The vertebrate ear functions as an organ of hearing and equilibrium. The organs of hearing and equilibrium convert the mechanical energy to action potential. Therefore, they are called mechanoreceptors.

The ear of rabbit is described in detail as an introduction to the study of vertebrate ear.

Location: The ears are located on the sides of the head above and behind the eyes.

Structure. The ear of rabbit consists of three parts: external, middle and internal. The first two serve to receive and transmit the sound waves to the last which sets up nerve impulses for transmission to the brain.

1. **External Ear:** The external ear has two regions pinna, or auricle, and external auditory canal, or meatus.

(i) Pinna (Auricle): It is a large, movable, trumpet- shaped, skin-covered flap projecting upward from the side of the head. It is supported by elastic cartilage and muscle. It encloses a funnel like cavity, the concha. It has three voluntary auricular muscles: anterior, posterior and superior, to direct it toward the source of sound. Man cannot move the pinna as its muscles are vestigial.

(ii) External Auditory Canal: It is a tubular passage leading inward from the concha. It follows an oblique course so as to prevent hard objects from hitting the tympanum directly. The canal is supported by cartilage in the outer portion and by bone in the inner portion. It is lined with skin continuous with that lining the concha and covering the pinna. The outer region of the canal bears hair that serve to keep out the dust particles. Its inner region has tubular ceruminous, or wax, glands. They secrete a fatty substance cerumen, or ear wax, which lubricates and protects the lining of the meatus and the tympanic membrane. It also helps to keep out insects. The warm, humid air enclosed in the meatus is essential for proper functioning of the tympanic membrane. The tympanic membrane is a thin, tightly stretched membrane closing the external auditory canal internally. It is composed of three layers sensing from different sources. In the middle is a sheet of mesodermal connective tissue with fibres radiating from the central region. It is covered externally by an ectodermal stratified epithelium, and internally by an endodermal mucous membrane continuous with that of tympanic cavity.

The external ear collects the sound waves like a funnel, concentrates them to slightly increase their pressure and directs them inward.

2. **Middle Ear:** The middle ear consists of an irregular, air-filled space, the tympanic cavity, enclosed in the tympanic bulla. It is lined by mucous membrane. It communicates with the pharynx by a passage called the Eustachian tube, or pharyngotympanic canal. The latter extend downward and inward. The pharyngeal opening of the Eustachian tube normally remains closed by the tensor palati muscle. It opens at the time of shouting, yawning and swallowing, when air enters or leaves the tympanic cavity to equalise the pressure of air on the two sides of 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 the sudden rise in air pressure cause by explosion or other loud noise.

Inner wall of the tympanic cavity is formed by the periotic bone. It has two apertures, which put it in communication with a narrow space around the internal ear. Of these, the upper is called the fenestra ovalis or, oval window, or vestibular window and the lower is termed the fenestra rotunda, or round

window, or cochlear window. The latter aperture is covered by a thin membrane. This membrane is composed connective tissue, covered externally by mucous membrane and internally by squamous epithelium.

The tympanic membrane is connected with the fenestra ovalis by a chain of three small, movably articulated bones, the ear, or auditory, ossicles, that cross the tympanic cavity (Fig. 8.20). The outer ossicle is hammer-shaped and is called the malleus.

The inner ossicle resembles the stirrup in shape and is known as the stapes. It fits into and plugs the fenestra ovalis like a piston fitting into a cylinder, having some freedom of movement.

The middle ossicle is anvil-like and is called incus. It articulates with the malleus by a synovial joint, and with the stapes by a ball- and-socket joint. The ear ossicles have articular cartilages at their ends. Small ligaments hold the ear ossicles together and keep them in place. The ear ossicles are covered with a thin layer of mucous membrane which is continuous with that lining the tympanic cavity. Malleus and stapes are connected to the wall of the middle ear by a small tensor tympani muscle and a tiny stapedius muscle respectively.

The tensor tympani muscle makes the tympanic membrane tense to receive high-frequency sound waves. The stapedius muscle protects the internal ear from injury by loud sounds through its action on stapes. The three ossicles form a system of levers, which reduces the extent (displacement amplitude) of vibrations but increases their force (pressure amplitude)). The movement of the stapes in the fenestra ovalis is only half as extensive as the movement of the tympanic membrane, but the force of movement is several times as great. Practically, the entire force affecting the tympanic membrane is conveyed to the perilymph through the fenestra ovalis and because the fenestra ovalis is smaller, the force per unit area is increased. Increase in the force of vibration is essential for an efficient transfer of vibrations from the tympanic membrane to the dense incompressible fluid of the internal car.

The middle ear transmits the vibrations from the tympanic membrane to the internal ear after increasing their force.

