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Human Hearing Mechanism: Functioning Process and Defects

Mr. Durgesh Kumar, Dr. Behzad Maqbool, Mr. Santosh Maurya.

Durgesh9374@gmail.com, drbehzadmaqbool@gmail.com, smaurya38@gmail.com

ABSTRACT

This paper aims to explain human hearing mechanism in a simplest and detailed manner. The human hearing mechanism is illustrated very simply theoretically as well as diagrammatically. The focus of writing this paper is to enable students, professionals, and other people related to this field to understand the whole hearing mechanism alongside functioning, process and defects' in a detailed and simplest way.

Key words: ***human ear, hearing process, hearing functioning, hearing defects.***

INTRODUCTION

Hearing impairment is a condition resulting from a structural abnormality (such as a hole in the eardrum) that may or may not produce a functional disability (such as diminished hearing). This however is a theoretical definition. We must see the meaning of a few words carefully. It would handicap. Hearing impairment does not necessarily mean hearing handicap.

HEARING MECHANISM

The human ear is amazing. It is one of the smallest and most complex organs in the body, capable of turning the tiniest disturbances in air molecules into a form the brain can understand and doing so instantaneously, over an enormous range of pitch and loudness. The ear is the organ of hearing and balance. It has three parts: Outer ear, Middle ear, Inner ear

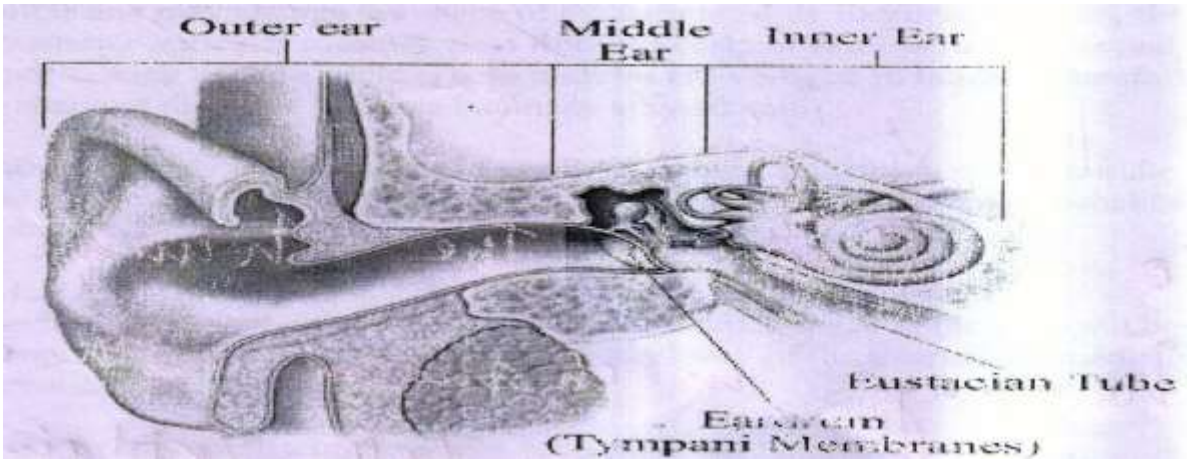

Figure 1: Parts of ear involved in conductive and sensorineural hearing loss.

A. OUTER EAR

The outer ear is trumpet-shaped, protruding part of the ear on each side of the head, and assists in capturing sound, called the auricle or pinna. It consists of cartilage covered into the ear, called the auditory canal; the opening is called the meatus. The external acoustic meatus extends from the deepest part of the concha to the tympanic membrane (eardrum), a distance of approximately 24 mm. The lateral 1/3rd is formed from cartilaginous extensions from some of the dauricular cartilages and the medial 2/3rd is a bony tunnel in the temporal bone.

The figure 2 shows the structure of pinna. The various curves and cavities in pinna help in capturing and funnelling the sound to the external auditory canal. The EAC and concha act as resonators and enhance the sound between the frequencies 2 to 5 KHz.

