Chapter

1

Anatomy of Ear

EN1.1: Describe the Anatomy of ear.
AN40.2: Describe and demonstrate the boundaries, contents, relations and functional anatomy of middle ear and auditory tube.
AN40.3: Describe the features of internal ear.

DEVELOPMENT OF EAR

The development of the pinna or the auricle starts on the 38th day of intrauterine life. The pinna develops from the first and second branchial arches. These arches give rise to 6 nodular mesenchymal condensations called **auricular hillocks of His** (Fig. 1.1), which later fuse together to form the auricle. The anatomical development of the auricle is complete by the 20th week of intrauterine life. The tragus and part of the anterior crus of the helix is contributed by the first arch and the rest is contributed by the second arch.

The auricle is initially placed at the level of the lower neck and with development of the mandible it ascends to the side of head at the level of the eyes. The external auditory canal develops from the dorsal portion of the first pharyngeal cleft (Fig. 1.1).

On the 22nd day of intrauterine life, ectodermal thickening appears on the sides of the rhombencephalon, which are called the ***otic placodes*** (Fig. 1.2). These rapidly invaginate to form the **otic vesicle or otocysts**. The ventral part of the otocyst gives rise to the saccule and cochlear duct and the dorsal part of the otocyst forms the utricle, semicircular canal and endolymphatic duct (Fig. 1.3).

The tympanic cavity is derived from the first pharyngeal pouch. On lateral expansion, the pouch comes in contact with the floor of the first pharyngeal cleft (Fig. 1.3). The proximal part of the pouch gives rise to the Eustachian tube and the distal part to the tubotympanic recess. The malleus and incus (from *Meckel's cartilage*) are derived from the first pharyngeal arch. The stapes (from Reichert's cartilage) is derived from the second pharyngeal arch. The stapes footplate is derived from the otic capsule. The ossicles ossify by the 4th month of intrauterine life.* The mastoid antrum** and mastoid air cell system is derived as an extension from the tympanic cavity.

ANATOMY OF EAR

For the purpose of description, the ear is anatomically divided into (Fig. 1.4):
1. External ear
2. Middle ear cleft
3. Inner ear.

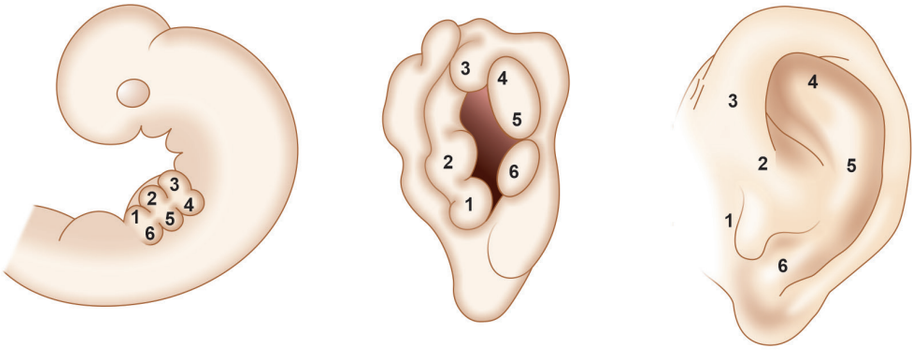
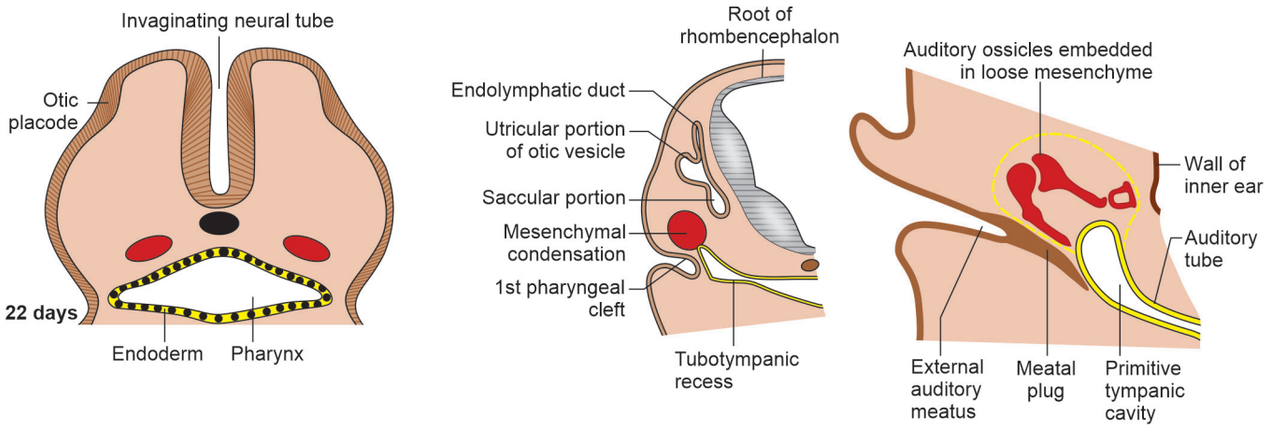


