Auditory & Vestibular Systems

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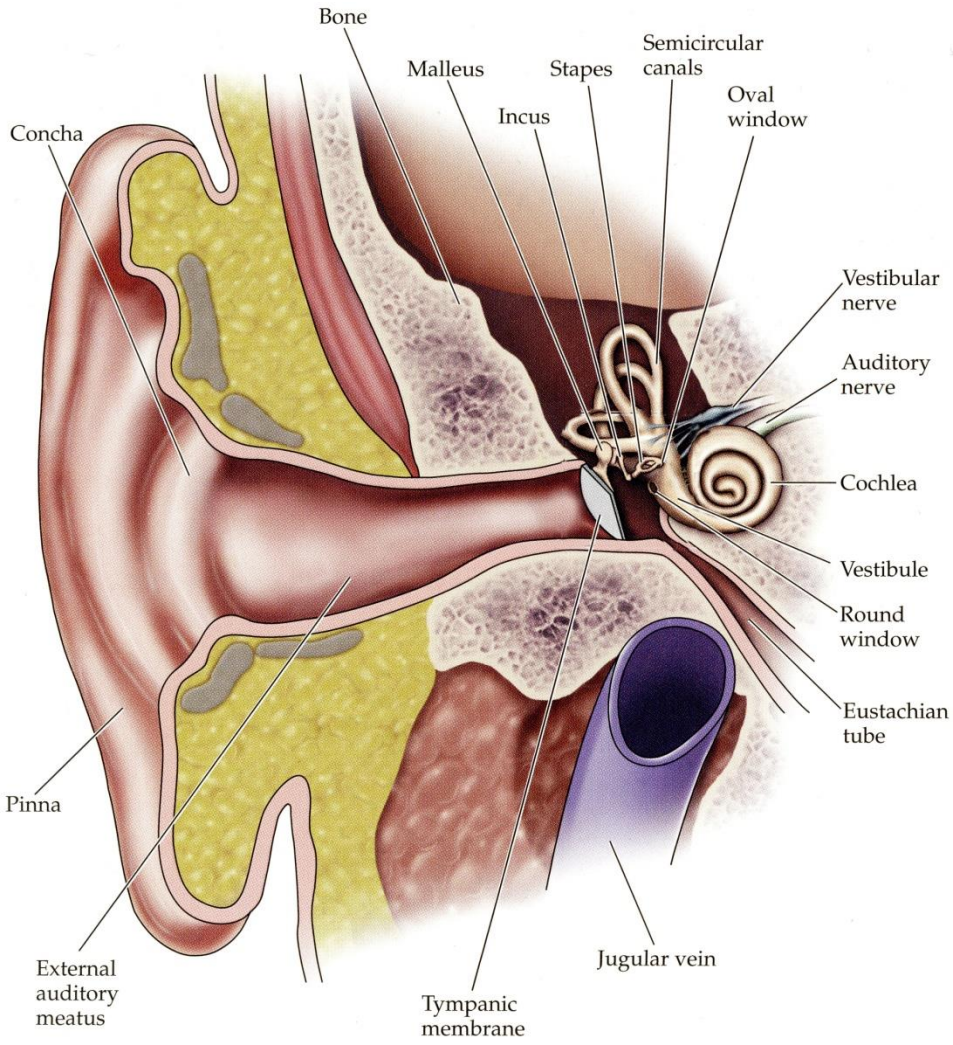
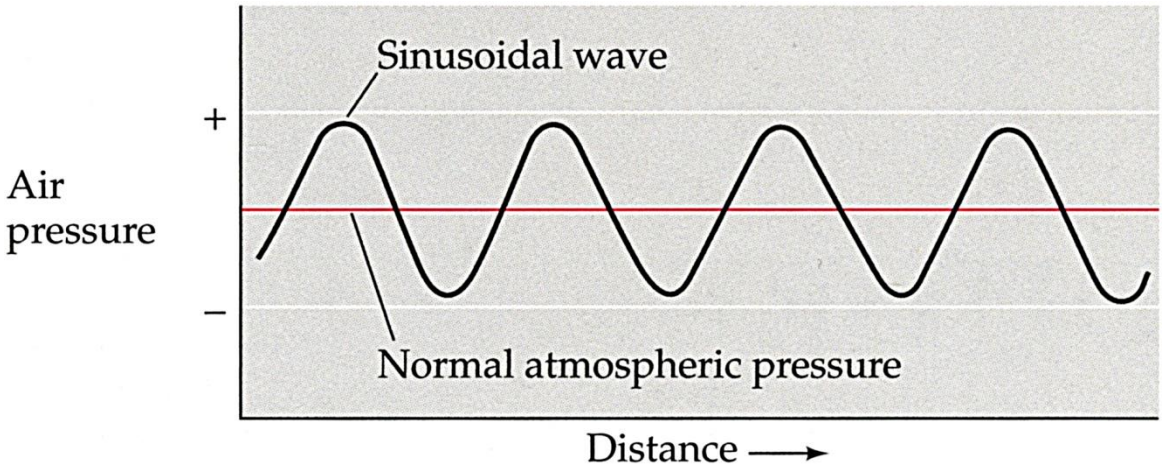
The auditory & vestibular systems have many similarities.

- The sensory apparatus for both are in canals embedded in the bone of the inner ear.
- Receptor cells (hair cells) for both are mechanosensory cells with fine stereocilia.
- Information for both is carried into the brain via the vestibulochoclear nerve (cranial nerve VIII).



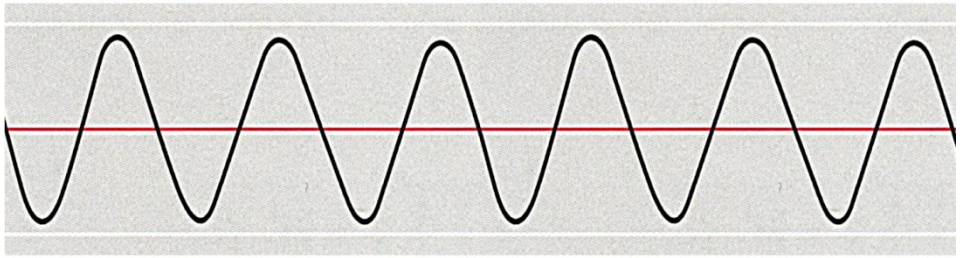
Auditory System

- The auditory system detects and interprets sound.
- Sound is the vibration of air molecules similar to ripples in water that propagate from a thrown rock.
- The sound waves have an amplitude (loudness) and frequency (pitch).

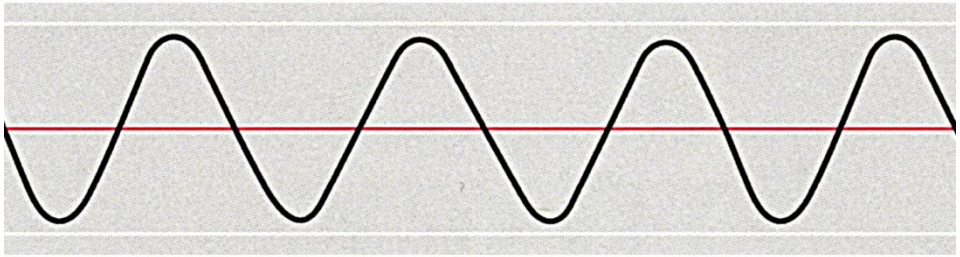


Auditory System

- Humans can typically hear 20 – 20,000 hertz (cycles per second).



higher frequency



lower frequency

Auditory System

- Humans can typically hear 20 – 20,000 hertz (cycles per second).