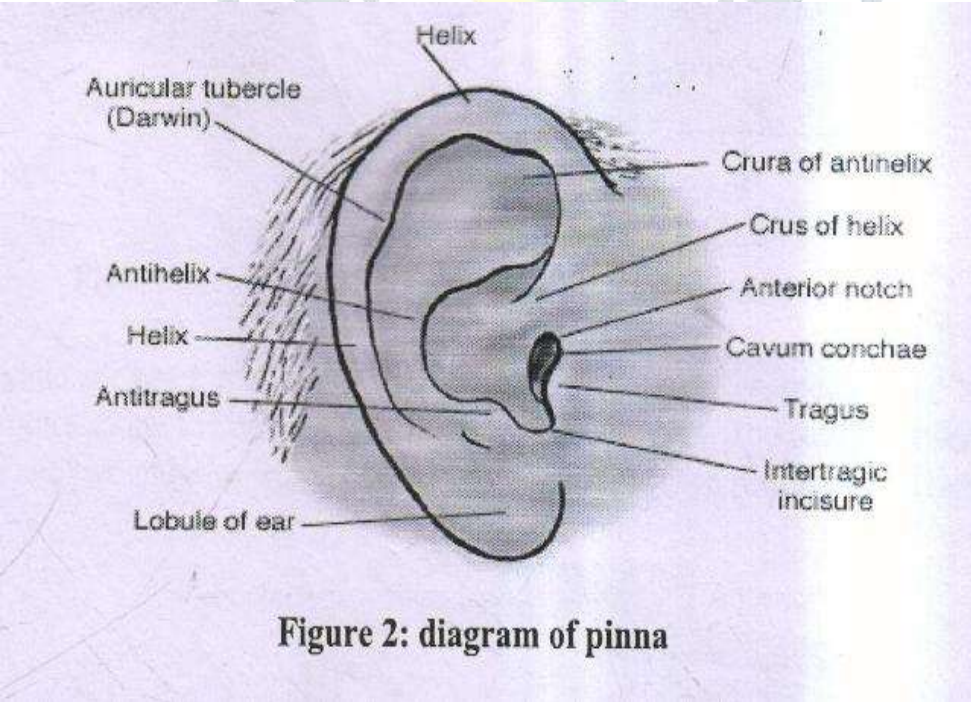

Figure 2: diagram of pinna

Numerous intrinsic and extrinsic muscles are associated with the auricle. Both groups of muscles are innervated by the facial nerve [VII]. Intrinsic muscles pass between the cartilaginous parts of the auricle and may change the shape of the auricle while Extrinsic muscles, the anterior, superior, and posterior auricular muscles, pass from the scalp or skull to the auricle and may also play a role in positioning of the auricle. These muscles are vestigial in humans therefore humans cannot change shape or direction of pinna but many animals can.

MIDDLE EAR

The middle ear is an air-filled, mucous membrane-lined space in the temporal bone between the tympanic membrane laterally and the lateral wall of the internal ear medially. It is described as consisting of two parts:

Tympanic cavity immediately adjacent to the tympanic membrane;
Epi tympanic recess superiorly
The tympanic membrane separates the external acoustic meatus form the middle ear it is at an angle of 55, sloping medially from top to bottom and posteriorly to anteriorly. It laterals skin on the outside and mucons membrane on the inside. The middle-ear chamber is filled with air. There is an opening from the middle ear to the throat through a tube called the Eustachian tube. The Eustachian tube helps to equalize pressure on both side of the eardrum.

