Auditory & Vestibular Systems

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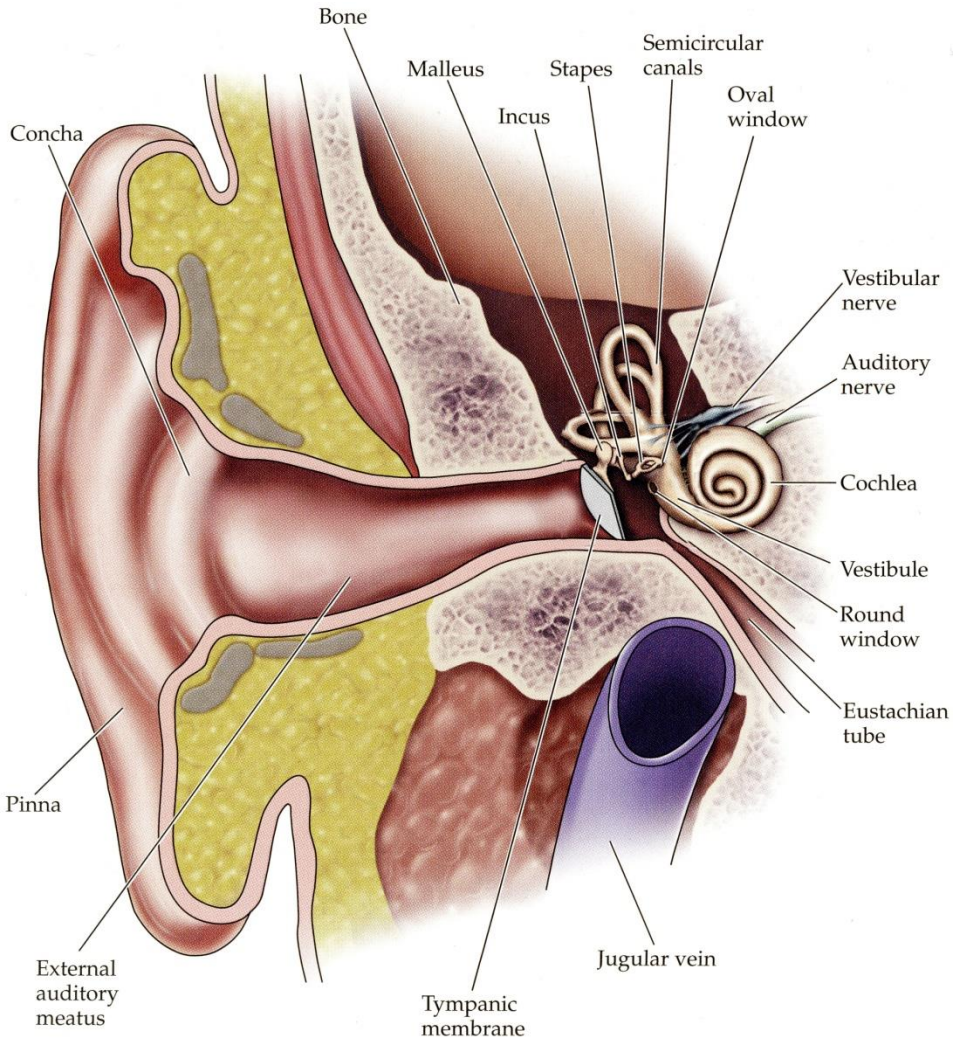
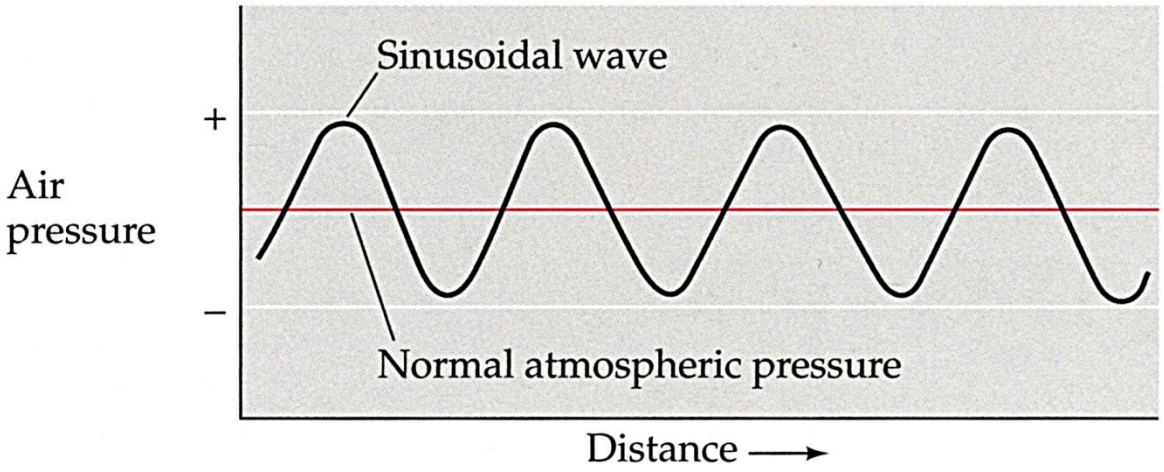
The auditory & vestibular systems have many similarities.

- 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).



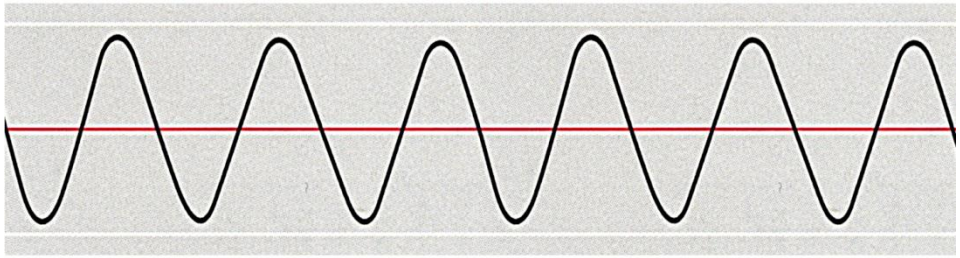
Auditory System

- 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).

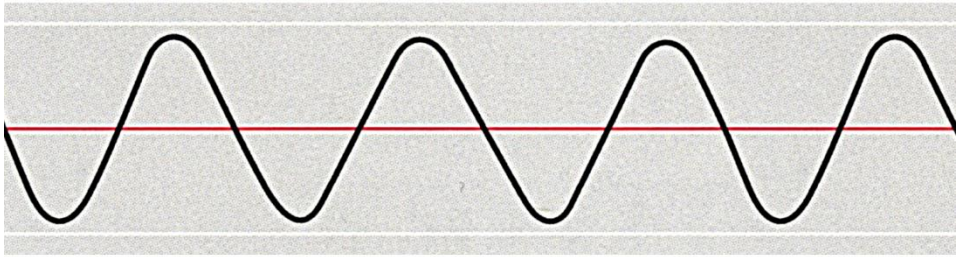


Auditory System

- 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

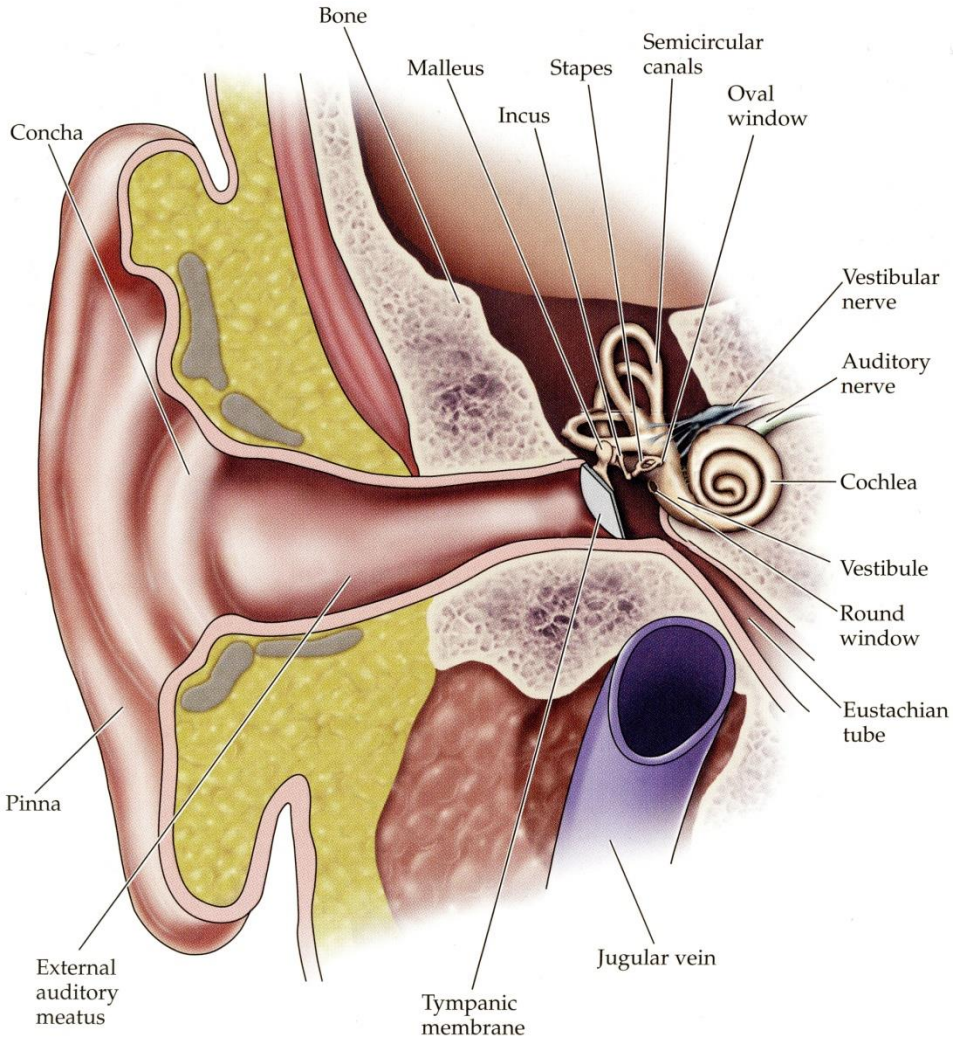
Auditory System

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

Auditory System

External ear:

