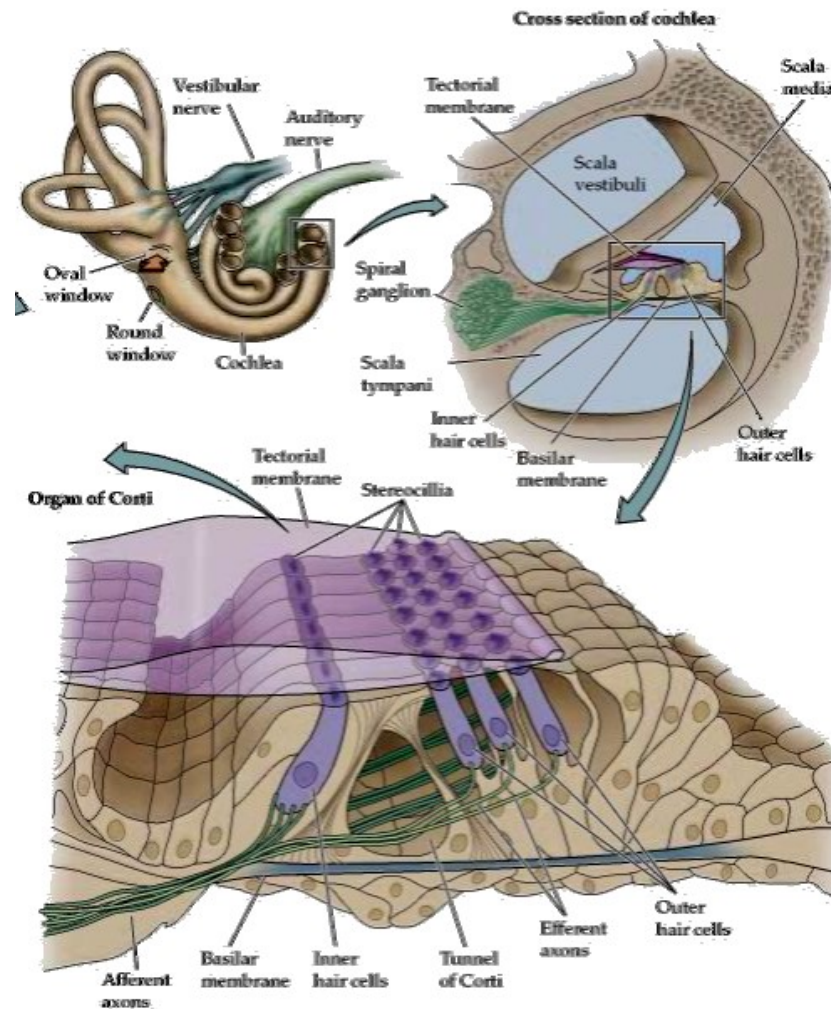
- A significant difference in acoustic impedance between air and perilymph
- Signal amplification
 - Tympanic membrane area/oval window area
 - Ossicles
- Protective function
 - m.stapedius and tensor tympani
 - Eustachian tube



<http://slideplayer.com/slide/3433153/>

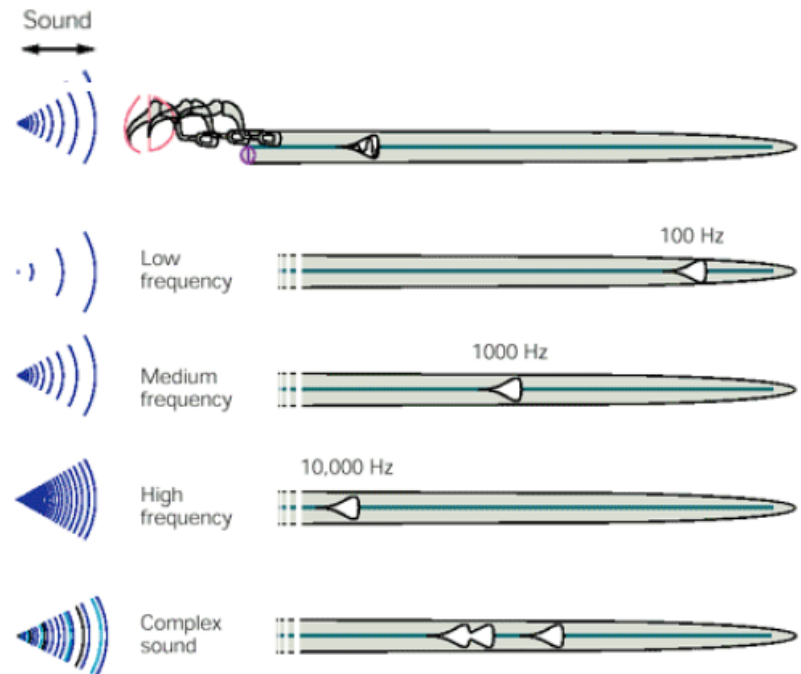
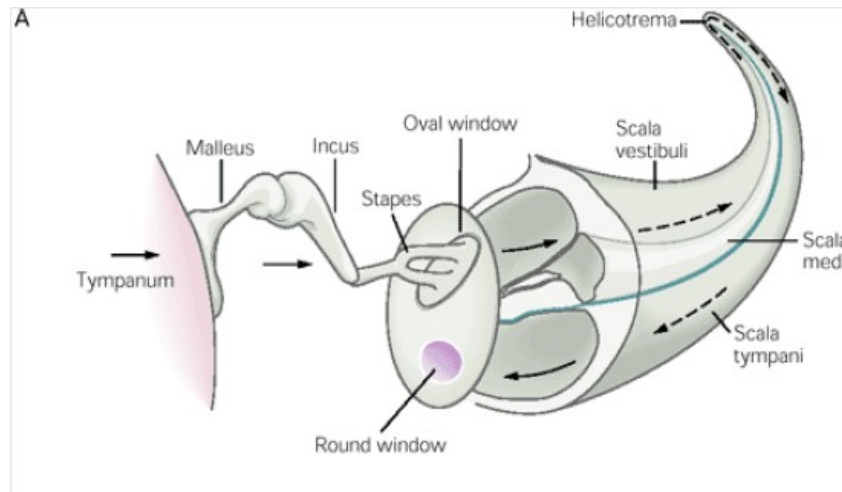
Inner ear