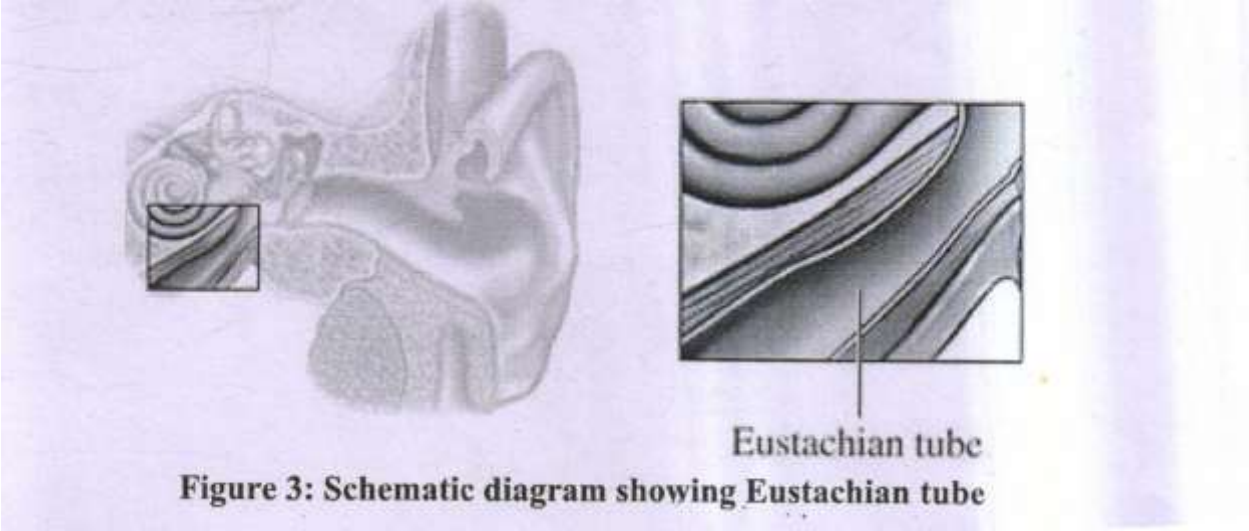

Figure 3: Schematic diagram showing Eustachian tube

The middle ear has a roof and a floor, and anterior, posterior, medial, and lateral walls. The Following figure shows the boundaries of a human middle ear. The cavity houses three small ossicles/bones and two muscles which play key role in hearing and hearing protection.

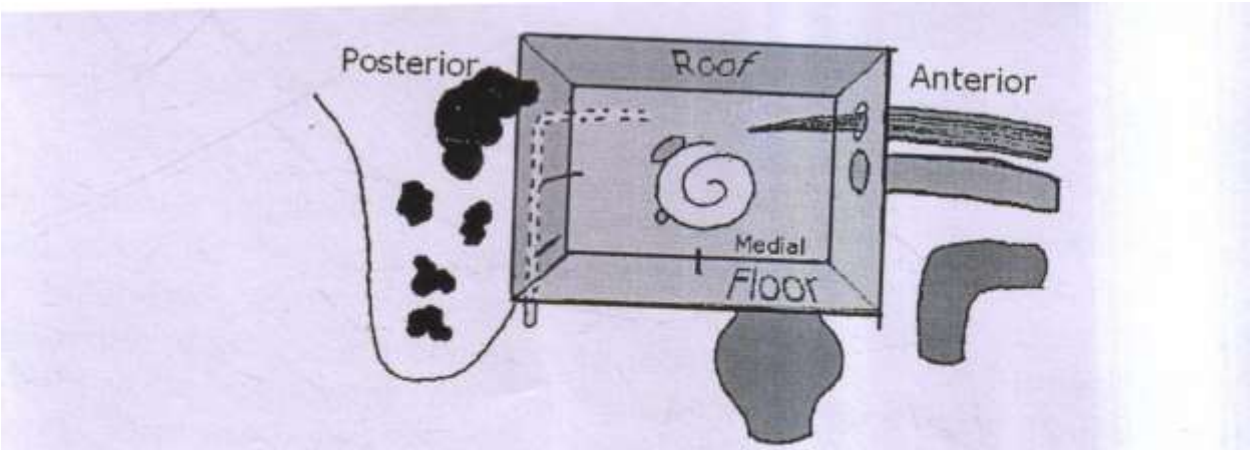

Figure 4: **Schematic diagram showing the walls of middle ear**

The auditory ossicles consist of three small bones found within a space (the tympanic cavity) in the temporal bone of the skull. The bones (which are named for their shape) are connected by synovial joints. Resting against the oval window of inner ear is the stapes (stirrup), which articulates with the middle ossicle called the incus(anvil). The incus articulates with the malleus (hammer), whose "handle" is attached to the internal surface of the tympanic membrane (eardrum). Sound-induced vibration of the tympanic membrane are thereby amplified and transmitted through these ossicles to the inner ear where they are interpreted as sound.