http://en.wikipedia.org/wiki/Audio_frequency

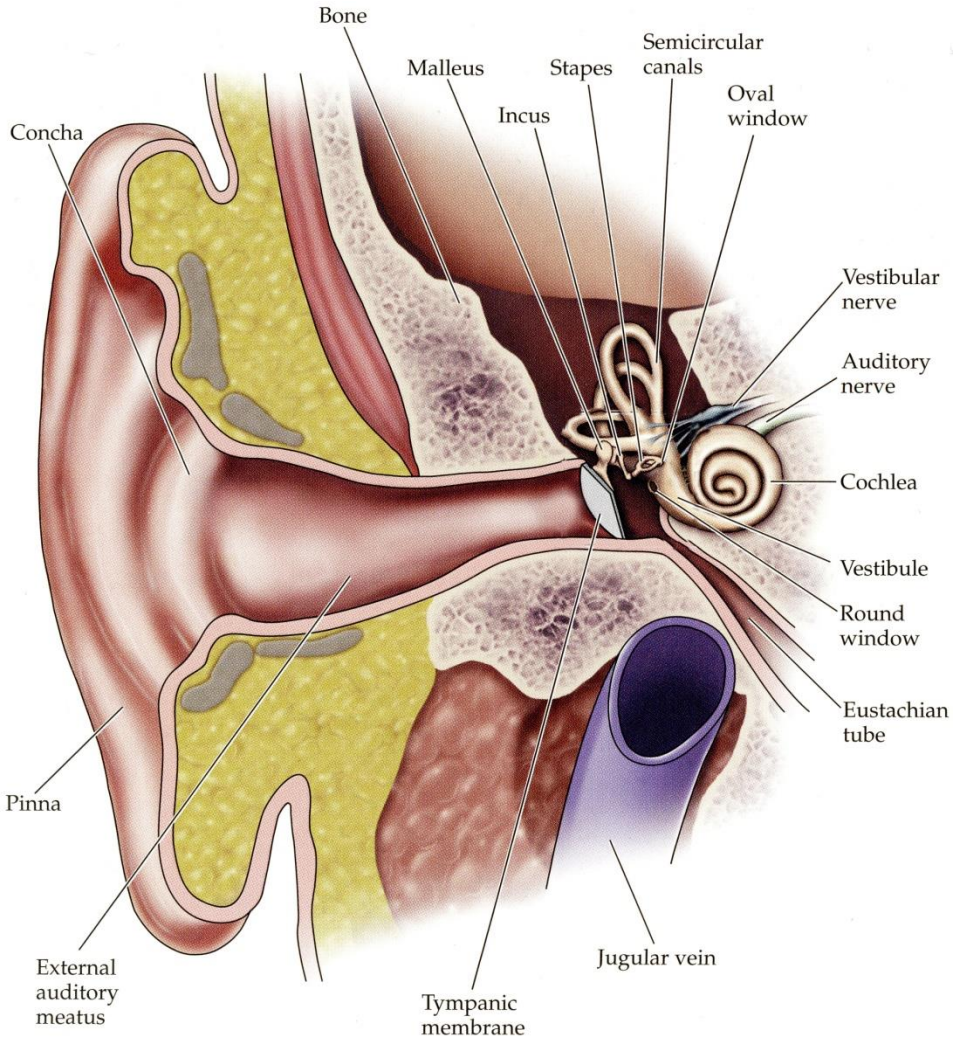
Auditory System

- As a person ages, he/she loses the ability to hear high and low frequencies.

Auditory System

External ear:

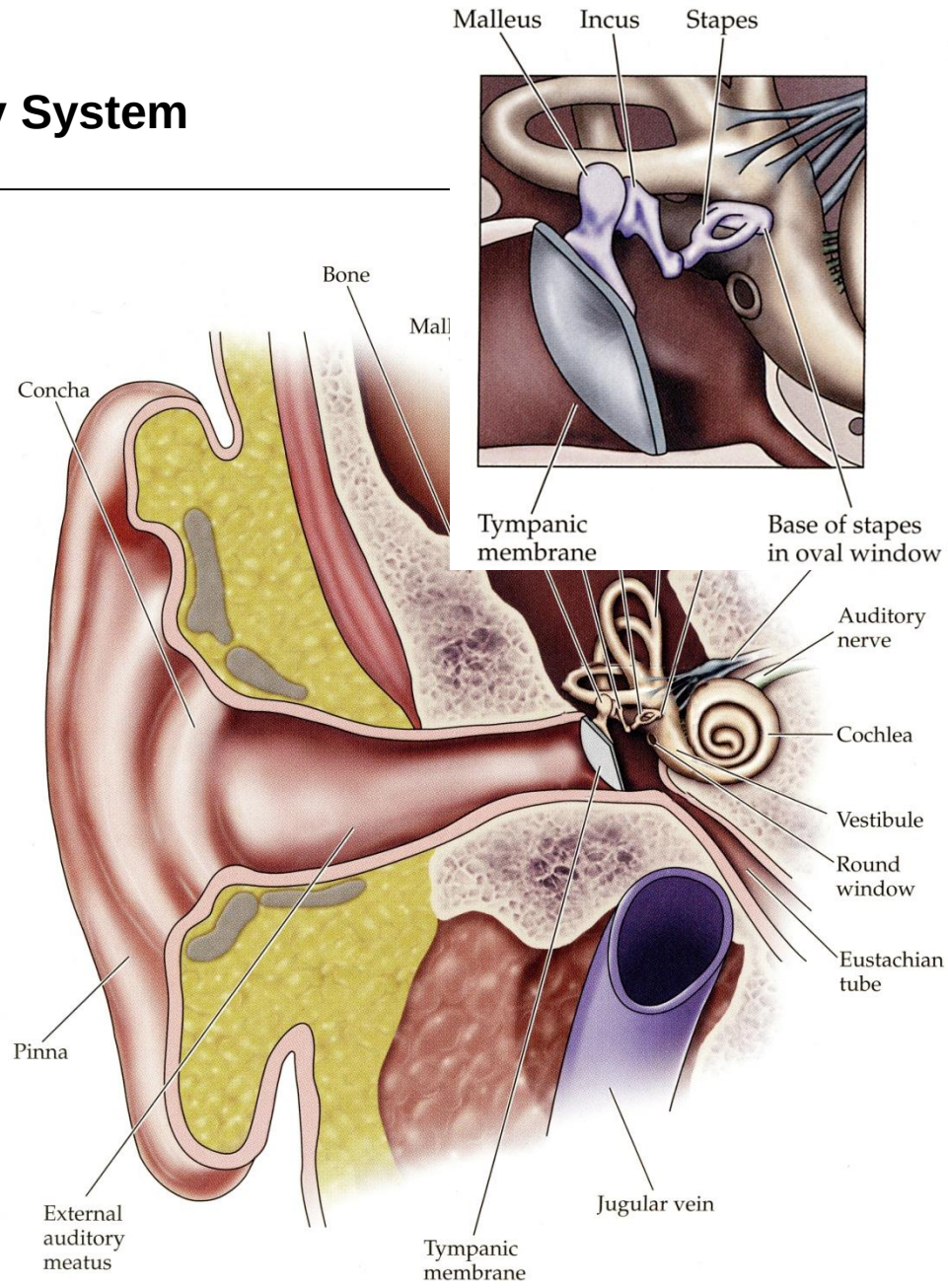
- includes the pinna, external auditory meatus (ear canal) and tympanic membrane (ear drum).
- The pinna and canal collect sound and guide it to the tympanic membrane.
- The tympanic membrane vibrates in response to sound.



Auditory System

Middle ear:

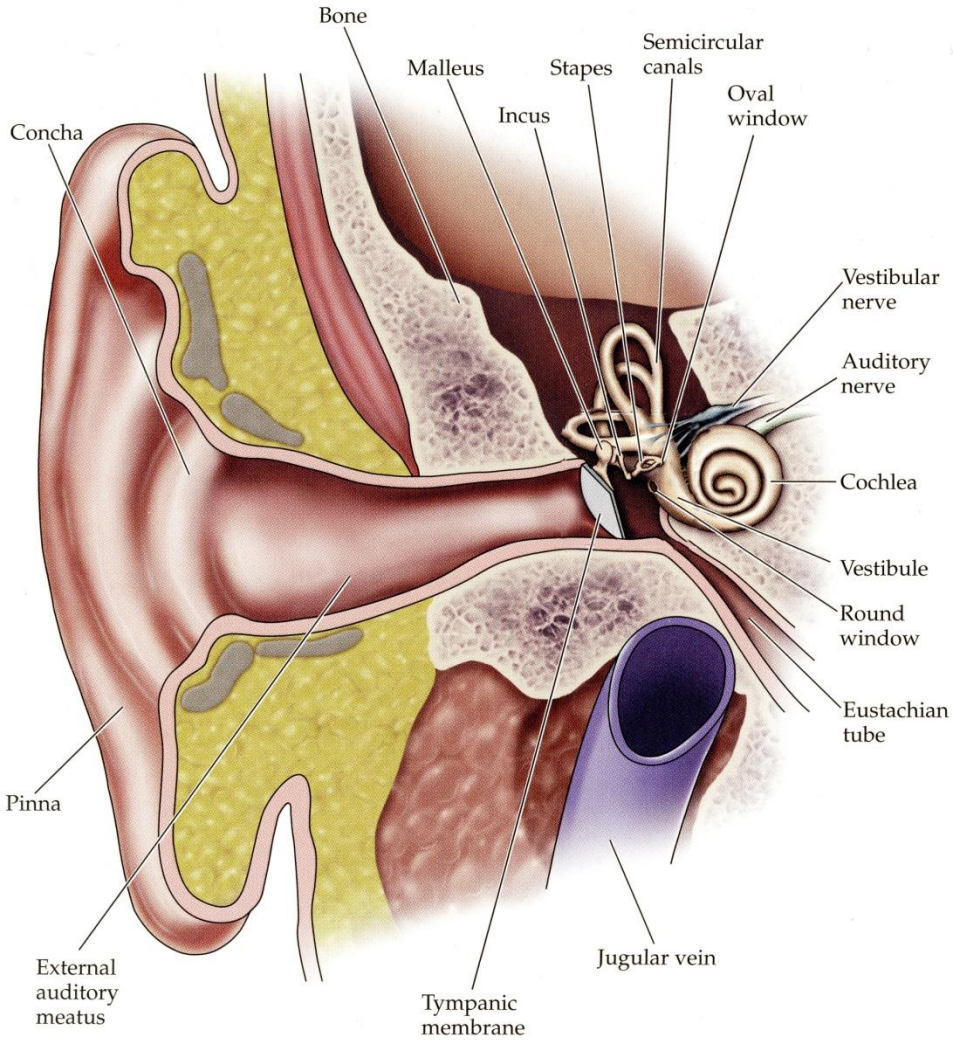
- It is an air filled chamber.
- The eustachian tube (auditory tube) connects the middle ear chamber with the pharynx (throat).
- Three tiny bones in the chamber transfer the vibration of the tympanic membrane to the oval window of the inner ear.
- Two tiny muscles can dampen the movement of the tympanic membrane and bones to protect against a loud sound.