Transduction of endolymph vibrations to receptor and action potential



Tonotopic arrangement

- Proximal part
– high frequency
- Distal part
– low frequency



<http://www.slideshare.net/drpsdeb/presentations>

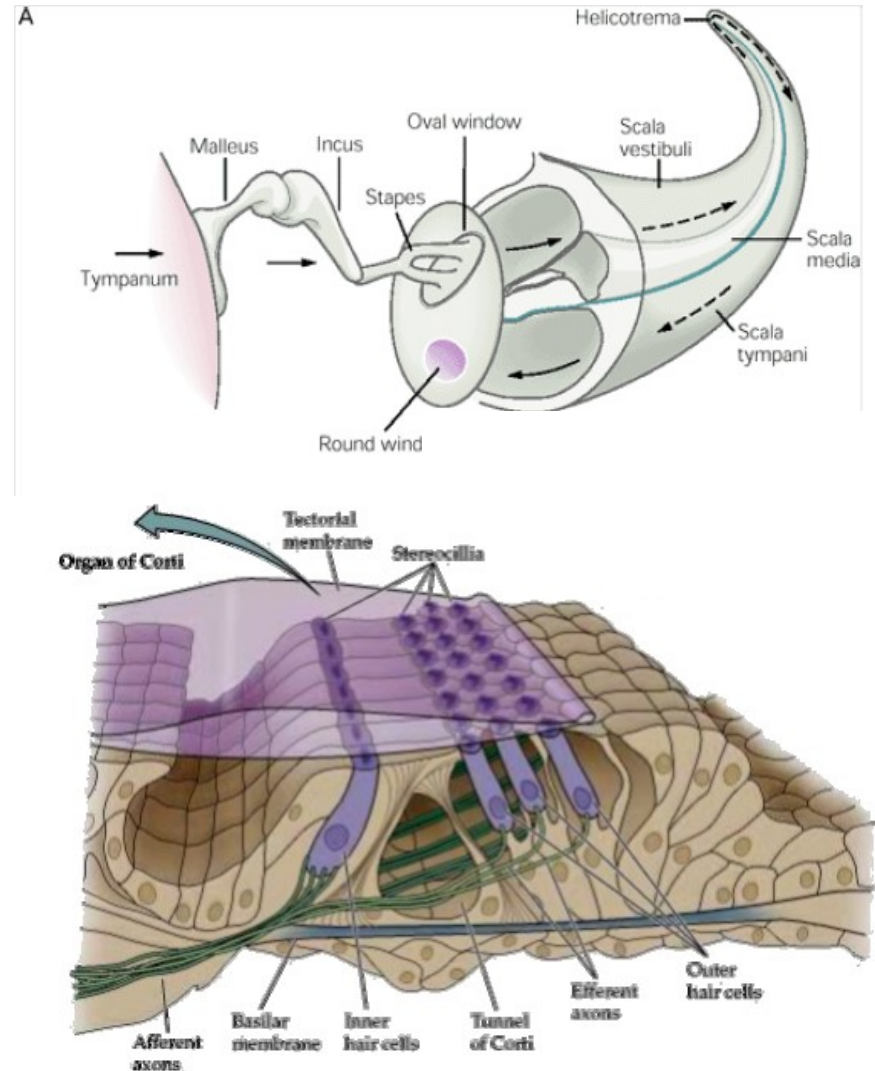
Organ of Corti

➤ Inner hair cells

➤ aprox. 3 500

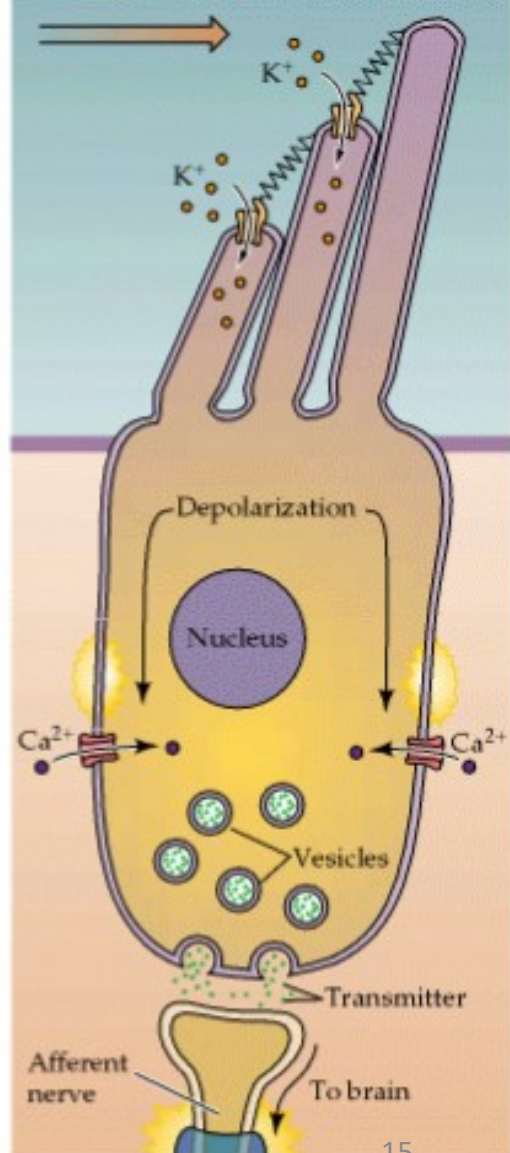
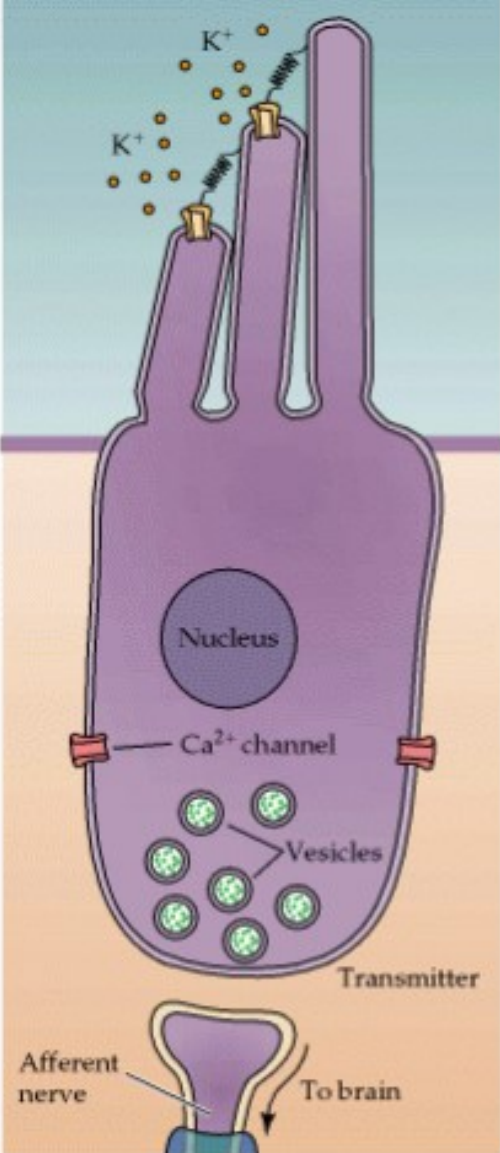
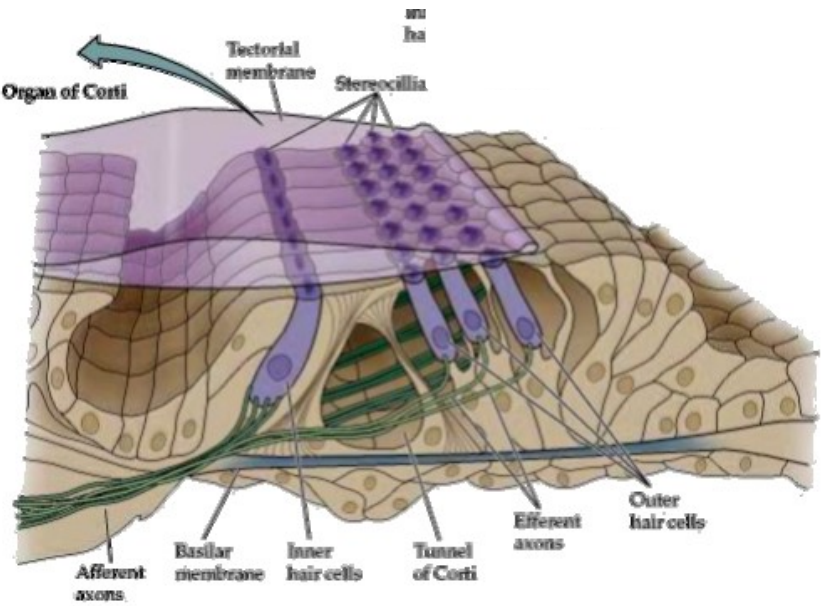
➤ Outer hair cells

