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8

Auditory and vestibular system

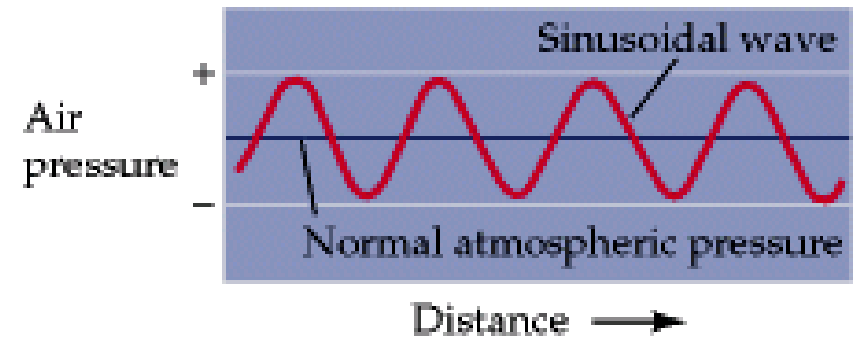
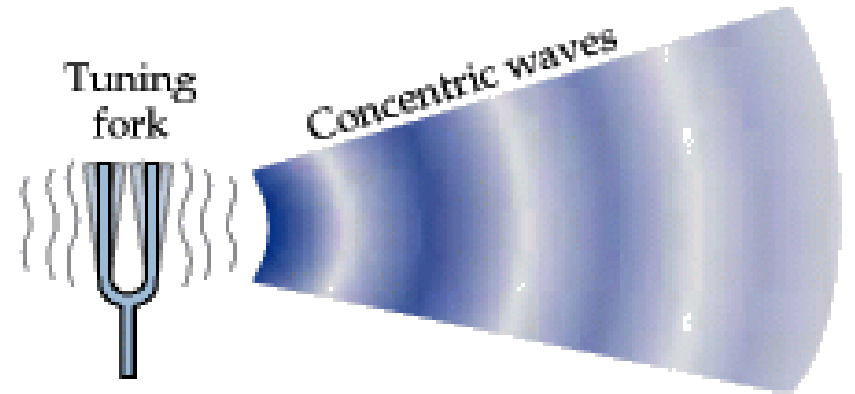
Auditory system

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

Auditory system

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

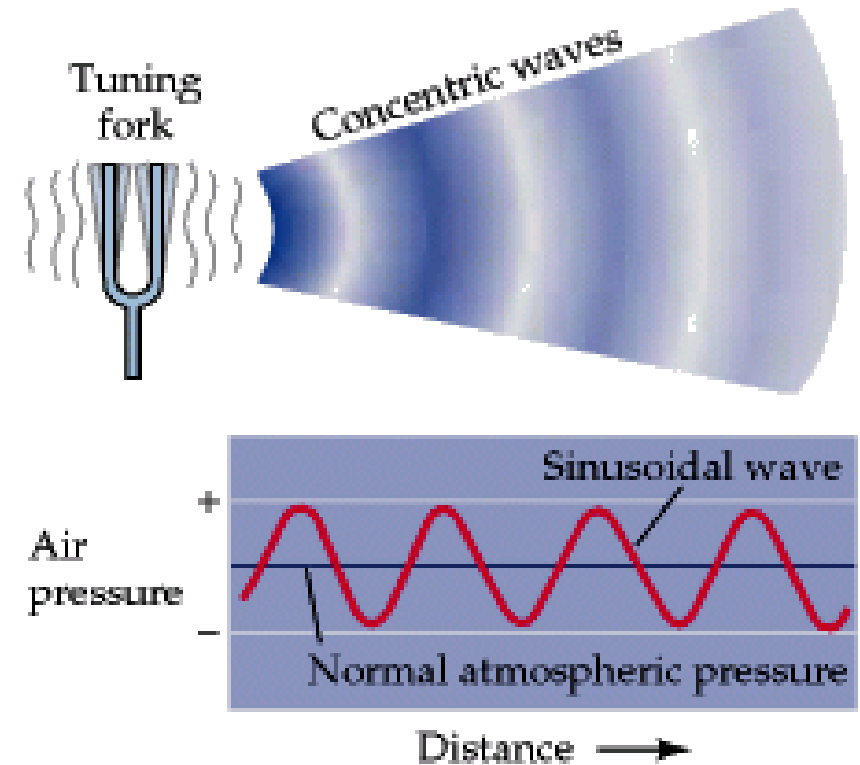
Sound is audible mechanical vibration of an elastic medium such as air



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Auditory system

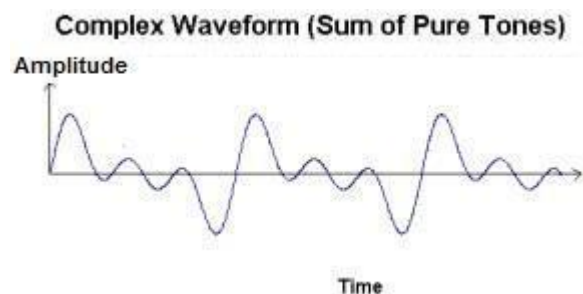
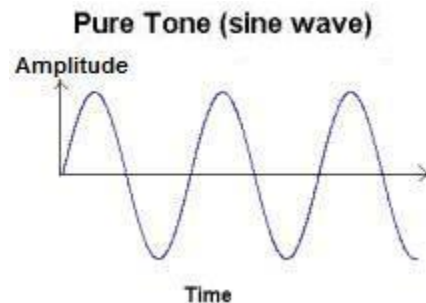
- Air/water vibration caused by solid object
- Sound characteristics
 - Frequency – pitch
 - Amplitude – intensity
 - Timbre – given by representation of harmonic frequencies of the oscillation
- Pure tone
- Complex sound



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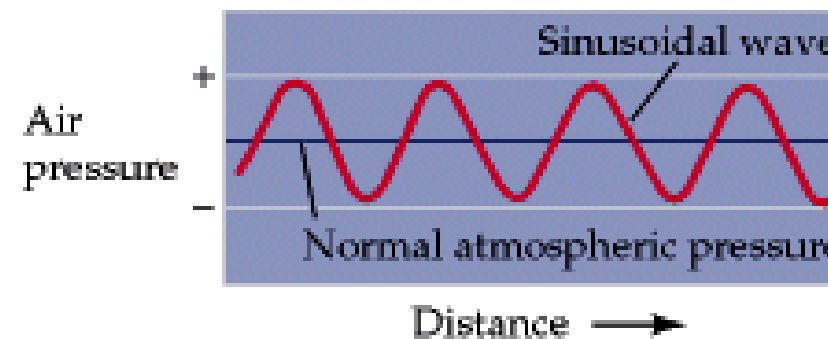
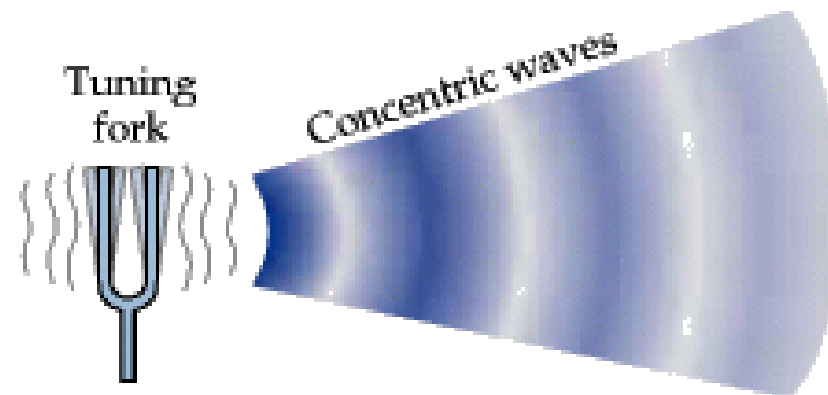
Sound

- Pure tone
 - Determined by frequency
- Complex sound
 - Sum of pure tones
 - Harmonic (musical)
 - periodic
 - Disharmonic (noise)
 - aperiodic



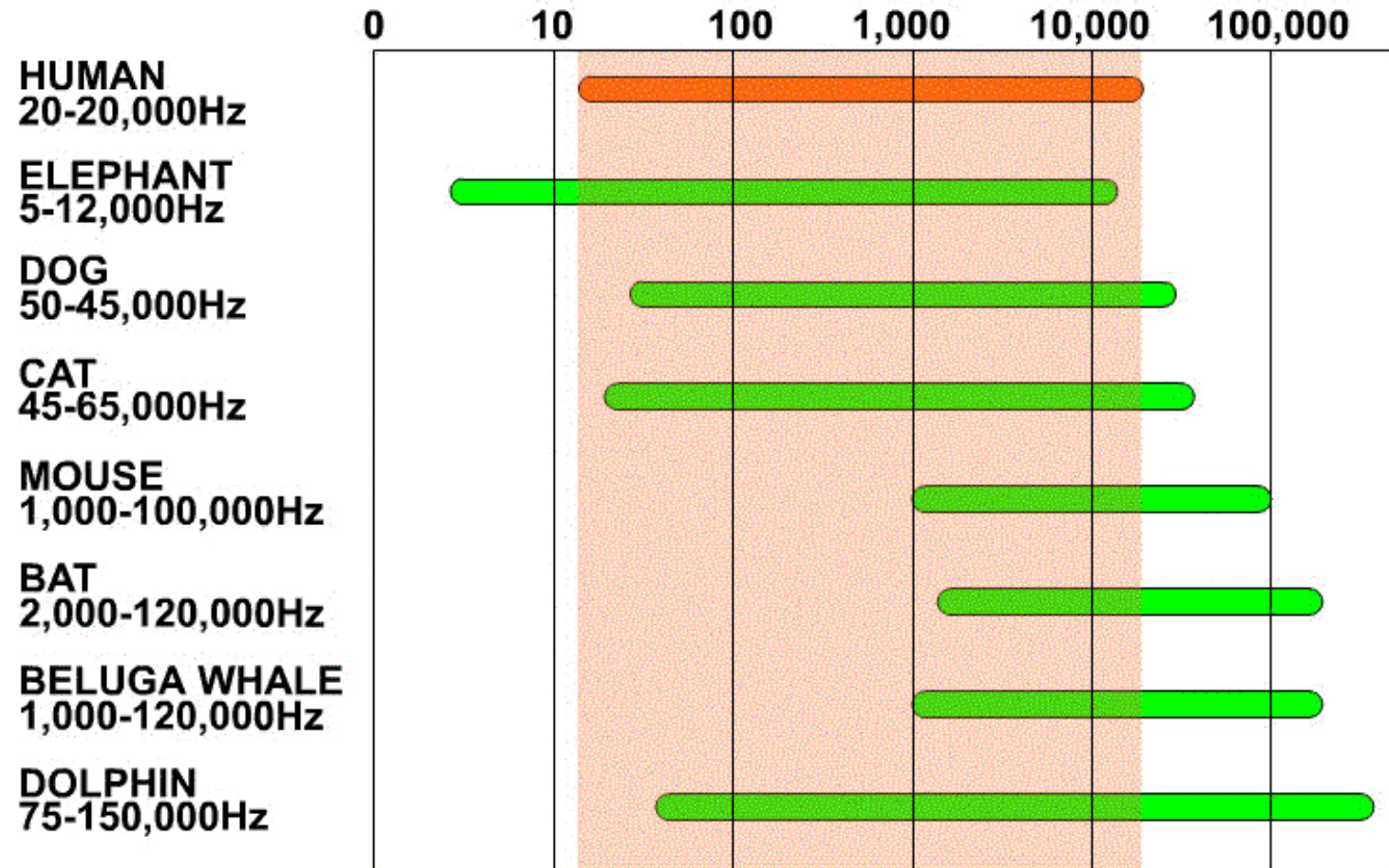
<http://www.earmaster.com/music-theory-online/ch03/chapter-3-2.html>