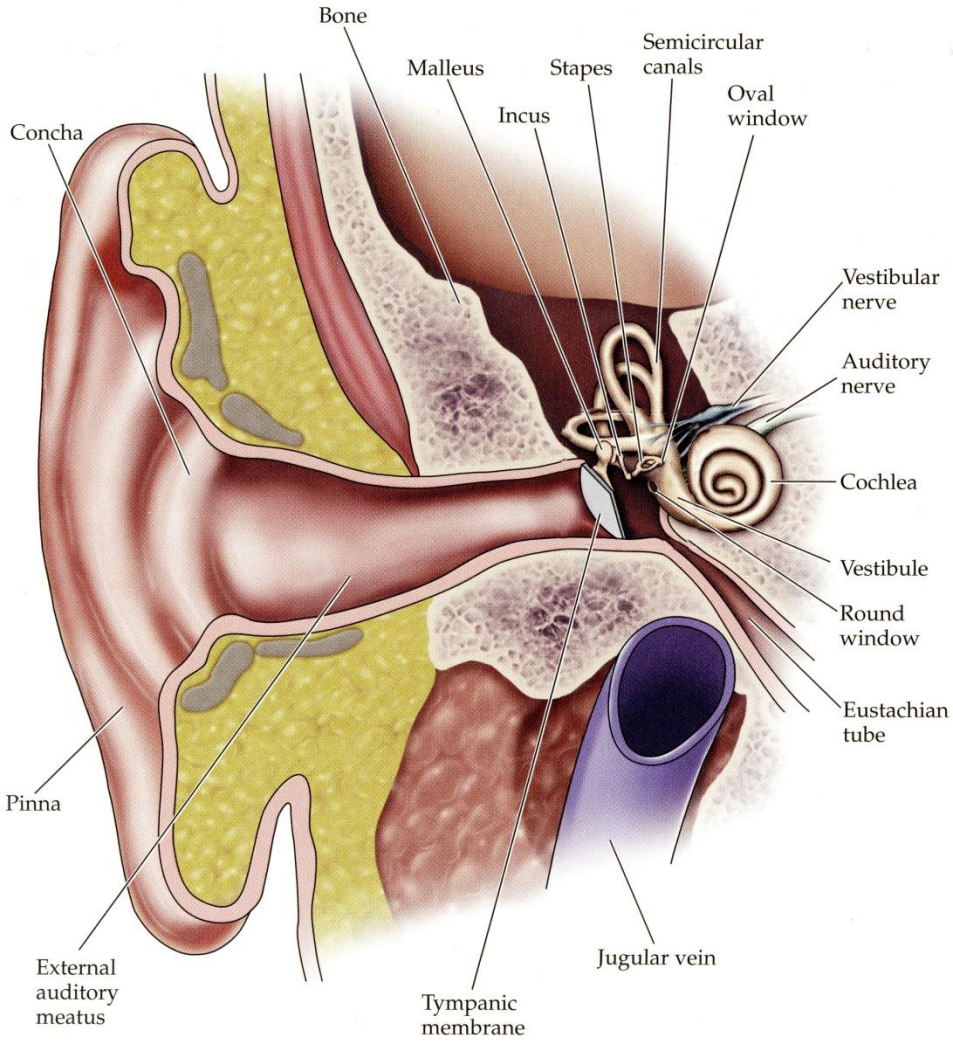
- includes the pinna, external auditory meatus (ear canal) and tympanic membrane (ear drum).
- The pinna and canal collect sound and guide it to the tympanic membrane.
- The tympanic membrane vibrates in response to sound.



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.



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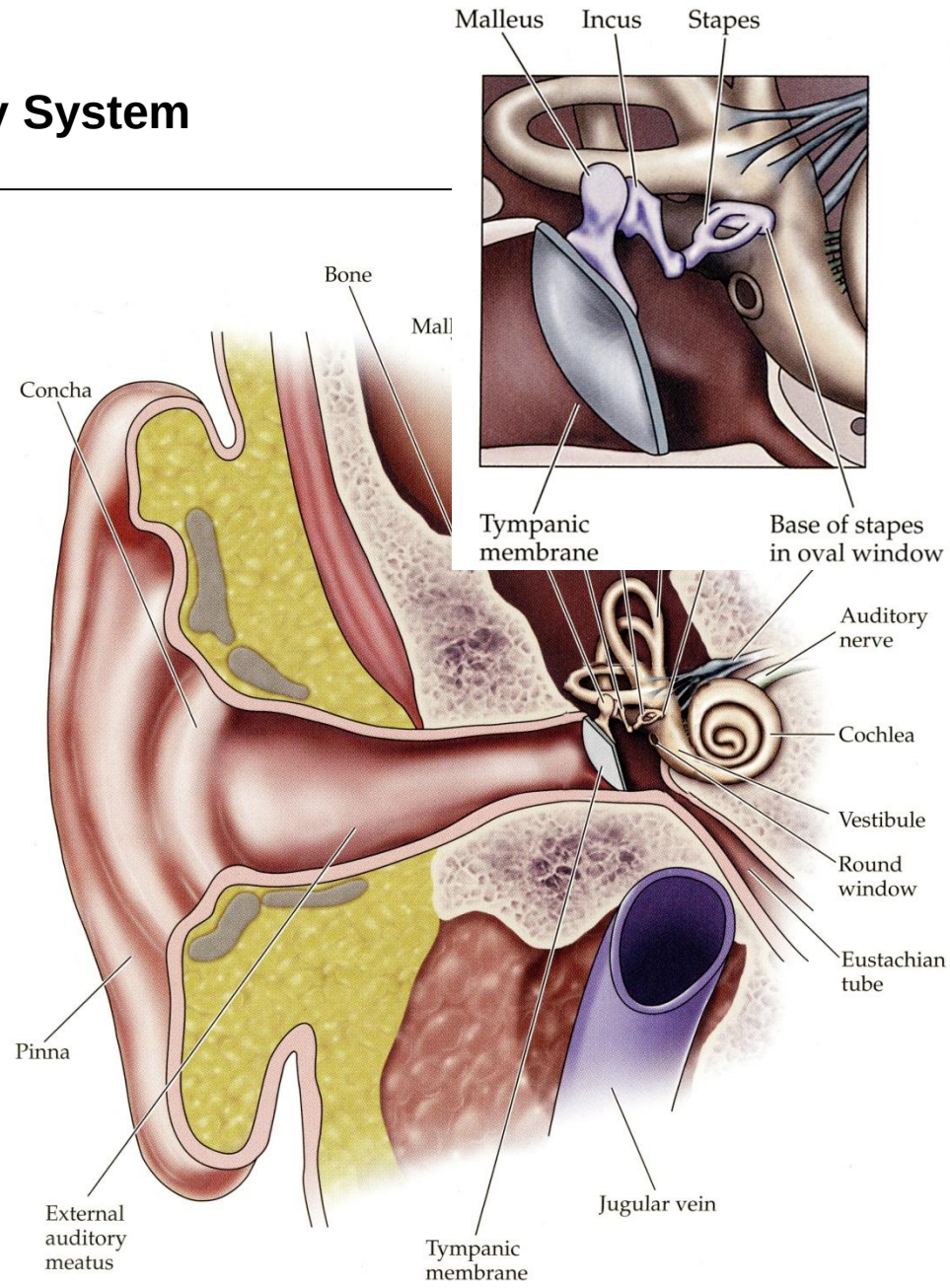
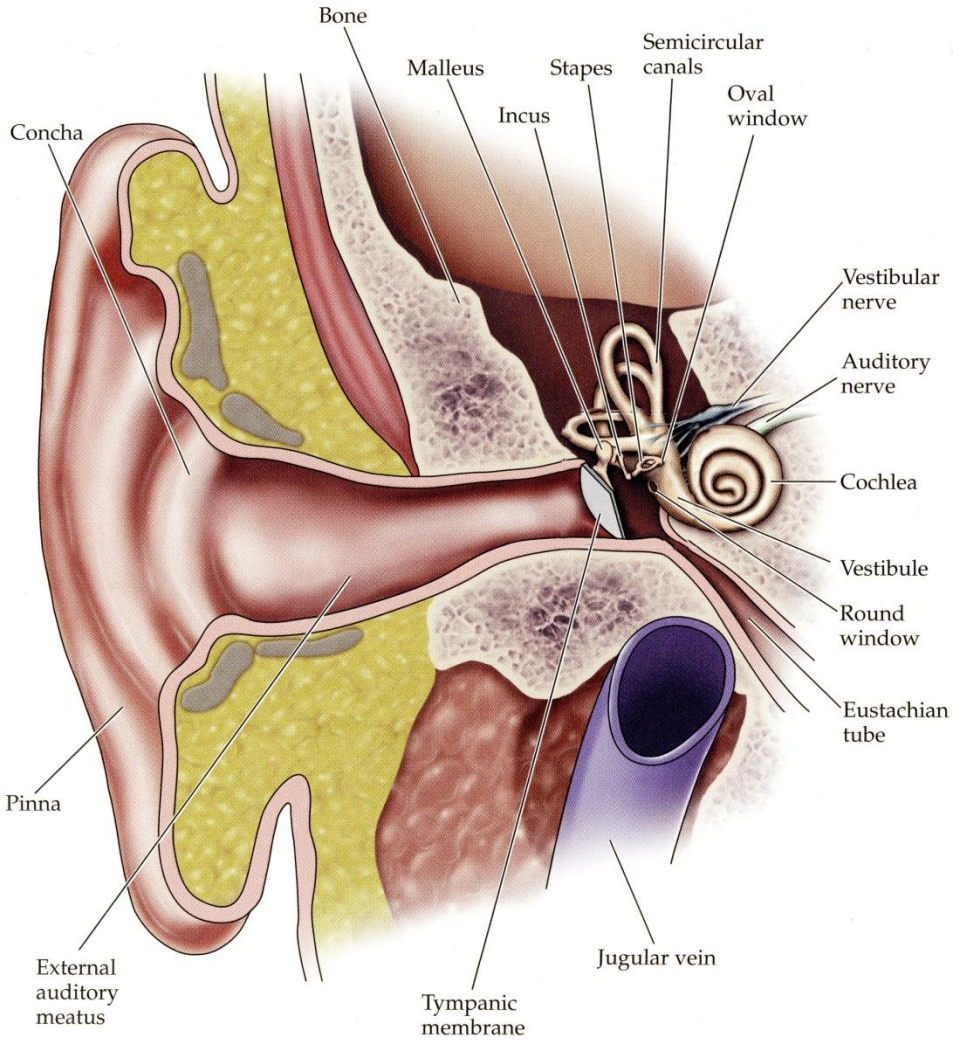


