Structure of Ear

■ EXTERNAL EAR

Ear consists of three parts, namely external ear, middle ear and internal ear (Fig. 172.1).

External ear is formed by two parts:

1. Auricle or pinna
2. External auditory meatus.

■ AURICLE OR PINNA

Auricle or pinna of the external ear consists of **fibrocartilaginous plate** covered by connective tissue and skin. This plate is characteristically folded and ridged. Skin covering this plate is thin and contains many fine hairs and sebaceous glands. On the posterior surface of auricles, many sweat glands are present.

In many animals, auricle can be moved and turned to locate the source of sound or the auricle can be folded to avoid unwanted sound. But in man, extrinsic and intrinsic muscles of auricles are rudimentary and the movement is not possible. The depression of auricle, which forms the orifice of external auditory meatus, is called **concha.**

■ EXTERNAL AUDITORY MEATUS

External auditory meatus starts from the concha and extends inside as a slightly curved canal, with a length of about 55 mm.

Meatus consists of two parts:

i. Outer cartilaginous part
ii. Inner bony part.

i. *Outer Cartilaginous Part*

Cartilaginous part is the initial part of external auditory meatus and is made up of cartilage. It is covered by thick skin, which contains stiff hairs. These hairs prevent the entry of foreign particles.

Large **sebaceous glands** and **ceruminous glands** are also present in the skin covering this portion. These glands are coiled and tubular in nature and open on the surface of the skin. Columnar epithelial cells of the glands contain brown pigment granules and fat droplets. Secretions of ceruminous glands, sebaceous glands and desquamated epithelial cells form the earwax.

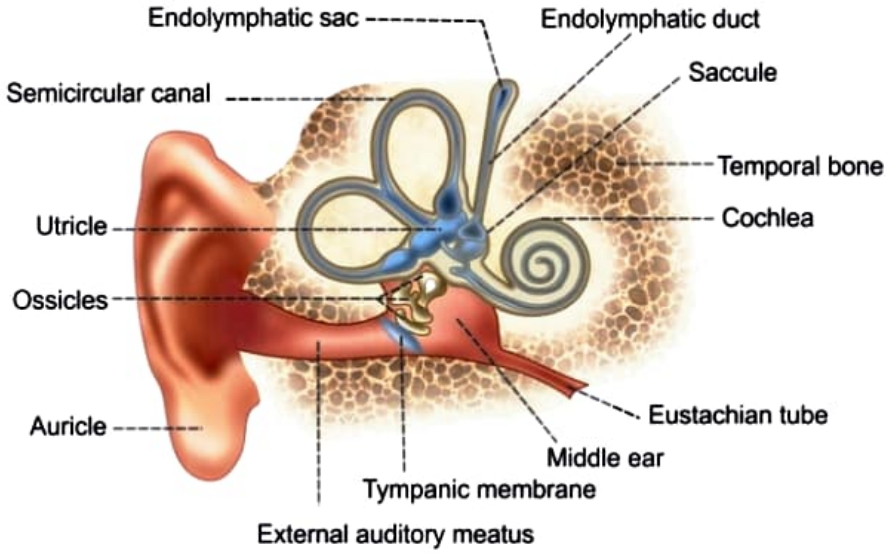

FIGURE 172.1: Diagram showing the structure of ear

ii. *Inner Bony Part*

Inner part of the external auditory meatus is also covered by skin, which adheres closely to periosteum. Only sebaceous glands are present here. Small fine hairs are present on the superior wall of the canal. Skin covering this portion is continuous with cuticular layer of tympanic membrane.

■ MIDDLE EAR

Middle ear or tympanic cavity is a small, narrow, irregular, laterally compressed chamber, situated within the temporal bone. It is also known as **tympanum.** It is separated from external auditory meatus by **tympanic membrane.**

Middle ear consists of the following structures:

1. Auditory ossicles
2. Auditory muscles
3. Eustachian tube.

Tympanic Membrane

Tympanic membrane is a thin, semitransparent membrane, which separates the middle ear from external auditory meatus. Periphery of the membrane is fixed to tympanic sulcus in the surrounding bony ring, by means of fibrocartilage (Fig. 172.2).

Structure of Tympanic Membrane

Tympanic membrane is formed by three layers:

1. Lateral cutaneous layer, which is the continuation of the skin of auditory meatus
2. Intermediate fibrous layer, which contains collagenous fibers
3. Medial mucus layer or tympanic mucosa, which is composed of single layer of cuboidal epithelial cells.