http://www.acoustics.salford.ac.uk/acoustics_info/sound_synthesis/



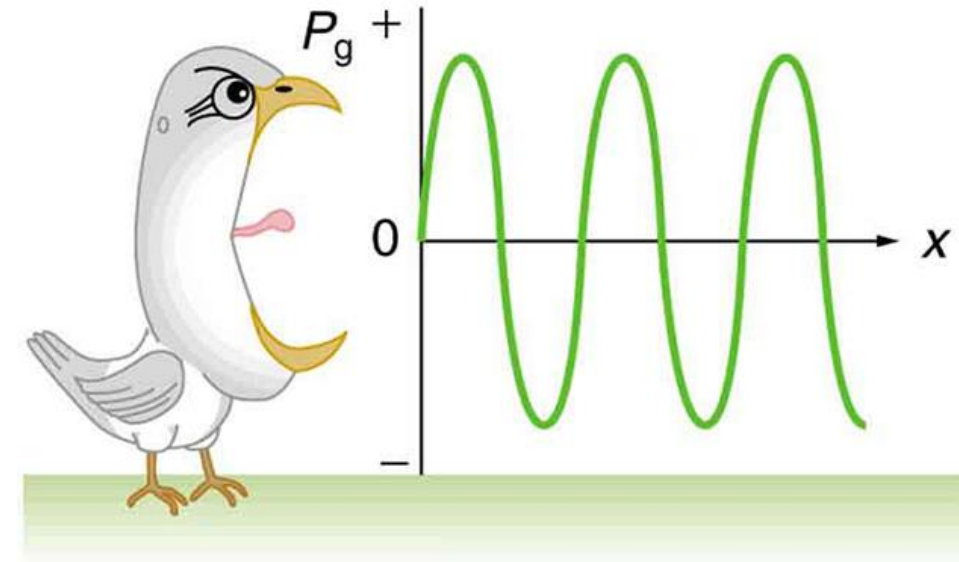
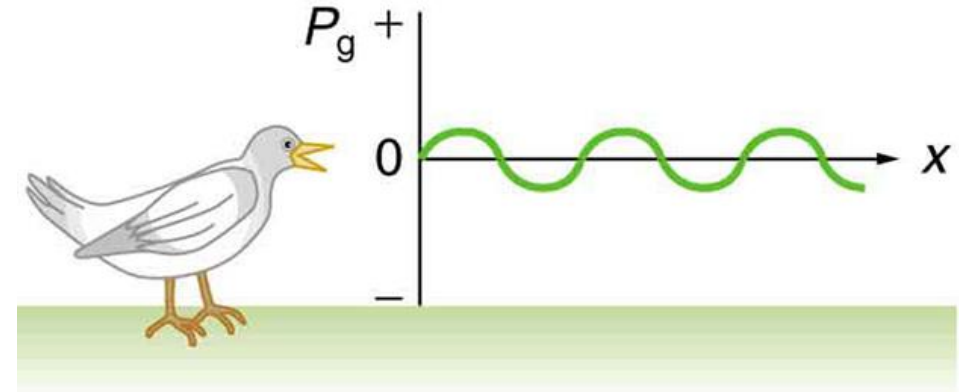
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Audible spectrum



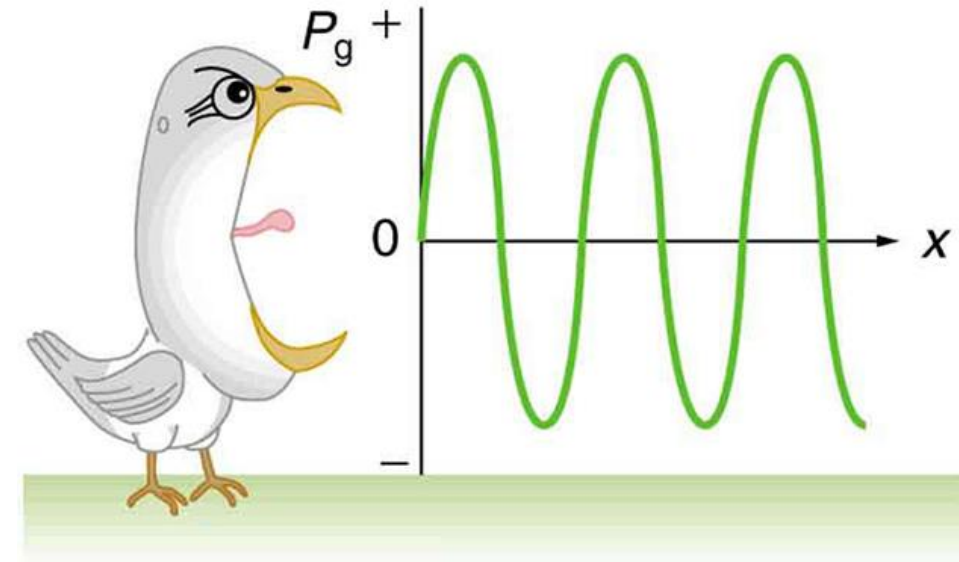
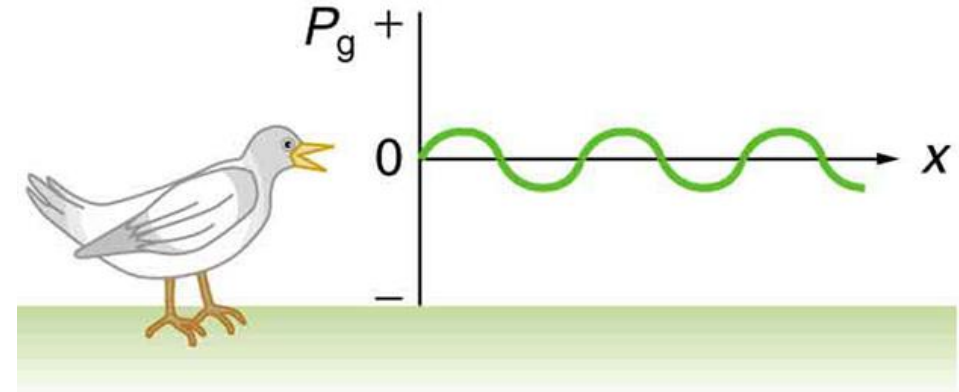
The intensity and volume of sound

