Structure of Ear

⇒ The human ear consists of 3 main parts :- the are filled external and middle ear, and a fluid filled inner ear. each part of ear serves a specific purpose in the task of detecting and interpreting sound.

(A) External Ear :→ It is comprised of two parts :- Pinna and External auditory canal.

Pinna :→ It is an oval, somewhat funnel-shaped, skin-covered flap of elastic cartilage and muscles. Sebaceous and a few sweat glands are present in its dermis.

⇒ Its outer stiff ridge is called helix, lower flexible lobe (only part of pinna which is not supported by cartilage) is termed lobule and it's cavity is known as Concha.

⇒ It collects sound waves and direct them into the external auditory canal. In other mammals, such as cattle, dog, rabbit and cat, the pinna is much larger and freely movable and is thus more effective in collecting sound waves.

⇒ Man cannot move the pinna as its muscles are vestigial, aquatic mammals, such as whale, seal lack pinna.

External auditory canal :→ It is an S-shaped tube leading inward from the pinna. It follows an oblique course, so as to prevent hard objects from hitting the tympanum directly.

⇒ The canal is supported by an elastic cartilage in the outer portion and by temporal bone in the inner portion. It is lined with skin continuous with that covering the pinna.

⇒ The outer region of the canal bears hairs that serve to keep out the dust particles. Its inner region has coiled, tubular, apocrine ceruminous or wax glands that are modified sweat gland. they secrete a brownish, semi solid, fatty substances the cerumen/earwax which lubricates and protects the lining of meatus. The warm, humid air enclosed in the meatus is essential for proper functioning of the tympanic membrane. It is thought as well to be an insect repellent.

(B) Middle Ear (Air filled) :→ It is an air filled cavity in the temporal bone that opens via the auditory (eustachian) tube into the nasopharynx and through the nasopharynx to the exterior, it includes the following parts :-

Tympanic membrane (tympanum/eardrum) :→ It separates the tympanic cavity from the external auditory meatus. It is thin and semi-transparent, almost oval, though somewhat broader above than below. It is covered externally by a stratified epithelium (epidermis) and internally by a simple cuboidal epithelium. The central part of the tympanic membrane is called the Umbo. The handle of the malleus is firmly attached to the membrane's internal surface.

Tympanic cavity :→ It is an irregular, air-filled space enclosed in the temporal bone. It is lined with simple ciliated columnar epithelium, it communicates with the pharynx by a passage called the Eustachian tube (auditory tube).

⇒ At the pharyngeal opening of the eustachian tube is a valve which normally remains closed. The valve opens during yawning, swallowing and during an abrupt change in altitude (ascent or descent in an aeroplane), when air enters or leaves the tympanic cavity to equalise the pressure of air on the two sides of the tympanic membrane. This enables the tympanic membrane to vibrate freely when the sound waves strike it. This also protects the tympanum from bursting due to sudden rise in air pressure caused by explosion or other loud noise.

⇒ Unfortunately, the Eustachian tube provides a path for micro-organisms infecting the pharynx to pass into the middle ear. Such an infection may result in ~~loss~~ loss of hearing.

Ear Ossicles :→ There is a small flexible chain of 3 small bones called **ear ossicles** – the malleus (hammer shaped), the incus (anvil shaped) and the stapes (stirrup shaped). The malleus is attached to the tympanic membrane on one side and to incus on the other side. The incus in turn is connected with the stapes which is attached to the oval membrane covering the fenestra ovalis (oval window) of the inner ear.

⇒ There are two small skeletal muscles – the tensor tympani which attaches to the malleus and the stapedius which attaches to the stapes. They contract reflexely and very quickly to protect the ear against loud noises.

⇒ Stapedius muscle is the smallest muscle and stapes is the smallest bone in the human body being roughly the size of a grain of rice.

⇒ Both the muscles increases the stiffness of the ossicular chain when they contract and thus reduce sound transmission by upto 15 dB depending on frequency.

⇒ The tensor tympani pulls the malleus away from the tympanic membrane while the stapedius pulls the stapes away from the oval window and changes its orientation 90 degrees. The stapedius muscle opposes the tensor in the latter action, paralysis of stapedius result in **hyperacusis**.