■ AUDITORY OSSICLES

Auditory ossicles are the three miniature bones, which are arranged in the form of a chain, extending across the middle ear from the tympanic membrane to oval window (Fig. 172.2).

Auditory ossicles are:

i. Malleus
ii. Incus
iii. Stapes.

i. *Malleus*

Malleus is otherwise called **hammer.** It has a handle, head and neck. **Hand** is called **manubrium** and it is attached to tympanic membrane. Neck extends from handle to the head. **Head** or **capitulum** articulates with the body of incus.

ii. *Incus*

Incus is also known as **anvil.** It looks like a premolar tooth. Incus has a body, one long process and one short process. Anterior surface of the body articulates with the head of malleus. The **short process** is attached to a ligament. The **long process** runs parallel to handle of malleus. Tip of the long process is like a knob called **lenticular process** and it articulates with the next bone, stapes.

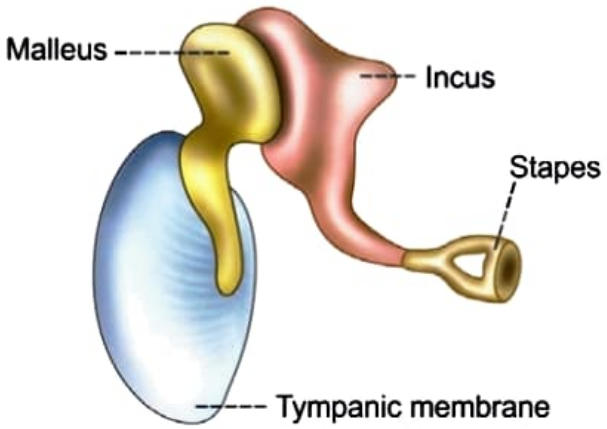

FIGURE 172.2: Tympanic membrane and auditory ossicles

iii. *Stapes*

Stapes is also called **stirrup.** It is the smallest bone in the body. It has a head, neck, anterior crus, posterior crus and a footplate. **Head** articulates with incus. **Footplate** fits into oval window.

■ AUDITORY MUSCLES

Two skeletal muscles are attached to ossicles:

i. Tensor tympani
ii. Stapedius.

i. *Tensor Tympani*

Tensor tympani is larger of the two muscles of tympanic cavity.

Origin, insertion and nerve supply

Tensor tympani arises from cartilaginous portion of eustachian tube (see below), adjacent to great wing of sphenoid bone and osseous canal. Its tendon is inserted on manubrium of malleus, which is in turn attached to tympanic membrane. Thus, the tensor tympani is attached to tympanic membrane through malleus. It is supplied by mandibular division trigeminal nerve.

Function

Tensor tympani muscle pulls and keeps the tympanic membrane stretched or tensed constantly. This constant stretching of tympanic membrane is essential for the transmission of sound waves, which may reach any part of the tympanic membrane. Paralysis of tensor tympani causes hearing impairment.

ii. *Stapedius*

Stapedius is the **smallest skeletal muscle** in human body with a length of just over 1 mm. It lies in a conical bony cavity, on the posterior wall of the tympanic cavity.

Origin, insertion and nerve supply

Stapedius arises from interior pyramid of tympanic cavity. Its tendon is inserted into the posterior surface of neck of stapes. It is supplied by branch of facial nerve.

Function

Stapedius prevents excess movements of stapes. When it contracts, it pulls the neck of stapes backwards and reduces the movement of footplate against the fluid in cochlea. Paralysis of stapedius allows wider range of oscillation of stapes, leading to **hyperreaction** of auditory ossicles to sound vibrations. This condition is called **hyperacusis.** Paralysis of stapedius occurs in the lesion of facial nerve.

Tympanic Reflex

Tympanic reflex is an **attenuation reflex** characterized by involuntary contraction of tensor tympani and stapedius muscles, in response to a loud noise. It has a latent period of 40 to 80 millisecond.

When both the muscles contract, manubrium of malleus moves inward and stapes is pulled outward. These two actions result in stiffness of auditory ossicles, so that the transmission of sound is decreased.

Significance of tympanic reflex

i. Tympanic reflex protects the tympanic membrane from being ruptured by loud sound
ii. It also prevents fixation of footplate of stapes, against oval window, during exposure to loud sound
iii. It helps to protect the cochlea from damaging effects of loud sounds. Contraction of tensor tympani and stapedius during exposure to loud sound develops stiffness of the auditory ossicles so that, the transmission of sound into cochlea is decreased.