There are mainly two middle ear muscles- Stapedius and Tensor Tympani. Stapedius muscle attaches itself to the neck of stapes and contracts on loud noises reflexively. This action of stapes is called acoustic reflex and protects the inner ear structures against loud sounds. The tensor tympani attaches to the malleus and contracts to loud sound like stapes. However the acoustic reflex is major response of stapedious.

INNER EAR:

The inner ear is a fluid-filled chamber divided into two parts: Vestibular labyrinth, which is the portion of the inner ear that functions as part of the body's balance mechanism. Cochlea, which contains the hearing-sensing nerve.

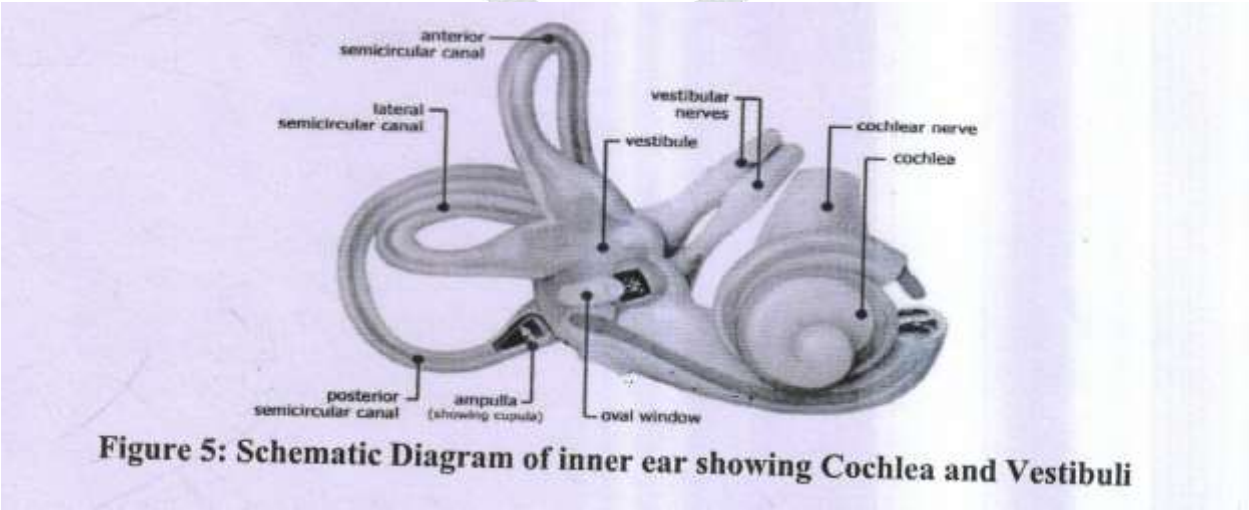

Figure 5: **Schematic Diagram of inner ear showing Cochlea and Vestibuli**

The cochlea is a hollow tube inside the inner ear that is coiled to resemble a snail's shell. It is divided into Scala media and Scala Tympani. The scala media It contains thin fluid (endolymph) and a highly specialized structure called the organ of Corti, which contains thousands of minute , sensory, hair-like cells (outer and inner hair cells). The organ of Corti functions as the switchboard of the hearing system. Figure 6 below shows the structure of organ of corti. There are 3 rows of outer hair sell and one row of inner hair cell. The sound reaching the organ of corti is converted form mechanical form to electrochemical form by the hair cells and the electrical impulse generated here is tranfered by the auditory nerve to the cortex.

