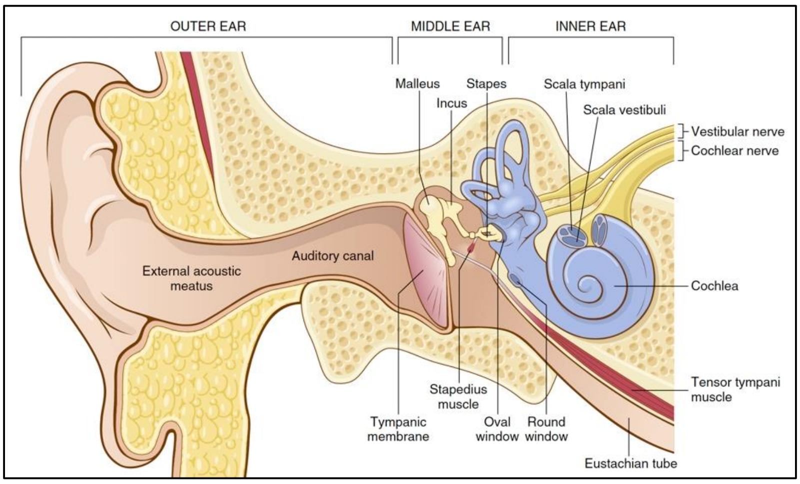
Audition



Hearing

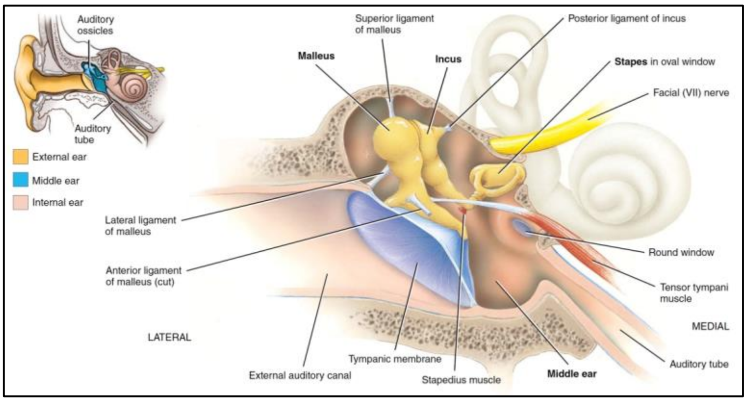
- Hearing is the ability to precieve sounds
- The ear is divided into three main regions:
  1- The external ear, which collects sound waves and channels them inward
  2- The middle ear, which conveys sound vibrations to the oval window
  3- The internal ear, which houses the receptors for hearing and equilibrium

Middle ear

- The middle ear is a small, air filled cavity in the petrous portion of the temporal bone. It is separated from the external ear by the tympanic membrane and from the internal ear by a thin bony partition that contains two small openings: the oval window and the round window
- Extending across the middle ear and attached to it by ligaments are the three smallest bones in the body, the auditory ossicles, which are connected by synovial joints. The bones are the malleus, incus, and stapes.

- The "handle" of the malleus attaches to the internal surface of the tympanic membrane.
- The head of the malleus articulates with the body of the incus.
- The incus articulates with the head of the stapes.
- The base or footplate of the stapes fits into the oval window.
- Directly below the oval window is another opening, the round window, which is enclosed by a membrane.

- Besides the ligaments, two tiny skeletal muscles also attach to the ossicles.
- The tensor tympani muscle, which is supplied by the mandibular branch of the trigeminal (V) nerve, limits movement and increases tension on the eardrum to prevent damage to the inner ear from loud noises.
- The stapedius muscle, which is supplied by the facial (VII) nerve, is the smallest skeletal muscle in the human body. By dampening large vibrations of the stapes due to loud noises, it protects the oval window.

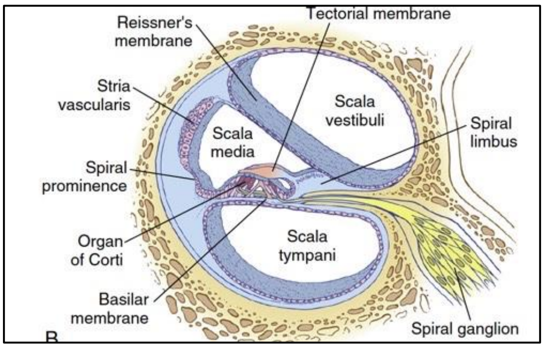


Inner ear

- The inner ear is also called the labyrinth. Structurally, it consists of two main divisions: an outer bony labyrinth that encloses an inner membranous labyrinth.
- The bony labyrinth is a series of cavities in the petrous portion of the temporal bone divided into three areas: (1) the semicircular canals, (2) the vestibule, and (3) the cochlea.
- The membranous labyrinth, a series of epithelial sacs and tubes inside the bony labyrinth that have the same general form as the bony labyrinth and house the receptors for hearing and equilibrium.