■ EUSTACHIAN TUBE

Eustachian tube or the **auditory tube** is the flattened canal extending from the anterior wall of middle ear to nasopharynx. Its upper part is surrounded by the bony wall and the lower part is surrounded by fibrocartilaginous plate.

Eustachian tube connects middle ear with posterior part of nose and forms the passage of air between middle ear and atmosphere. So, the pressure on both sides of tympanic membrane is equalized.

■ INTERNAL EAR

Internal ear or labyrinth is a membranous structure, enclosed by a bony labyrinth in petrous part of temporal bone. It consists the sense organs of hearing and equilibrium. Sense organ for hearing is the cochlea and the sense organ for equilibrium is the vestibular apparatus. Vestibular apparatus is already explained in Chapter 158.

■ COCHLEA

Cochlea is a coiled structure like a snail's shell (cochlea = snail's shell). It consists of two structures:

1. Central conical axis formed by spongy bone called **modiolus**
2. Bony canal or tube, which winds around the modiolus.

In man, the **bony canal** makes two and a half turns, starting from the base of the cochlea and ends at the top (apex) of cochlea. End of the canal is called **cupula.** Base of modiolus forms the bottom of internal auditory meatus, through which cochlear nerve fibers pass and enter the modiolus. Thus, a section through the axis of cochlea reveals the central **bony pillar,** modiolus and **periotic or osseous canal,** which coils around the modiolus.

From modiolus, a bony ridge called **osseous spiral lamina** projects into the canal, winding around modiolus like the thread of a screw. Spiral lamina follows the spiral turns of cochlea and ends at the cupula in a hook-shaped process called **hamulus.**

■ COMPARTMENTS OF COCHLEA

Two membranous partitions extend between the osseous spiral lamina and outer wall of the **spiral canal.** Both the membranes divide the spiral canal of cochlea into three compartments.

Membranes of cochlea:

1. Basilar membrane
2. Vestibular membrane.

1. *Basilar Membrane*

Basilar membrane is a connective tissue membrane. It stretches from the tip of the osseous spiral lamina to tough dense fibrous band called **spiral ligament,** which lines the outer wall of the canal. Basilar membrane is also called **membranous spiral lamina.** Along the basilar membrane are twenty thousand to thirty thousand tiny fibers that are called **basilar fibers.** Each fiber has different size and shape. Fibers near the oval window are short and stiff. While approaching towards **helicotrema** (see below) the basilar fibers gradually become longer and soft.

2. *Vestibular Membrane*

Vestibular membrane is also known as **Reissner membrane** and it is a thin membrane. It is placed obliquely between the upper surface of osseous spiral lamina and upper part of spiral ligament.

Basilar membrane and vestibular membrane divide the spiral canal of cochlea into three compartments called scalae (Fig. 172.3).

Compartments of spiral canal of cochlea:

i. Scala vestibuli
ii. Scala tympani
iii. Scala media.

All the three compartments are filled with fluid. Scala vestibuli and scala tympani contain **perilymph.** Scala media is filled with **endolymph.**

i. *Scala vestibuli*

Scala vestibuli lies above scala media. It arises from **oval window (fenestra vestibuli),** which is closed by the

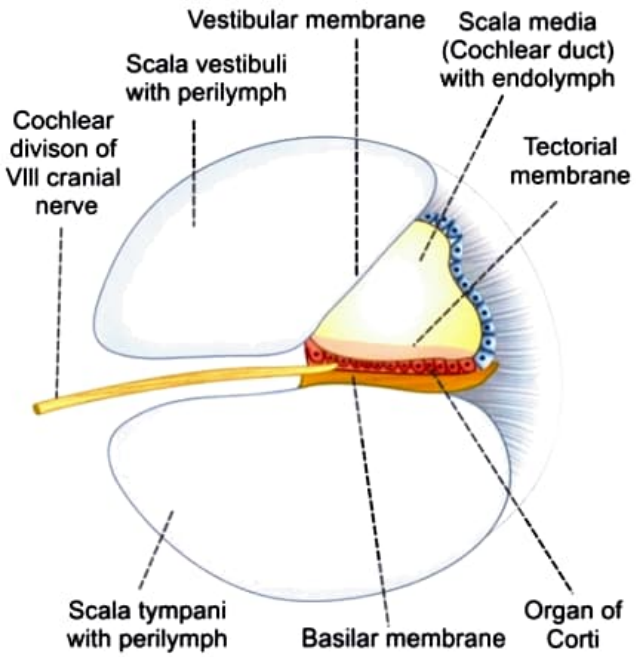

FIGURE 172.3: Cross-section of spiral canal of cochlea

footplate of stapes. It follows the bony canal up to its apex. At the apex, it communicates with the scala tympani through a small canal called **helicotrema.**