➤ aprox. 12 000



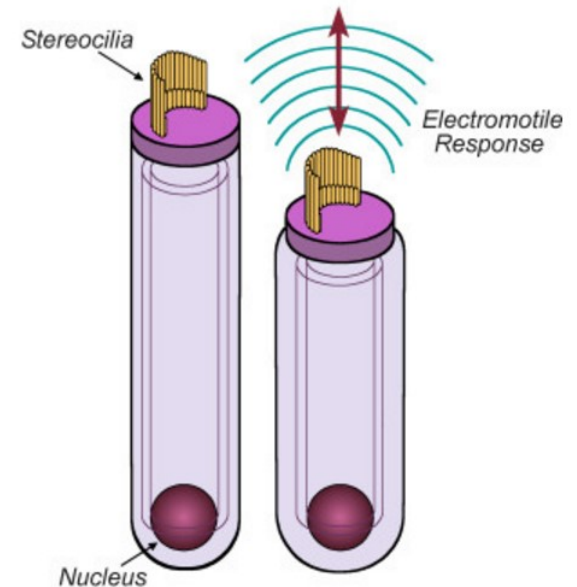
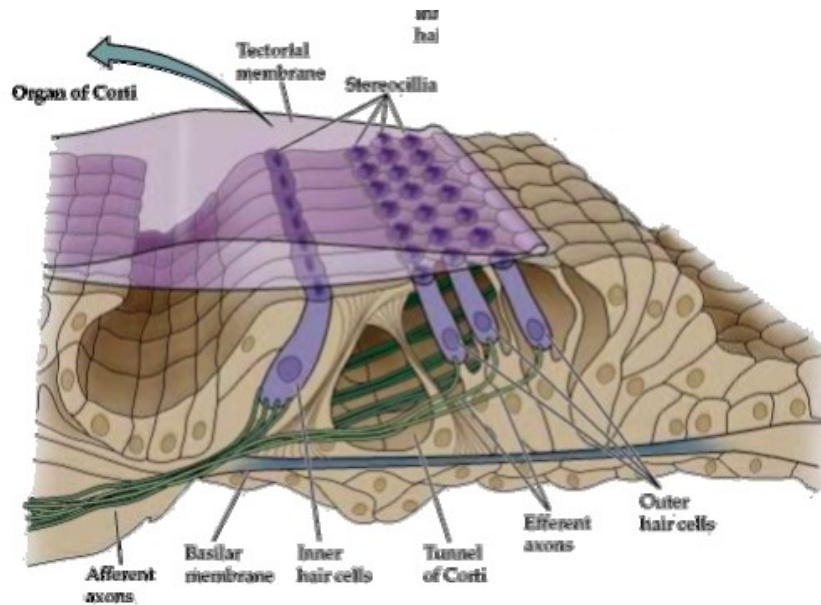
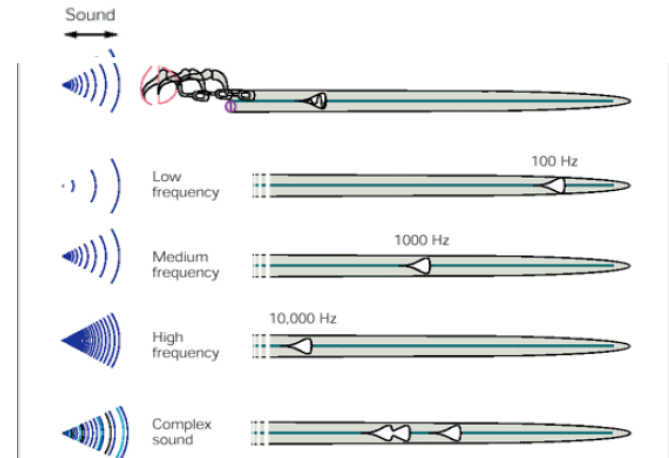
Inner hair cells

➤ Sensory function



Outer hair cells

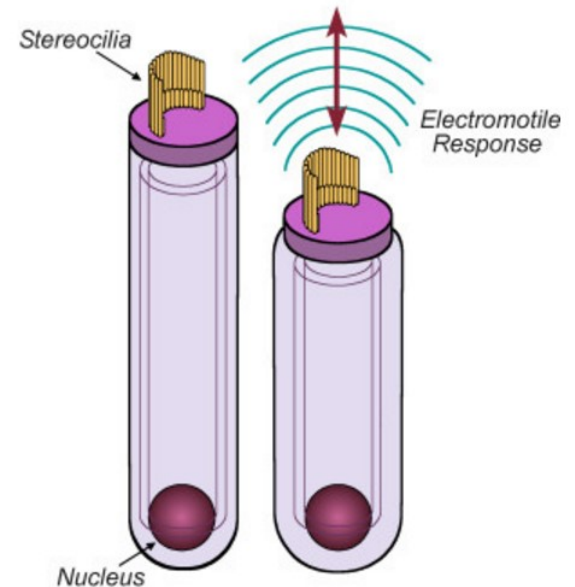
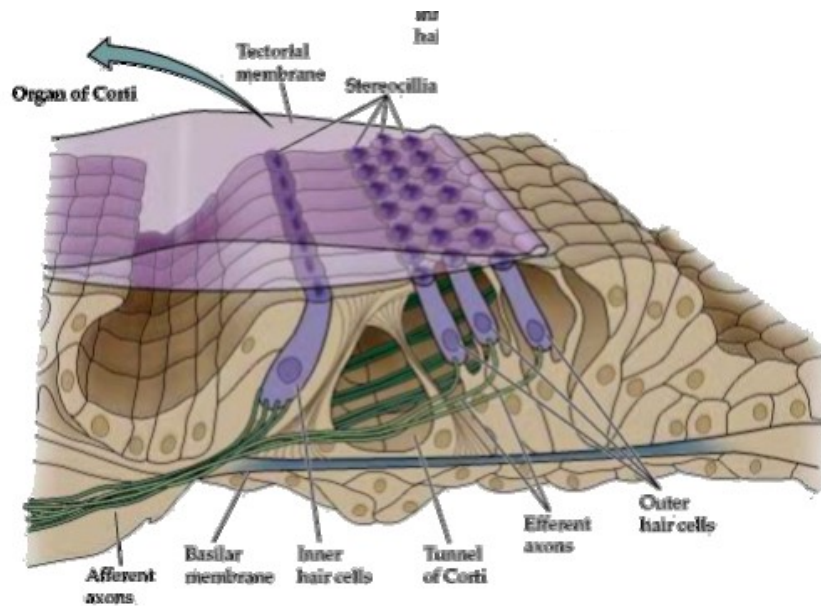
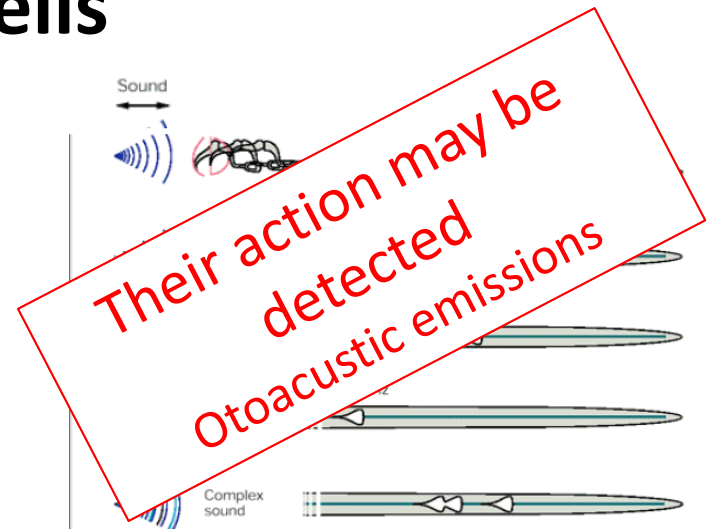
- Modulation of the signal
 - ✓ Amplification of required frequencies
- The number increases towards apex (low frequencies)