⇒ Unlike other bones, the ossicles stop growing early in life and a 60 year old has the same size ossicles as does a 1 year old.

⇒ The function of the ossicles is to transmit and amplify sound waves across the tympanic cavity from the tympanic membrane to the oval window. This is necessary since vibrations in the inner ear travel through fluid which is much more dense than air. The ossicles amplify in two ways :–
(i) Concentrate vibrations of the large tympanic membrane onto the small footplate of the stapes (an amplification of about 17 times).
(ii) Act as a fulcrum and so (because of the way they are hinged) benefit from the lever principle (another amplification of 1.3 times).

⇒ The ossicles are connected in such a way as to act as a lever system to ↑↑ the force of the vibration from the ear drum. In addition the force of vibration is intensified as it is transmitted from the relatively large surface of the ear drum to the smaller surface area of the oval window. The combined effect ↑↑ the force of vibrations.

⇒ The middle ear is connected with the inner ear through two small openings closed by the membranes. These openings are (1) fenestra ovalis (oval window) and (2) fenestra rotunda (round window).

Functions of middle ear :→ It transmits sound waves from external to the internal ear through the chain of ear ossicles.

⇒ The intensity of sound waves is increased ↑↑ 10 times by the ear ossicles. the frequency of sound does not change.

⇒ From the tympanic cavity extra sound is carried to the pharynx through eustachian tube.

(C) Internal ear (fluid filled) :→ The internal ear is a delicate, irregular organ called membranous labyrinth. It is surrounded by an almost similarly shaped bony labyrinth. The membranous labyrinth is joined to the bony labyrinth at certain points, but its greater part is separated from the bony labyrinth by a narrow perilymphatic space. This space contains a watery fluid called **perilymph** which closely resembles cerebrospinal fluid (CSF) in composition. (Na⁺ rich and K⁺ poor.) In fact there is a communication b/w perilymph space and the subarachnoid space.

⇒ The membraneous labyrinth is itself filled with another fluid, the endolymph. It resembles the intracellular fluid in its ionic composition (K^+ rich and Na^+ poor). The membranous labyrinth consists of 3 parts:- Vestibule, Semicircular ducts and Cochlear duct.

Vestibule:- The vestibule is a central sac-like part of the membranous labyrinth. It is suspended into the bony labyrinth by trabeculae of connective tissue. It further consists of 2 chambers:- larger, somewhat oblong sac, the utricle (utriculus) which communicates with the semicircular ducts and smaller, roughly globular sac the saccule (sacculus) that leads into the cochlear duct. The two saccule and utricle are called otolithic organs.

⇒ From the posterior end of the saccule arises the ductus endolymphaticus which is joined by the utriculosaccular duct from the utricle. The ductus endolymphaticus passes downward and ends in a blind pouch, the saccus endolymphaticus, from the lower part of the saccule arises a short tube the ductus reuniens that joins the cochlear duct.

⇒ The vestibule has 2 sensory spot:- macula of utricle and macula of saccule located in the wall of the utricle and saccule respectively.

⇒ A macula consists of hair cells and supporting cells, the supporting cells are columnar. The hair cells are sensory and of two types:- flask-shaped and cylindrical. They bear non motile 'hair' or stereocilia (modified microvilli) and also have one cilium (kinocilium) arising from a centriole at the free surface, and form at their bases synapses with the dendrites of cells in the vestibular ganglion.

⇒ Tips of the 'hair' and cilium project into a thick gelatinous, glycoprotein sheet the otolithic membrane. The latter is secreted by the supporting cells and contains numerous minute, irregular particles, called otoliths/otoconia composed of protein and calcium carbonate.

Semicircular Canal:- There are 3 semicircular ducts, the anterior, the posterior and the lateral semicircular ducts. They arise from the utricle.

⇒ The anterior and posterior semicircular ducts arise from Crus Commune. each semicircular duct is enlarged at one end to give rise to a small rounded ampulla.

⇒ The anterior and lateral semicircular ducts bear ampullae at their anterior ends, while the posterior ducts contains an ampulla at its posterior end.