ii. *Scala tympani*

Scala tympani lies below scala media. It is parallel to scala vestibuli and ends at the round window. **Round window** is closed by a strong thin membrane known as **secondary tympanic membrane.**

iii. *Scala media*

Scala media is otherwise called **cochlear duct, membranous cochlea** or **otic cochlea.** It is a triangular compartment enclosed by basilar and vestibular membranes. It ends blindly at the apex and at the base of cochlea. A slender **ductus reuniens** arises from the basal end and connects scala media with the saccule of otolith organ.

Scala media is formed by upper, outer and lower walls. Upper wall or vestibular wall is formed by **vestibular membrane.** Outer wall is formed by spiral ligament, which is the thickening of periosteum. Lower wall is called **tympanic wall.** It is formed by **basilar membrane** (membranous spiral lamina) and a part of osseous spiral lamina. Scala media stretches between the tip of osseous spiral lamina and spiral ligament.

Basilar membrane consists of straight unbranched connective tissue fibers, which are called basilar fibers or the auditory fibers. On the upper surface of the basilar membrane, epithelial cells are arranged in the form a special structure called the organ of Corti. It is the sensory part of cochlea.

■ ORGAN OF CORTI

Organ of Corti is the **receptor organ** for hearing. It is the neuroepithelial structure in cochlea (Fig. 172.4).

Situation and Extent

Organ of corti rests upon the lip of osseous spiral lamina and basilar membrane. It extends throughout the cochlear duct, except for a short distance on either end. Roof of the organ of Corti is formed by **gelatinous tectorial membrane.**

Structure

Organ of Corti is made up of sensory elements called **hair cells** and various supporting cells. All the cells of organ of Corti are arranged in order from center towards the periphery of the cochlea.

Cells of organ of Corti:

1. Border cells
2. Inner hair cells
3. Inner phalangeal cells
4. Inner pillar cells
5. Outer pillar cells
6. Outer phalangeal cells
7. Outer hair cells
8. Cells of Hensen
9. Cells of Claudius
10. Tectorial membrane and lamina reticularis.

1. *Border Cells*

Border cells are the slender columnar cells, arranged in a single layer on the tympanic lip along the inner side of inner hair cells. Surfaces of the border cells have **cuticle.**

2. *Inner Hair Cells*

Inner hair cells are flask-shaped cells and are broader than the outer hair cells. Inner hair cells are arranged in a single row and occupy only the upper part of epithelial layer. Rounded base of each cell rests on the adjacent supporting cells called the inner phalangeal cell. Surface of the inner hair cell bears a **cuticular plate** and a number of short stiff hairs, which are called **stereocilia.** Each hair cell has about 100 sterocilia. One of the sterocilia is larger and it is called **kinocilium.** Stereocilia are in contact with the **tectorial membrane.** Inner hair cells and outer hair cells together form the receptor cells. Sensory nerve fibers are distributed around the hair cells. Both inner hair cells and outer hair cells have afferent and efferent nerve fibers (Chapter 173).

3. *Inner Phalangeal Cells*

Inner phalangeal cells are the supporting cells of inner hair cells and are arranged in a row along the inner surface of inner pillar cells. Their bases rest on the basilar membrane. Cuticular plate of cells (formed by the lower portion of cells) look like the finger bones, phalanges.

4 and 5. *Inner and Outer Pillar Cells – Rods of Corti*

Inner and outer pillar cells are called rods of Corti. Each pillar cell has a broader base, an elongated body