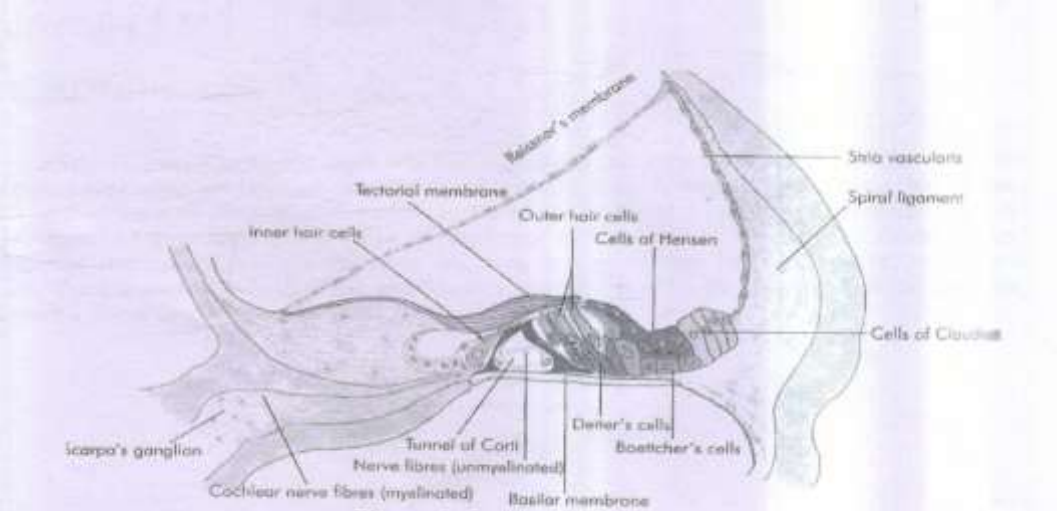

Figure 6: Organ of Corti

The acoustic nerve (also called the eighth cranial or auditory nerve) leads from the inner ear to the brain, serving as the pathway for the nerve impulses that the brain will interpret as sound. The auditory nerve goes from cochlea to the cochlear nucleus, then superior olivery complex, followed by lateral Lemniscus inferior coliculus and medial geniculate body to the cortex. This pathway is shown in the figure 7 below.