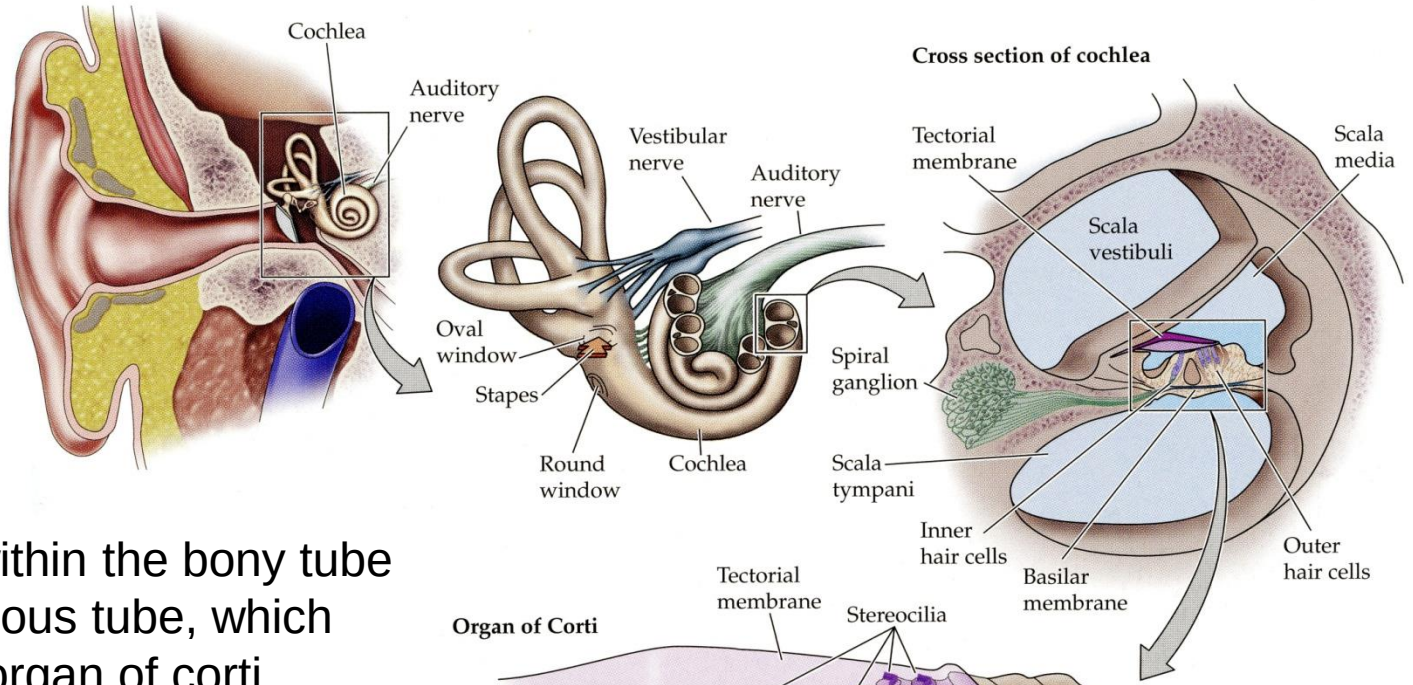
Auditory System

Inner ear:

- The cochlea is a snail shaped tube incased in bone.
- The cochlea has two membrane covered openings into the middle ear, the oval and round windows.
- The auditory (choclear) nerve, a branch of the vestibulochochlear (CN VIII) runs out of the cochlea.
- The cell bodies of the auditory nerve axons are in the spiral ganglion in the center of the cochlea.

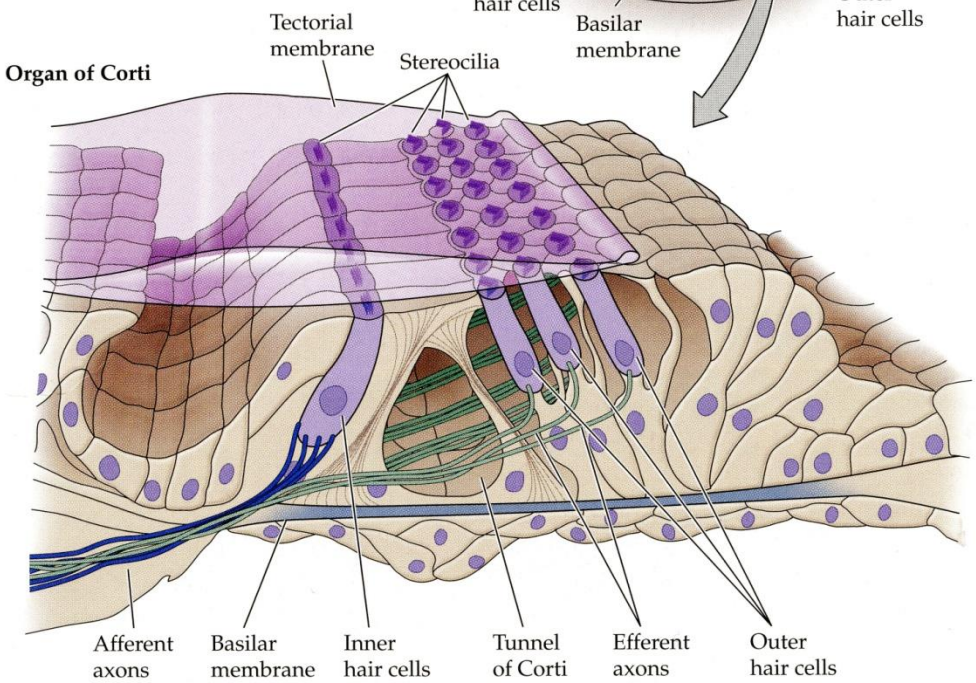


Auditory System



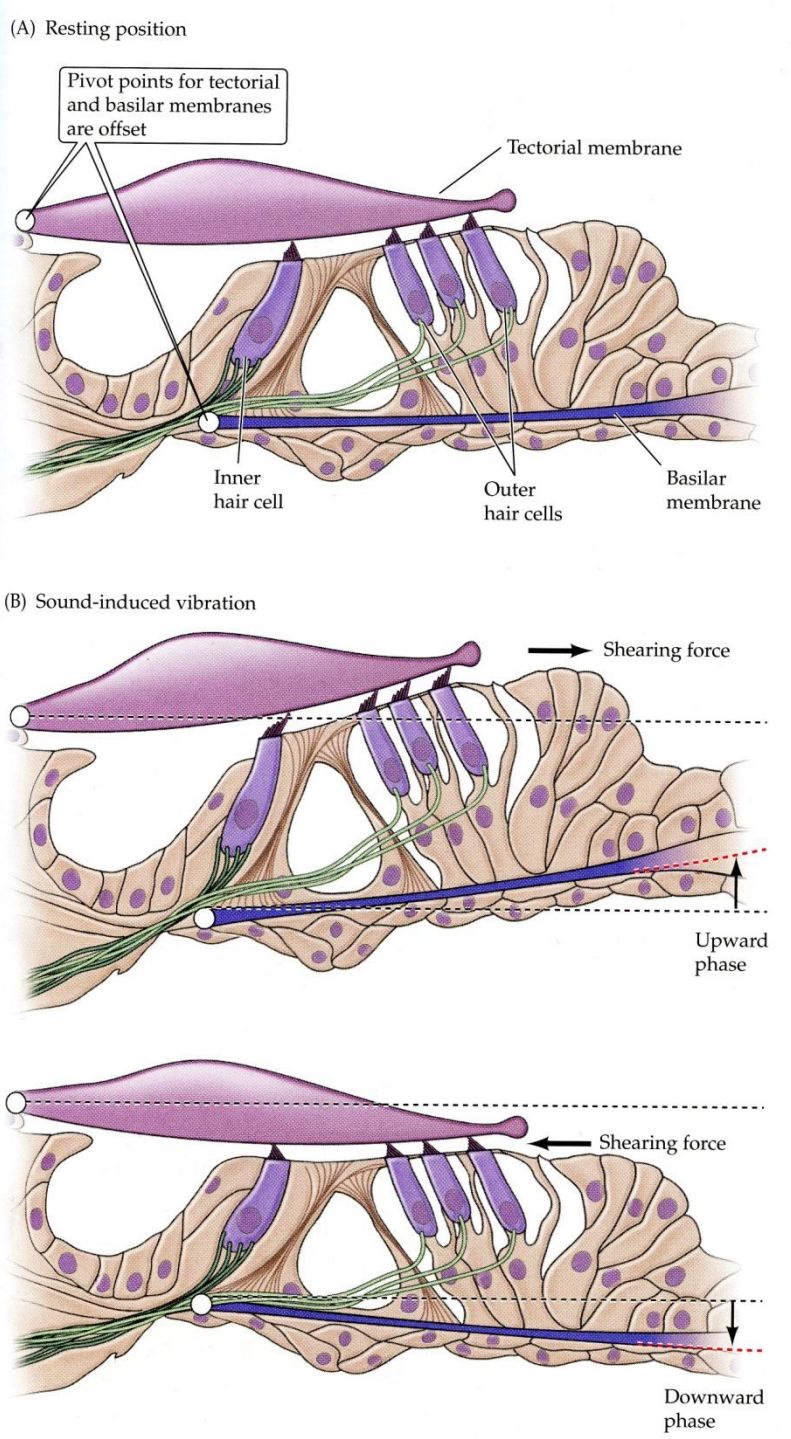
- Suspended within the bony tube is a membranous tube, which contains the organ of corti.