The Outer Hair Cell

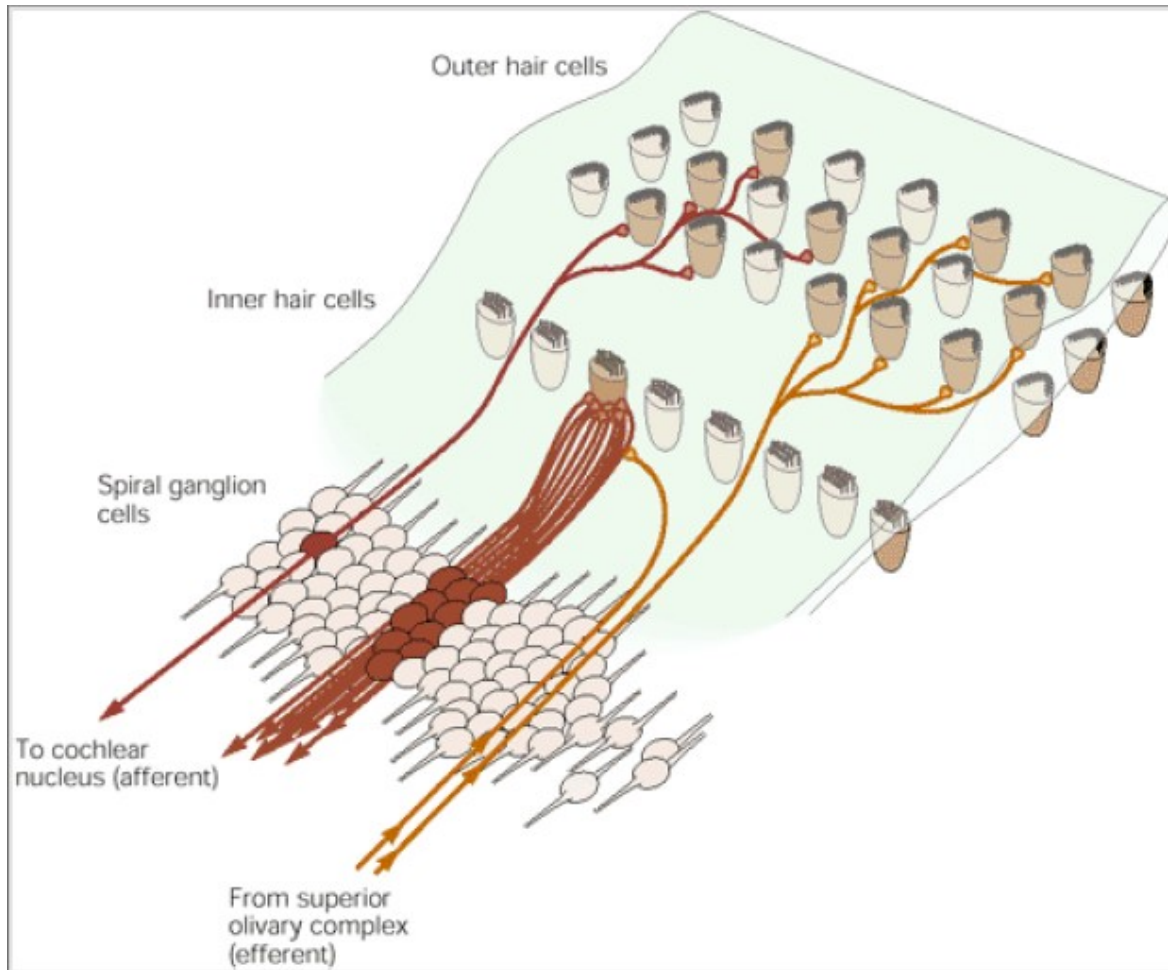
Outer hair cells

- Modulation of the signal
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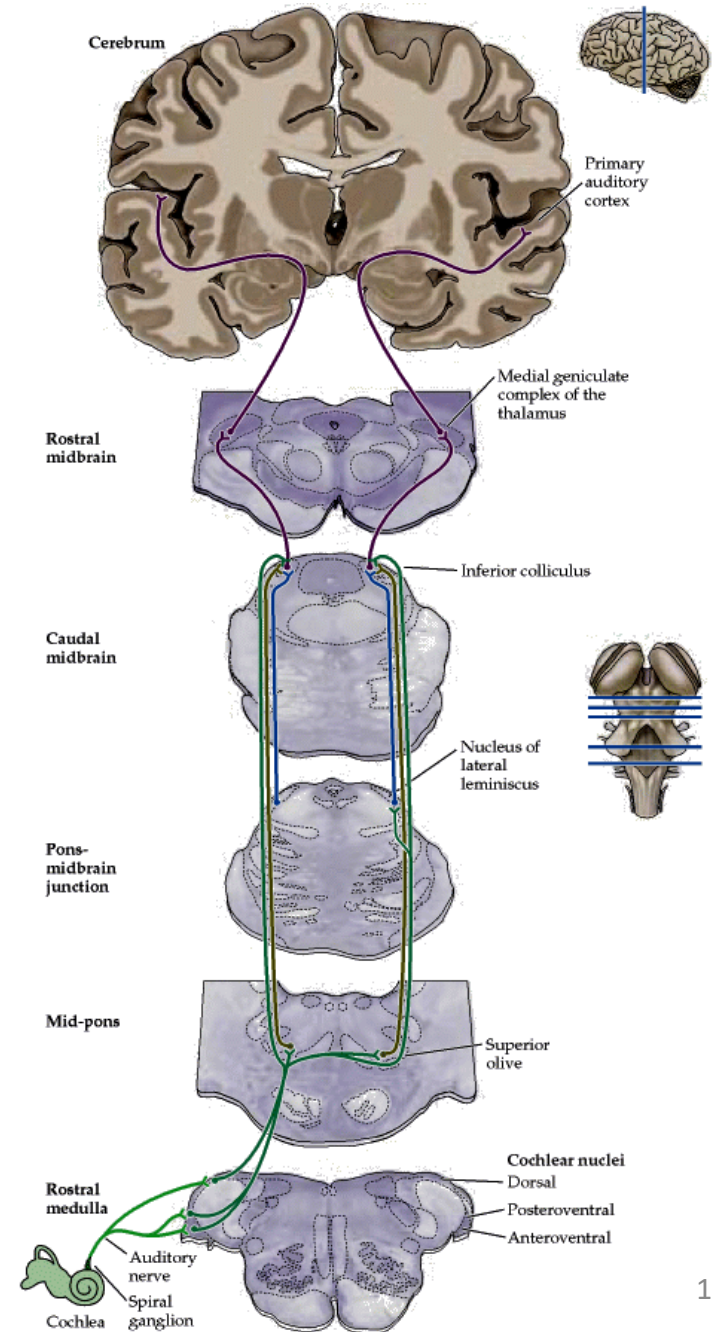


The Outer Hair Cell

Inervation of the organ of Corti



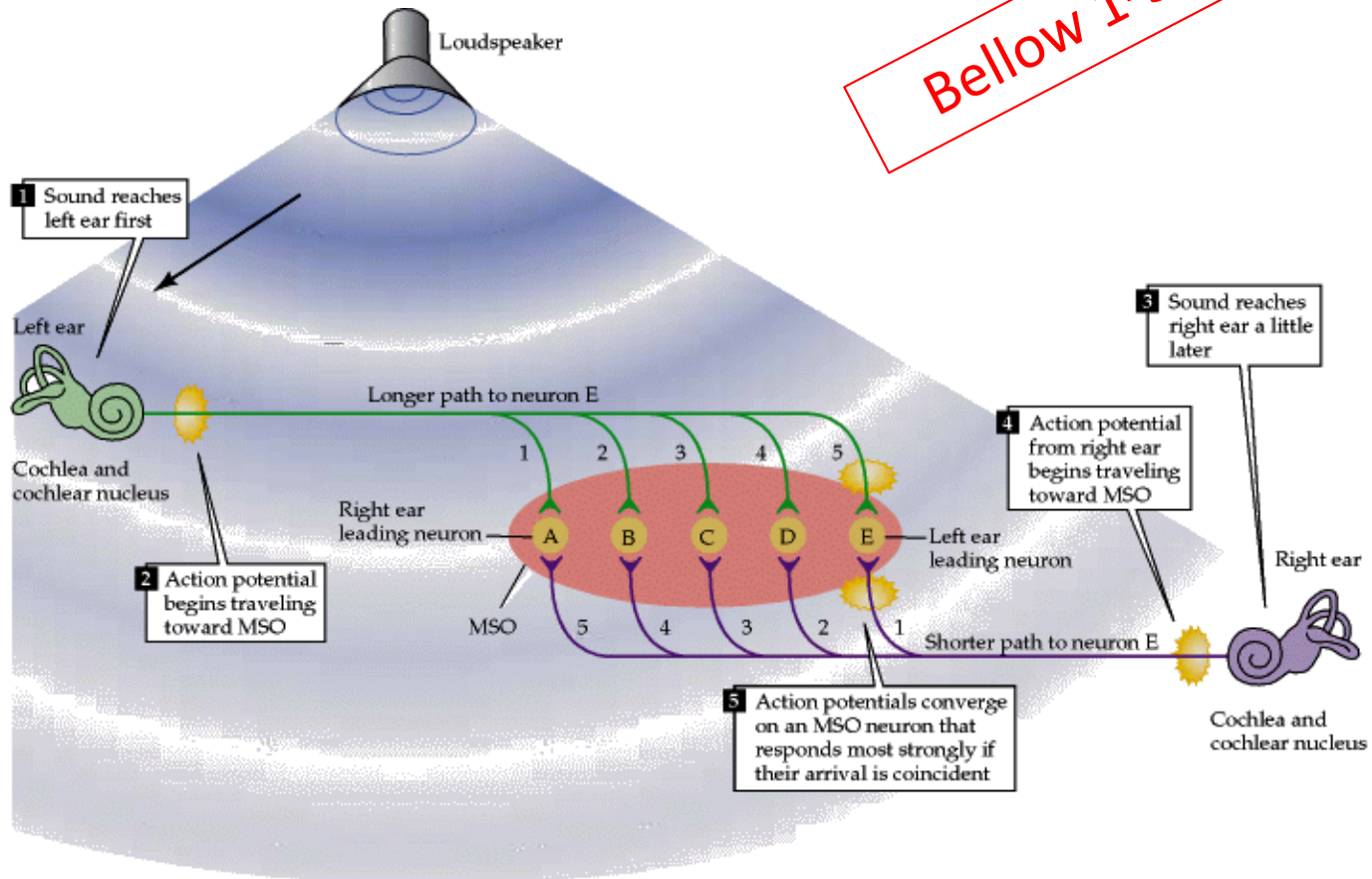
- Nucleus spiralis cochleae
- Nucleus cochlearis ventralis
 - Information about intensity
 - Time delay – the sound direction
- Nucleus cochlearis dorsalis
 - Information about frequency
- Olivary nuclei
 - Analysis of direction
 - Modulation (increase) of the outer hair cells sensitivity
- Colliculi inferiores
 - Integration of information from the lower structures
 - Centre of acoustic reflexes
- N. corporis geniculati medialis
 - Thalamus
- Auditory cortex