3. **Internal Ear:** The internal ear (Fig. 8.21) consists of a delicate, irregular, ectodermal sac, called the membranous labyrinth. It is surrounded by a similarly shaped bony labyrinth formed of the periotic bone. The bony and the membranous labyrinths are joined together at certain places only. Elsewhere, there is a narrow perilymphatic space between the two and this space is filled with a lymph like fluid called the perilymph. The membranous labyrinth is also filled with a similar fluid, the endolymph. The endolymph is thought to be secreted by certain cells of Shambaugh located in the outer wall of the cochlear duct. The membranous labyrinth consists of three parts; vestibule, semi-circular ducts and cochlear duct, or lagena.

(a) Vestibule. The vestibule is the central sac like part of the membranous labyrinth. It is differentiated into two chambers the upper large utriculus, which communicates with the semi-circular ducts, and the lower small sacculus, which communicates with the cochlear duct. The two are joined by a narrow tube, the sacculo utricular duct. The vestibule bears in it two sensory spot, the maculae, for equilibrium. One of these lies in the wall of the utriculus and is called the macula utriculi. The other lies in the wall of the sacculus and is named the macula sacculi. Each macula consists of a group of receptor hair cells and supporting cells. The supporting cells are columnar. The sensory cells in the human ear are of two types flask-shaped and cylindrical.

They bear nonmotile "hair" and also have one cilium. The tips of the "hair" and cilium project into a gelatinous sheet, the otolithic membrane secreted by supporting cells. This membrane contains numerous minute, irregular particles called otoliths, or otoconia, composed of protein and calcium carbonate. Changes in the position of the otoliths in response to gravitational forces affect the hair cells which set up nerve impulses.

(b) Semi-circular Ducts. There are three semi-circular ducts arranged in three planes in such a way that each is almost at right angles to the planes of the other two. According to their position, they are named anterior vertical duct, posterior vertical duct and horizontal duct. Each duct opens into the utriculus by both the ends. The anterior and posterior vertical ducts unite by their adjacent ends to form a common duct, the crus commune, which then opens into the utriculus. One (lower) end of each semi-circular duct is enlarged to form an ampulla. The ampulla of the horizontal duct is situated anteriorly close to that of the anterior duct. Each ampulla has a sensory spot for equilibrium. This is called the crista ampullaris. A crista consists of sensory hair cells situated among the columnar supporting cells. The sensory cells of a crista resemble those of a macula in structure and innervation. The "hair" and cilium of each sensory cell are embedded in a dome-shaped gelatinous mass, the cupula. Movements of endolymph stimulate the sensory "hair" cells, thereby setting up a nerve impulse.

(c) Cochlear Duct. The cochlear duct is spirally coiled like a snail's shell, and is sometimes called snail's shell. It comprises 2.50 turns. Part of the bony labyrinth that encloses the cochlear duct is called the cochlear canal. The cochlear duct and the cochlear canal are together referred to as the cochlea. Wall of the cochlear duct is fused with that of the cochlear canal on the sides, but is free above and below. With the result, the cochlea has three longitudinal chambers, called the scalae, inside it upper, middle and lower. These chambers become progressively smaller from the base of cochlea to the apex. The middle chamber is called the scala media. It is filled with endolymph.

The floor of the scala media is called the basilar membrane, and its roof, the Reissner's membrane. The upper and lower chambers of the cochlea are termed the scala vestibuli and the scala tympani respectively. They contain perilymph and both communicate with each other at the distal end of the cochlea by a narrow passage, called the helicotrema. The scala media tapers to a point and ends blindly at the helicotrema. At the proximal end, the scala vestibuli and scala tympani communicate with oval and round window respectively (Fig. 8.19). The basilar membrane bears on it a ribbon-like organ of hearing called the organ of Corti. The latter extends the length of the scala media and consists of five longitudinal rows of receptor cells (photoreceptors) and columnar supporting cells. Each receptor cell bears a tuft of stiff "hair at the free surface and has a synaptic contact with dendrites of neurons at the base. The tips of the "hair" are embedded in a smooth, gelatinous sheet, the tectorial membrane. The supporting cells are of two types: long pillar cells and short phalangeal cells. A tunnel-like, space exists between the pillar cells. Bending of "hair" reduces the membrane potential of sensory cells, causing release of chemical transmitter and initiation of action potential in the sensory nerve. An adequate supply of oxygen is necessary for proper functioning of organ of Corti.