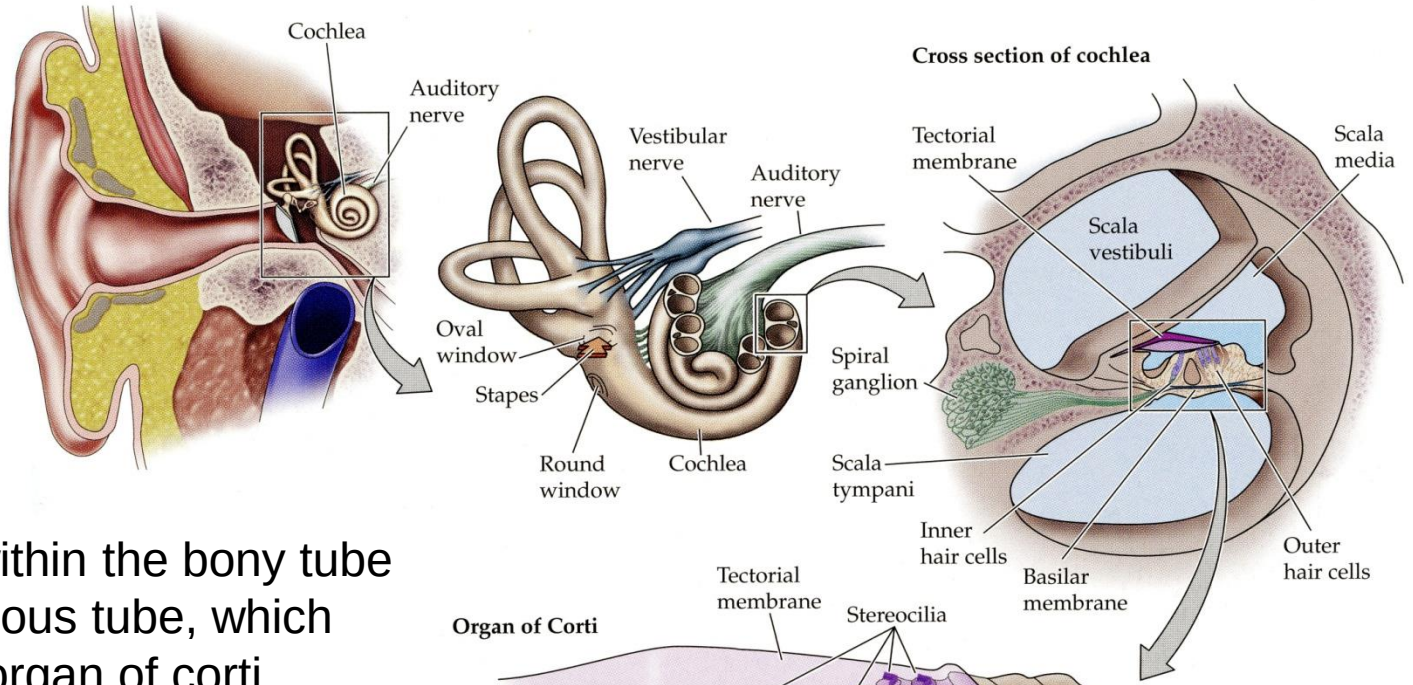
Auditory System

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.