Nucleus olivaris superior medialis

Time delay based sound localization

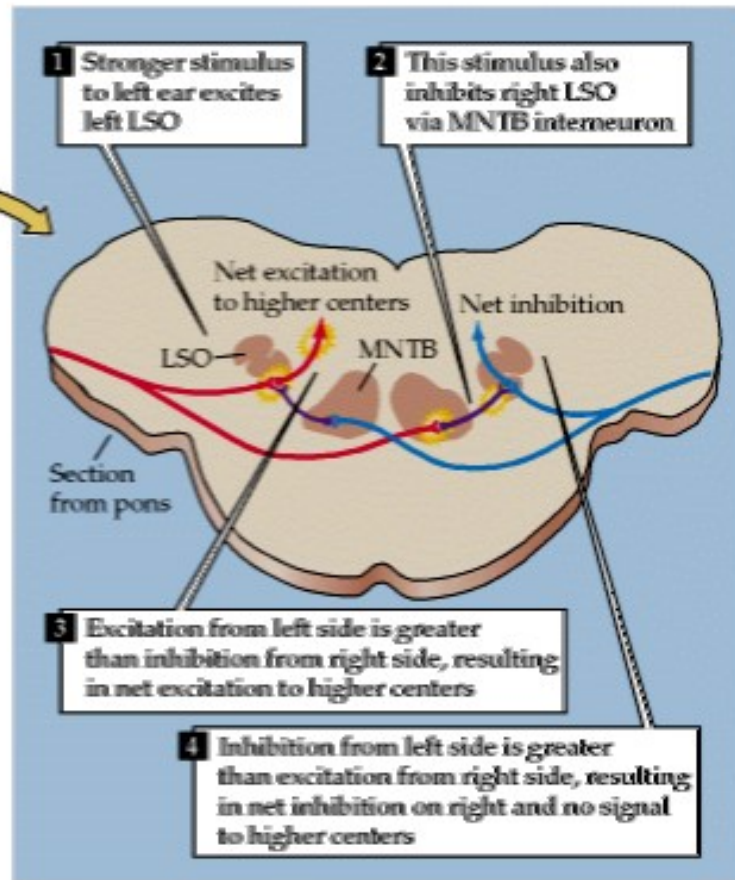
Bellow 1-3 kHz



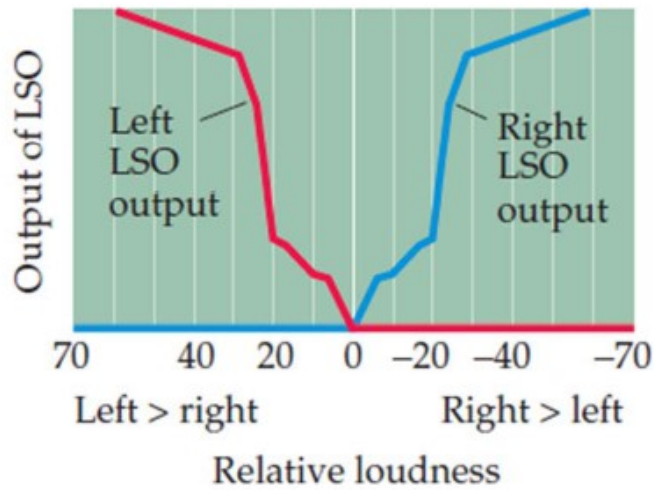
Nucleus olivaris superior lateralis

Intensity analysis based sound localization

(A)