⇒ Each ampulla contains a sensory patch of cells, the Crista. each crista consists of two kinds of cells, the sensory and supporting cells. The sensory cells bear long sensory hair at their free ends and nerve fibres at the other end. The sensory hairs are partly embedded in a gelatinous mass the Cupula. The Cristae are concerned with balance of the body.

Cochlea:- It is the main hearing organ which is connected with saccule by a short ductus reuniens leading from the saccule.

⇒ It is spirally coiled (35mm long) that resembles a snail shell in appearance. It tapers from a broad base to an almost pointed apex.

⇒ Internally it consists of 3 fluid filled chambers or canals, the upper Scala vestibuli lower Scala tympani and the middle Scala media.

⇒ Both Scala vestibuli and Scala tympani are filled with perilymph however Scala media is filled with endolymph.

⇒ Both the Scala vestibuli and Scala tympani are connected with each other at the apex of the cochlea by a small canal the helicotrema. The lamina spiralis divides the spiral canal of the cochlea incompletely into scala tympani scala vestibuli.

⇒ Near the base of the scala vestibuli the wall of the membranous labyrinth comes in contact with the fenestra ovalis, while at the lower end of the scala tympani lies the fenestra rotunda.

⇒ The scala media is the most important canal of the cochlea. It bears an upper membrane the Reissner's membrane and lower membrane basilar membrane, on the basilar membrane a sensory ridge the Organ of Corti is present.

⇒ The Organ of Corti consists of hair cells (phonoreceptores) rods of Corti and ~~two~~ supporting cells. Hair cells, bear 'hair' (modified microvilli or stereocilia) at the free surface and have synaptic contacts with the dendrites of neurons at the bases. The tips of 'hair' are embedded in a smooth, gelatinous sheet, the tectorial membrane that is attached to spiral limbus a thickening of periosteum.

⇒ The supporting cells are of two types :- long pillar cells and short phalangeal / Deiter's cells.

Functions of Ear :→ (I) Mechanism of hearing (Organ of hearing - Cochlea) :-

(1) As the sound waves enter the external ear, they pass through the ear canal and strike the ear drum, the vibrations of the ear drum are transmitted to the 3 ear ossicles.

(2) From there the vibrations enters the internal ear via fenestra ovalis.

(3) The perilymph of the internal ear receives the vibrations through the fenestra ovalis.

(4) From the perilymph the vibrations are transferred to the Scala vestibuli of cochlea and then to Scala media through Reissner's membrane. thereafter, the movements of endo-lymph and tectorial membrane stimulate the sensory hairs of the organ of Corti.

(5) The resulting movement of the sensory hair may cause the sensory cells to become depolarised. When hair cell is stimulated in this way generator potential develop in it producing an action potential (nerve impulse). The sound waves converted to nerve impulses travel through the auditory nerve to the auditory cortex (temporal lobe of each cerebral hemisphere) region of the brain.

⇒ Bending of 'hair' reduces the membrane potential of the hair cells, causing release of their transmitter and initiation of action potential in the sensory nerve endings. each organ of Corti has about 24,000 receptor cells.

⇒ The sensory hairs project from the outer ends of the hair cells into the scala media, while from the inner end of the cells nerve fibres arise, which unite to form the cochlear nerve.

⇒ The tectorial membrane determines the pattern of vibration of sound waves.

⇒ Electromotility when the stereocilia (of outer hair cells) are bent by interaction with tectorial membrane and the hair cell is depolarized, this depolarized activates contraction of a plasma membrane asso- cytoskeleton causing the hair cell to shorten and elongate. This serves to amplify the vibration of the basilar membrane and assists in hearing very low amplitude sounds.

(6) During loud sound, some sound waves are transferred from scala vestibuli to scala tympani through helicotrema. From scala tympani the sound waves are transmitted to the tympanic / middle ear cavity through the membrane covering the fenestra rotunda. from the tympanic cavity the sound waves are transferred to the pharynx through the Eustachian tube.

Audible range :→ Man can hear frequencies as low as 20 Hz and as high 20,000 Hz. If it were more sensitive, it would have picked up the random movements of the air molecules, which would result in constant hiss or buzzing.

⇒ The audible range of dog reaches 40,000 Hz and that of bat 100,000. Bat produce and receive ultrasonic sounds of pitches much beyond human hearing to be guided during flight.