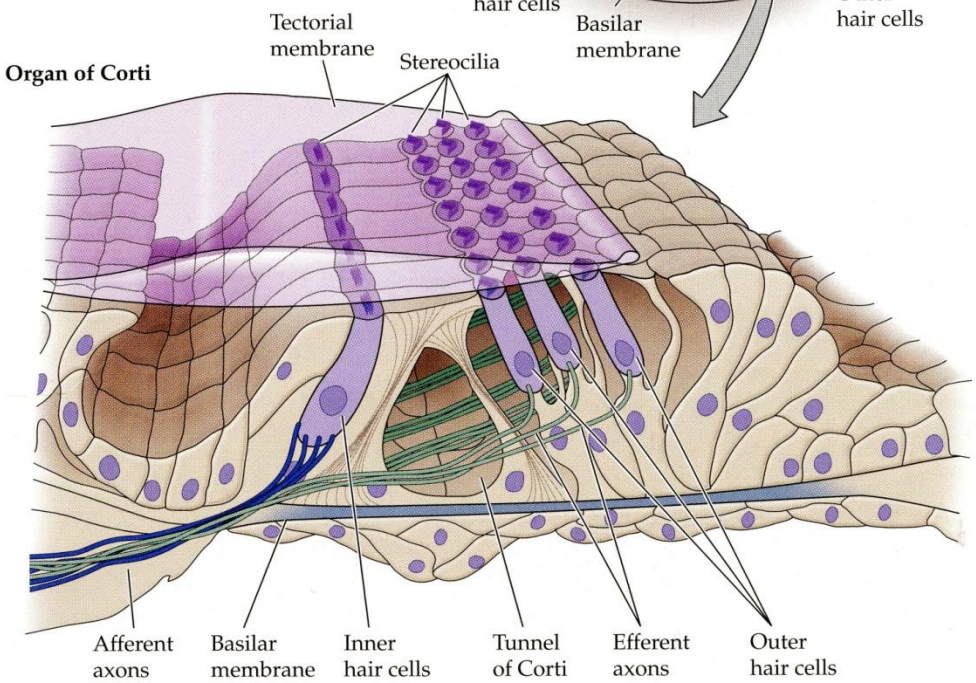


Auditory System



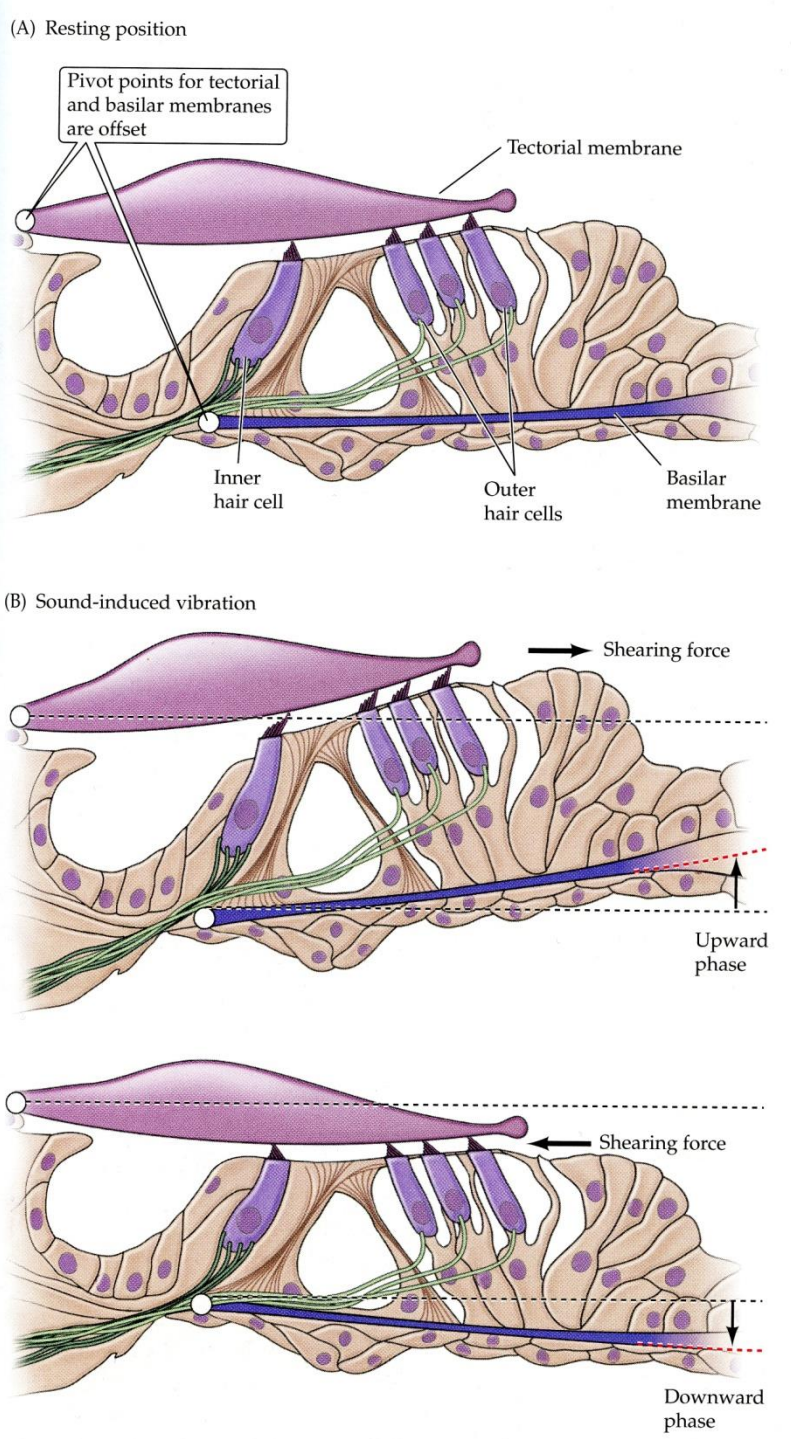
- Suspended within the bony tube is a membranous tube, which contains the organ of corti.

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



Auditory System

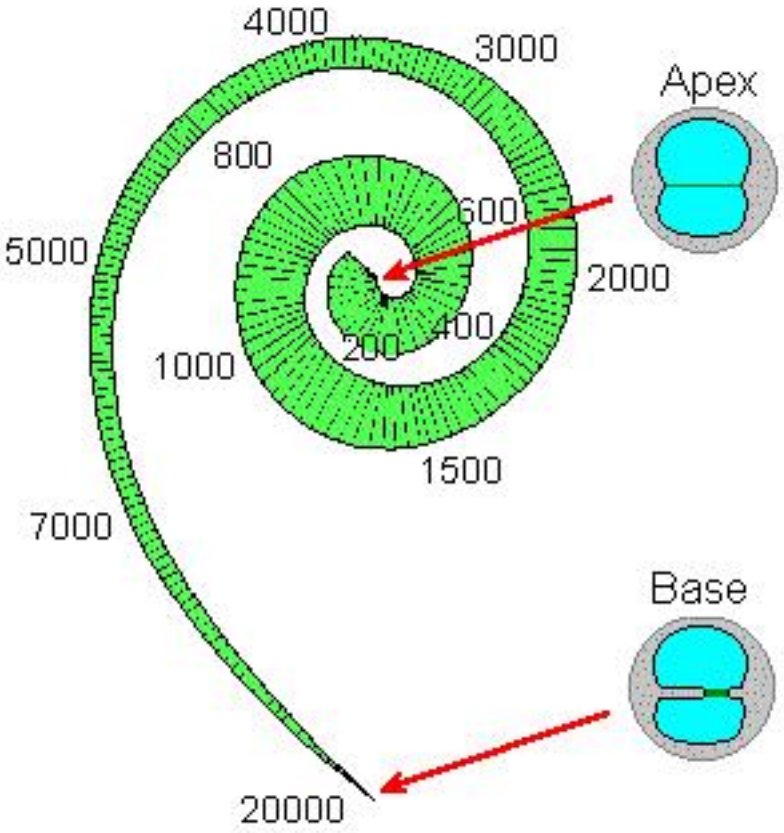
- A sound vibration entering via the oval window travels up the cochlea.
- This causes vibration of the basilar membrane, which distorts the stereocilia bundles of the hair cells that are in contact with the overlying membrane.
- The mechanosensory hair cells are depolarized by movement of their stereocilia.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

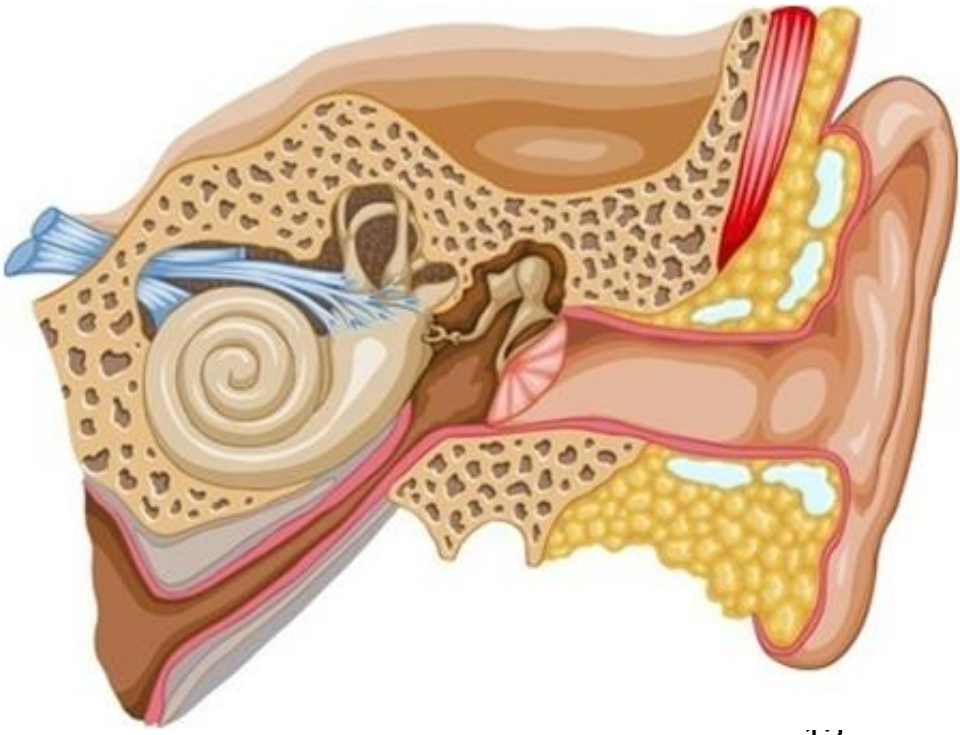


Auditory System

- 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.