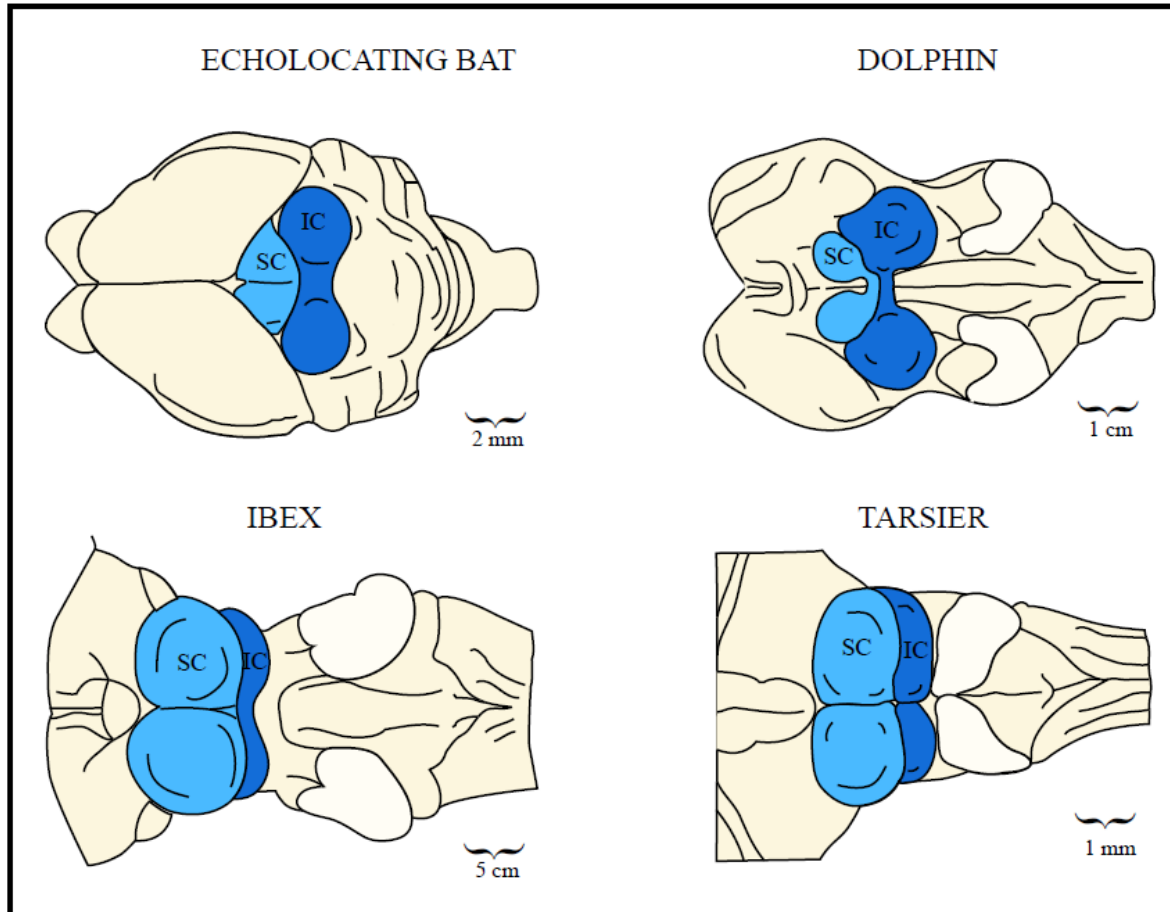


Above 1-2 kHz

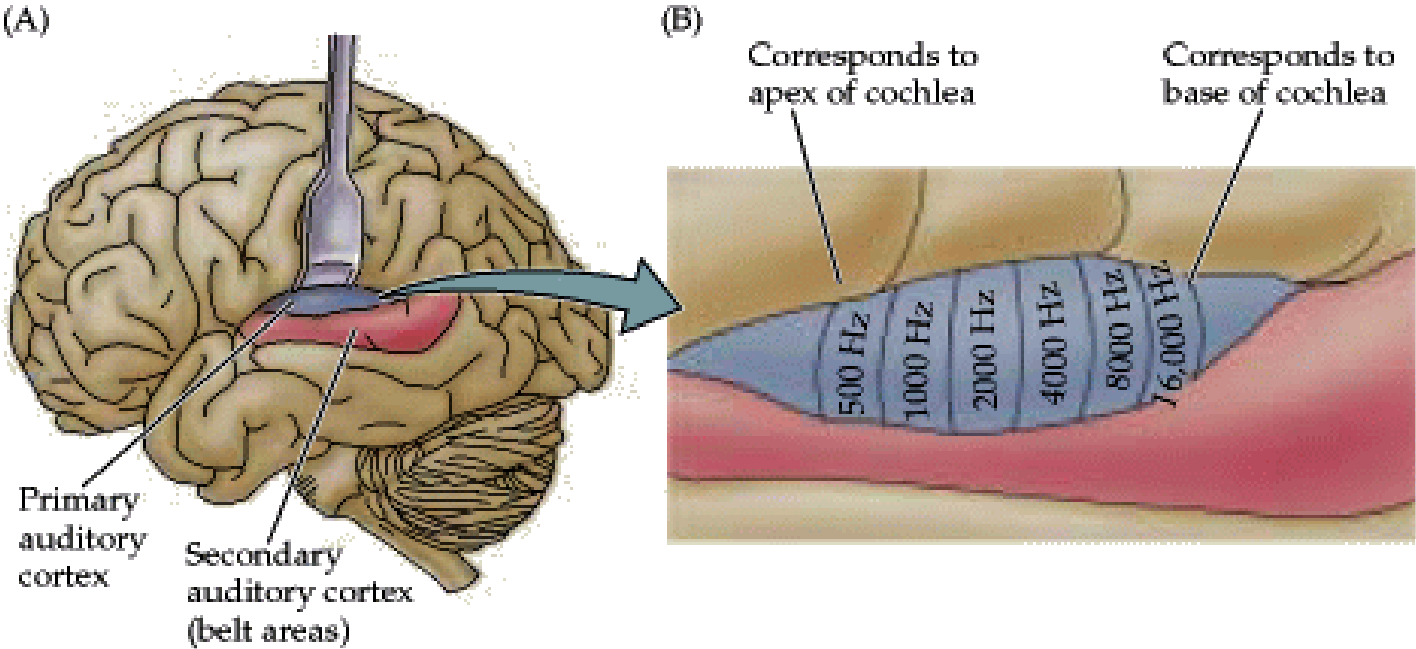


MNTB – medial nucleus trapezoid body

Colliculi inferiores in various animal species

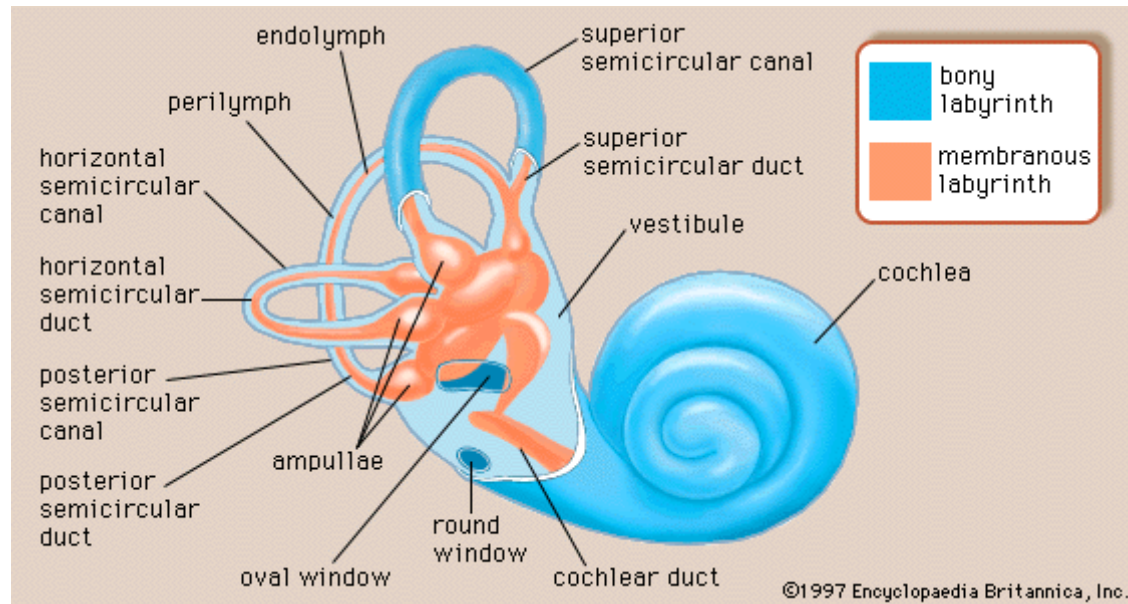


Auditory cortex



Vestibular system

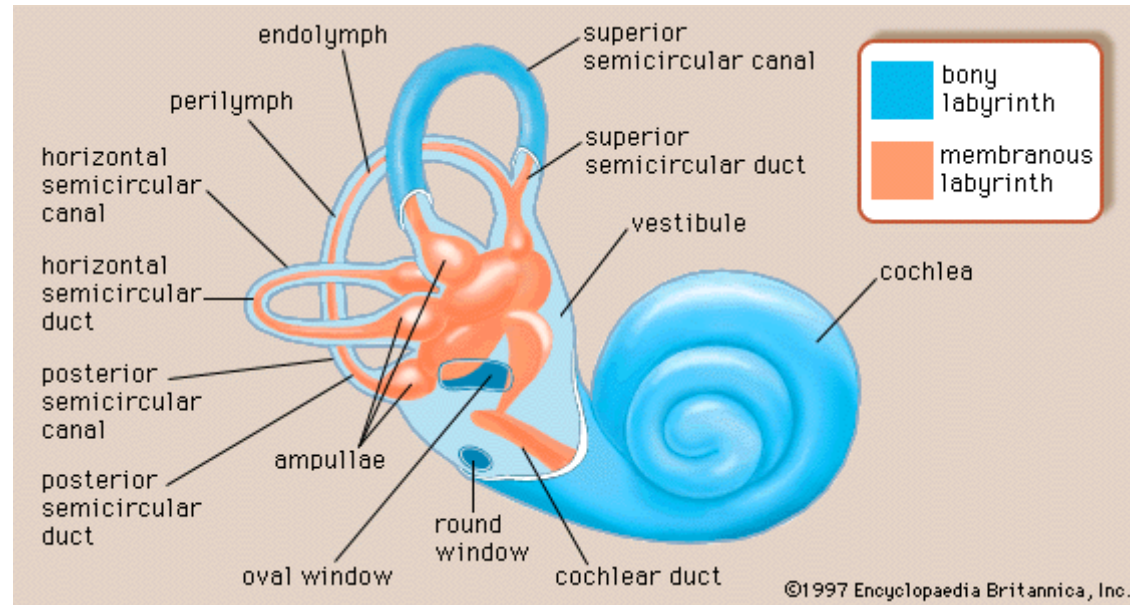
- Anatomic localization
- Hair cells
- Information about
 - Position
 - Acceleration
 - ✓ Linear
 - ✓ Angular