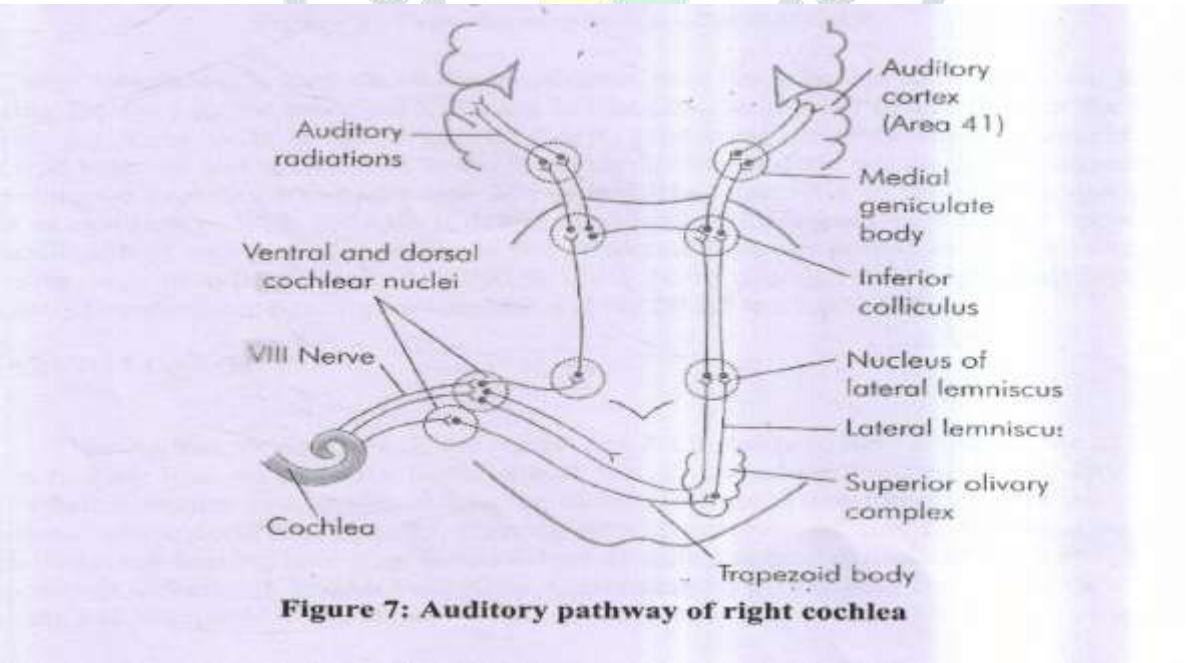

Figure 7: Auditory pathway of right cochlea

HEARING PROCESS

Hearing involves a complex chain reaction within the ear. Sound creates vibrations in the air somewhat similar to the rippling waves created when a stone is thrown into a pond. The outer ear "trumpet" collects these sound waves, and they are funnelled down the external ear canal to the eardrum. As the sound waves strike the eardrum, they sause it to vibrate. The vibratons are transmitted through the middle ear over the bony bridge formed by the hammer, anvil, and stirrup. The ear ossicle increases the amplitude of the vibration 15-20 times because of leverage and the ear drum to oval window ratio.

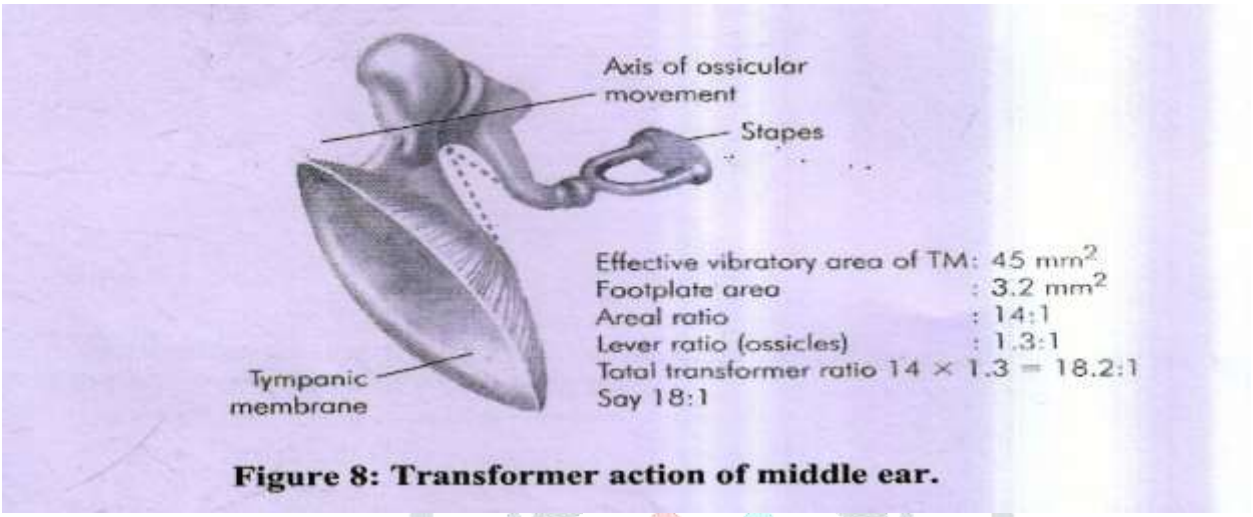

Figure 8: Transformer action of middle ear.

These vibrations, in turn, cause the membranes over the openings to the inner ear to vibrate, causing the fluid in the inner ear to be set in motion. The motion of the fluid in the inner ear excites the nerve cells in the organ of Corti, producing electrochemical impulses that are gathered together and transmitted to the brain along the acoustic nerve. As the impulses reach the brain, we experience the sensation of hearing. The sensitivity of the hearing mechanism is most extraordinary. With the softest detectable sound, the eardrum only moves approximately on-millionth of an inch. Our ability to detect sound from the softest to the loudest covers an intensity range of approximately 100,000,000 to 1. Many young, healthy humans (through teens and early twenties)can hear frequencies form about 20 Hz to 20,000 Hz.