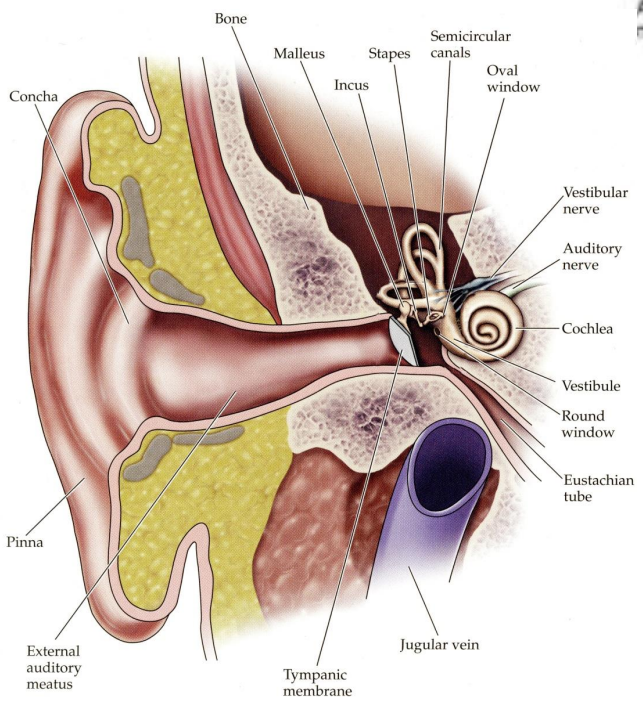


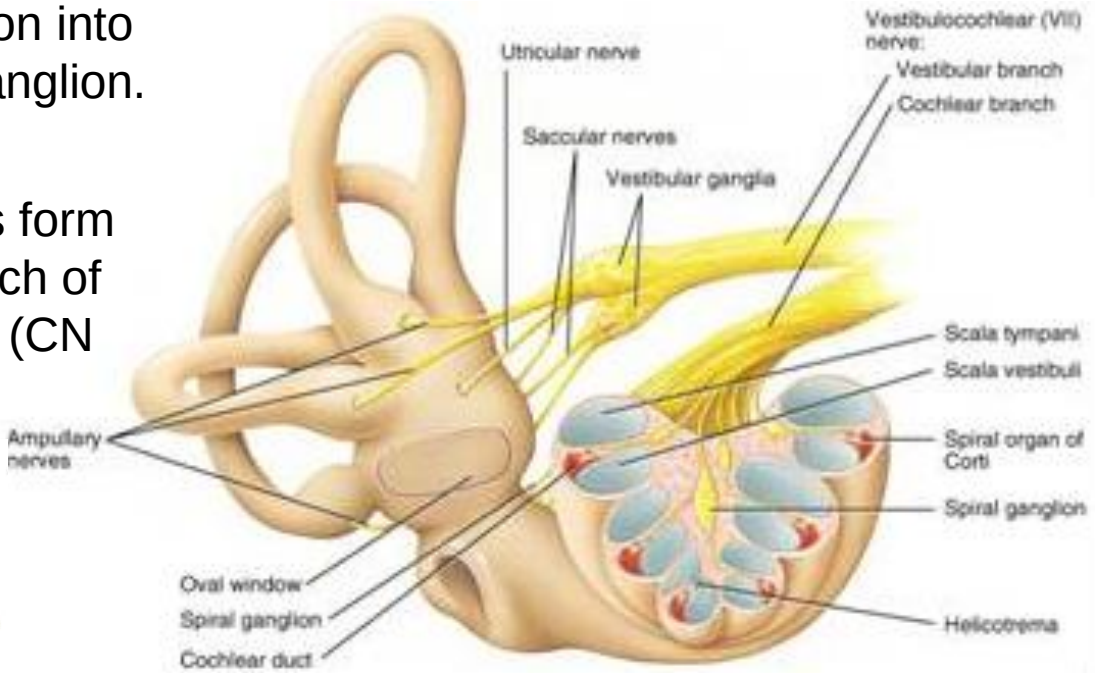


Auditory System

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

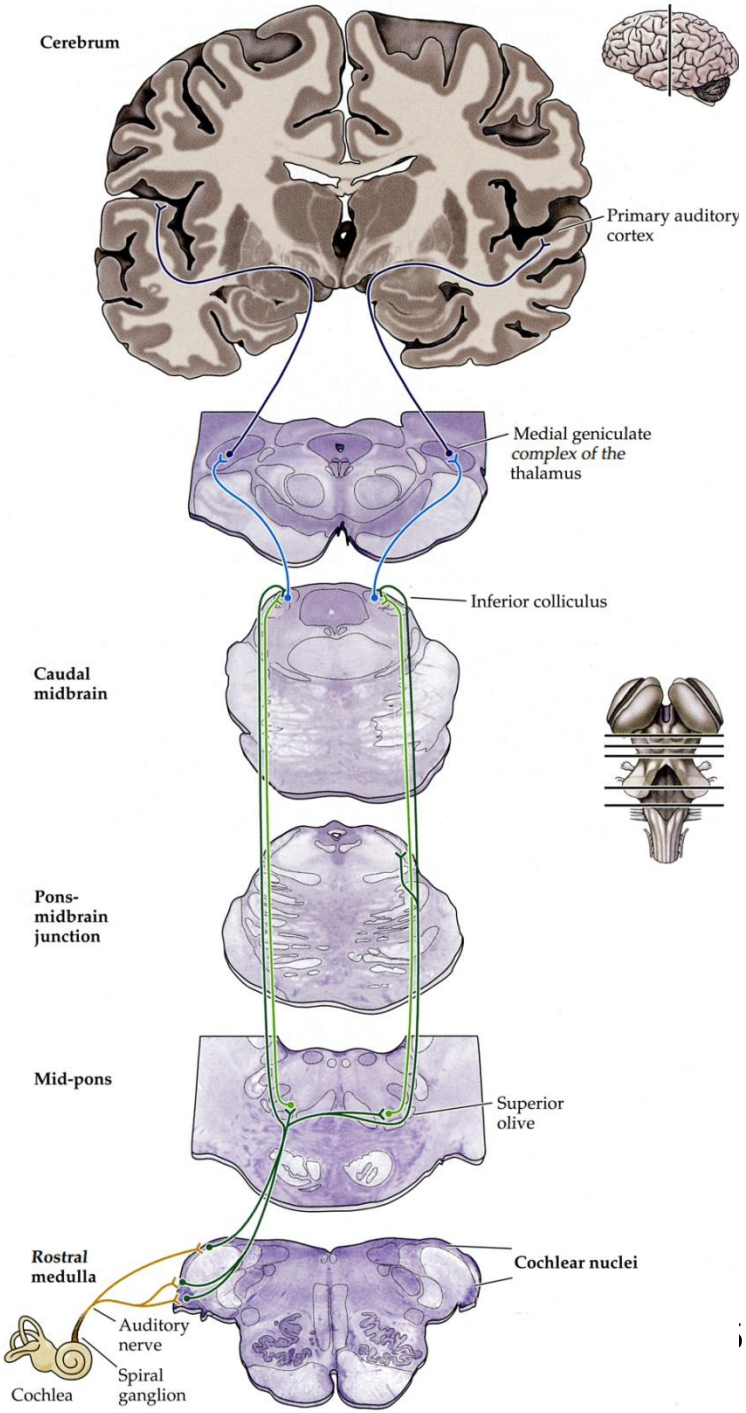
- The axons of these neurons form the auditory (cochlear) branch of the vestibulocochlear nerve (CN VIII).





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.

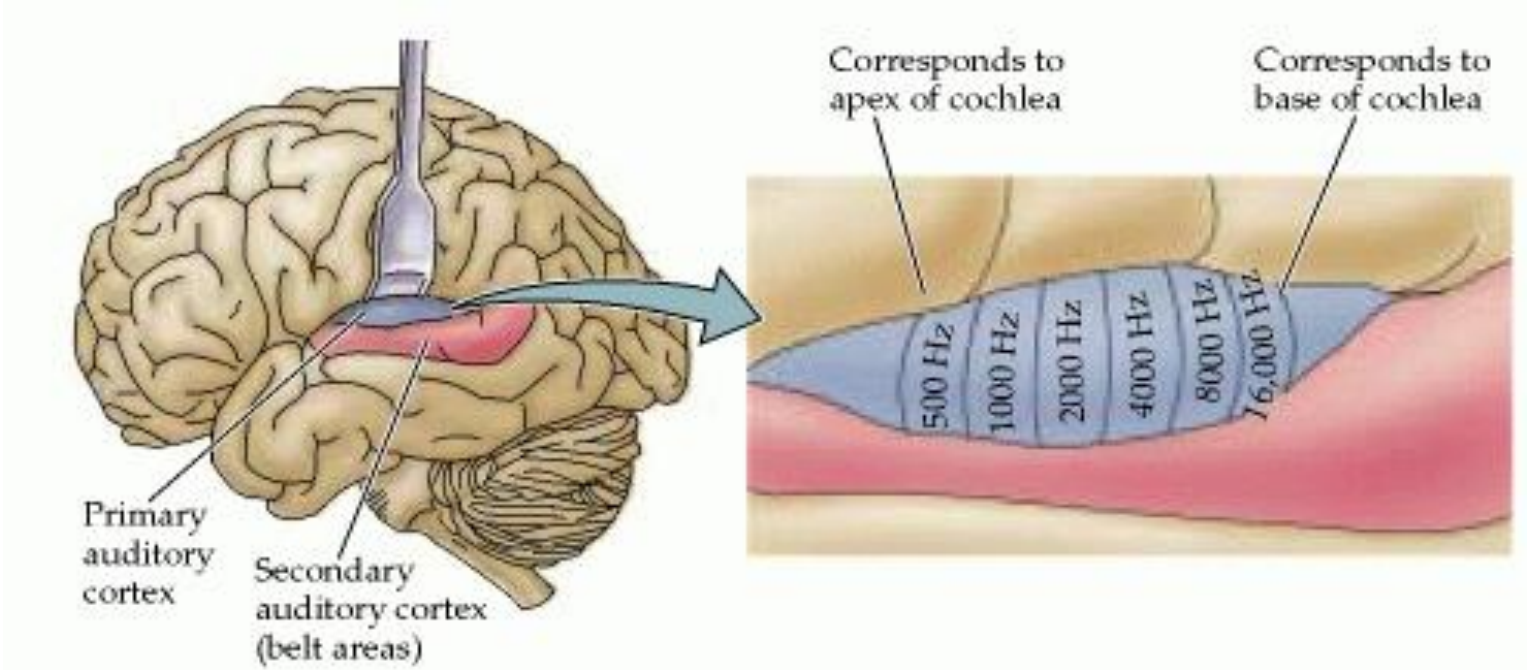


Auditory System

- 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.