- The cochlea, which is a spiral-shaped structure composed of three tubular canals or ducts, contains the organ of Corti.
- The organ of Corti contains the receptor cells and is the site of auditory transduction.
- The inner ear is fluid filled, and the fluid in each duct has a different composition.

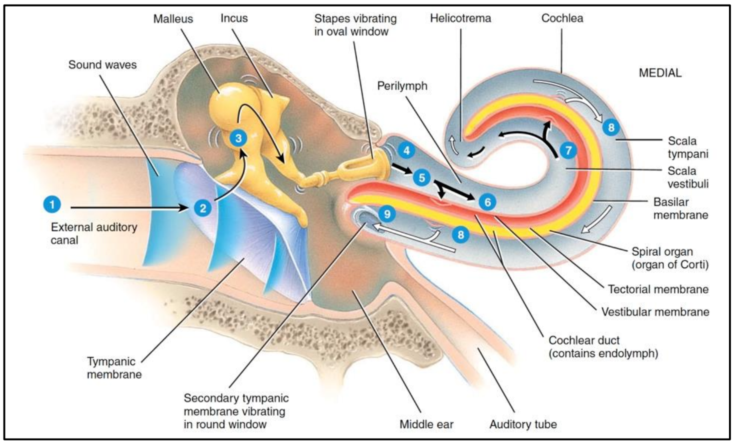
- The fluid in the scala vestibuli and scala tympani is called perilymph, which is similar to extracellular fluid (CSF).
- The fluid in the scala media is called endolymph, which has a high potassium (K+) concentration and a low sodium (Na+) concentration. Thus endolymph is unusual in that its composition is similar to that of intracellular fluid, even though, technically, it is extracellular fluid.



Sound waves

- Sound waves are alternating high- and low-pressure regions traveling in the same direction through a medium. They originate from a vibrating object.
- The higher the frequency of vibration, the higher is the pitch.
- The larger the intensity (or amplitude) of the vibration, the louder is the sound. Sound intensity is measured in decibels (dB).
- An increase of one decibel represents a tenfold increase in sound intensity.
- The hearing threshold—the point at which an average young adult can just distinguish sound from silence— is defined as 0 dB at 1000 Hz.
- Most sounds are mixtures of pure tones. The human ear is sensitive to tones with frequencies between 20 and 20,000 Hz (a cycle/sec) and is most sensitive between 2000 and 5000 Hz.
- The usual range of frequencies in human speech is between 300 and 3500 Hz, and the sound intensity is about 65 dB.
- Sound intensities greater than 100 dB can damage the auditory apparatus, and those greater than 120 dB can cause pain.

Auditory transduction

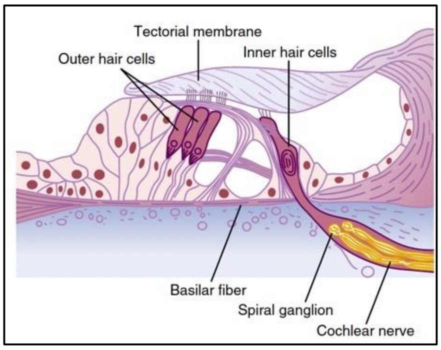


- The external and middle ears are air filled, and the inner ear, which contains the organ of Corti, is fluid filled.
- Thus before transduction can occur, sound waves traveling through air must be converted into pressure waves in fluid.
- The acoustic impedance of fluid is much greater than that of air.
- The combination of the tympanic membrane and the ossicles serves as an impedance-matching device that makes this conversion.

- Impedance matching is accomplished by the ratio of the large surface area of the tympanic membrane to the small surface area of the oval window and the mechanical advantage offered by the lever system of the ossicles.
- The external ear directs sound waves into the auditory canal, which transmits the sound waves onto the tympanic membrane. When sound waves move the tympanic membrane, the chain of ossicles also moves, pushing the footplate of the stapes into the oval window and displacing the fluid in the inner ear.

- The vestibular membrane is so thin and so easily moved that it does not obstruct the passage of sound vibrations from the scala vestibuli into the scala media.
- Therefore, as far as fluid conduction of sound is concerned, the scala vestibuli and scala media are considered to be a single chamber.