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



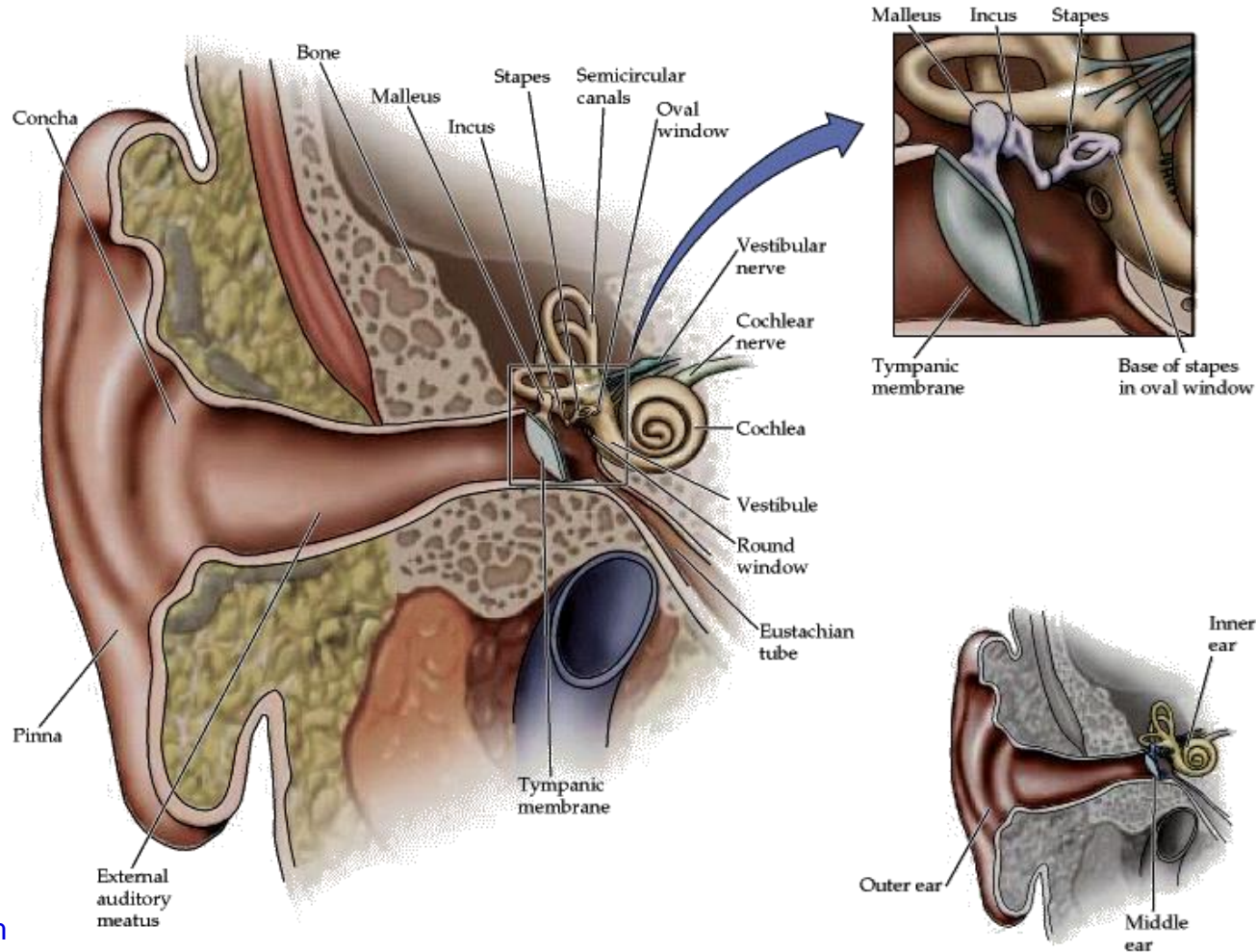
The intensity and volume of sound

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



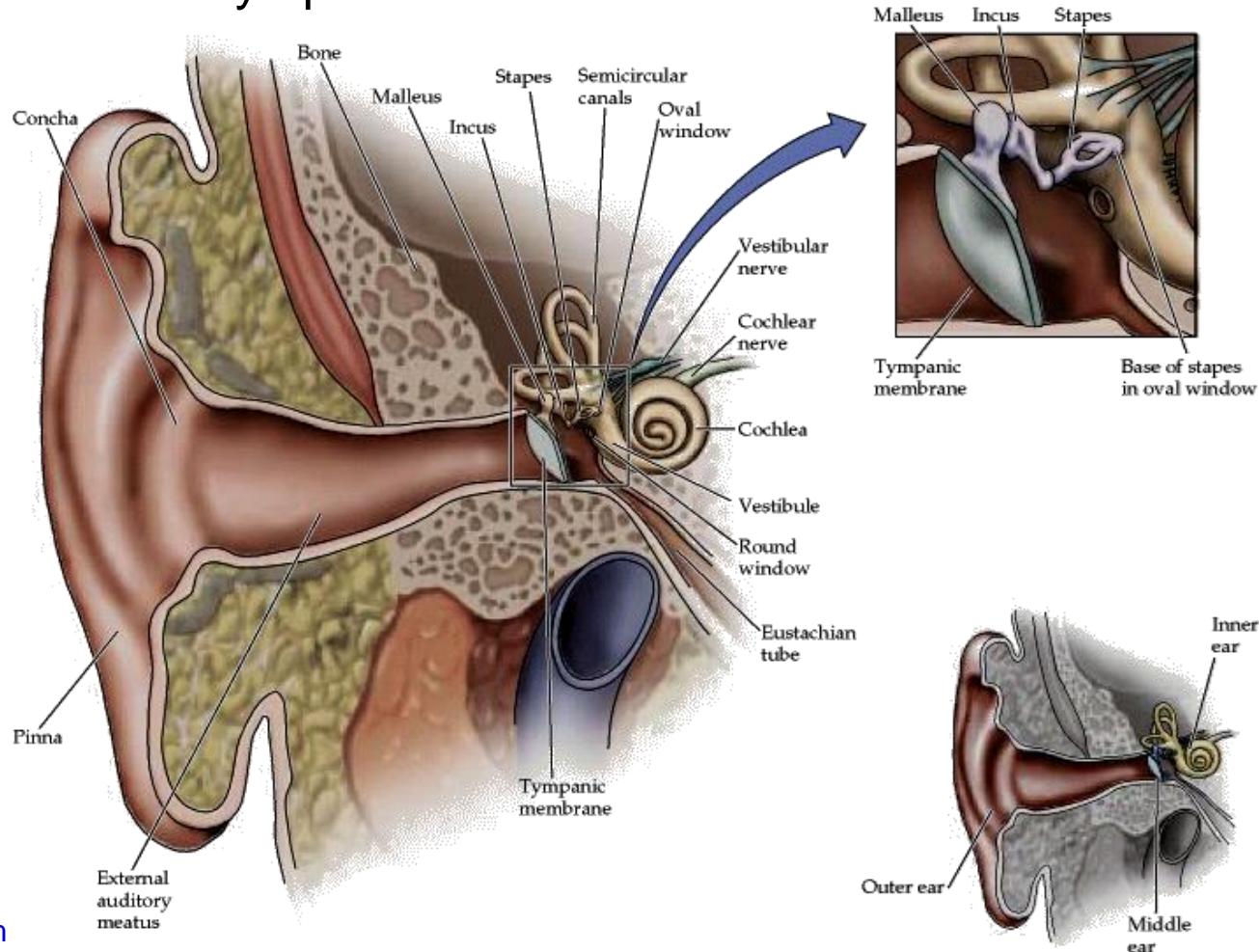
External ear

- ✓ Transmission of acoustic signal from environment to the tympanic membrane



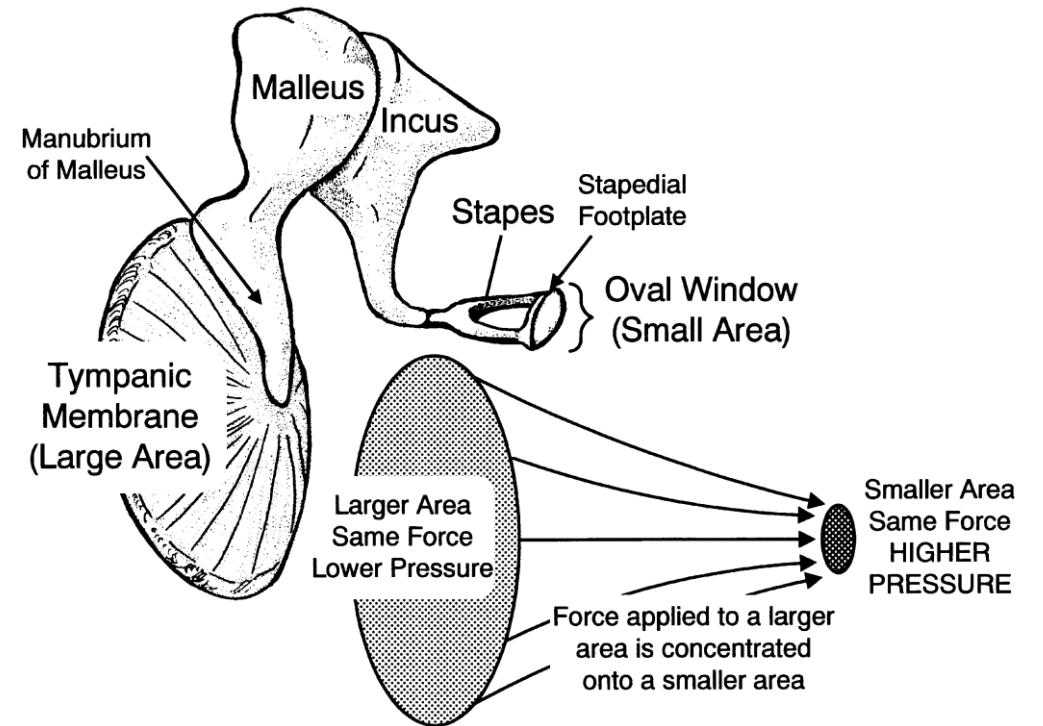
Middle ear

- ✓ Transmission of acoustic signal from the tympanic membrane to the oval window and endolymph/basilar membrane –ossicular vs bone conduction



Middle ear

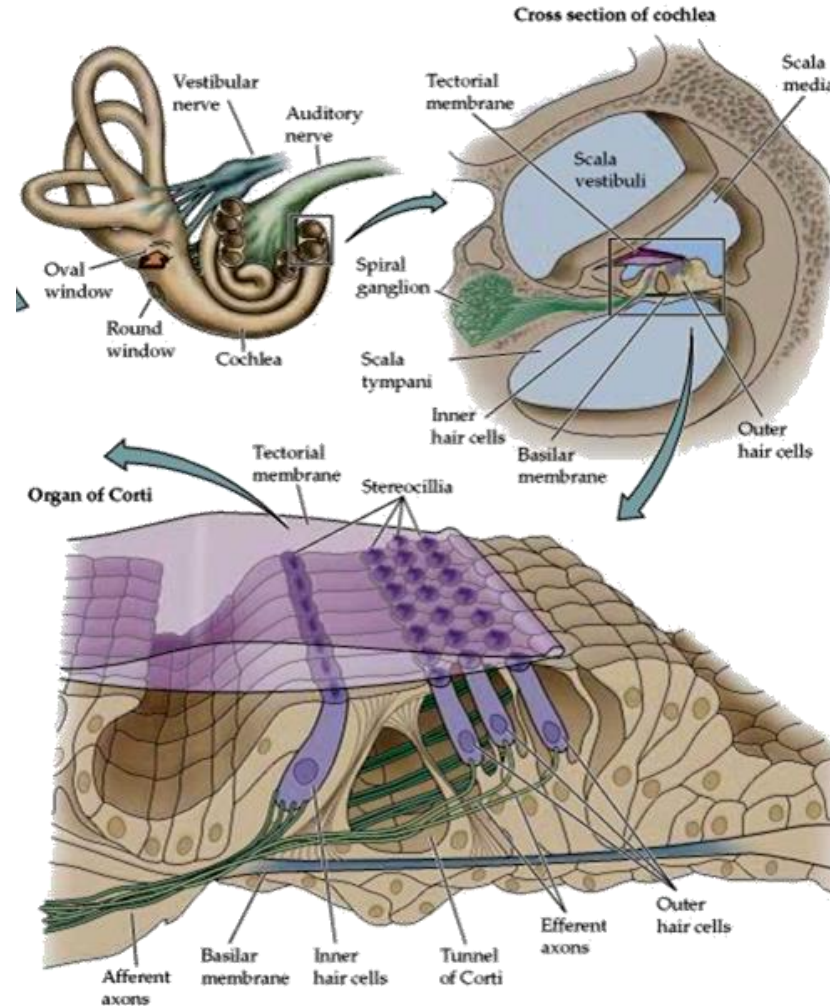
- A significant difference in acoustic impedance between air and endolymph
- Signal amplification
 - Tympanic membrane area/oval window area
 - Ossicles
- Protective function
 - m.stapedius and tensor tympani
 - Eustachian tube



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

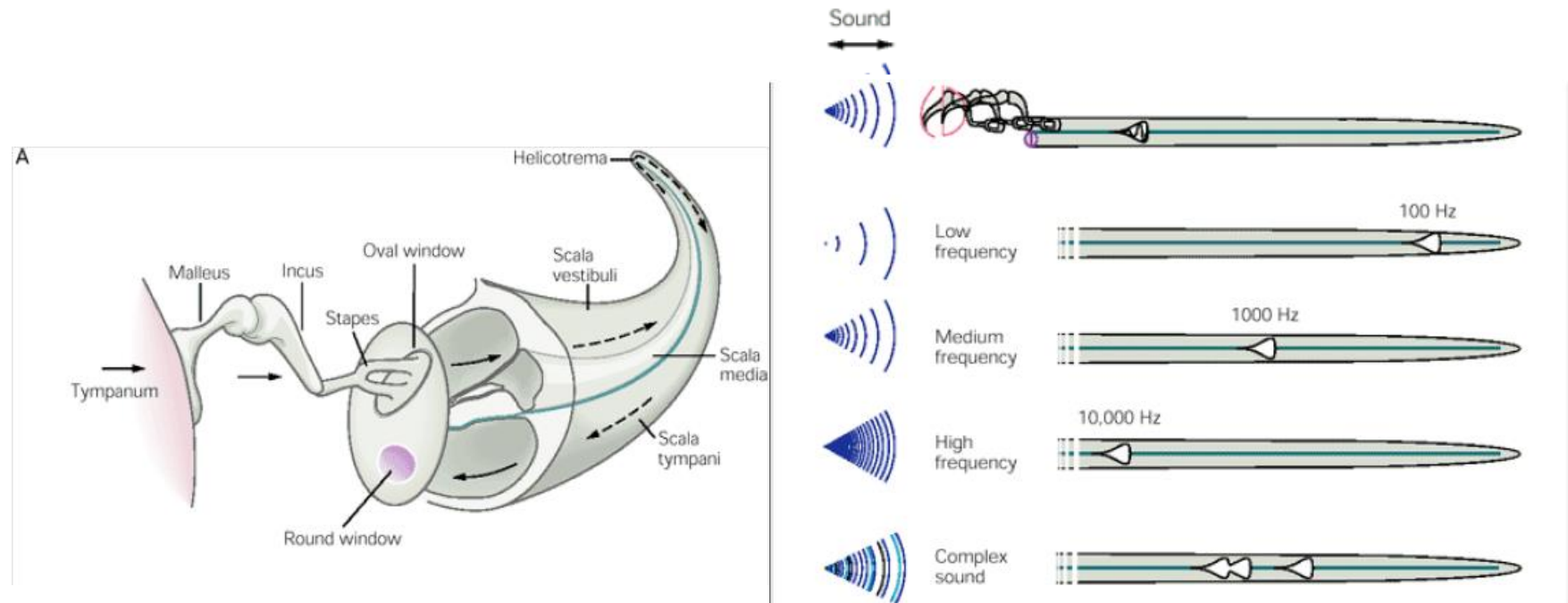
Inner ear

- ✓ Transduction of endolymph/basilar membrane vibrations to receptor and action potential