<http://www.slideshare.net/CsillaEgri/presentations>

Vestibular system

- Anatomic localization
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<http://www.slideshare.net/CsillaEgri/presentations>

Maintenance of the balance

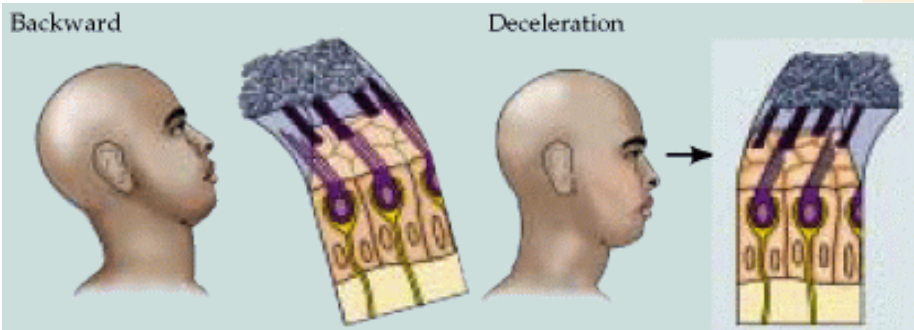
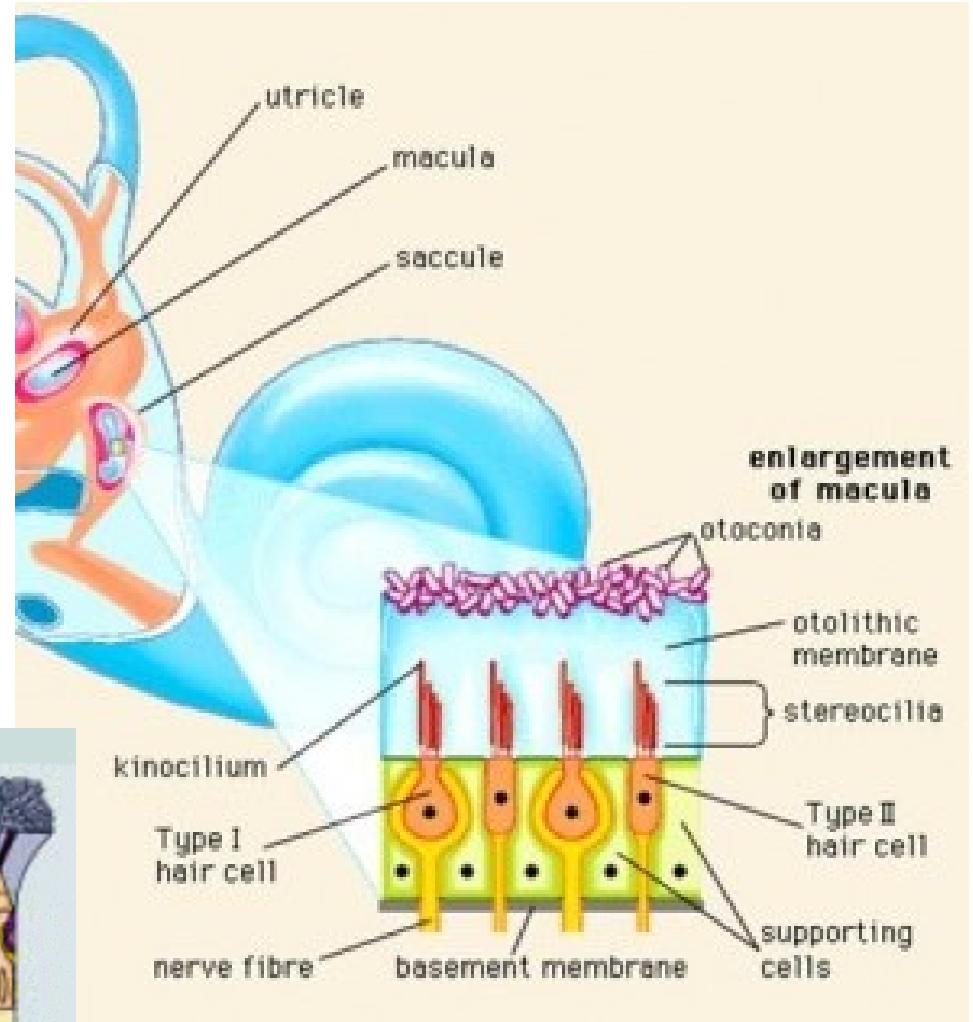
Muscle tone modification

„Maintenance of the balance“ of the sight

Vestibuloocular reflexes (VOR)

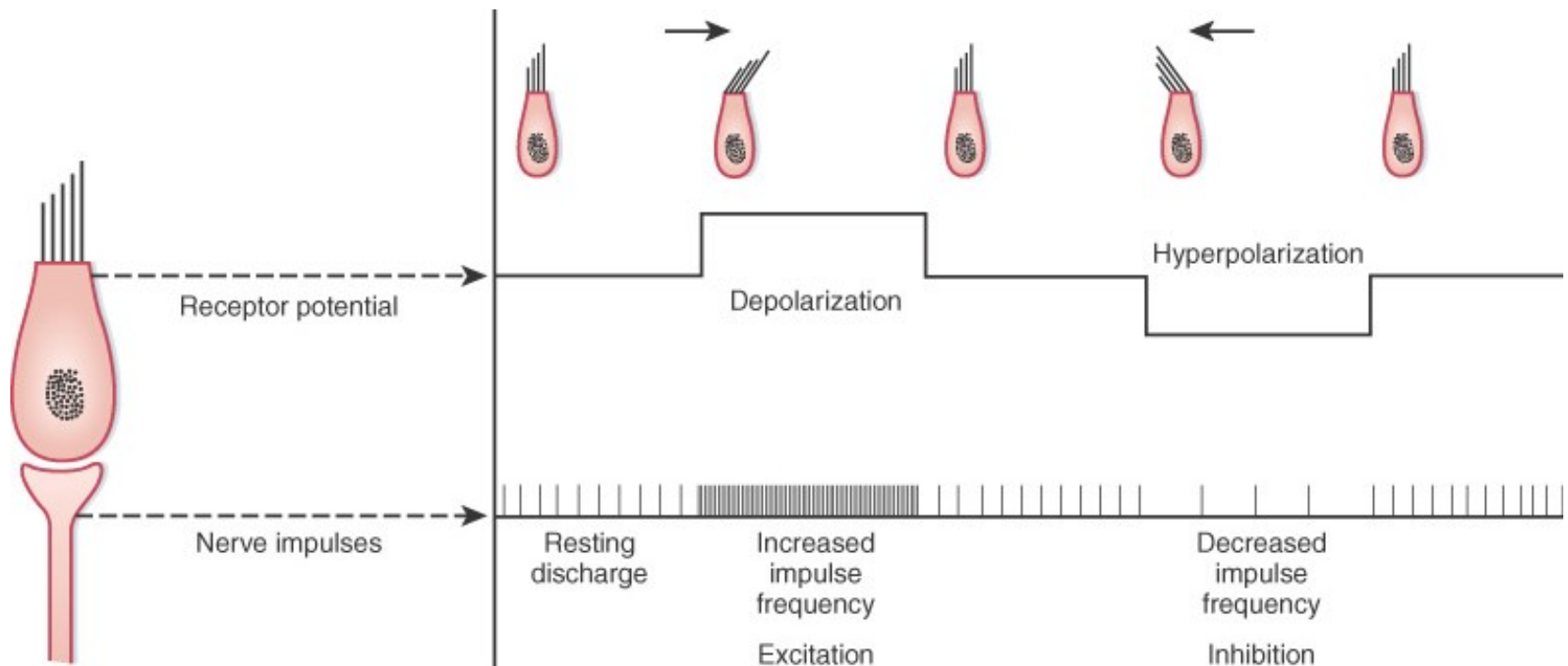
Information about position and linear acceleration

- Macula
 - CaCO_3 crystals
- Utriculus
 - Horizontal macula
- Sacculus
 - Vertical macula