Organ of Corti

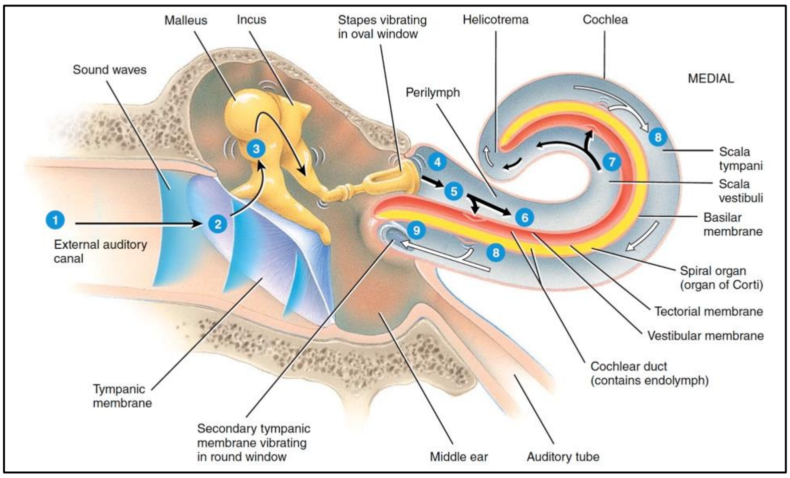


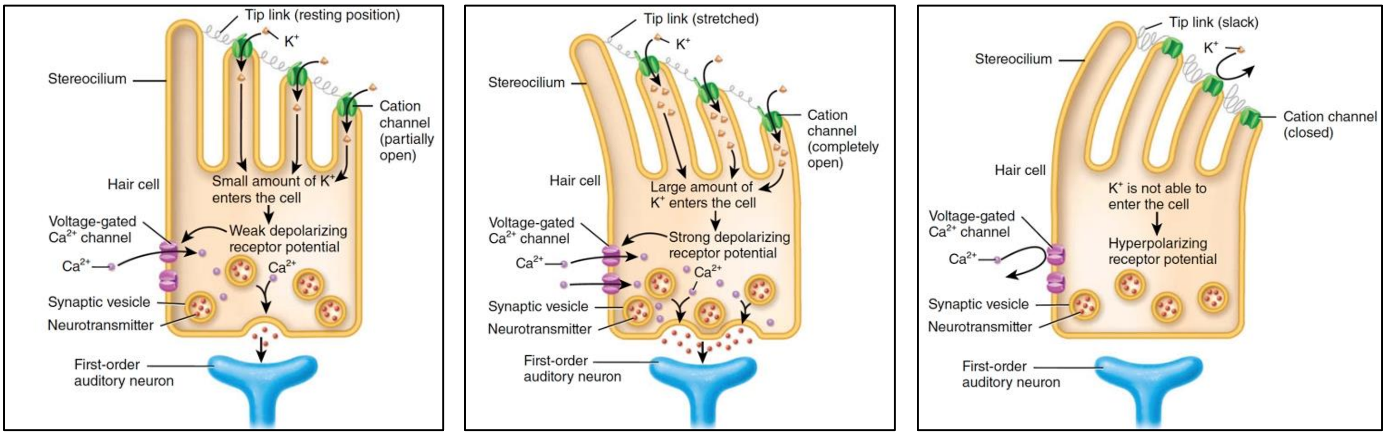
- The organ of Corti lies on the basilar membrane of the cochlea and is bathed in the endolymph contained in the scala media.
- Auditory hair cells in the organ of Corti are the sites of auditory transduction.
- The organ of Corti contains two types of receptor cells: inner hair cells and outer hair cells.
- There are fewer inner hair cells, which are arranged in single rows. Outer hair cells are arranged in parallel rows and are more numerous.

- Cilia, protruding from the hair cells, are embedded in the tectorial membrane.
- Thus the bodies of the hair cells are in contact with the basilar membrane, and the cilia of the hair cells are in contact with the tectorial membrane.

- The nerves that serve the organ of Corti are contained in the vestibulocochlear nerve (CN VIII). The cell bodies of these nerves are located in spiral ganglia, and their axons synapse at the base of the hair cells.
- These nerves will transmit information from the auditory hair cells to the CNS

Steps in auditory transduction



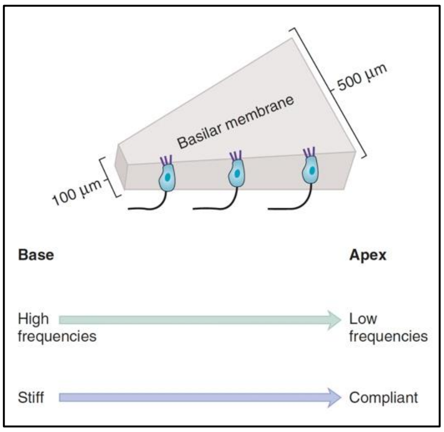


Encoding of sound

- Encoding of sound frequencies occurs because different auditory hair cells are activated by different frequencies.
- The frequency that activates a particular hair cell depends on the position of that hair cell along the basilar membrane.
- The base of the basilar membrane is nearest the stapes and is narrow and stiff. Hair cells located at the base respond best to high frequencies