(II) Equilibrium:→ Vestibular apparatus is concerned with the maintenance of static and dynamic equilibrium (i.e. balance orientation etc.) This apparatus consists of endolymph filled utriculus, sacculus, 3 semicircular canals and their ampulla).

⇒ Ampulla of these utriculus, sacculus are committed to maintenance of vertical static equilibrium and to respond to alterations in linear acceleration (utriculus) e.g. gravity effect.

⇒ The semicircular canals relate to stimulation by circular/angular acceleration.

Dynamic equilibrium:→ Cristae detect turning or rotational movement of the head. (angular acceleration). When the head is turned, the endolymph in the semicircular ducts due to its inertia does not move as fast as the head and the sensory cells of the crista, but continues to move after the head stop moving.

⇒ Because of this difference in the rate of movement, the sensory hair of the cristae are swept through the endolymph and become bent over.

⇒ This disturbance stimulates the sensory cells and produces generator potential in the them.

⇒ The latter sets up action potential in the fibres of the auditory nerve, which transmits it to the brain.

⇒ Since the 3 semicircular ducts are arranged in three different planes, a movement of head in any direction will stimulate the sensory cells of at least one crista

Static Equilibrium and linear acceleration:→ Maculae detect changes in the head (or body) at rest (static equilibrium) and in the forward movement (linear acceleration)

⇒ With a change in the position of the body, the otoliths press upon the sensory hair of the maculae.

⇒ This stimulates the sensory cells which produce generator potential. The latter then initiates nerve impulse in the fibres of the auditory nerve.

⇒ The macula of utricle respond to vertical movt of the head, and the macula of saccule responds to lateral (sideways) movement of the head.

⇒ On rapid forward, the otoliths, because of having greater inertia than the surrounding endolymph, lag behind and press back the sensory hair, stimulating the sensory cells to generate nerve impulses.

Ear defects:→ (1) **Deafness:→** It may be partial or complete and may be caused by damage to the conduction system or to the nerve fibres/receptor cells.

(A) Conduction deafness can be due to a simple cause like accumulation of wax in the ear. It may also come from a more complex cause such as otosclerosis, in which the bones of the middle ear become fused together and fail to transmit vibrations. otosclerosis can be treated surgically.

⇒ Damage/destruction of tympanic membrane can also cause conduction deafness, in many cases a ruptured tympanic membrane will grow back across the opening and repair itself to some degree.

(B) **Nerve deafness:→** (Nerve.) results from damage to receptors or nerve fibres. It can be caused by excessive exposure to loud noises, tumors, or other kinds of brain damage.

⇒ Some loss of function in the cochlear nerve accompanies ageing.

(2) **Vertigo:→** It is the sensation of rotation in the absence of actual rotation and is a prominent symptom when once labyrinth is inflammed.

(3) **Otalgia:→** Ear pain.

(4) **Otitis:→** Inflammation of ear.

(5) **Otitis externa:→** Inflammation of the skin of the external auditory canal.

(6) Presbyacusis :→ Hearing loss occuring with age. It occurs due to decreased ↓↓ blood supply to the inner ear possibly due to heart diseases, high BP / arteriosclerosis or hereditary factors.

(7) Hyperacusis :→ A collapsed tolerence to normal environmental sounds. It is a rare hearing disorder whereby a person becomes highly sensitive to noise. It can affect people of all ages and is almost always accompanied by tinnitus.

(8) Tinnitus :→ A ringing sensation in the ear caused by irritative stimulation of either the inner ear or the vestibulo-cochlear nerve. In this person hears when there is no real sound. It is usually accompanied by hearing loss.

(9) Eustachitis :→ Inflammation of the mucous membrane of the eustachian tube.

(10) Meniere's disease :→ It is due to an increased ↑↑ amount of endolymph that enlarges the membranous labyrinth. Its symptoms are fluctuating hearing loss and roaring tinnitus (ringing). Spinning / whirling vertigo (dizziness) is characteristics of meniere's disease.

(11) ottis media :→ This is an acute infection of the middle ear caused mainly by bacteria and associated with infection of the nose and throat. The symptoms of ottis media are severe pain, pus discharge, fever and a reddening and outward bulging of the tympanic membrane.