- The hair cells, the auditory receptor neurons, are in the basilar membrane of the organ of corti.



Auditory System

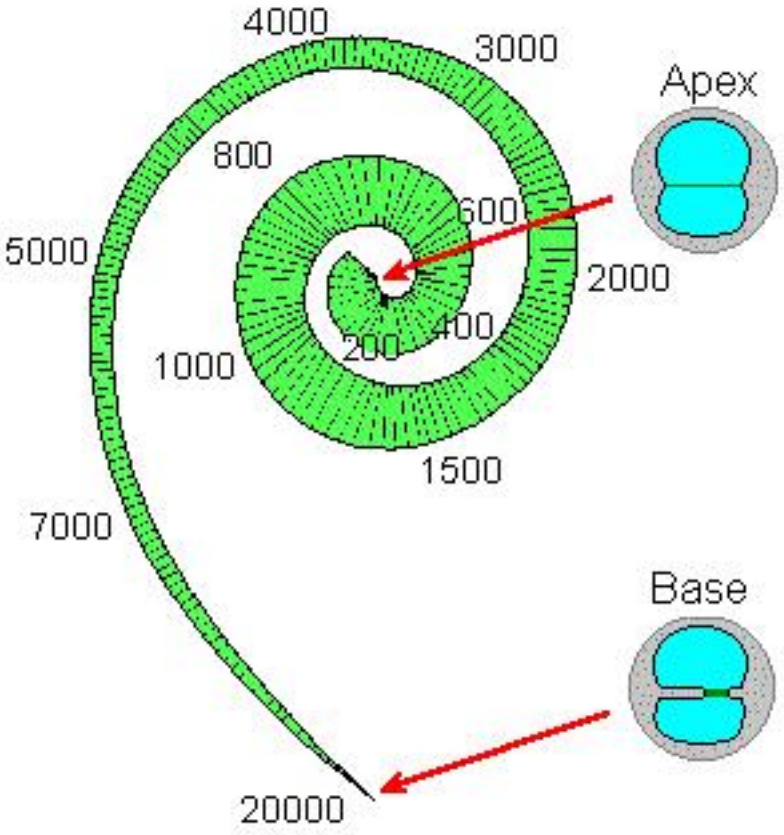
- A sound vibration entering via the oval window travels up the cochlea.
- This causes vibration of the basilar membrane, which distorts the stereocilia bundles of the hair cells that are in contact with the overlying membrane.
- The mechanosensory hair cells are depolarized by movement of their stereocilia.
- The depolarized hair cells release neurotransmitter that activates the dendrites of spiral ganglion neurons.

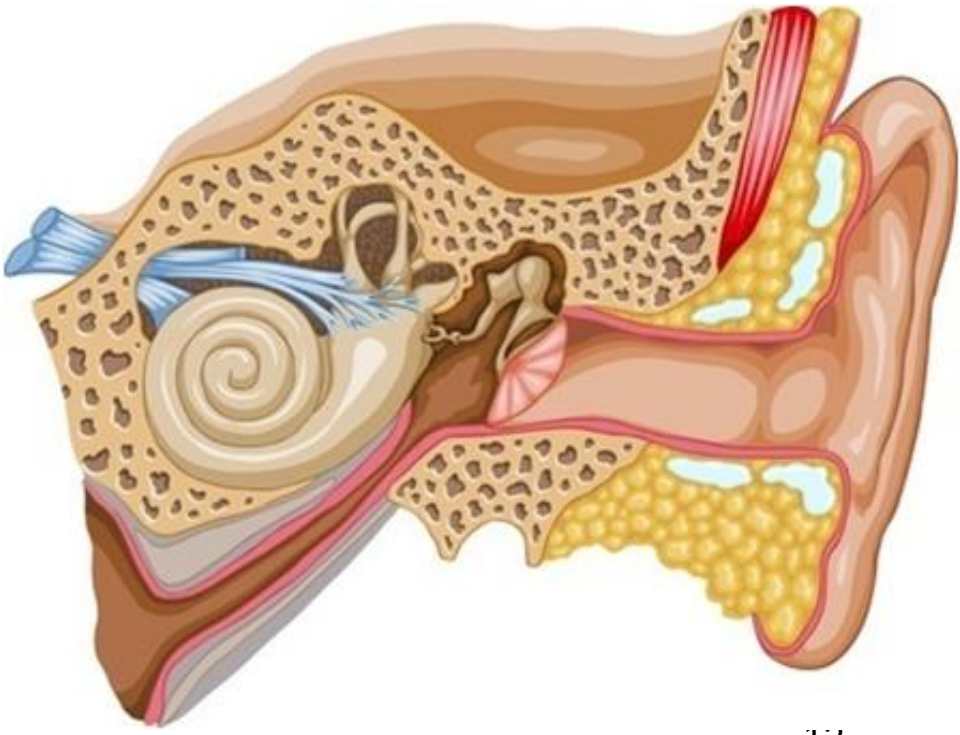


Auditory System

- Hair cells in different parts of the cochlea are sensitive to different frequencies.

  Hair cells at the base of the cochlea are sensitive to high frequency sound; hair cells at the apex are sensitive to low frequency sound.

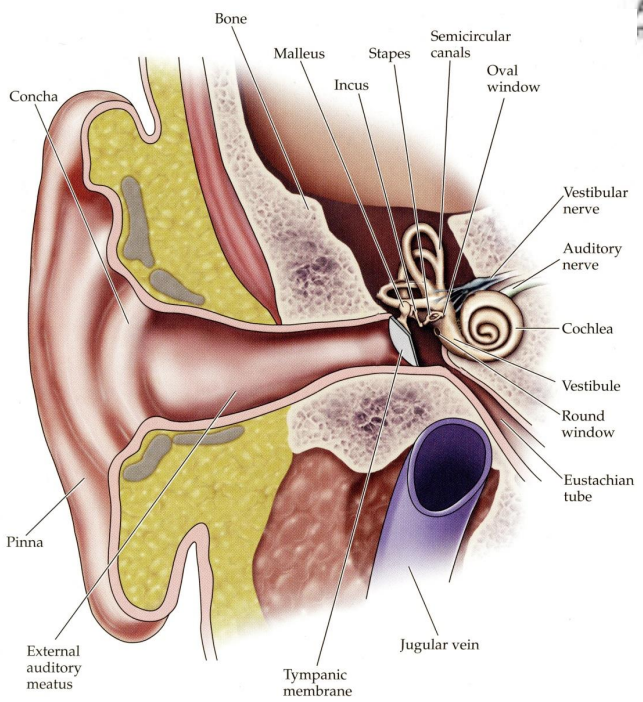


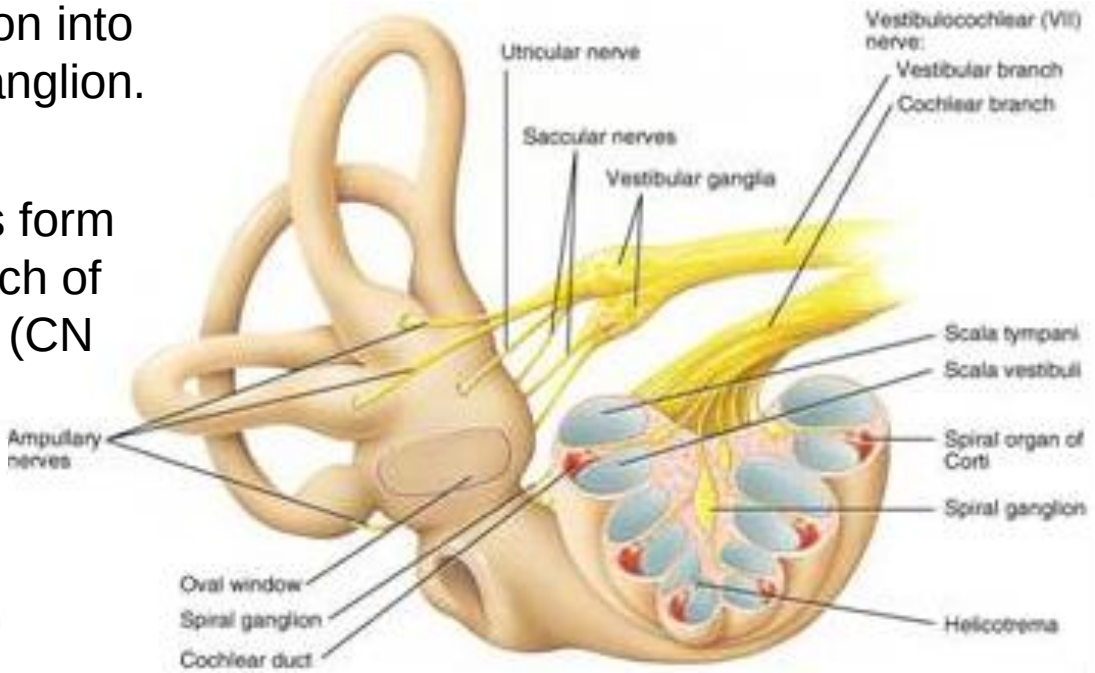


Auditory System

- The cell bodies for the neurons that relay auditory information into the brain are in the spiral ganglion.