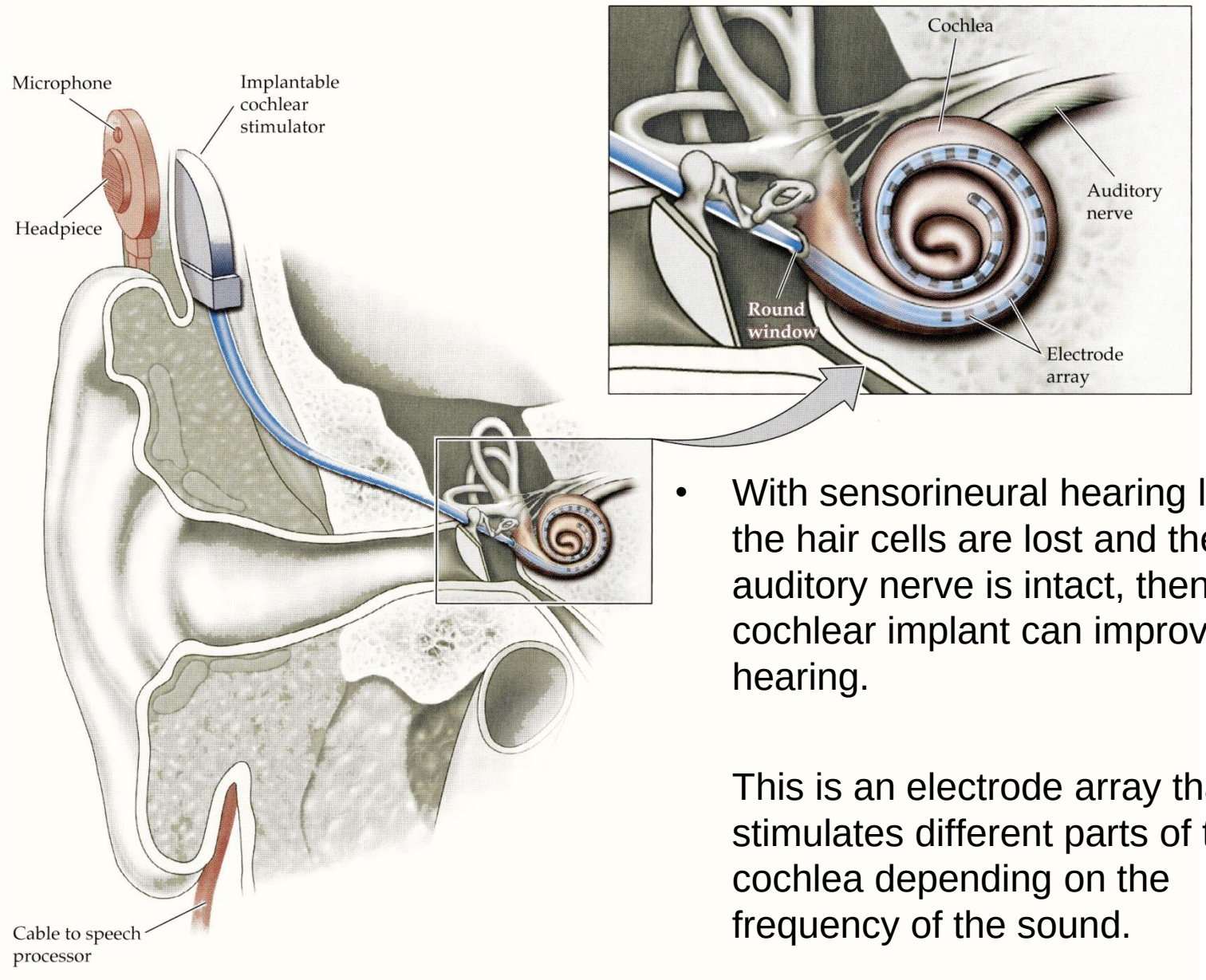
- Factors affecting the inner ear or auditory nerve result in sensorineural hearing loss.

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.

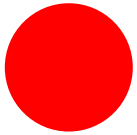
Auditory System



- 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.

Look at the dot while moving your head.



How are you able to keep you eyes on the dot while moving your head, even if you move rapidly?