HEARING LOSS (HL)

Hearing loss, or deafness, is the partial or total inability to hear sound in one or both ears. When hearing loss occurs early in childhood, it's devastating consequences are more obvious than when it occurs late in life. A hearing deficit in infants can interfere with psychological, emotional and speech development. Hearing loss makes even routine communication difficult. High frequency hearing loss often involves loss of ability to hear consonants such as s, f, t, and z, even though vowels can be heard normally. Consequently, people hear but cannot make out what is being said. People lose the ability to take in the sounds like bird songs, rustling of leaves, and the voices of children. In general, these infringements on the quality of life can be overcome through medical or surgical treatment or with hearing aids. Psychosocial problem- This may result in frustration, withdrawal from social activities, depression, and marital discord. Even more mild forms of hearing loss early in life can cause great difficulties, including poor attention and bad grades in school.

Types of Hearing Loss

There are different types of hearing loss, depending on which part of the hearing pathway is affected.

The type of hearing loss that occurs depends on what part of the ear is not working properly. For example, if there is something not working in the

- ear canal
- eardrum
- middle ear bones, or
- middle ear space (e.g. fluid)

It may result in a conductive hearing loss (sometimes called “mechanical hearing loss”). If, on the other hand, something is not working in the

- Cochlea
- auditory nerve, or
- brain

It more commonly results in a sensorineural hearing loss (also called “nerve hearing loss”).

The following diagram shows the part of the ear affected in different types of loss.

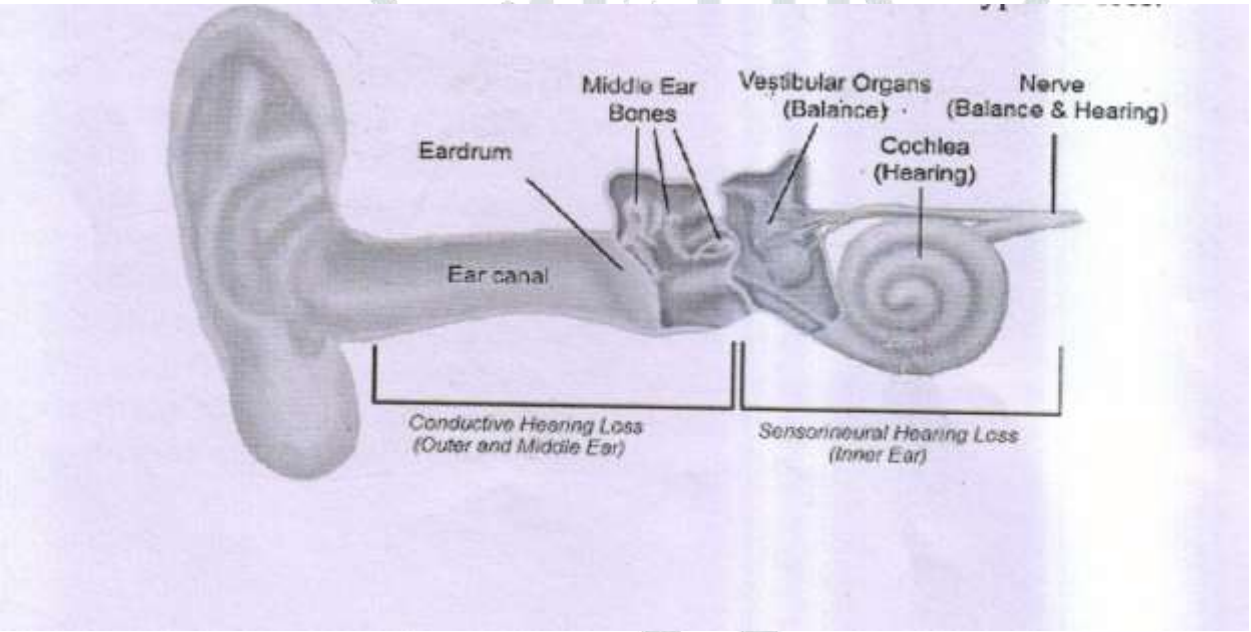

Figure 9: part of ear affected in different types of hearing loss

There are different types of hearing loss, depending on which part of the hearing pathway is affected Conductive Hearing Loss

Conductive Hearing Loss is due to any condition that interferes with the transmission of sound through the outer and middle ear to the inner ear. This type of hearing loss can be successfully treated in most cases.