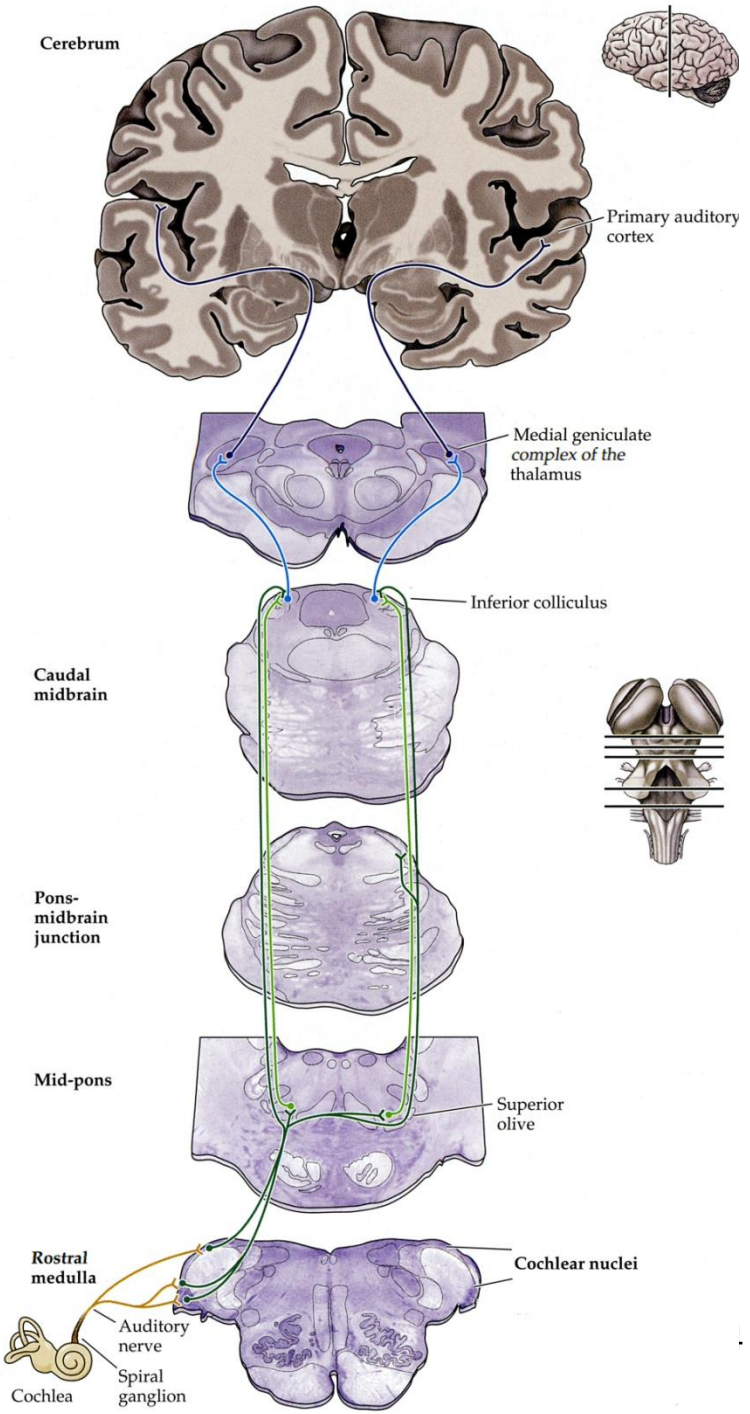
- The axons of these neurons form the auditory (cochlear) branch of the vestibulocochlear nerve (CN VIII).





Auditory System

- The axons of the auditory nerve synapse in the cochlear nuclei in the medulla.
- Neurons in the cochlear nuclei project bilaterally to the inferior colliculus (and other places).
- Neurons in the inferior colliculus project to the medial geniculate nucleus in the thalamus.
- Neurons in the medial geniculate project to primary auditory (A1) cortex in the temporal lobe.

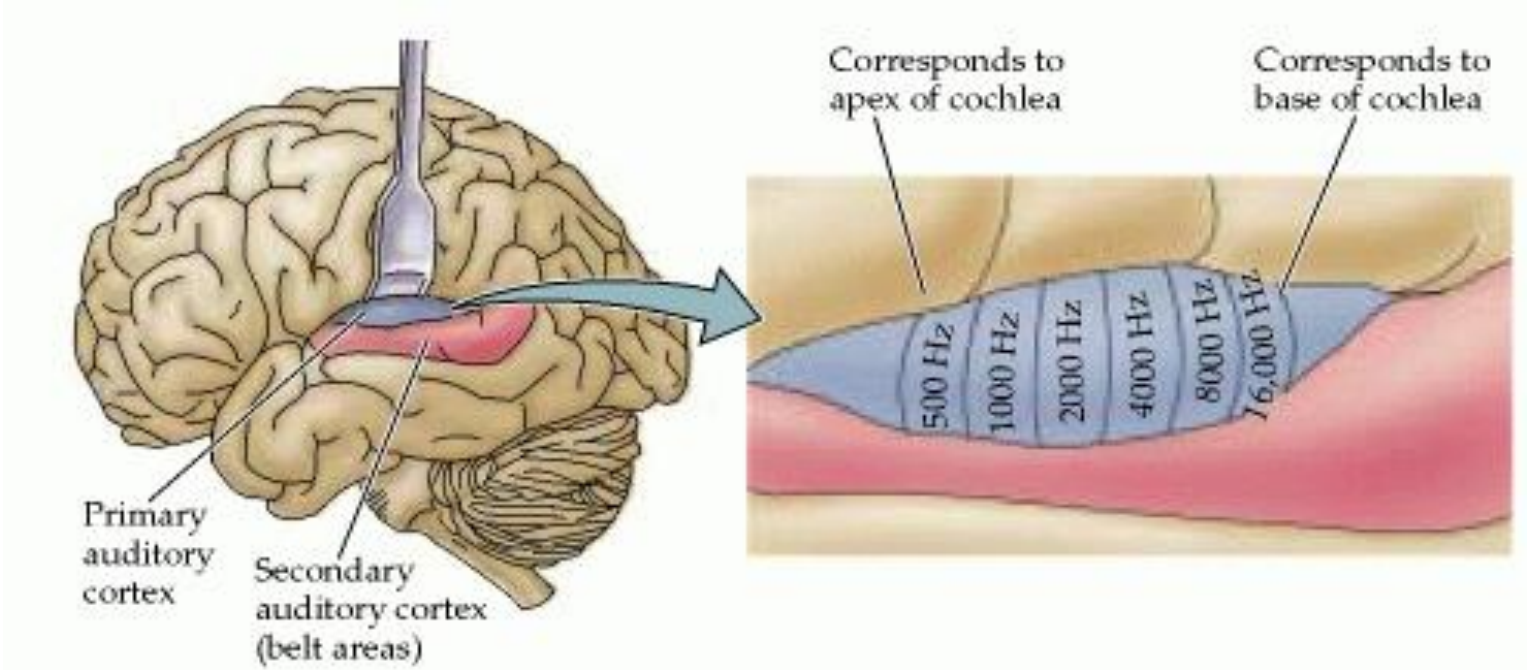


Auditory System

- The bilateral processing of auditory information from the two ears allows positional localization of a sound based on comparison of the timing and volume of the sound in the two ears.

Auditory System

- Auditory information arrives in the cortex in tonotopic order.



Auditory System

- Four major causes of acquired hearing loss:
  - Ear infection
  - Acoustical trauma
  - Ototoxic drugs
  - Aging

Auditory System

- Factors affecting the outer and middle ear result in conductive hearing loss.