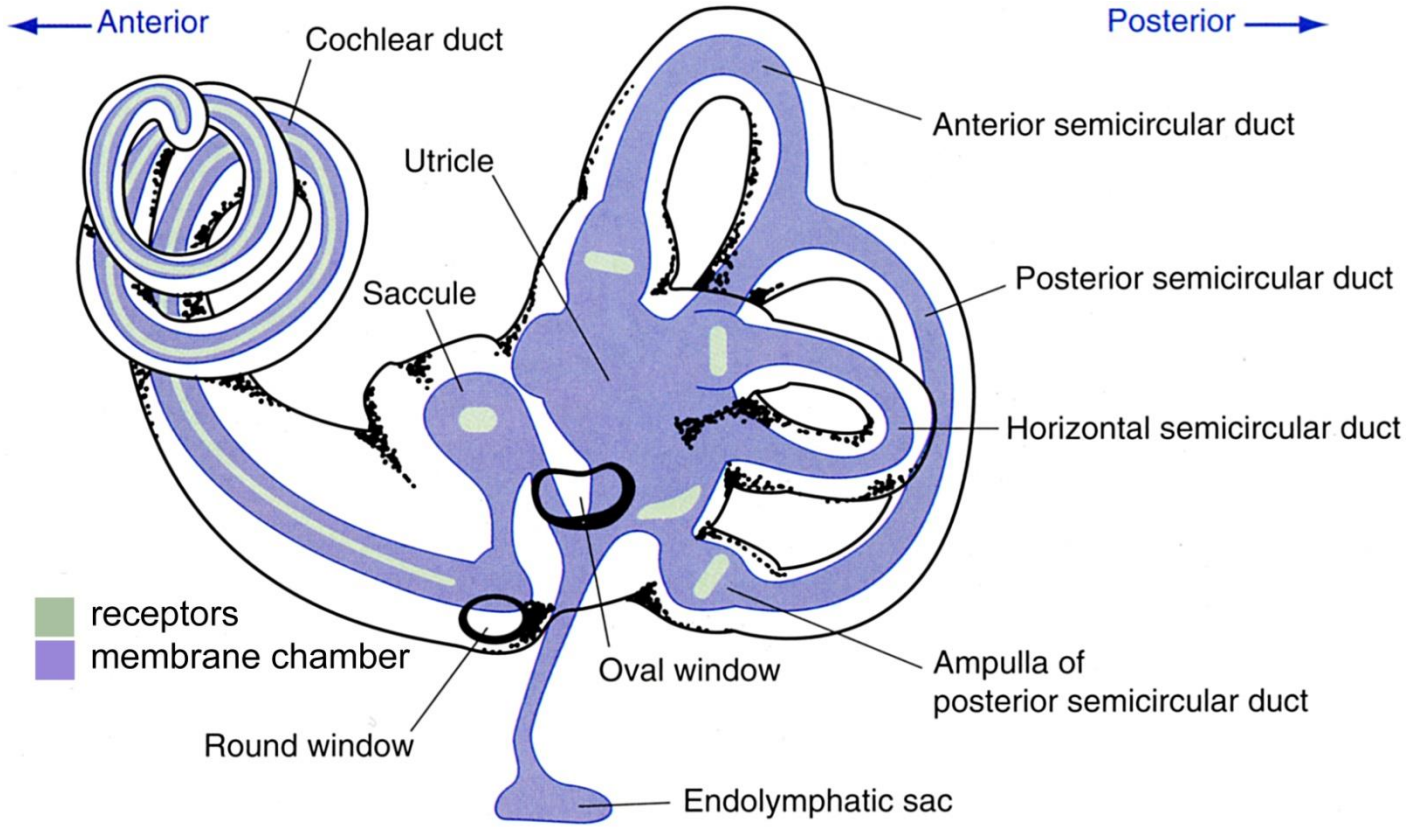
Vestibular System

- 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

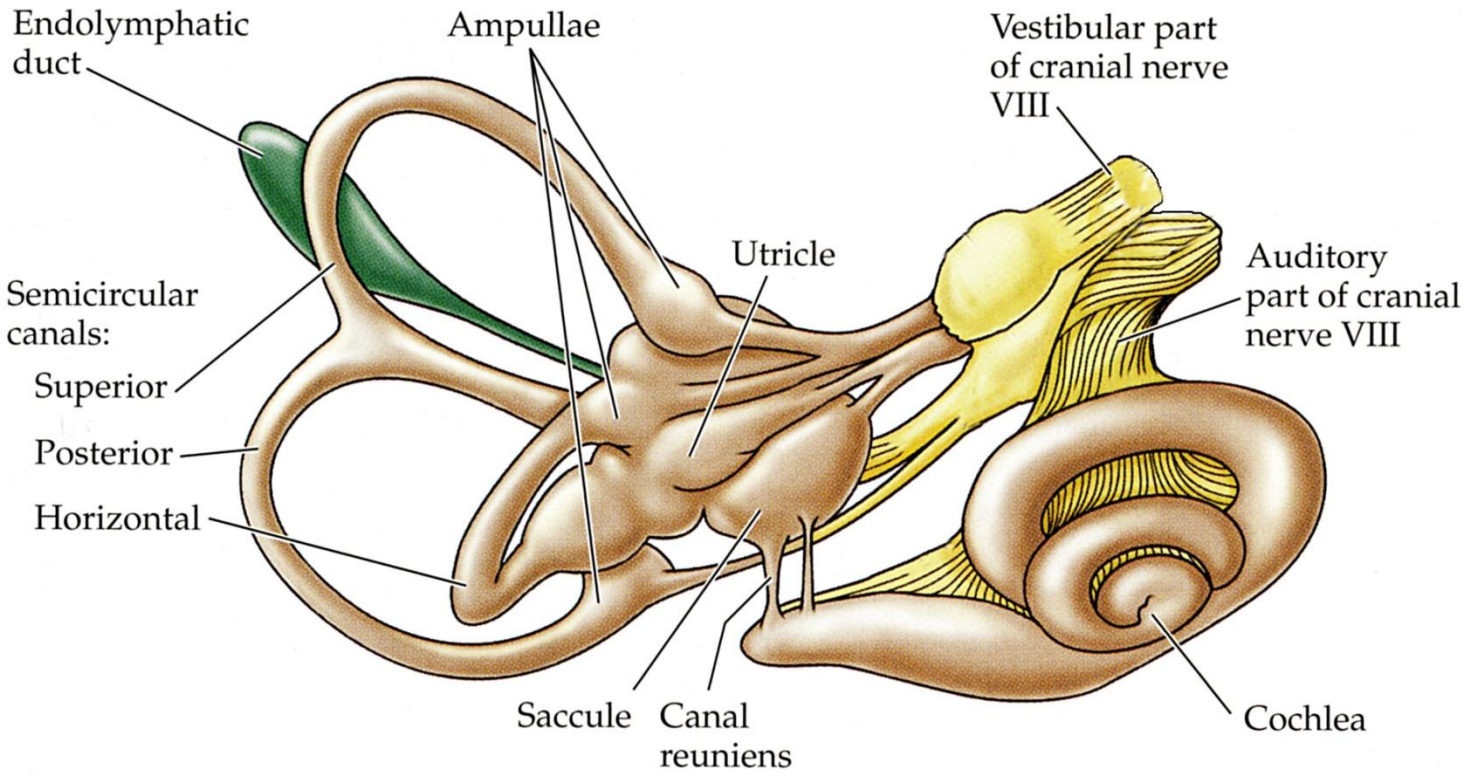
- The vestibular sensory apparatus is part of the inner ear labyrinth that includes the cochlea.

- The fluid-filled chambers are incased in bone.



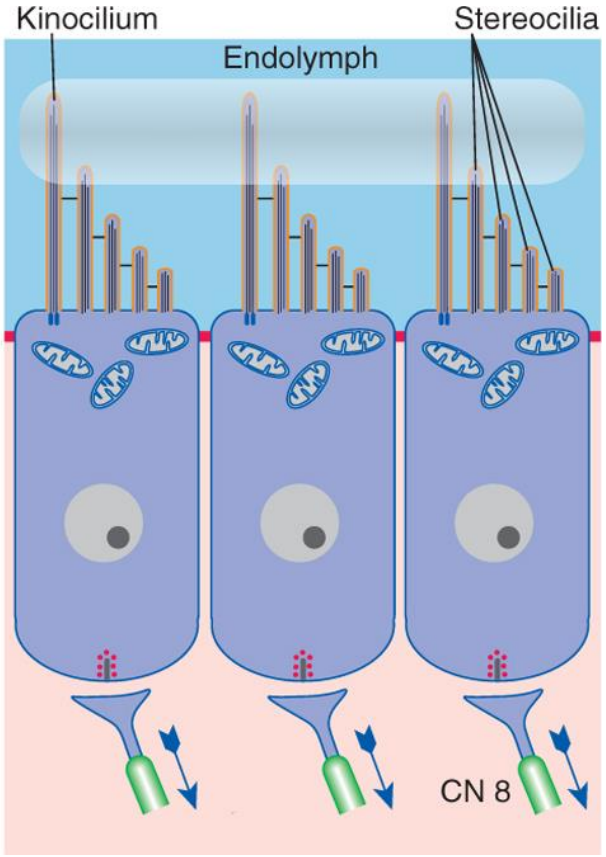
Vestibular System

- 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.



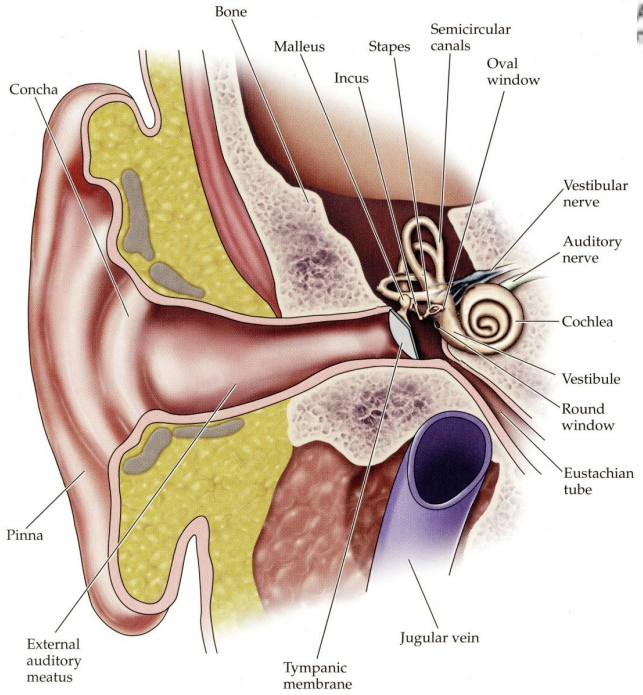
Vestibular System

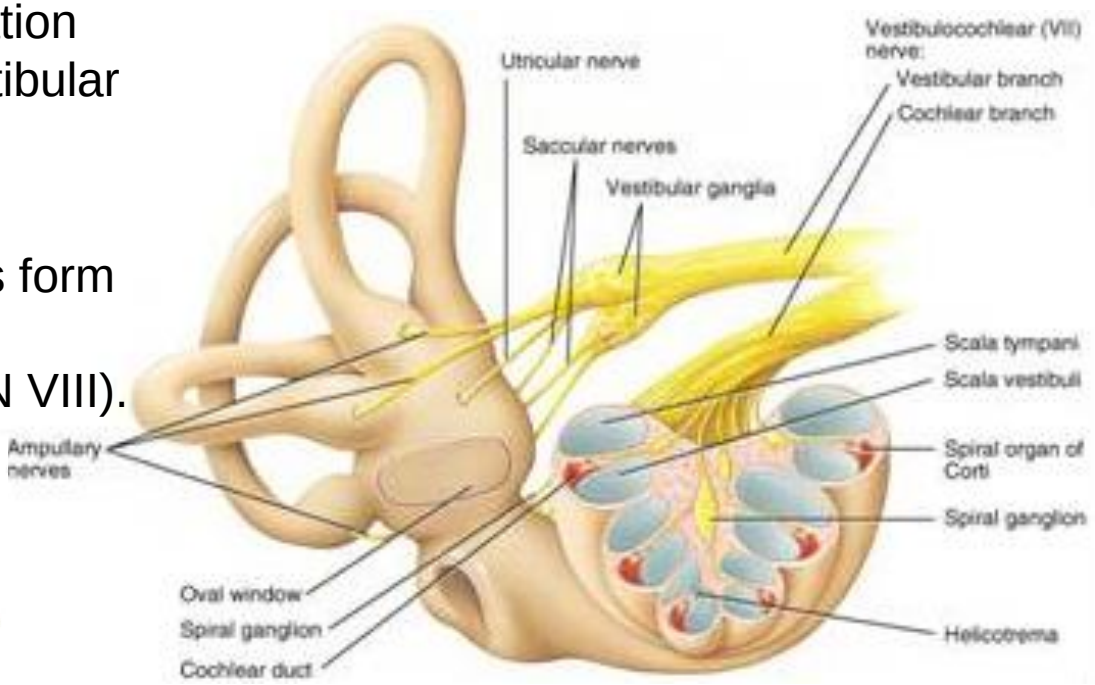
- The otoliths respond strongest to linear movement.
- The semicircular canals respond strongest to angular acceleration.
- Each is most sensitive to movement in a particular orientation. Among the 10 vestibular receptors, all positions and directions of movement are covered.