In cases of conductive hearing loss, sound waves are not transmitted effectively to the inner ear because of some interference in:

- The external ear canal
- The mobility of the eardrum (problems with the mobility of the eardrum are often caused by accumulation of fluid in the Eustachian tube, the tube that connects the middle ear to the back of the throat)

- The three tiny bones inside the middle ear
- The middle-ear cavity
- The openings into the inner ear
- The Eustachian tube

Sensorineural Hearing Loos

In sensorineural hearing loss, the damage lies in the inner ear, the acoustic nerve, or both. Most physicians call this condition "nerve deafiness."

The cochlea ha approximately 30,000 hearing nerve endings (hair cells). Which in the larger end respond to very high-pitched sounds, and those in the small end respond to low-pitched sounds. These hair cells, and the nerve that connects them to the brain, are susceptible to damage from a variety of causes.

- .The term "sensory" hearing loss is applied when the damage is in the inner ear. Common synonyms are"cochlear" or "inner-ear" hearing loss.
- "Neural" hearing loss is the correct term to use when the damage is in the acoustic nerve, anywhere between its fibers at the base of the hair cells and the relay stations in the brain (the auditory nuclei). Other common names for this type of loss are "nerve deafness" and "retrocochlear"

Central Hearing Loss

In central hearing loss, the problem lies in the central nervous system, at some point within the brain. A condition called central auditory processing disorder frequently leads people to think they have hearing loss when their hearing is actually normal.

Basically, the problem involves a person's inability to filter out competing auditory signals.

People with central auditory processing disorders have difficulties that include:

- Problems "hearing" when there are several conversations going on
- Inability to read or study with the radio or television on
- Problems reading if someone turns on a vacuum cleaner or air conditioner near them
- Generally missing the first sentence from people talking to them if they are involved in an auditory attention task (such as watching television)

Although such people (and their families and friends) frequently suspect that they have a hearing loss, the function of the ears is usually normal, and routine hearing tests are normal. Naturally, people with this condition may also develop hearing loss from other causes, and this can make it even more difficult for them to function under everyday circumstances.

Functional Hearing Loss

Functional hearing loss involves a psychological or emotional problem, rather than physical damage to the hearing pathway. Individuals with this type of hearing loss do not seem to hear or respond; yet, in reality, they have normal hearing.

Mixed Hearing Loss

Frequently, a person experiences two or more types of hearing impairment, and this is called mixed hearing loss. This term is used only when both conductive and sensorineural hearing losses are present in the same

ear. However, the emphasis is on the conductive hearing loss, because available therapy is so much more effective for this disorder.

Depending on the cause, hearing loss may be temporary or permanent. Temporary hearing losses are almost always conductive and are far more common than permanent hearing losses. Permanent hearing losses are usually sensorineural, but may also be conductive.

Causes of hearing loss

Temporary hearing loss: There are several causes of temporary hearing loss. The most common cause is fluid in the middle ear (i.e. due to ear infections). Other causes may include:

- Eardrum perforation (when there is a hole in the eardrum froma bad ear infection, or ear trauma)
- Narrowing of the ear canal due to surgery or disease
- Excessive ear wax that plugs the ear canal
- Infections of external ear
- infections of middle ear
- Eustachian tube bloks
- Otosclerorsis

Permanent hearing loss

Permanent hearing losses are less common than temporary hearing losses. There are many causes of permanent hearing losses. These include genetic, infectious, drug-related, physical trauma and structural causes. A rough distribution of these is seen below:

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