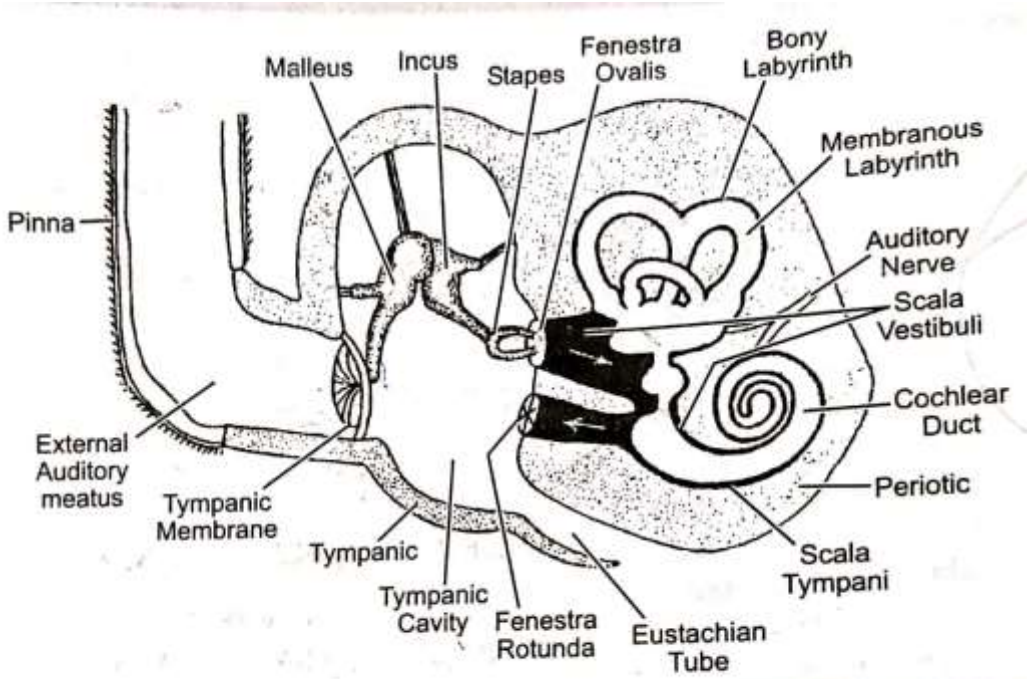

FIGURE 8.19. T.S. Head of rabbit through the left ear.

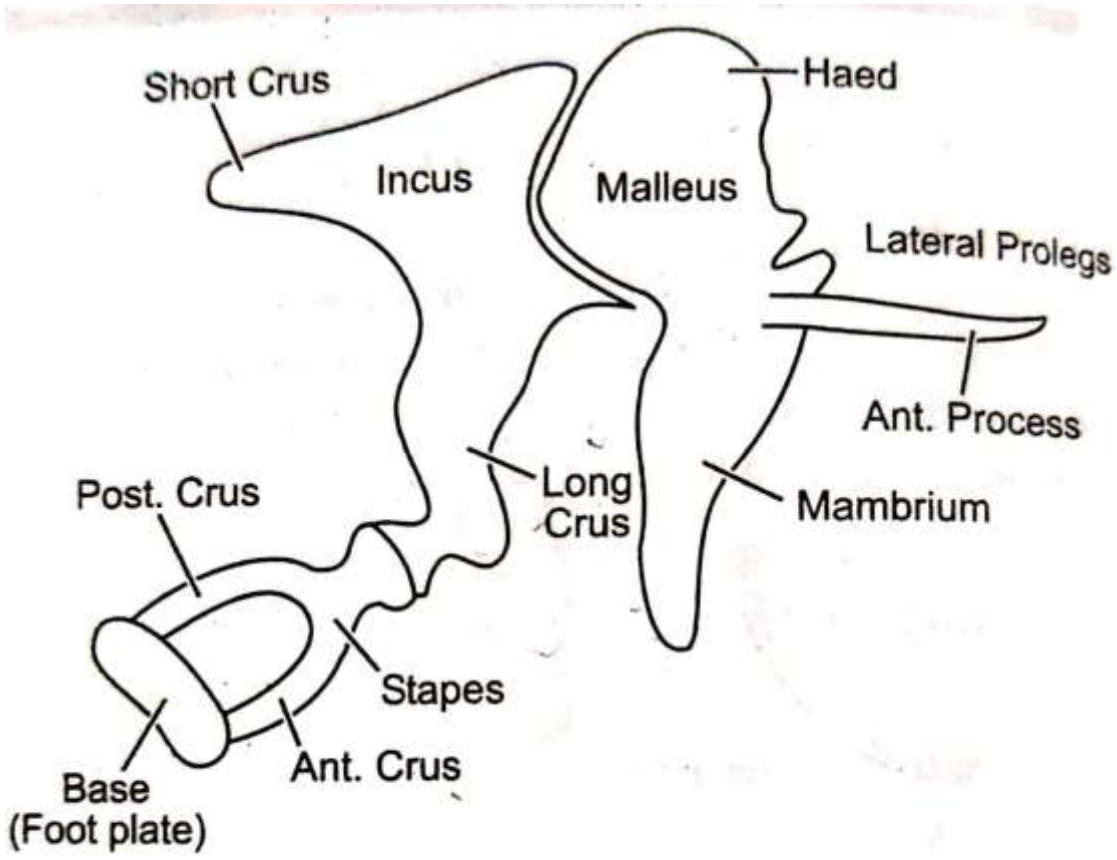

FIGURE 8.20. Ear ossicles of luman ear.