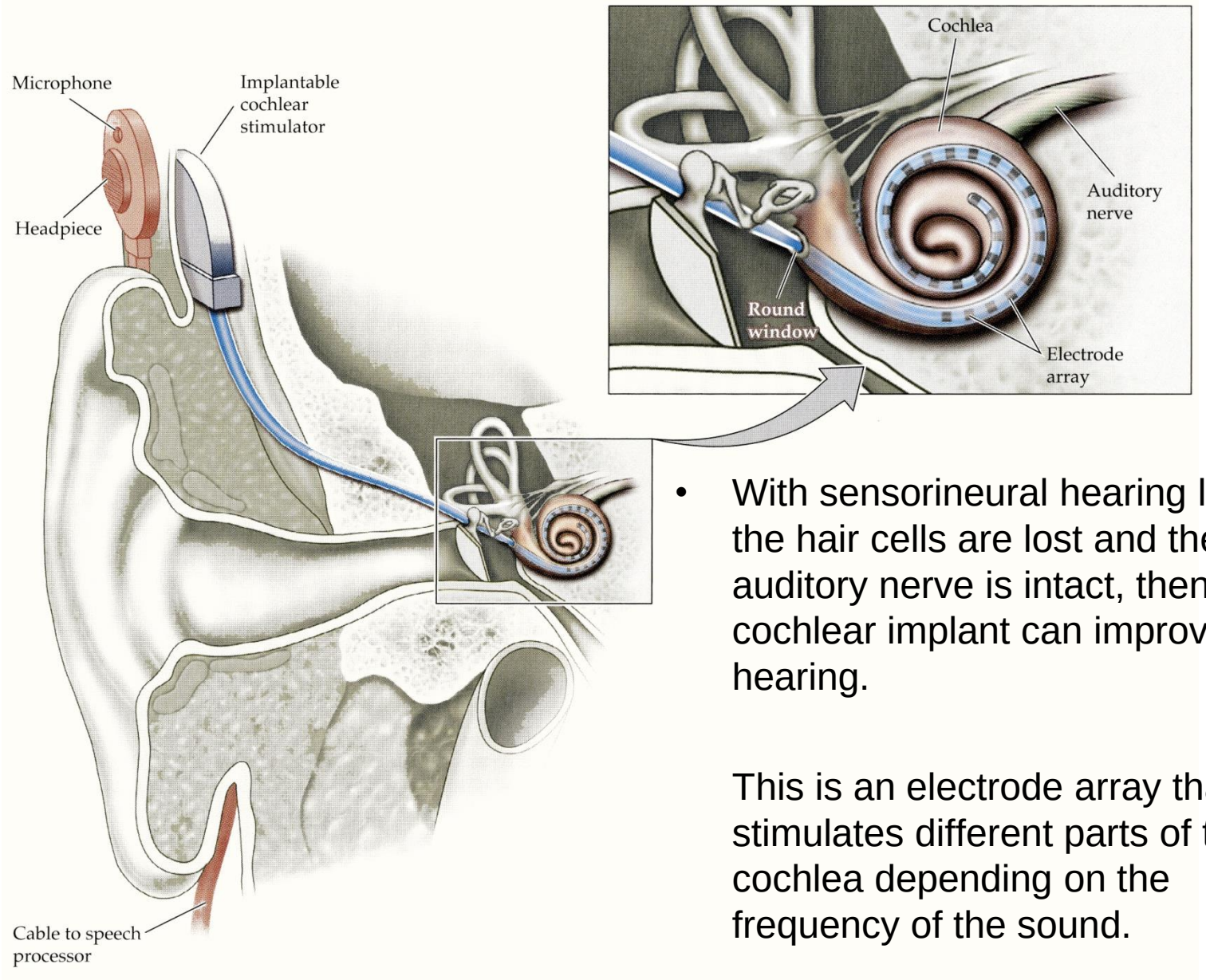
- Factors affecting the inner ear or auditory nerve result in sensorineural hearing loss.

Auditory System

- A hearing aid can often help conductive hearing loss by increasing the volume of the incoming sound.

  A hearing aid has a microphone, amplifier and speaker.

Auditory System



- With sensorineural hearing loss, if the hair cells are lost and the auditory nerve is intact, then a cochlear implant can improve hearing.

  This is an electrode array that stimulates different parts of the cochlea depending on the frequency of the sound.

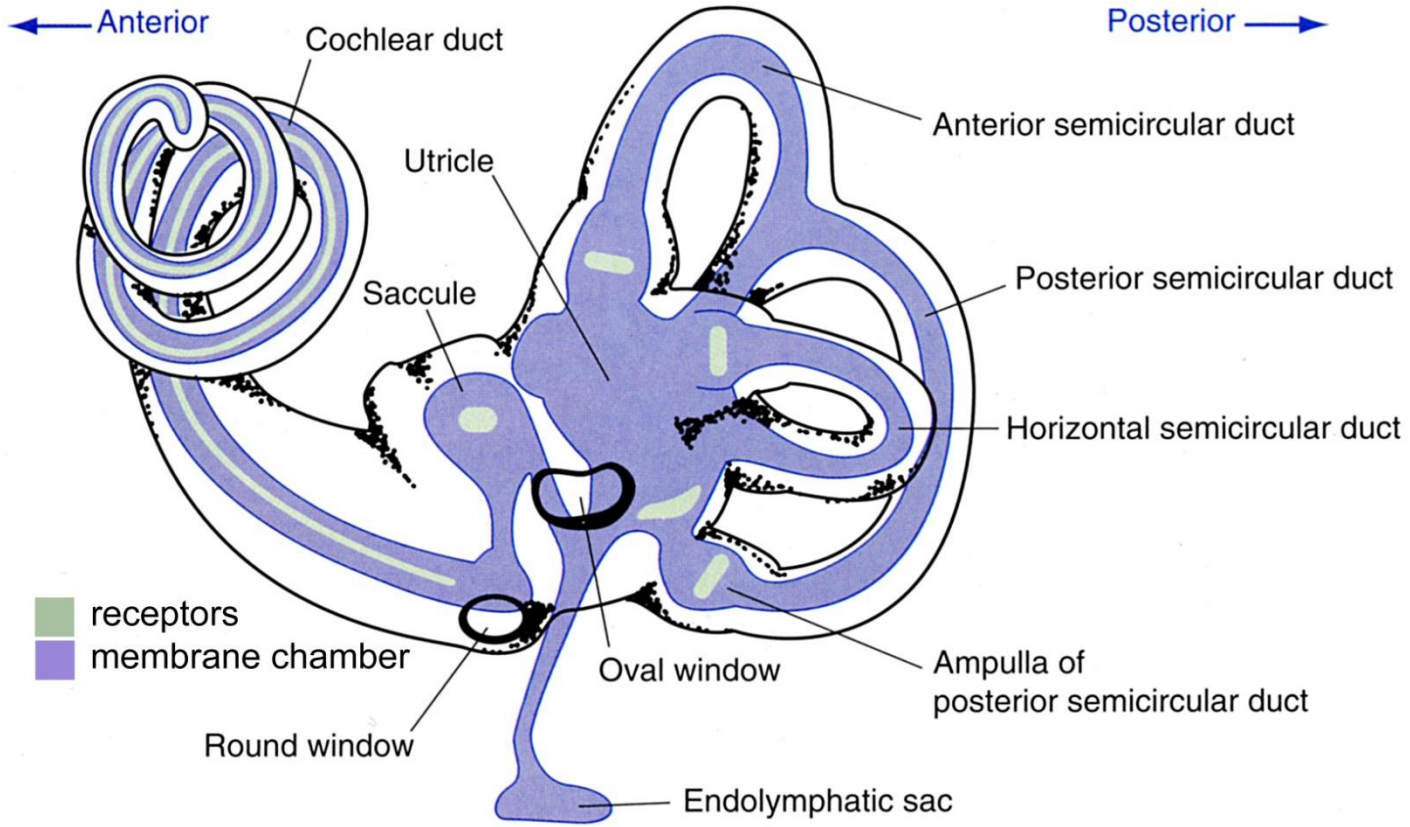
Vestibular System

- Vestibular sense is a special sense.
- The sensory apparatus senses head movement and position, as well as gravity.
- The sensory apparatus is part of the inner ear, and vestibular information is carried to the brainstem via the vestibulocochlear nerve (CN VIII).
- Vestibular function is important for balance, controlling eye movements and numerous reflexes associated with movement and changes in body position.

Vestibular System

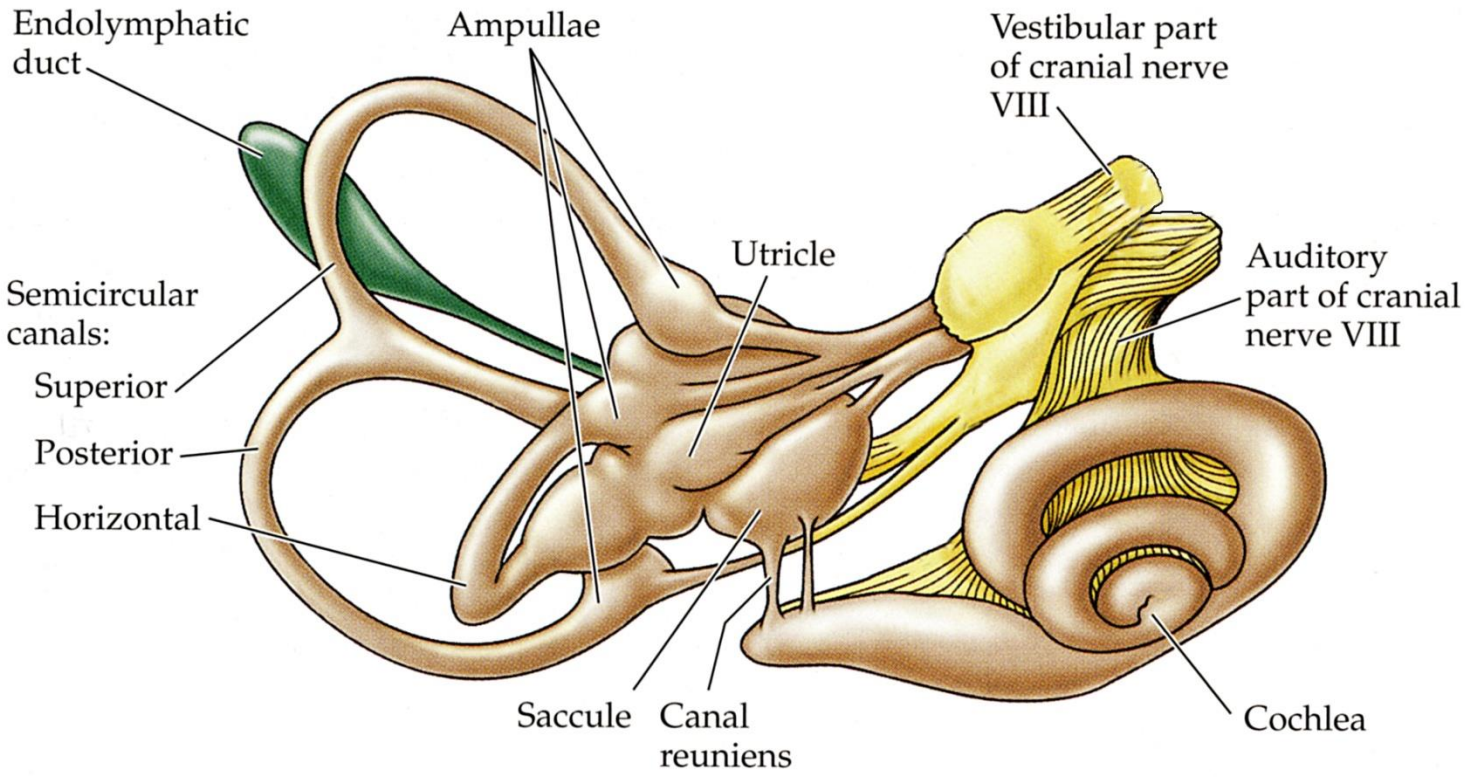
- The vestibular sensory apparatus is part of the inner ear labyrinth that includes the cochlea.

