



*A diagram of the ear's structure*

## THE OUTER EAR

The outer ear includes the portion of the ear that we see – the pinna/auricle and the ear canal.

The pinna or auricle is a concave cartilaginous structure, which collects and directs sound waves travelling in air into the ear canal or external auditory meatus.

The ear canal or external auditory meatus is approximately 1.25 inches long and .25 inch in diameter. The inner two-thirds of the ear canal is imbedded in the temporal bone. The outer one-third of the canal is cartilage. Although the shape of each ear canal varies, in general the canal forms an elongated 's' shape curve. The ear canal directs airborne sound waves towards the tympanic membrane (eardrum). The ear canal resonates sound waves and increases the loudness of the tones in the 3000-4000 Hz range.

The ear canal maintains the proper conditions of temperature and humidity necessary to preserve the elasticity of the tympanic membrane. Glands, which produce cerumen (earwax) and tiny hairs in the ear canal, provide added protection against insects and foreign particles from damaging the tympanic membrane.

The outer ear collects sound waves in the air and channels them to the inner parts of the ear. The outer ear along with its canal has been shown to enhance sounds within a certain frequency range. That range just happens to be the same range that most of the characteristics of human speech sounds fall into. This allows the sounds to be boosted to twice their original intensity.

The Tympanic membrane which is also called the eardrum divides the external ear from the middle ear.

The eardrum is very sensitive to sound waves and vibrates back and forth as the sound waves strike it. The eardrum transmits the airborne vibrations from the outer to the middle ear and also assists in the protection of the delicate structures of the middle ear cavity and inner ear.

### **Middle ear (tympanic cavity), consisting of:**

The middle ear, separated from the external ear by the eardrum, is an air-filled cavity (tympanic cavity) carved out of the temporal bone. It connects to the throat/nasopharynx via the Eustachian tube. This ear-throat connection makes the ear susceptible to infection (otitis media). The Eustachian tube functions to equalize air pressure on both sides of the eardrum. Normally the walls of the tube are collapsed. Swallowing and chewing actions open the tube to allow air in or out, as needed for equalization. Equalizing air pressure ensures that the eardrum vibrates maximally when struck by sound waves.

Adjoining the eardrum are three linked, movable bones called ‘ossicles,’ which convert the sound waves striking the eardrum into mechanical vibrations. The smallest bones in the human body, the ossicles are named for their shape. The hammer (malleus) joins the inside of the eardrum. The anvil (incus), the middle bone, connects to the hammer and to the stirrup (stapes). The base of the stirrup, the footplate, fills the oval window, which leads to the inner ear.

The middle ear is connected and transmits sound to the inner ear via the ossicular chain. The ossicular chain amplifies a signal approximately 25 decibels as it transfers signals from the tympanic membrane to the inner ear.

The ossicular chain consists of the three smallest bones in the body: the malleus, incus, and stapes. The malleus is attached to the tympanic membrane. The footplate of the stapes inserts into the oval window of the inner ear. The incus is between the malleus and the stapes.

Attached to the ossicular chain are two tiny muscles, the stapedius and tensor tympani muscles. These muscles contract to protect the inner ear by reducing the intensity of sound transmission to the inner ear from external sounds and vocal transmission.

The middle ear transforms the acoustical vibration of the sound wave into mechanical vibration and passes it onto the inner ear. Incoming forces are magnified by about 30%. This increased force allows the fluid in the cochlea of the inner ear to be activated.

The middle ear cavity is located in the mastoid process of the temporal bone. The middle ear cavity extends from the tympanic membrane to the inner ear. It is approximately two cubic centimetres in volume and is lined with mucous membrane. The middle ear cavity is actually an extension of the nasopharynx via the Eustachian tube.

The Eustachian tube helps to equalize the pressure between the outer ear and the middle ear. Having the same pressure allows for the proper transfer of sound waves. The Eustachian tube is lined with mucous, just like the inside of the nose and throat. The Eustachian tube acts as an air pressure equalizer and also ventilates the middle ear. Normally the tube is closed but opens while chewing or swallowing. When the Eustachian tube opens, the air pressure between the outer and middle ear is equalized. The transmission of sound through the eardrum is optimal when the air pressure is equalized between the outer and middle ear. When the air pressure between the outer and middle ear is unequal, the eardrum is forced outward or inward causing discomfort and the ability of the eardrum to transmit sound is reduced.