Tonotopic arrangement

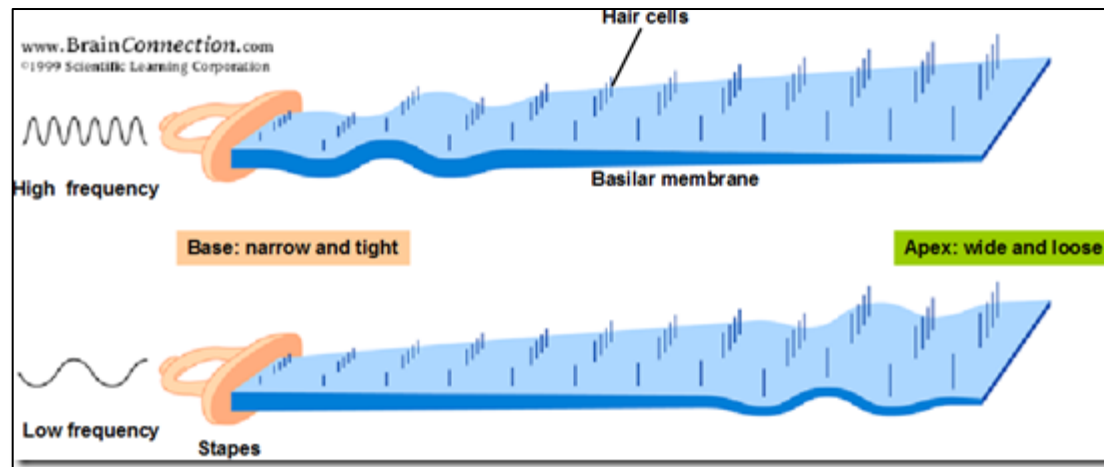
- Proximal part
– high frequency
- Distal part
– low frequency



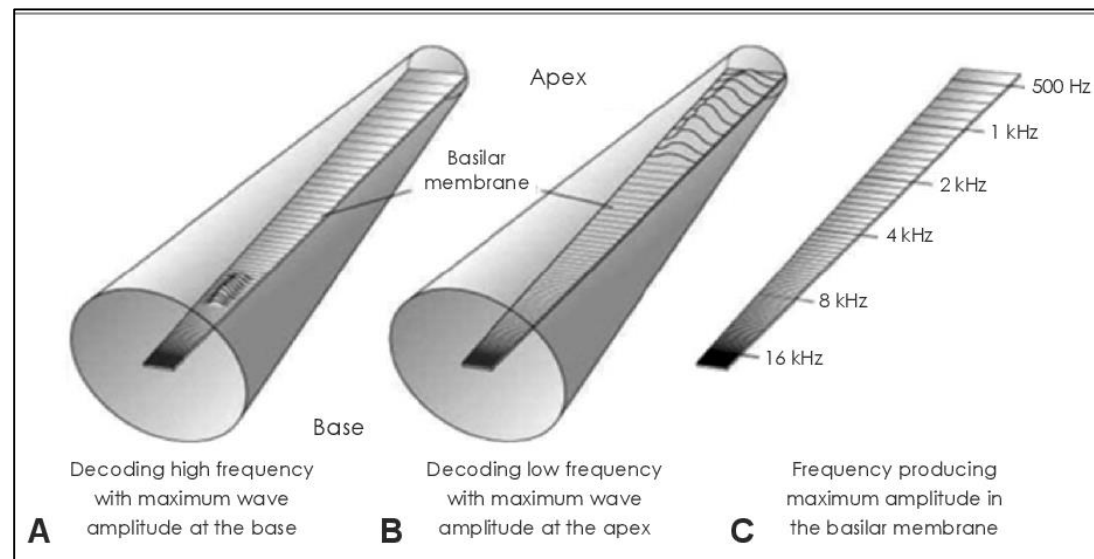
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Basilar membrane

- Basal part
 - Narrow and tight
 - High frequencies
- Apical part
 - Wide and loose
 - Low frequencies



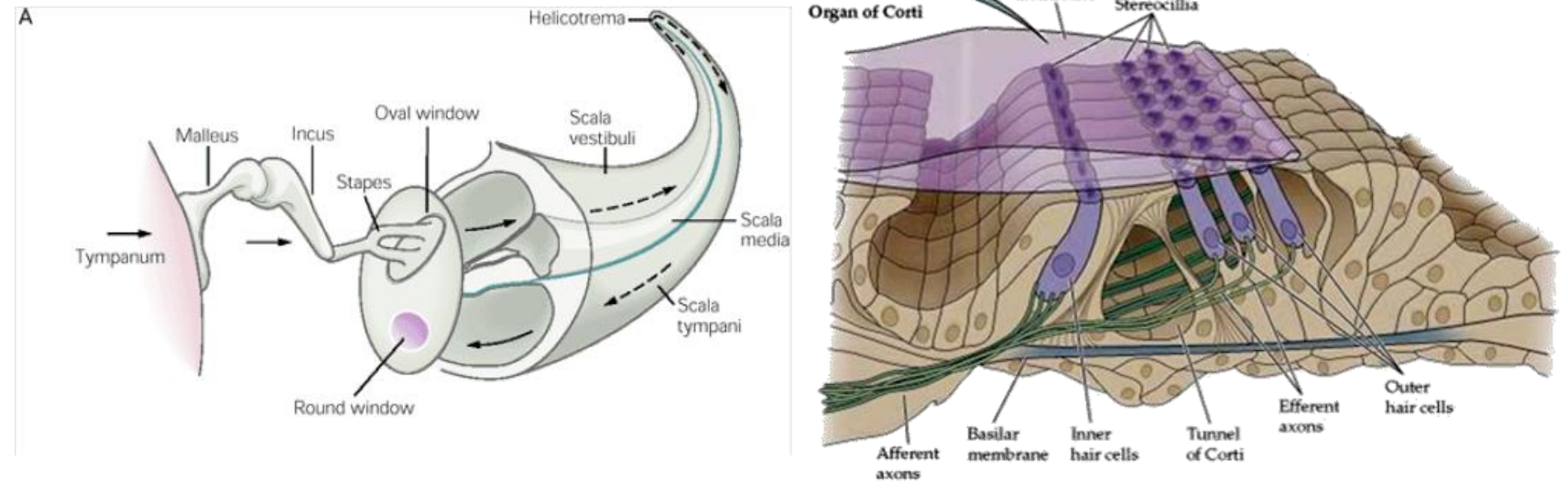
http://lh6.ggpht.com/_RIjx_Mg4ZVM/TNeYbcwJOYI/AAAAAAACmAI/9S_7HaZu5DI/s1600-h/image%5B62%5D.png



<https://www.semanticscholar.org/paper/Mass-and-Stiffness-Impact-on-the-Middle-Ear-and-the-Kim-Koo/16a2a6b5ffd1c963efd906cea109277bfbf0d7e3/figure/3>

Organ of Corti

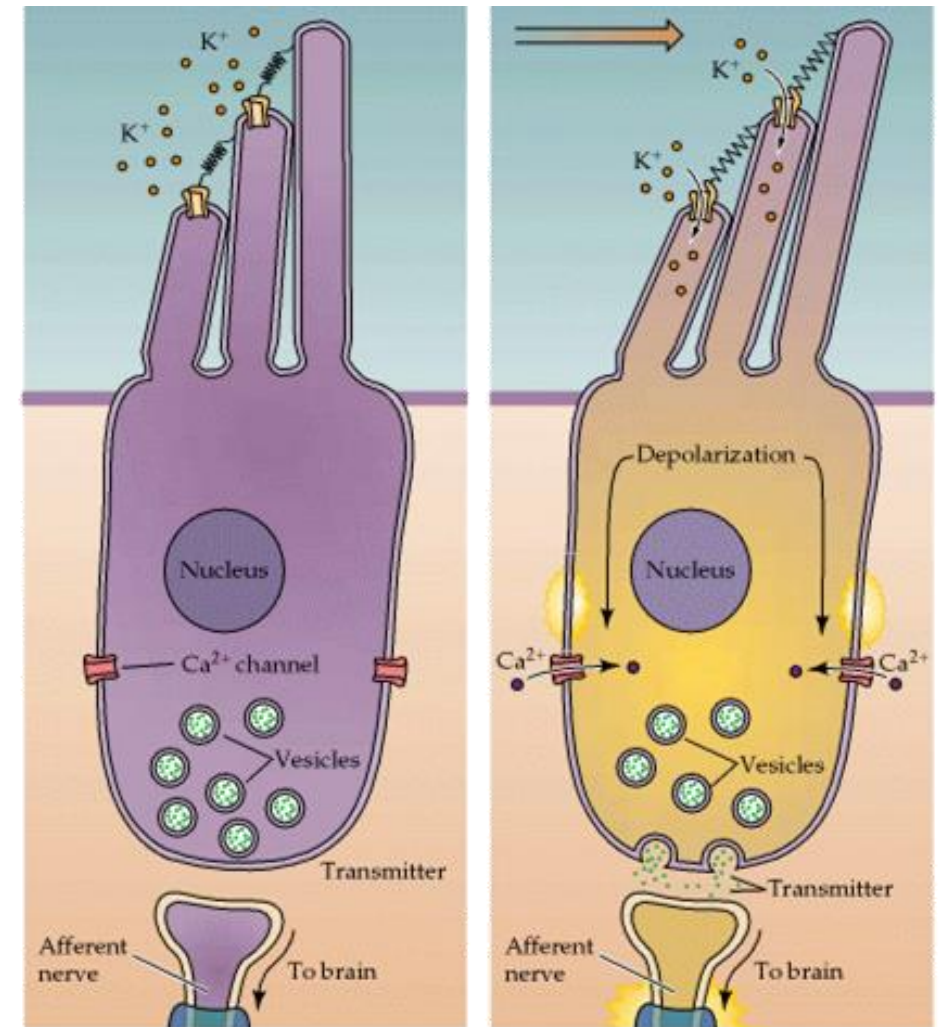
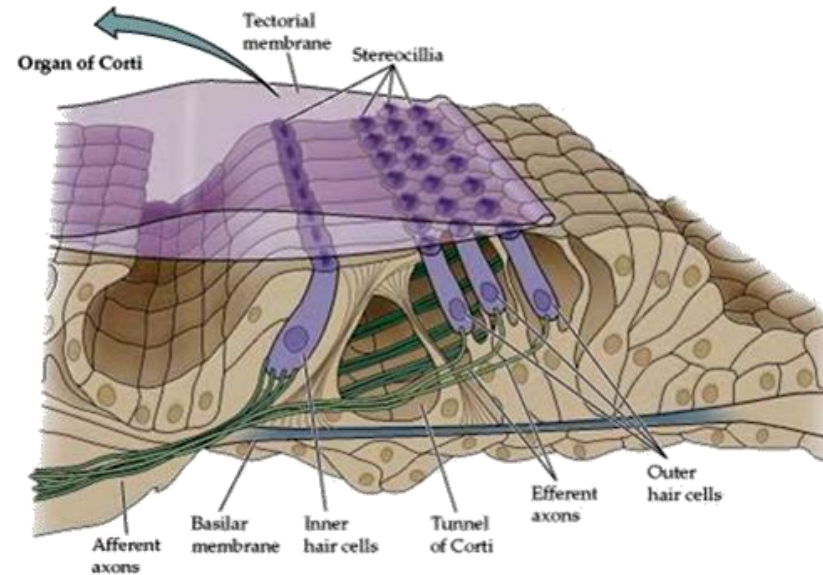
- Inner hair cells
 - aprox. 3 500
- Outer hair cells
 - aprox. 12 000
- Tectorial membrane