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

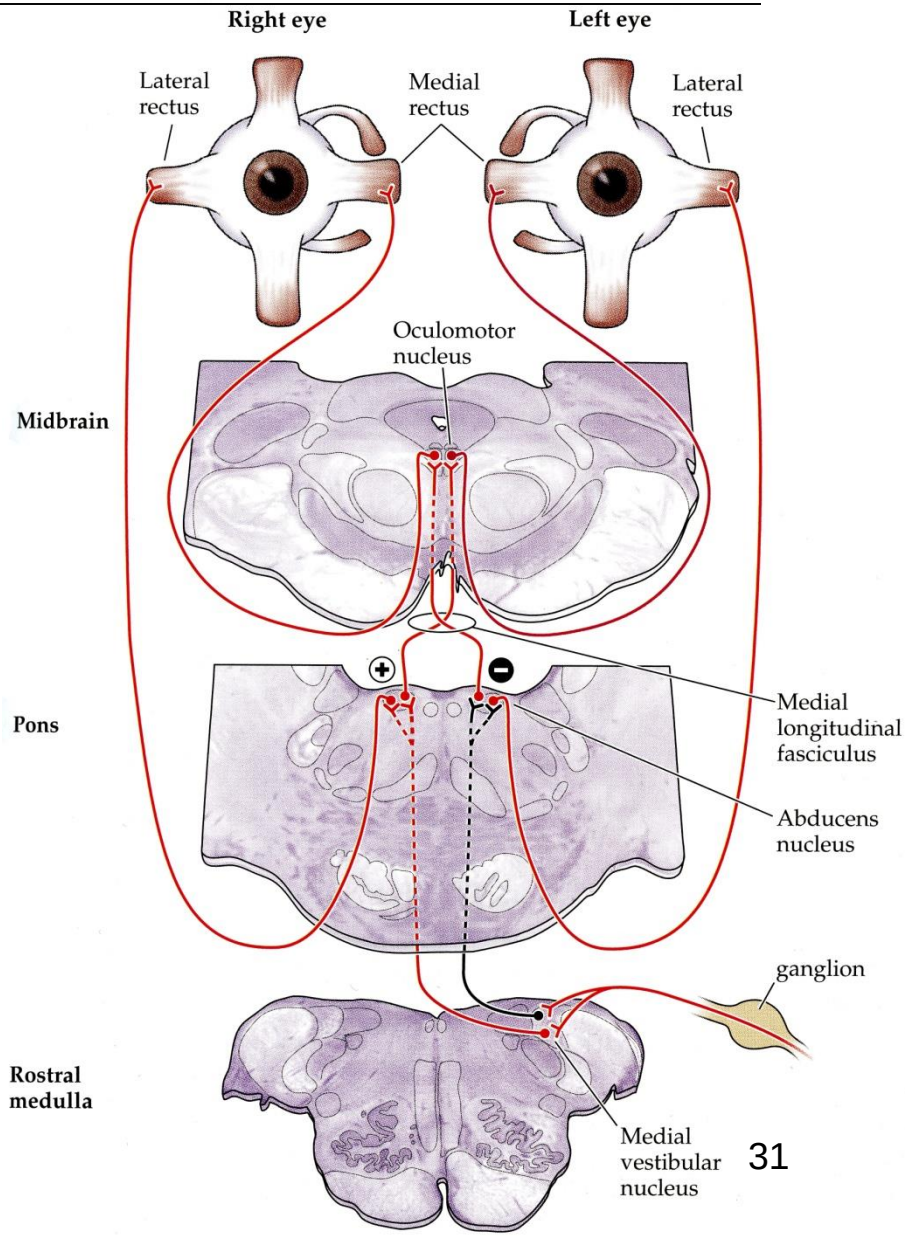
- The vestibular axons of the vestibulocochlear nerve (CN VIII) synapse in the vestibular nuclei in the medulla and pons.

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.

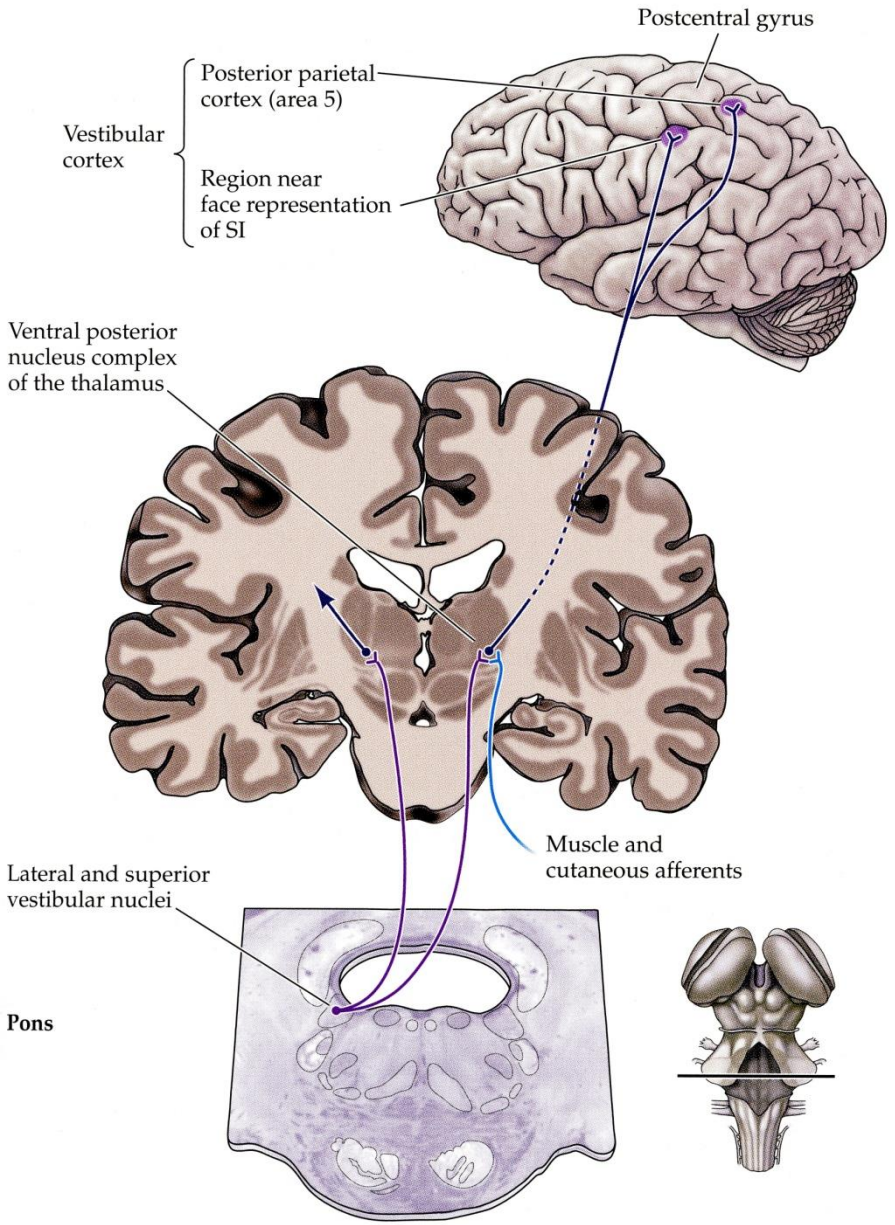
Vestibular System

- 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).



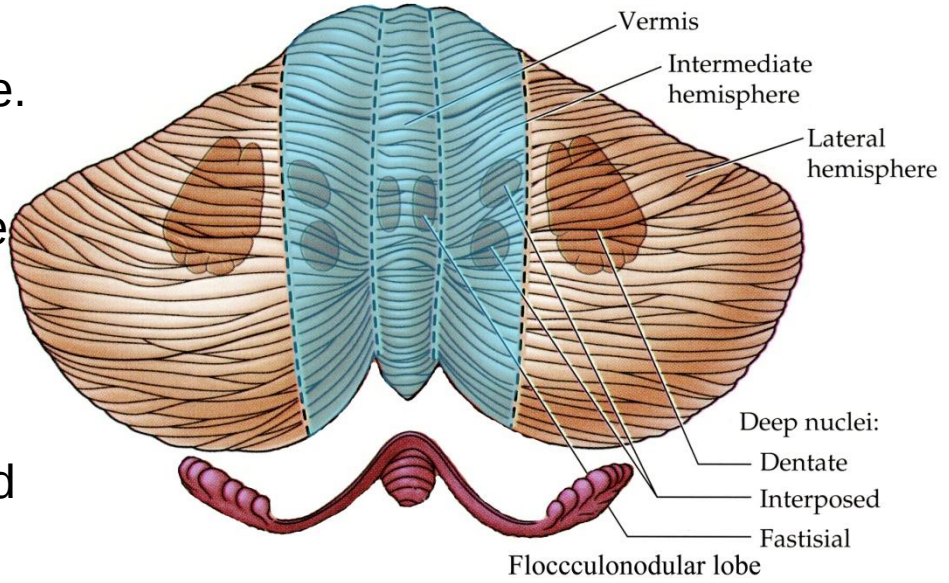
Vestibular System

- 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