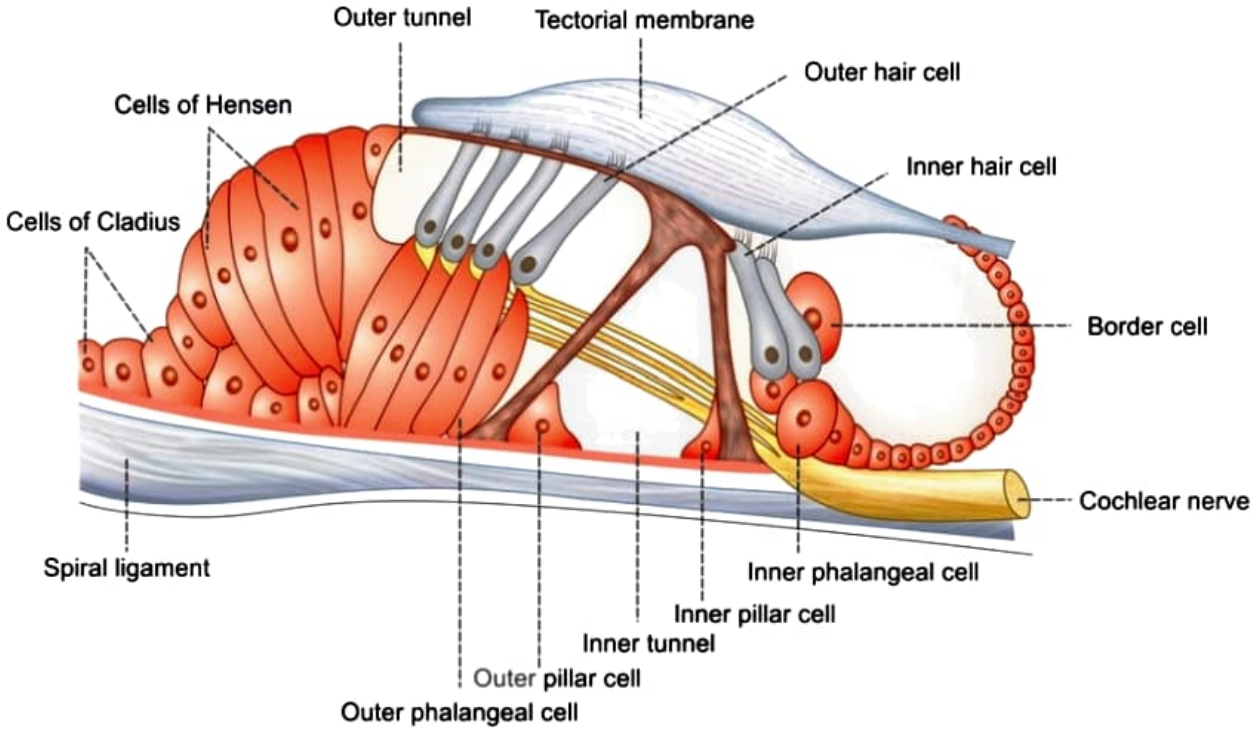

FIGURE 172.4: Organ of Corti

or pillar and a head at the tip of pillar. Bases of inner pillar cells are close to the lip of osseous spiral lamina (tympanic lip), whereas the bases of outer pillar cells are close to basilar membrane. Pillars of inner and outer pillar cells slope towards each other and their heads articulate. Thus, the pillars of cells form series of arches, which enclose a triangular tunnel called **inner tunnel** or **tunnel of Corti.**

6. *Outer Phalangeal Cells*

Outer phalangeal cells or the cells of Deiters are the supporting cells of outer hair cells. Outer phalangeal cell is the tall columnar cell. It sends stiff phalangeal processes upward between the hair cells, to form the part of **lamina reticularis.**

Rows of outer phalangeal cells vary in different regions of cochlear duct like the outer hair cells, i.e. from three to five rows. Between the inner most outer phalangeal cells and outer pillar cells, is a fluid space known as the **space of Nuel.**

7. *Outer Hair Cells*

Outer hair cells are the columnar cells occupying the superficial part of epithelium of organ of Corti. Their bases are supported by outer phalangeal cells. Structure of outer hair cells is similar to that of inner hair cells (see above).

8. *Cells of Hensen*

Cells of Hensen are tall columnar cells forming the outer border cells of organ of Corti. These cells are arranged in several rows on basilar membrane, lateral to outer phalangeal cells. The space between outer phalangeal cells and cells of Hensen is called outer tunnel.

9. *Cells of Claudius*

Cells of Claudius are cuboidal in nature and line the lower surface of external spiral sulcus. In certain areas, some groups of cells are present between the cells of Claudius and basilar membrane. These cells are called Boettcher cells.

10. *Tectorial Membrane and Lamina Reticularis*

Tectorial membrane extends from vestibular lip to the level of cells of Hensen. It forms the roof of organ of Corti. It is in contact with the processes of hair cells. It is assumed that the processes of hair cells are stimulated by the movements of tectorial membrane, in relation to vibrations in endolymph.

Cuticular plates of all the supporting cells collectively form a reticular membrane, which is known as lamina reticularis. It covers the organ of Corti. It looks like a mosaic and has rows of holes, through which the heads of hair cells are inserted.