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Inner hair cells

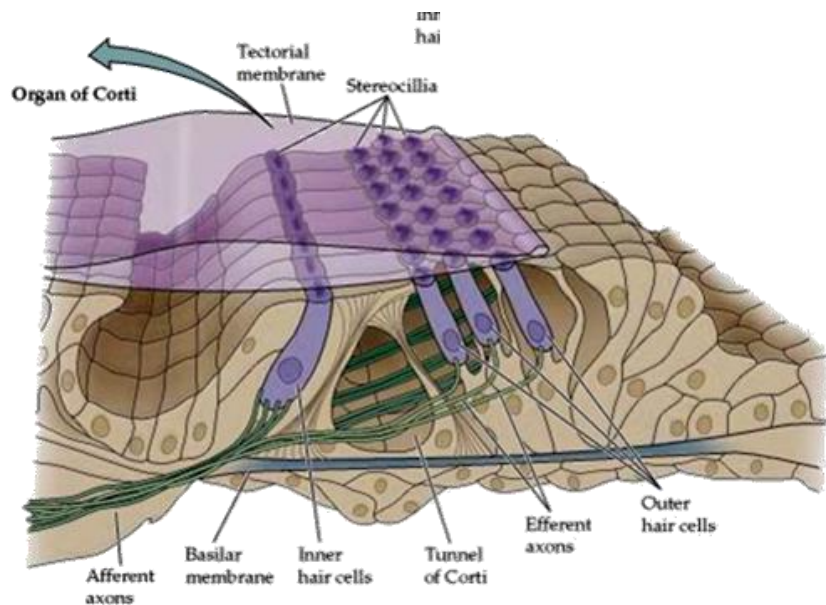
➤ Sensory function



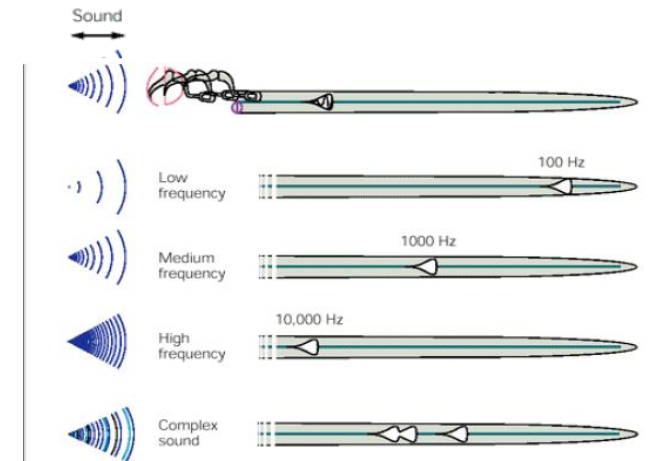
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Outer hair cells

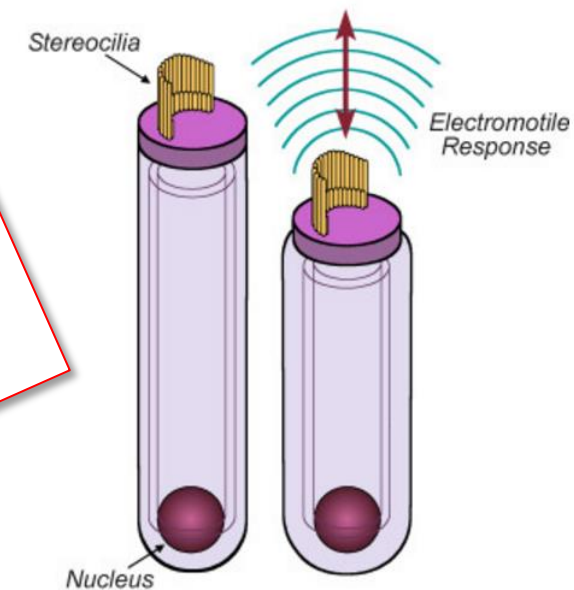
- Modulation of the signal
 - ✓ Amplification of required frequencies
- The number increases towards apex (low frequencies)



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



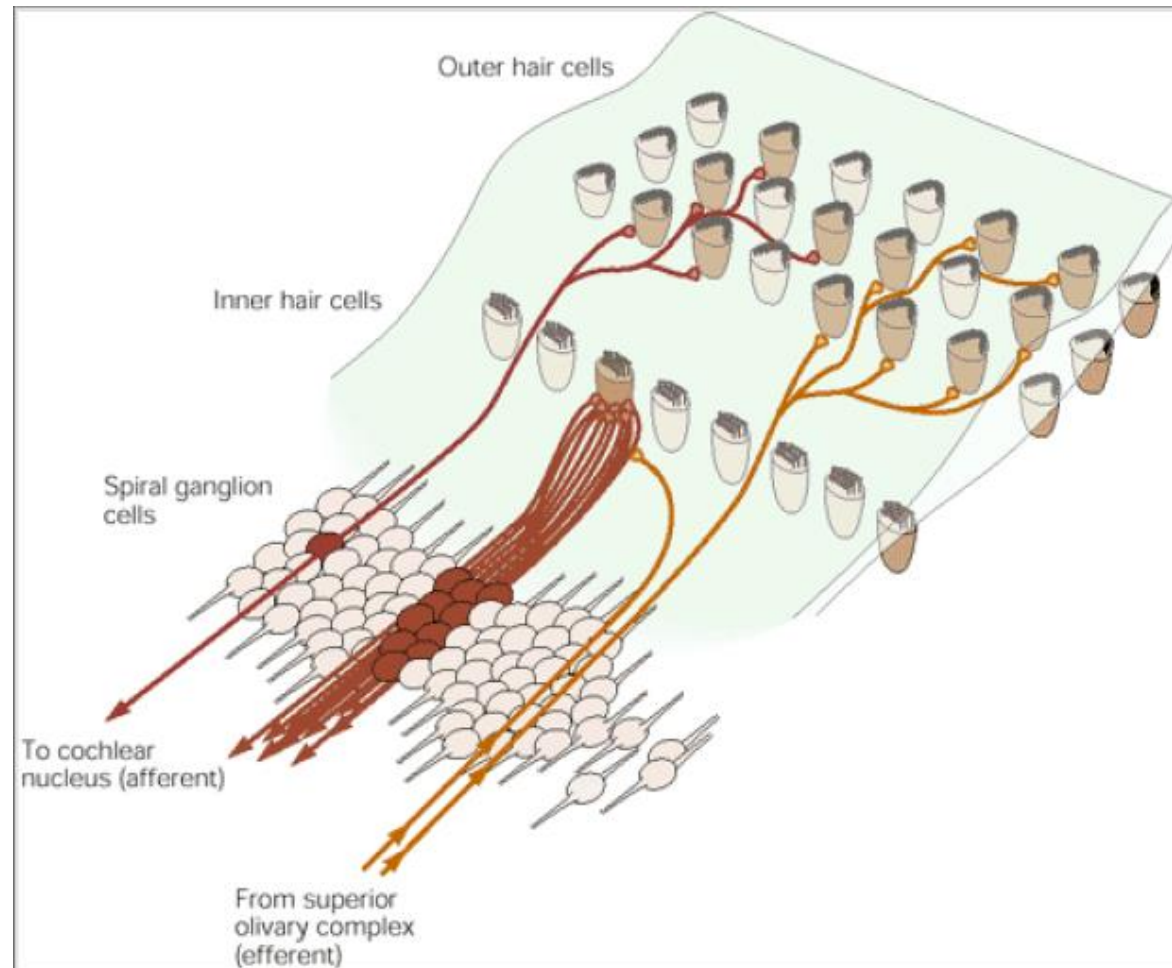
Their action may be detected
Otoacoustic emissions



The Outer Hair Cell

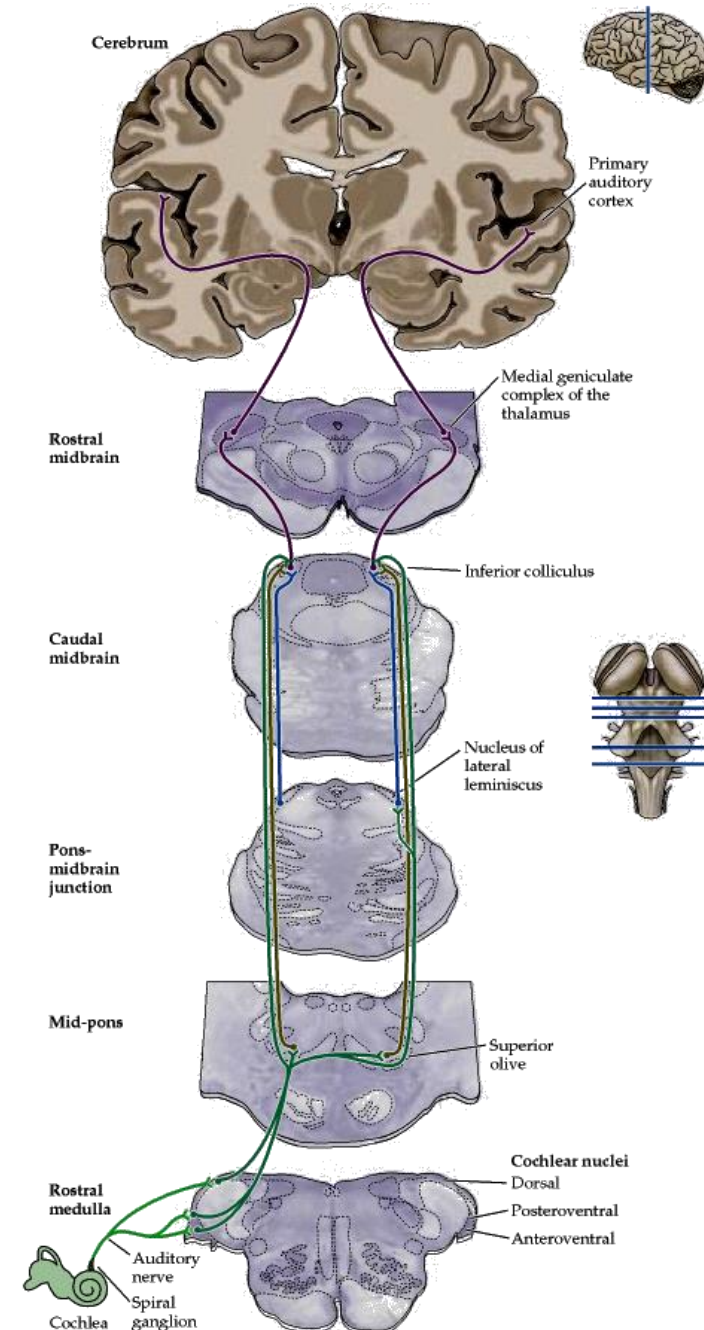
<http://www.neurophys.wisc.edu/auditory/johc.html>