## **THE INNER EAR**

The inner ear is composed of the sensory organ for hearing – the cochlea, as well as for balance – the vestibular system. The systems are separate, yet both are encased in the same bony capsule and share the same fluid systems.

The semi-circular canals in the inner ear allow us to maintain balance and coordination.

The balance part of the ear is referred to as the vestibular apparatus. It is composed, in part, of three semicircular canals located within the inner ear. The vestibular system helps to maintain balance, regardless of head position or gravity, in conjunction with eye movement and sensory input. The semicircular canals are innervated by the VIIIth cranial nerve.

The hearing part of the inner ear is the cochlea. The cochlea is spiral-shaped, similar to the shape of a snail.

The cochlea, which is a bundle of three fluid filled canals coiled up in a spiral, is set in motion by the stirrup in the middle ear. Moving in and out it sets up hydraulic pressure in the fluid. As these waves travel to and from the apex of the spirals, they cause the walls separating the canals to undulate. Along one of these walls is a sensitive organ called the Corti. It is made up of many thousands of sensory hair cells. From here thousands of nerve fibres carry information about the frequency, intensity and timbre of all these sounds to the brain, where the sensation of hearing occurs.

### **How do we hear?**

Hearing starts with the outer ear.

When a sound is made outside the outer ear, the sound waves, or vibrations, travel down the external auditory canal and strike the eardrum (tympanic membrane). The eardrum vibrates.

The vibrations are then passed to three tiny bones in the middle ear called the ossicles.

The ossicles amplify the sound and send the sound waves to the inner ear and into the fluid-filled hearing organ (cochlea).

Once the sound waves reach the inner ear, they are converted into electrical impulses, which the auditory nerve sends to the brain.

The brain then translates these electrical impulses as sound.

All sounds (music, voice, a mouse-click, etc.) send out vibrations, or sound waves. Sound waves do not travel in a vacuum, but rather require a medium for sound transmission, e.g. air or fluid. What actually travels are alternating successions of increased pressure in the medium, followed by decreased pressure. These vibrations occur at various frequencies, not all of which the human ear can hear. Only those frequencies ranging from 20 to 20,000 Hz (Hz = hertz = cycles/sec) can be perceived.

In hearing, air-borne sound waves funnel down through the ear canal and strike the eardrum, causing it to vibrate. The vibrations are passed to the small bones of the middle ear (ossicles), which form a system of interlinked mechanical levers: First, vibrations pass to the malleus (hammer), which pushes the incus (anvil), which pushes the stapes (stirrup). The base of the stapes rocks in and out against the oval window – this is the entrance for the vibrations. The stapes agitates the perilymph of the bony labyrinth. At this point, the vibrations become fluid-borne. The perilymph, in turn, transmits the vibrations to the endolymph of the membranous labyrinth and, thence, to the hair cells of the organ of Corti it is the movement of these hair cells which convert the vibrations into nerve impulses. The round window dissipates the pressure generated by the fluid vibrations, thus serves as the release valve: It can push out or expand as needed. The nerve impulses travel over the cochlear nerve to the auditory cortex of the brain, which interprets the impulses as sound.

### **How We Balance – The Vestibular System**

The semicircular canals and vestibule function to sense movement (acceleration and deceleration) and static position. The three semicircular canals lie perpendicular to each other, one to sense movement in each of the three spatial planes. At the base of the canals are movement hair cells, collectively called the crista ampullaris. Depending on the plane of movement, the endolymph flowing within the semicircular canals stimulates the appropriate movement hair cells. Static head position is sensed by the vestibule, specifically, its utricle and saccule, which contain the position hair cells. Different head positions produce different gravity effects on these hair cells. Small calcium carbonate particles (otoliths) are the ultimate stimulants for the position hair cells.

The hair cells for both position and movement create nerve impulses. These impulses travel over the vestibular nerve to synapse in the brain stem, cerebellum, and spinal cord. No definite connections to the cerebral cortex exist. Instead, the impulses produce reflex actions to produce the corrective response.

For example, a sudden loss of balance creates endolymph movement in the semicircular canals that triggers leg or arm reflex movements to restore balance.

Hearing can be defined as the ability to receive and process acoustic stimuli (i.e. sound).

Hearing is an important function for communication and provides people with pleasurable experiences such as listening to music. The loss of ability to hear has important consequences in ones day-to-day life and ability to function within the hearing culture (vs. the deaf culture). Hearing loss can be broadly defined as the decreased ability to receive or process acoustic stimuli. It has several causes which can be classified into five (5) groups: conductive, sensorineural, mixed, central or functional.