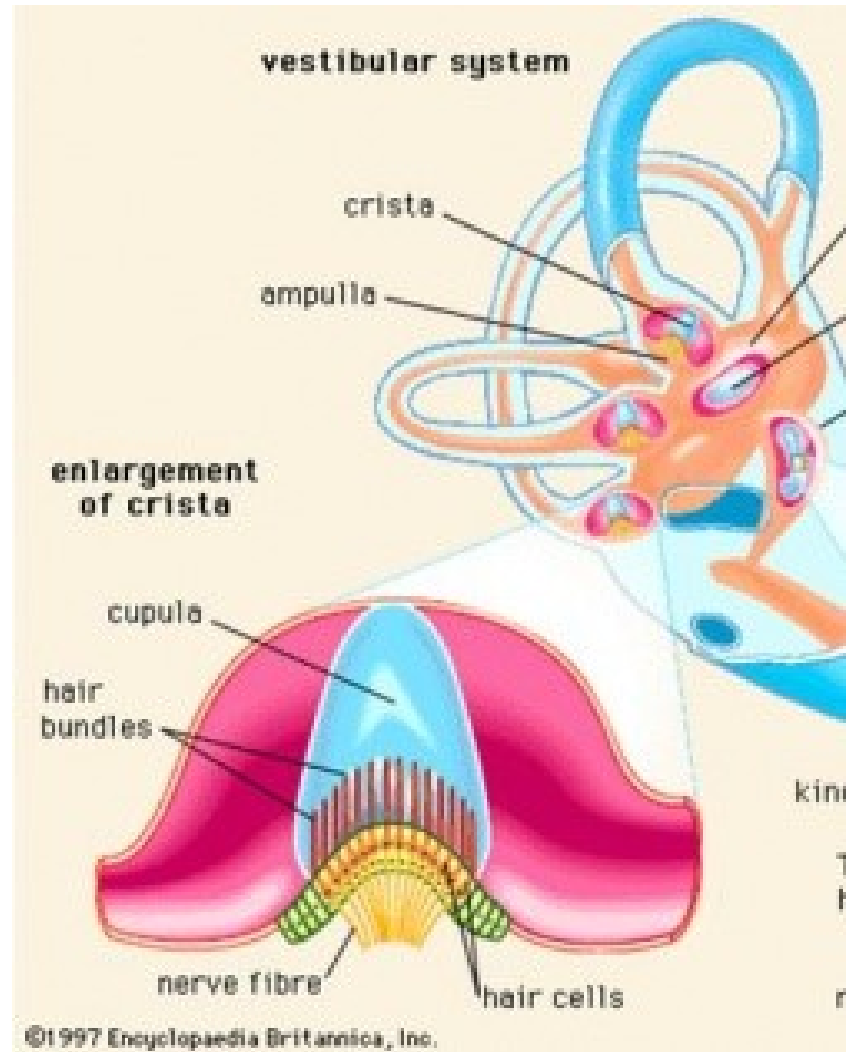
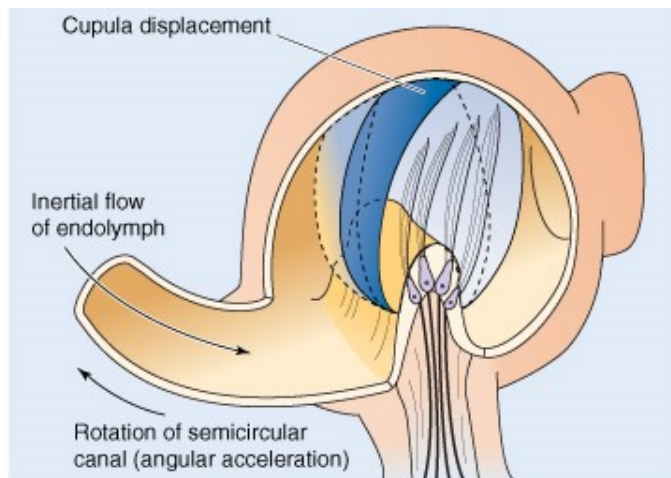
Mechanism

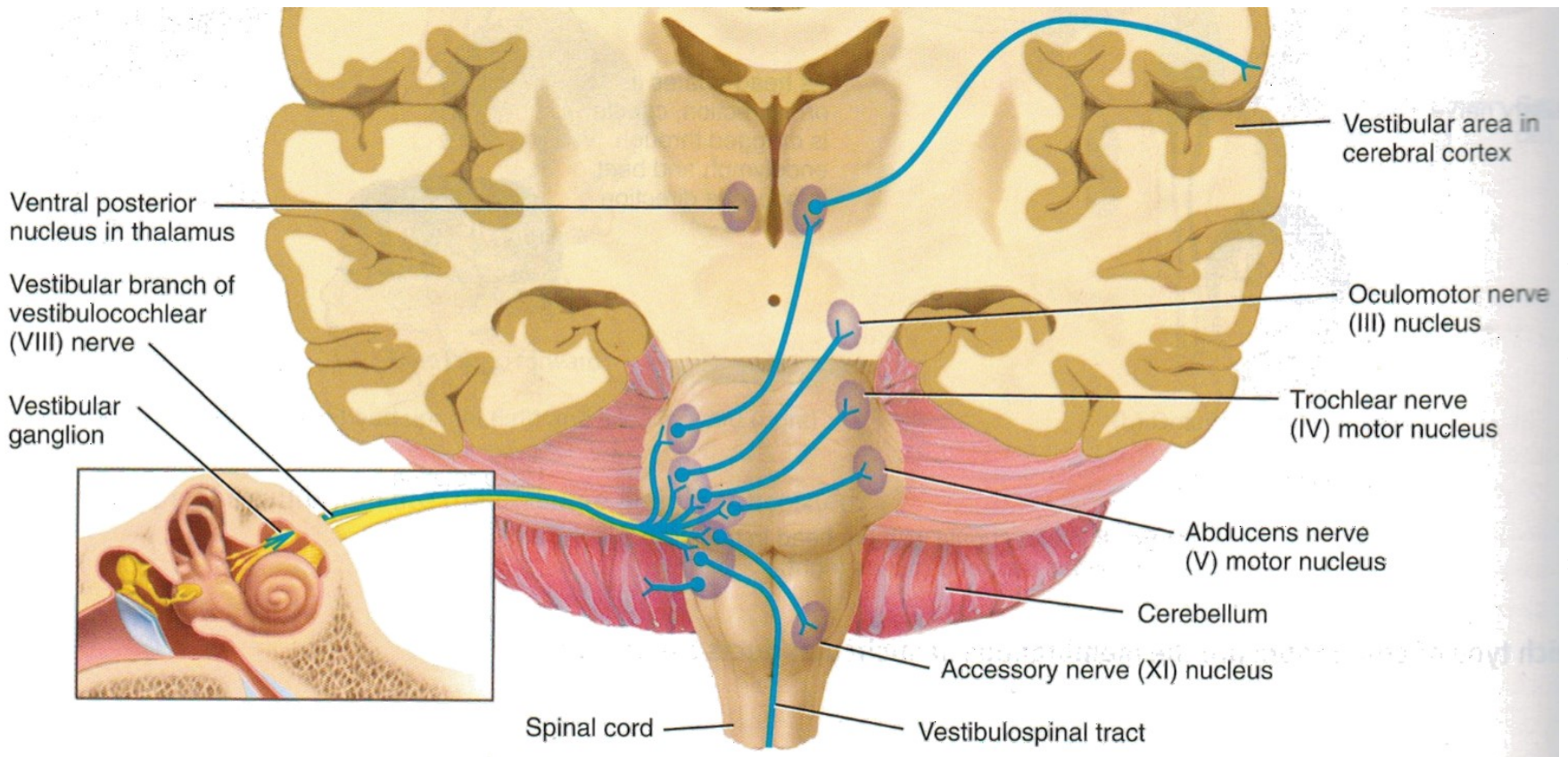
- Flexion towards stereocilia
 - Opening of mechanically activated K^+ channels –depolarization
- Flexion away from stereocilia
 - Closing of the channels - hyperpolarization



Information about angular acceleration

- Ampulla
- Semicircular canals
 - Upper
 - Horizontal
 - Posterior





Vestibular nuclei

Integration of vestibular, visual and somatosensory information

Projections

- Cerebellum
- Oculomotoric nuclei
- Nucleus of n. Accessorius – the muscles of the neck
- Thalamus - cortex