Inervation of the organ of Corti



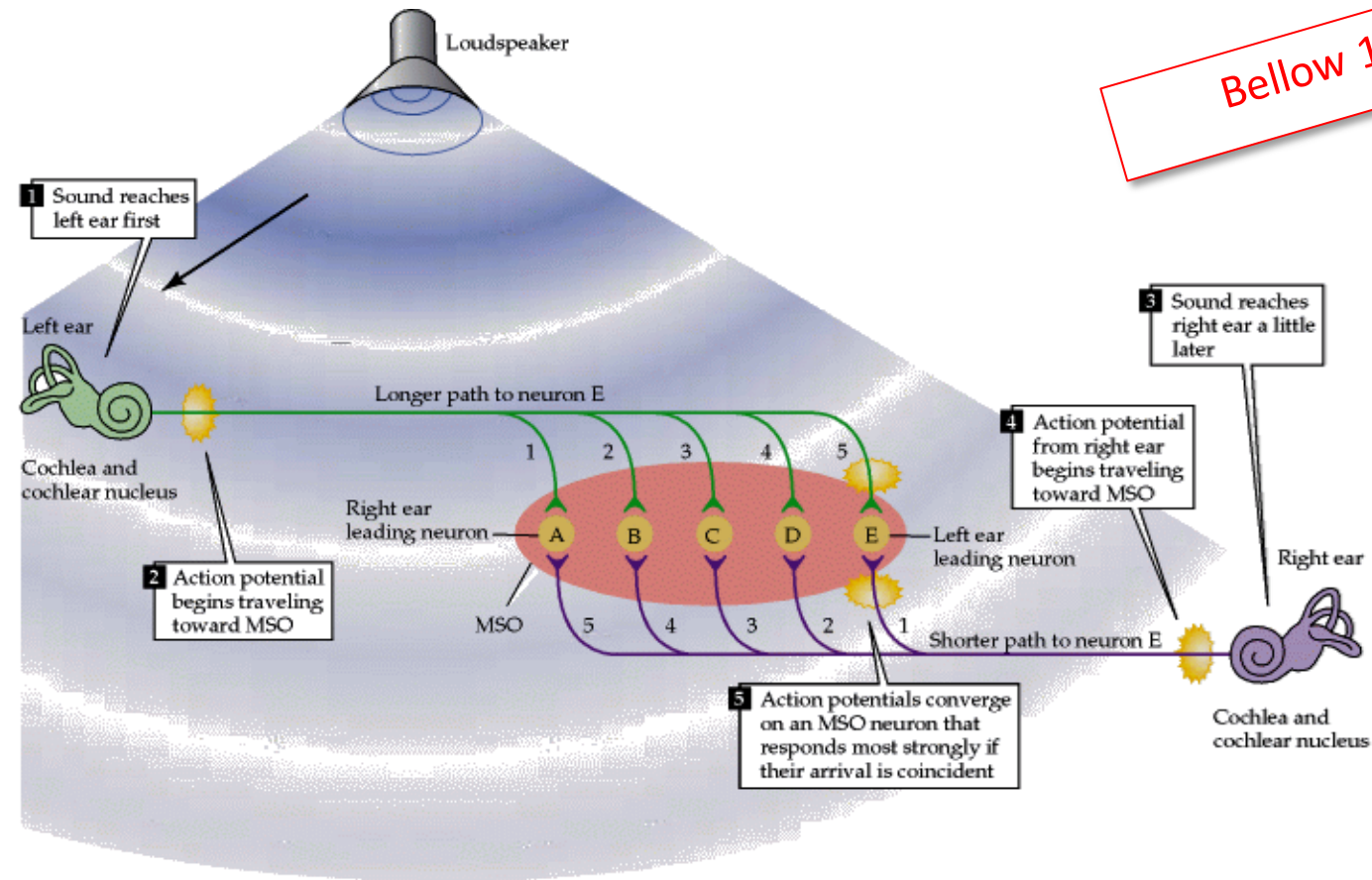
Sound processing

- 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



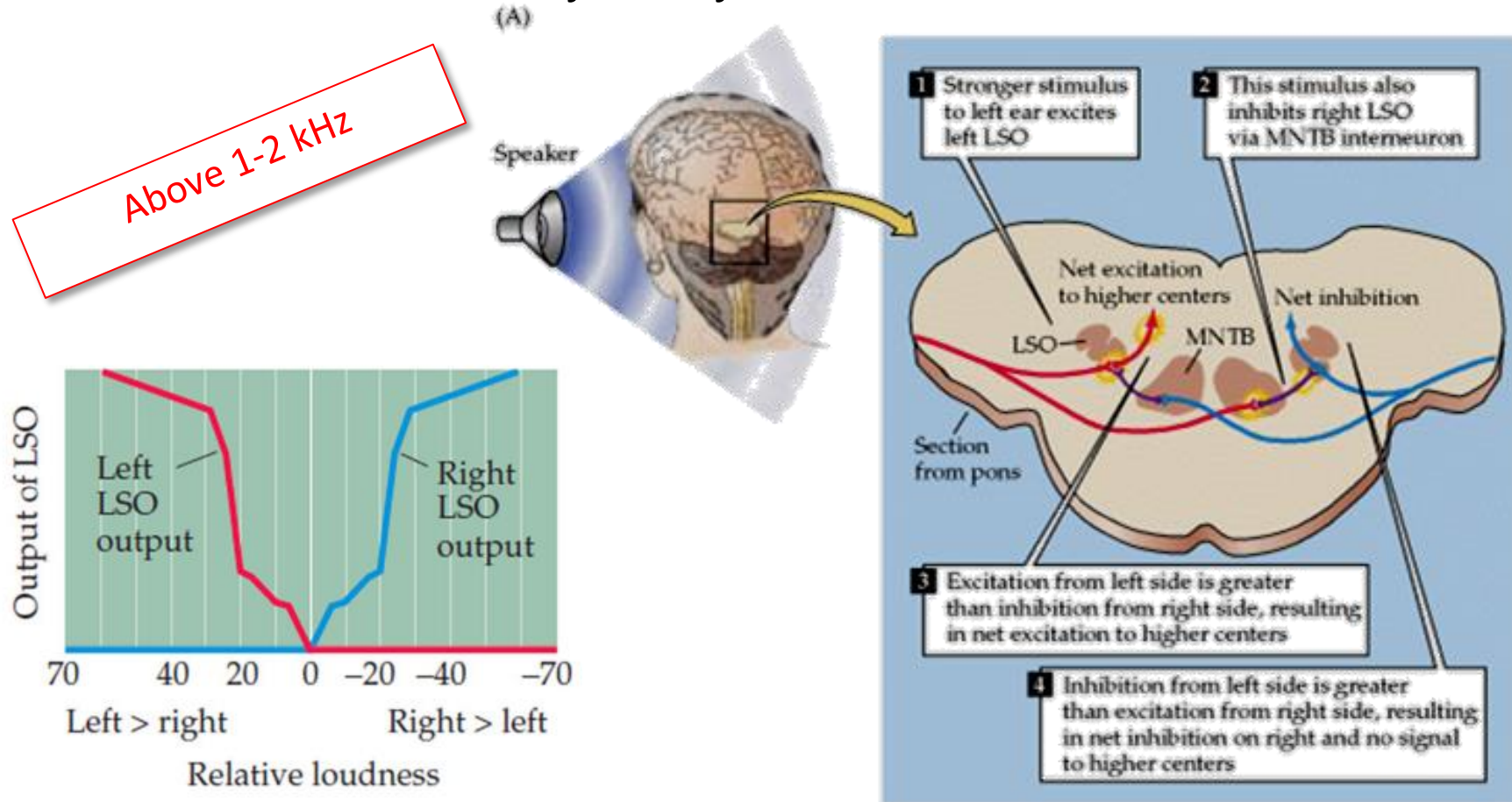
Nucleus olivaris superior medialis

✓ Time delay based sound localization



Nucleus olivaris superior lateralis

- ✓ Intensity analysis based sound localization

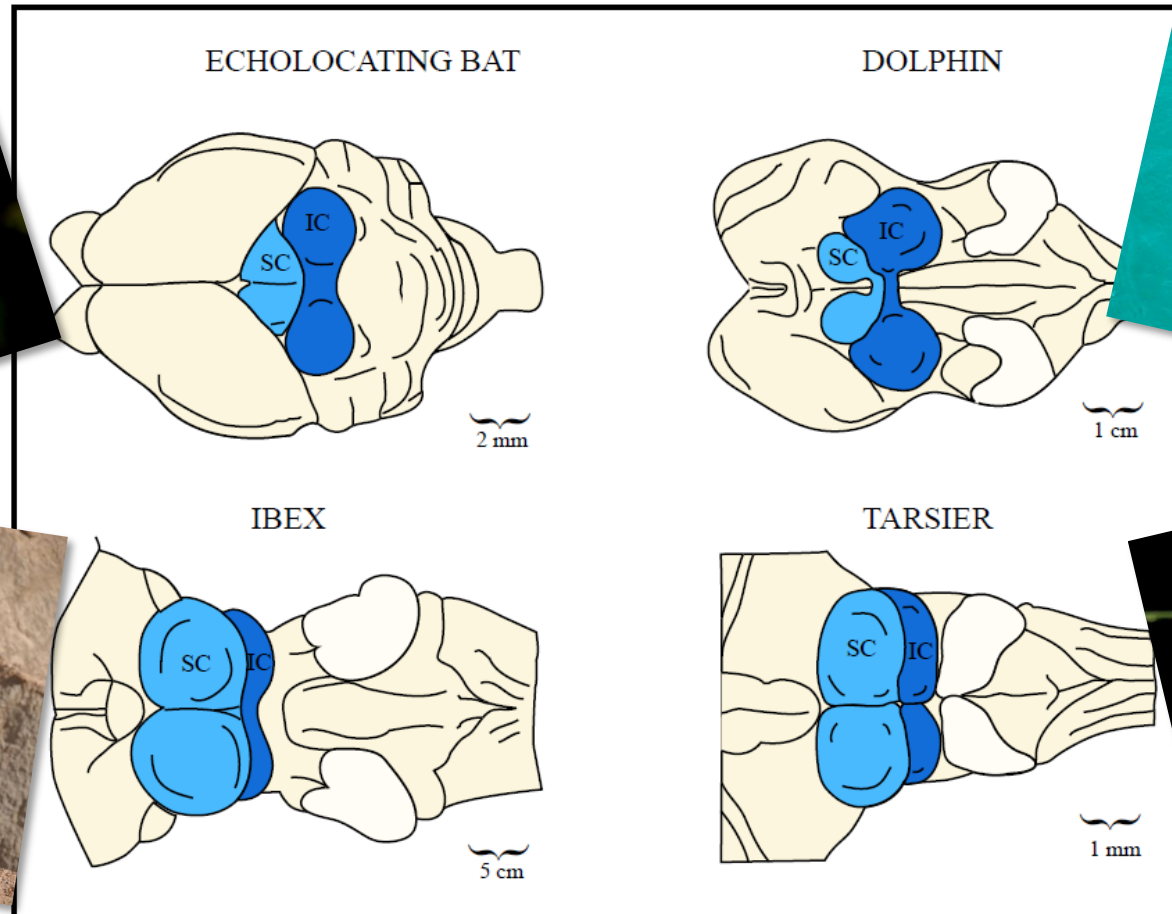


Colliculi inferiores in various animal species

<https://www.earth.com/news/bats-mammal-longevity/>



https://en.wikipedia.org/wiki/Nubian_ibex



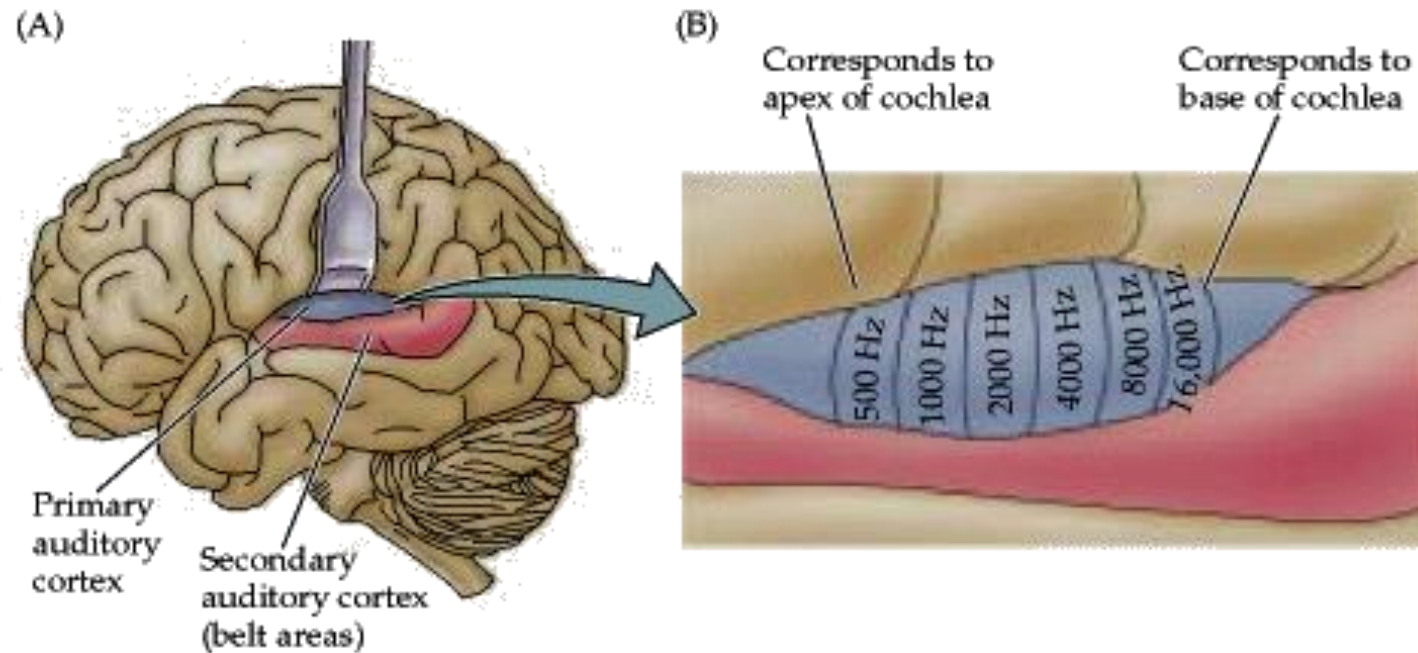
<https://www.thesun.co.uk/tech/3543919/humans-communicate-with-dolphins-by-2021/>

<https://www.animalfactscyclopedia.com/Tarsier-facts.html>