- The fluid-filled chambers are incased in bone.



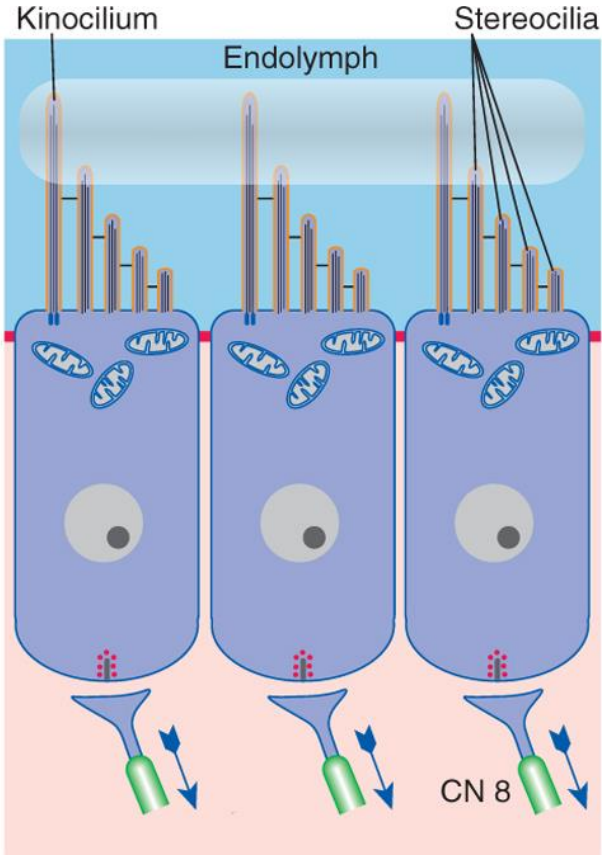
Vestibular System

- The vestibular sensory apparatus in each ear includes:
  - 3 semicircular canals
  - 2 otoliths (utricle and saccule)



Vestibular System

- Each semicircular canal and otolith has a sensory apparatus with hair cells that have stereocilia extending into a gelatinous weight.
- When the head moves in the optimal orientation for the particular sensor, the fluid in the chamber, the endolymph, moves, thus moving the weight.
- Movement of the weight moves the cilia, which depolarizes the hair cells.
- Hair cells synapse with the dendrites of the vestibular ganglion neurons.



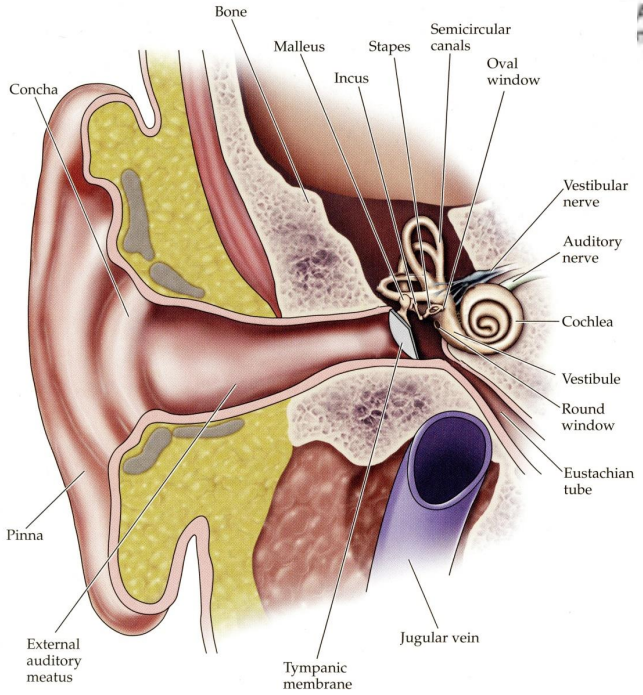
Vestibular System

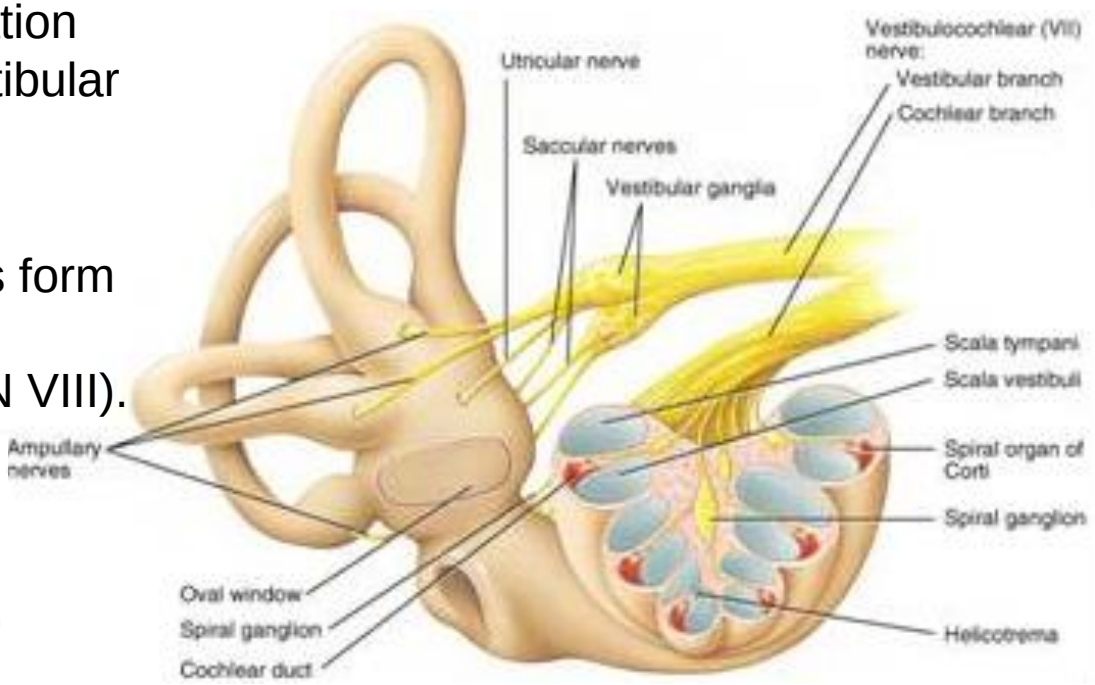
- The otoliths respond strongest to linear movement.
- The semicircular canals respond strongest to angular acceleration.
- Each is most sensitive to movement in a particular orientation. Among the 10 vestibular receptors, all positions and directions of movement are covered.

Vestibular System

- The cell bodies for the neurons that relay vestibular information into the brain are in the vestibular ganglion in the inner ear.

- The axons of these neurons form the vestibular branch of the vestibulocochlear nerve (CN VIII).