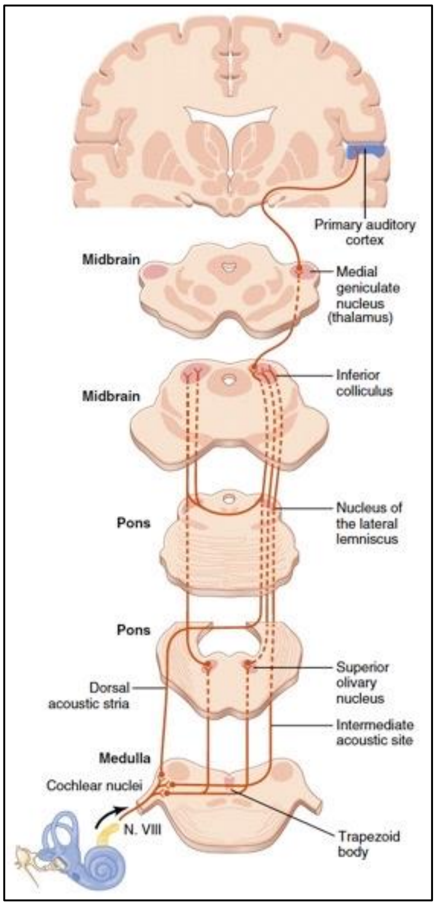
- The apex of the basilar membrane is wide and compliant. Hair cells located at the apex respond best to low frequencies.
- Thus the basilar membrane acts as a sound frequency analyzer, with hair cells positioned along the basilar membrane responding to different frequencies.

- This spatial mapping of frequencies generates a tonotopic map, which then is transmitted to higher levels of the auditory system.



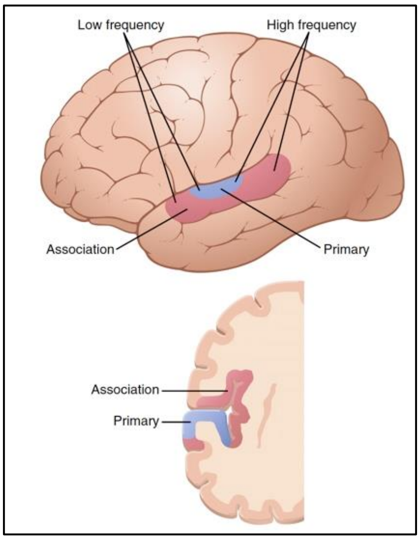
Auditory pathway

- Nerve fibers from the spiral ganglion of Corti enter the dorsal and ventral cochlear nuclei located in the upper part of the medulla.
- At this point, all the fibers synapse, and second-order neurons pass mainly to the opposite side of the brain stem to terminate in the superior olivary nucleus.
- A few second-order fibers also pass to the superior olivary nucleus on the same side.



- Signals from both ears are transmitted through the pathways of both sides of the brain, with a preponderance of transmission in the contralateral pathway.
- Many collateral fibers from the auditory tracts pass directly into the reticular activating system of the brain stem. This system projects diffusely upward in the brain stem and downward into the spinal cord and activates the entire nervous system in response to loud sounds.

- Other collaterals go to the vermis of the cerebellum, which is also activated instantaneously in the event of a sudden noise.
- A high degree of spatial orientation is maintained in the fiber tracts from the cochlea all the way to the cortex.



Auditory cortex

- Destruction of both primary auditory cortices in the human being greatly reduces one’s sensitivity for hearing.
- Destruction of one side only slightly reduces hearing in the opposite ear; it does not cause deafness in the ear because of many crossover connections from side to side in the auditory neural pathway.

- However, it does affect one's ability to localize the source of a sound because comparative signals in both cortices are required for sound localization.

- Lesions that affect the auditory association areas but not the primary auditory cortex do not decrease a person's ability to hear and differentiate sound tones.
- However, the person is often unable to interpret the meaning of the sound heard (ex. Wernicke's area).

Determination of the direction of sound

- A person determines the horizontal direction from which sound comes by two principal means:
  (1) the time lag between the entry of sound into one ear and its entry into the opposite ear.
  (2) the difference between the intensities of the sounds in the two ears.

- These two mechanisms cannot tell whether the sound is emanating from in front of or behind the person or from above or below.
- This discrimination is achieved mainly by the pinnae, which act as funnels to direct the sound into the two ears.
- The shape of the pinna changes the quality of the sound entering the ear, depending on the direction from which the sound comes.

- The neural analyses for the direction detection process begin in the superior olivary nuclei in the brain stem, even though the neural pathways all the way from these nuclei to the cortex are required for interpretation of the signals.