Gerald Schneider. *9.14 Brain Structure and Its Origins, Spring 2014*. (Massachusetts Institute of Technology: MIT OpenCourseWare), <http://ocw.mit.edu> (Accessed). License:Creative Commons BY-NC-SA

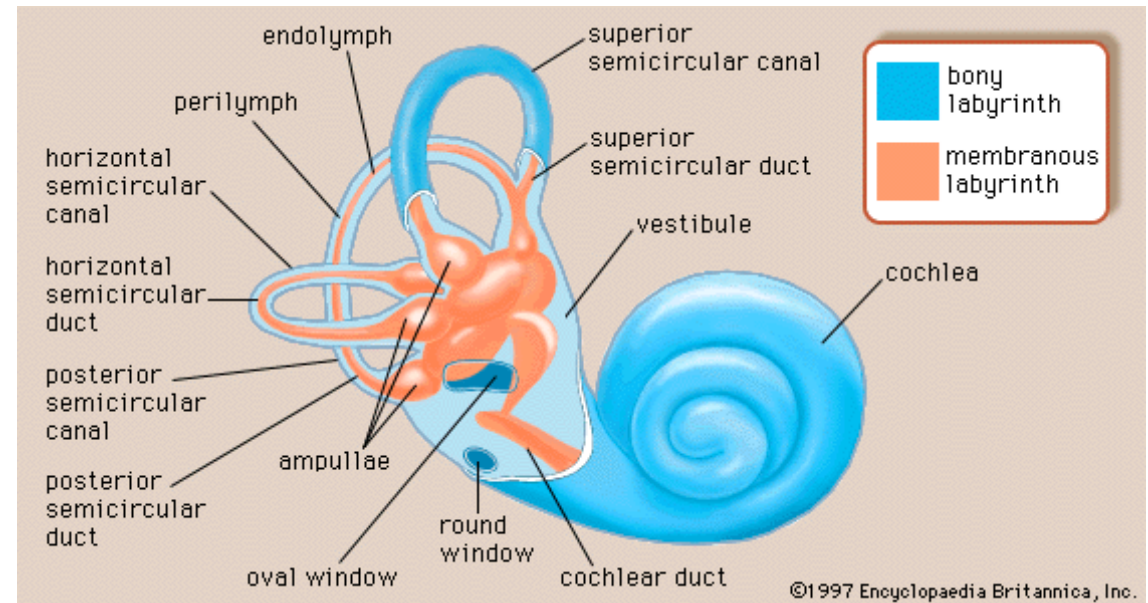
Auditory cortex



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Vestibular system

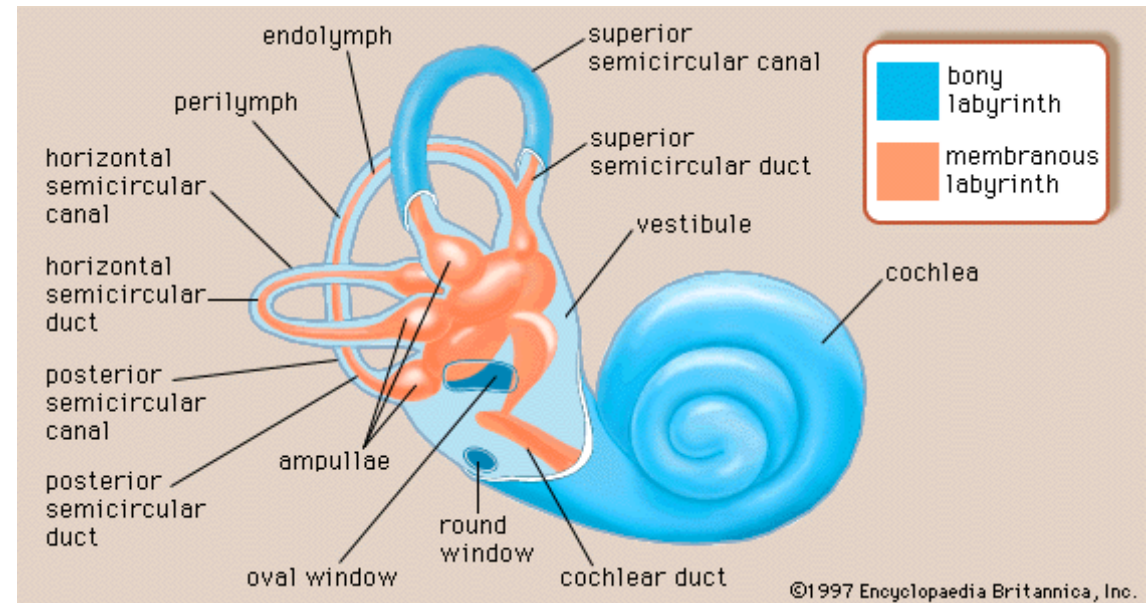
- Associated with auditory system
 - Anatomic localization
 - Hair cells
- Information about
 - Position
 - Acceleration
 - ✓ Linear
 - ✓ Angular



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

Vestibular system

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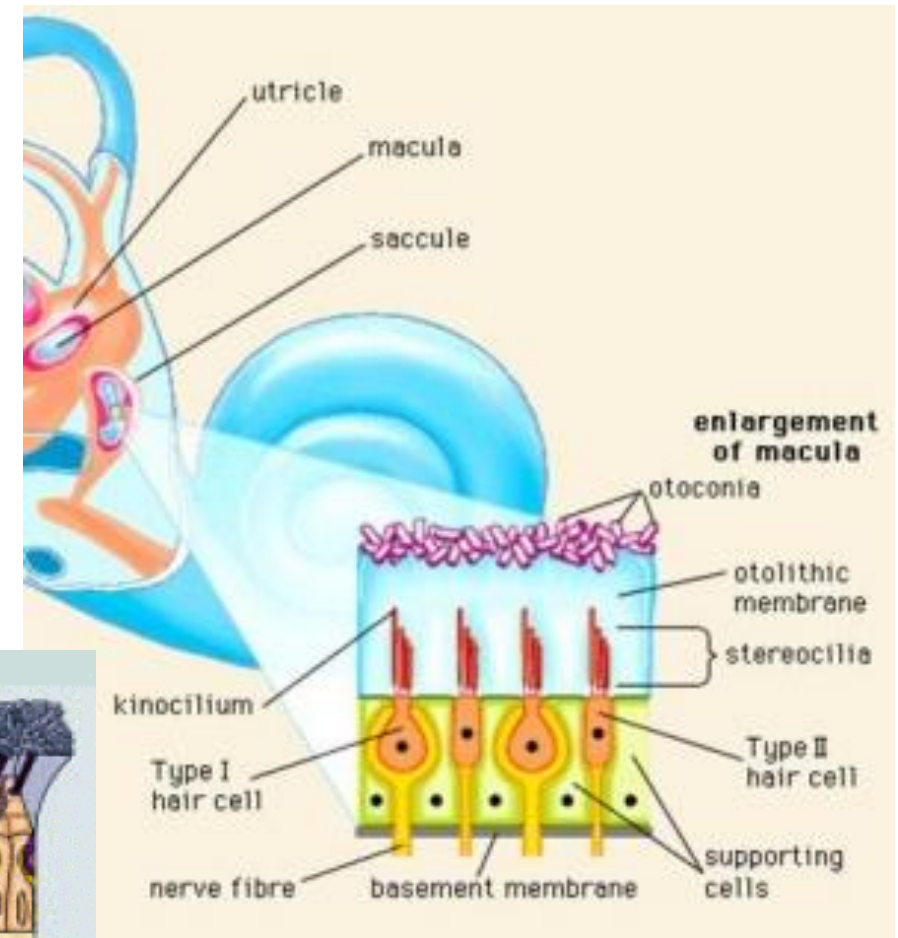
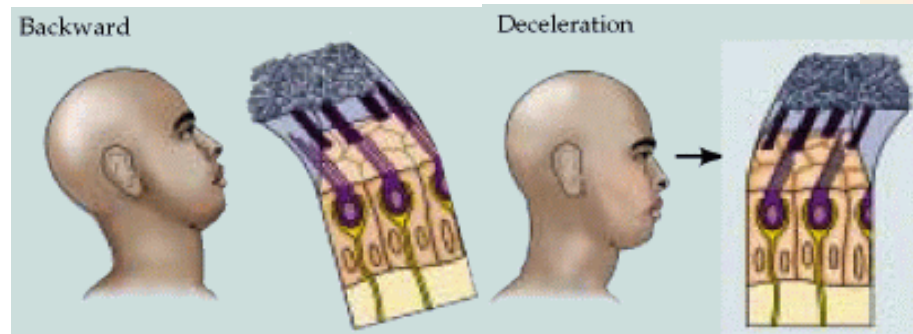
<http://www.slideshare.net/CsillaEgri/presentations>