Vestibular System

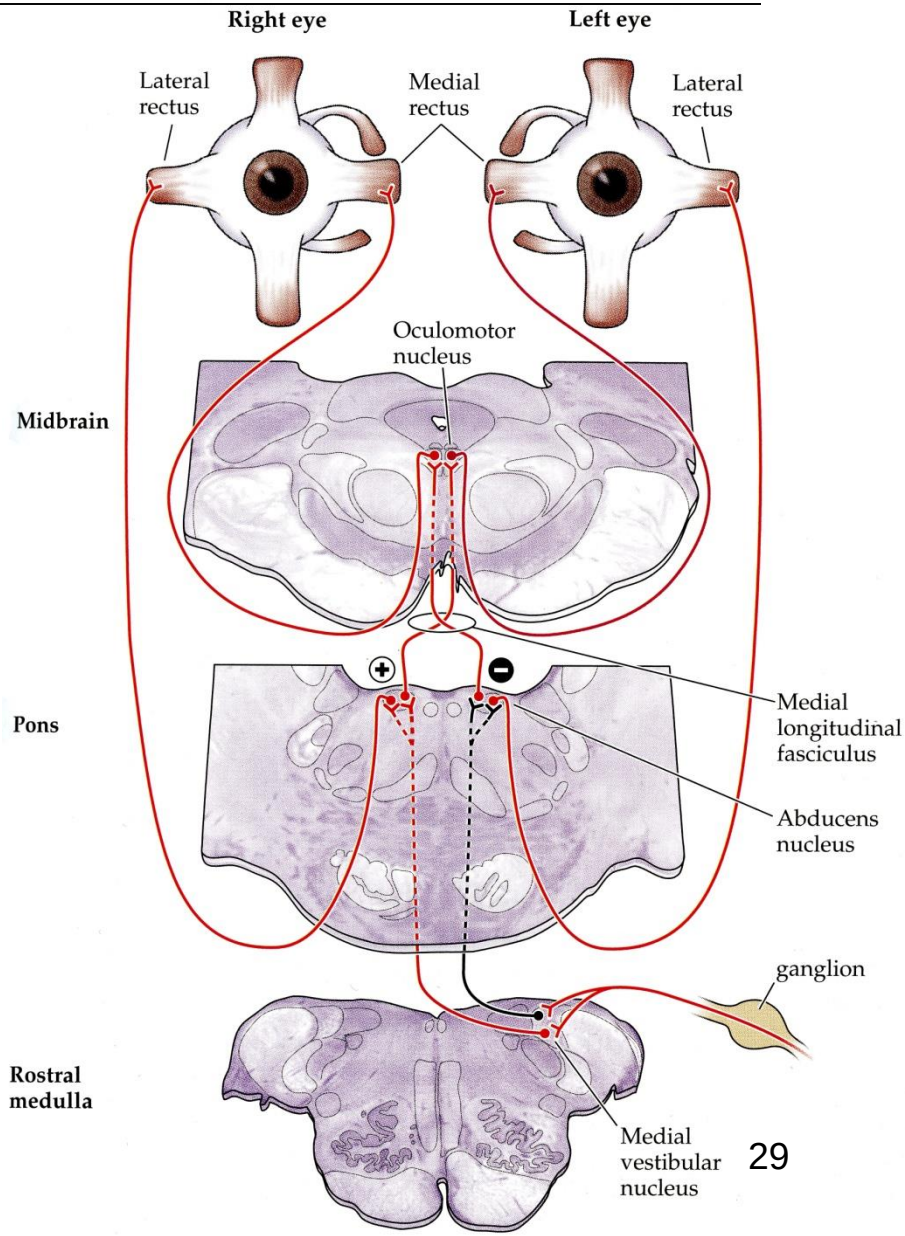
- The vestibular axons of the vestibulocochlear nerve (CN VIII) synapse in the vestibular nuclei in the medulla and pons.

Vestibular System

- The vestibular nuclei connect to many parts of the CNS, including:
  - Vestibulo-oculomotor projection to brainstem nuclei that control the muscles of the eyes.
  - Vestibulospinal projection to influence motor neuron activity in the spinal cord, particularly to cervical cord.
  - Vestibulocerebellar projection to cerebellum for maintaining balance.
  - Vestibulothalamic projection & relay to cortex for conscious perception of head position and movement.

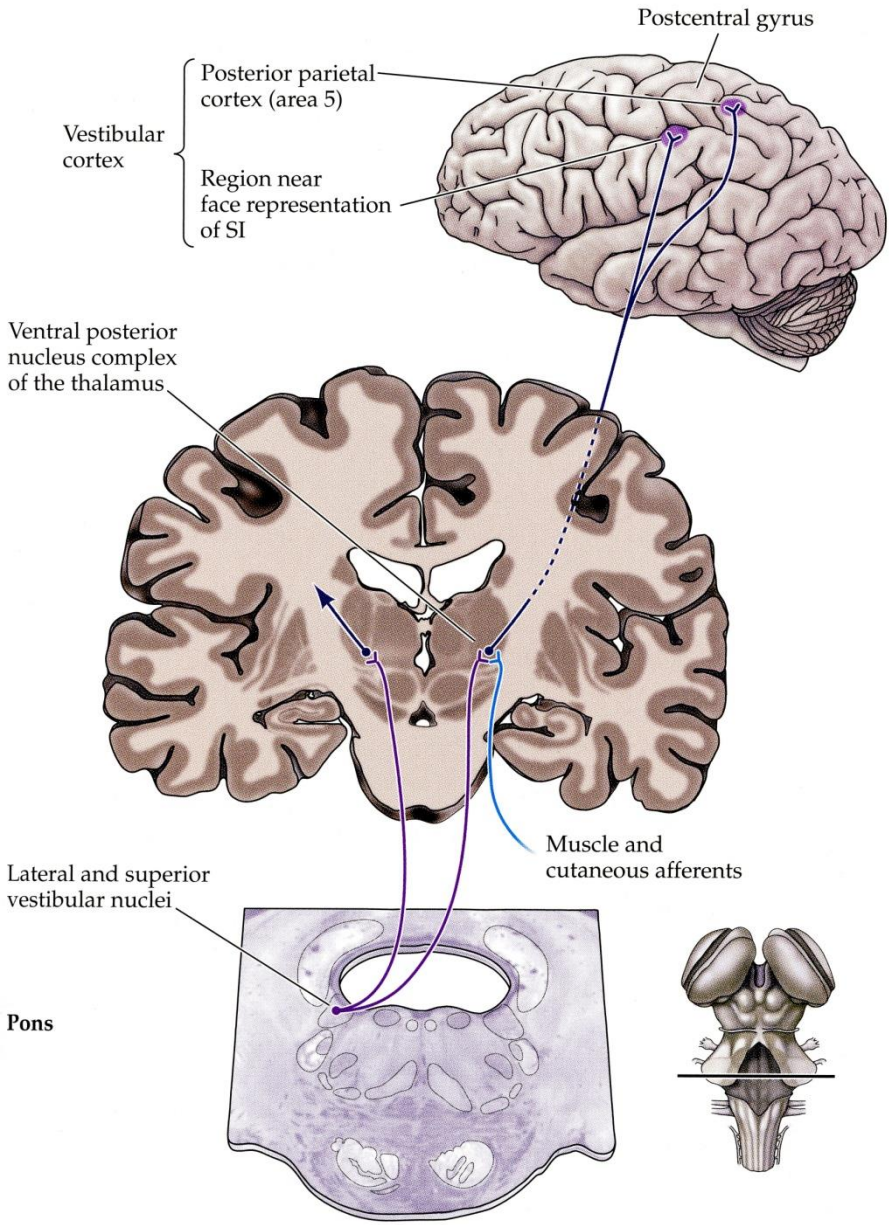
Vestibular System

- The direct connections from the vestibular nuclei to the three motor nuclei that control the eye muscles allows a rapid change in eye position when the head is moving (the vestibulo-ocular reflex).



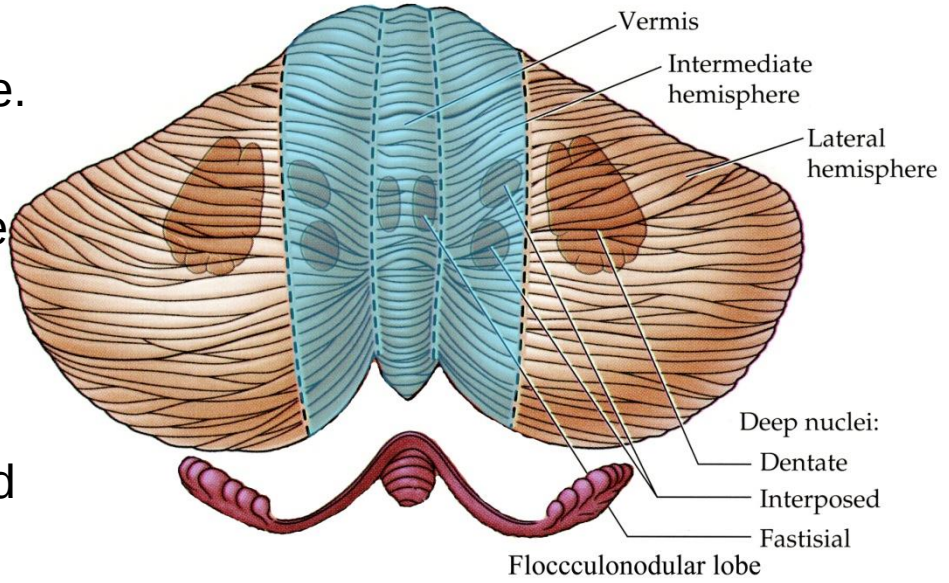
Vestibular System

- Vestibular sense is conveyed to the ventral posterior thalamus and then relayed to regions of parietal cortex.



Vestibular System

- The flocculonodular lobe of the cerebellum receives input from vestibular nuclei and vestibular nerve.
- Cerebellum also has an output to the vestibular nuclei.
- Vestibular-cerebellar crosstalk is essential for maintaining balance and coordinating movements.



Balance

- Balance is maintained by the interplay of three sensory systems:
  - vestibular
  - visual
  - somatosensory

- Sensory information from all three systems meets in the vestibular nuclei.

- We can maintain reasonable balance with the loss of one system, but not with the loss of two systems.

- Conflicting information between two systems causes vertigo.

Vestibulocochlear Nerve (CN VIII)

vestibular nerve + cochlear nerve = vestibulocochlear nerve