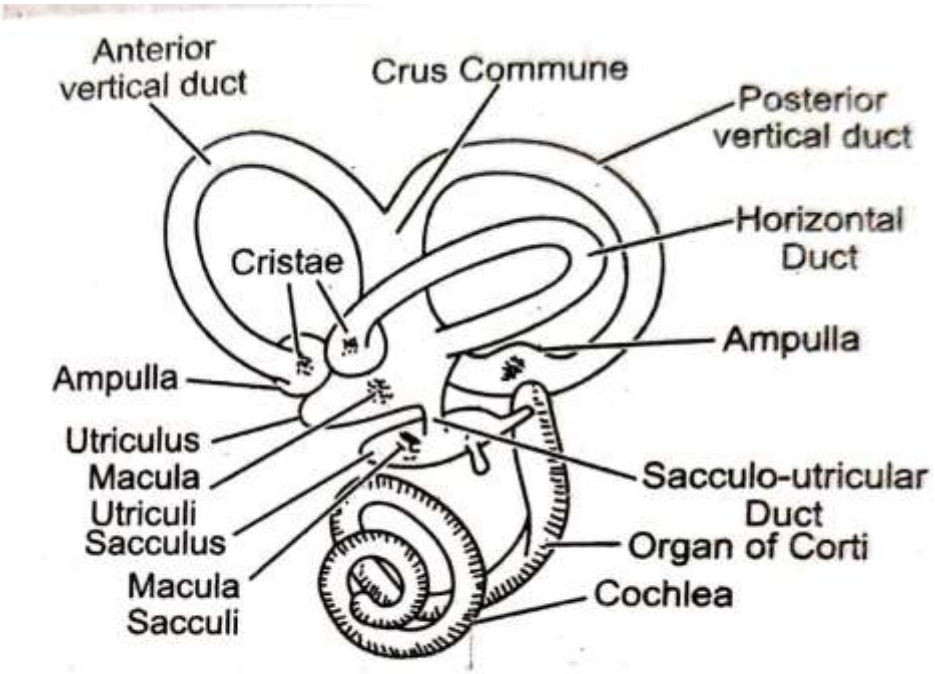

FIGURE 8.21. Internal ear of rabbit.

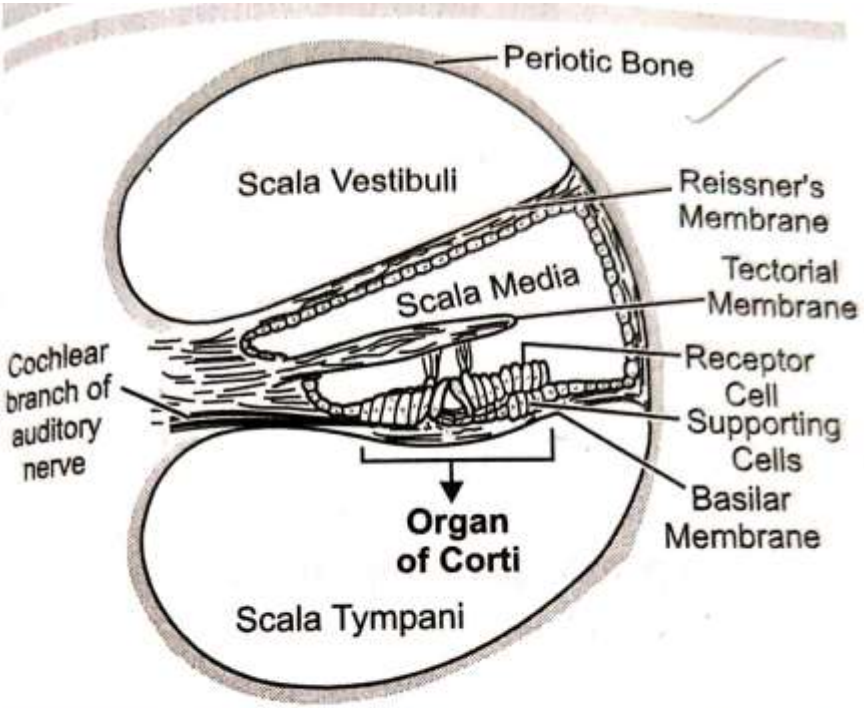

FIGURE 8.24. T.S. Cochlea of rabbit.