**Maintenance of the balance
Muscle tone modification**

**„Maintenance of the balance“ of the sight
Vestibuloocular reflexes (VOR)**

Information about position and linear acceleration

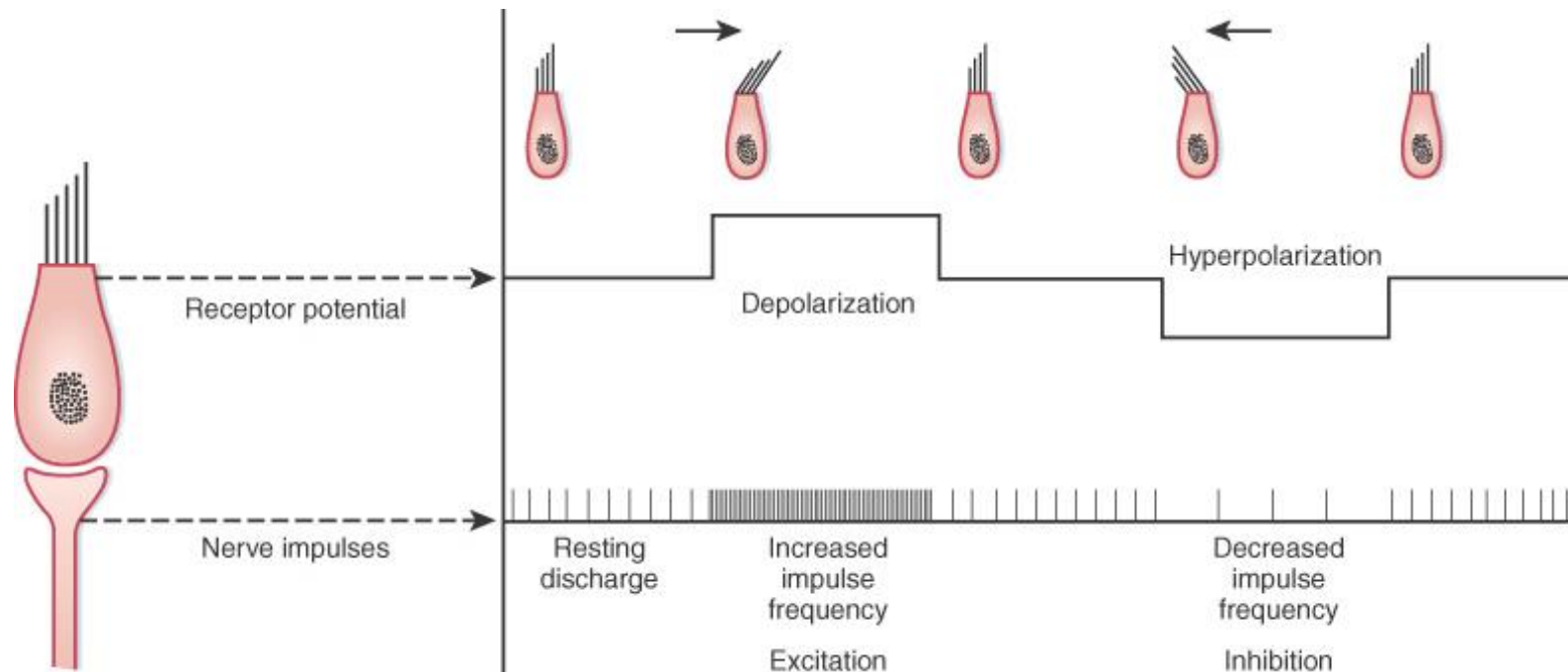
- Macula
 - CaCO_3 crystals
- Utriculus
 - Horizontal macula
- Sacculus
 - Vertical macula



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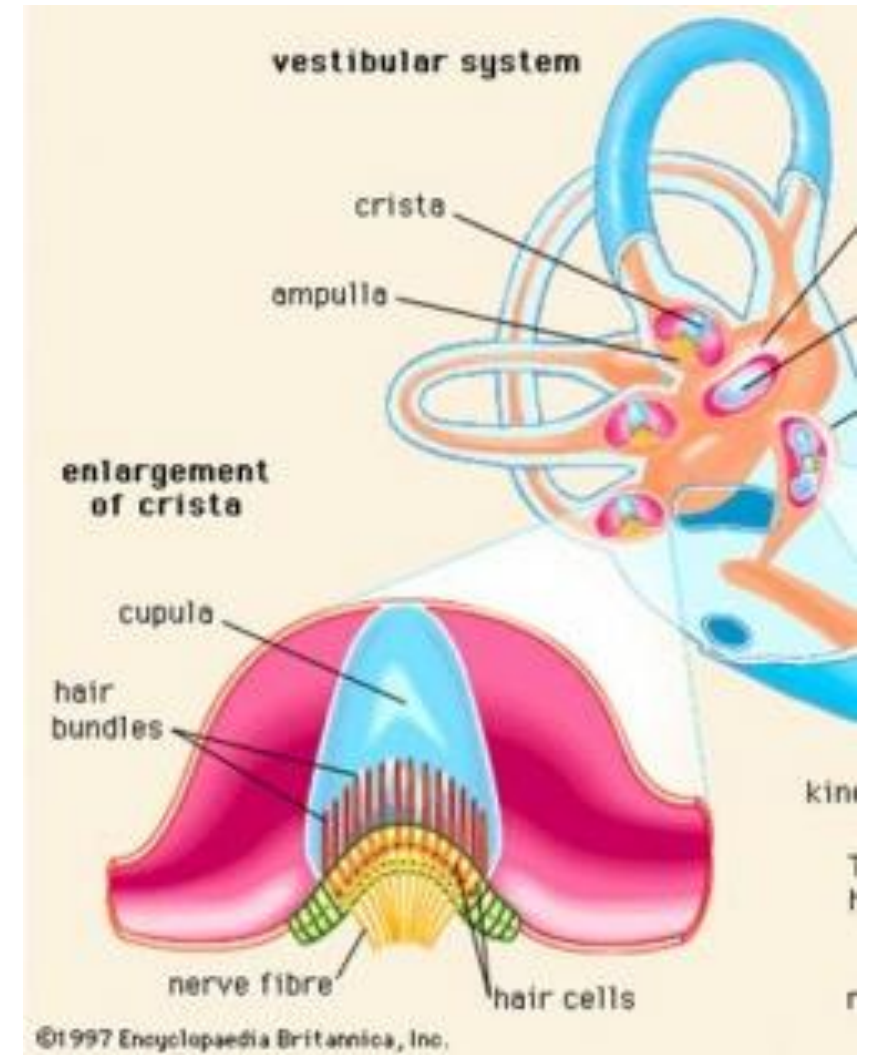
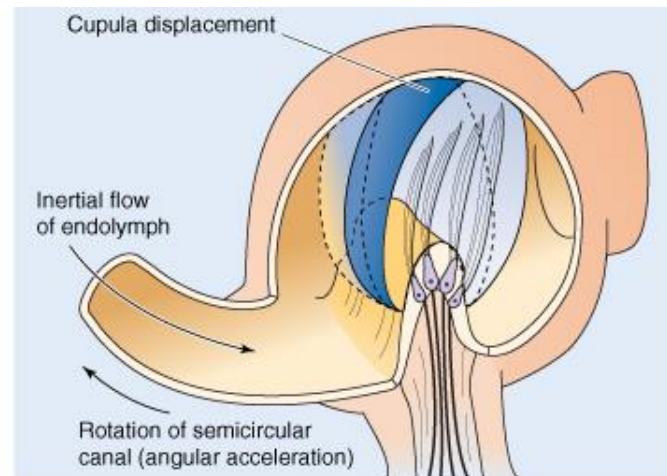
Mechanism of reception

- Flexion towards stereocilia
 - Mechanically activated K^+ channels are opened –depolarization
- Flexion away from stereocilia
 - The channels are closed - hyperpolarization



Information about angular acceleration

- Ampulla
- Semicircular canals
 - Upper
 - Horizontal
 - Posterior



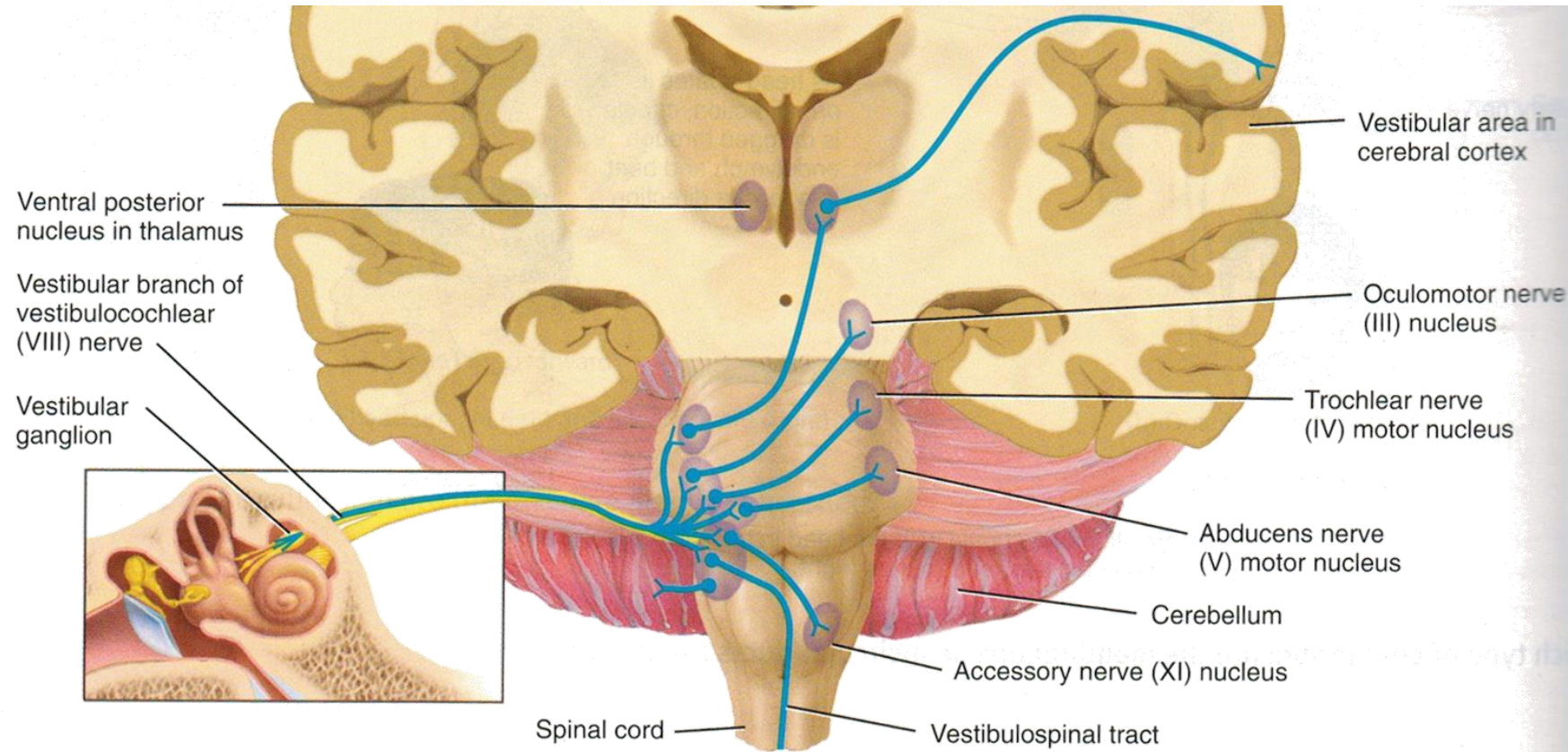
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Vestibular nuclei

✓ Integration of vestibular, visual and somatosensory information

✓ Projections

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



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76. The basic physiology of auditory and vestibular system – brief characterization of the modality, basic information about signal detection and processing

- The auditory and vestibular systems are interconnected by similar mechanisms of reception (“hair cells” activated by mechanical stimuli)
- Auditory system
 - Brief characteristic of sound
 - Overview of ear anatomy and physiology
 - Middle ear more in details
 - Inner ear in details (anatomy, hair cells categorization and function...)
- Main structures involved in signal processing and source localization
- Vestibular system
 - Overview of anatomy with respect to function (detection of position, linear and angular acceleration)
 - Main projections from vestibular nuclei
- Nystagmus (presentation Vision II)

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