Fig. 1.1: Development of external ear

*Ossicles are the first bones to ossify in human body
**The antrum reaches adult size by birth.



Figs 1.2 and 1.3: Development of middle and inner ear

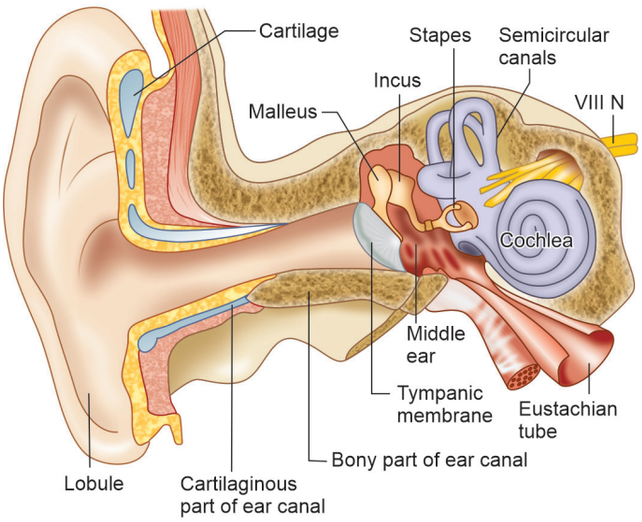


Fig. 1.4: Parts of ear

EXTERNAL EAR

External ear consists of:

1. Pinna or auricle
2. External auditory canal (EAC)
3. Outer layer of tympanic membrane.

AURICLE (PINNA)

Structure: The pinna is the outward projecting part of the external ear, which functions to collect, concentrate the sounds and direct them to the external auditory canal. It is made up of a single piece yellow elastic cartilage framework which is covered with skin. It has several prominences and depressions which are specific for an individual.

The outermost curved rim of pinna is called the **helix**, which might have a prominence called the *Darwin's tubercle*. Parallel to the helix, there is another elevation which is called an **antihelix**. Antihelix superiorly divides into two crura and form the **triangular fossa**. The **scaphoid fossa** lies superior to these crura.

The antihelix surrounds the depression called the **concha**. The concha is divided by the descending limb of the superior portion of the helix into two parts called the **cymba concha** and the **cavum concha**.

Note: The cymba concha anatomically overlies the suprameatal triangle of the temporal bone.

A triangular prominence called the **tragus** lies below the crus of the helix. **Antitragus** lies opposite to the tragus on the antihelix. Below the antitragus lies the **lobule**, which is composed of fibrous and fatty tissue (Fig. 1.5).

Fig. 1.5: Parts of pinna. 1. helix, 2. triangular fossa, 3. antihelix, 4. tragus, 5. cymba concha, 6. cavum concha, 7. antitragus, 8. lobule, 9. supratragal notch, 10. scaphoid fossa

Ligaments: Two extrinsic ligaments connect the auricle to the temporal bone. The anterior extrinsic ligament, runs from the tragus and crus of the helix to the root of the zygomatic arch. The posterior extrinsic ligament runs from the medial surface of the pinna to the mastoid bone. The intrinsic ligaments connect various parts of cartilaginous pinna.

Muscles: Various intrinsic and extrinsic muscles are attached to the perichondrium of the pinna cartilage. There are three extrinsic muscles namely auricularis anterior, superior and posterior. Noise evokes some postauricular myogenic response in these muscles. They are supplied by the posterior auricular branch of the facial nerve. There are six intrinsic muscles which are smaller in size and without much function.

Nerve Supply of Pinna (Fig. 1.6)

Nerve	*Area of pinna supplied*
Greater auricular (C2, C3)	Medial surface and posterior portion of lateral surface
Lesser occipital (C2, C3)	Superior part of medial surface
Auricular branch of X nerve	Concha and antihelix
Auriculotemporal branch of V3	Tragus, crus of helix
Facial nerve	Root of concha

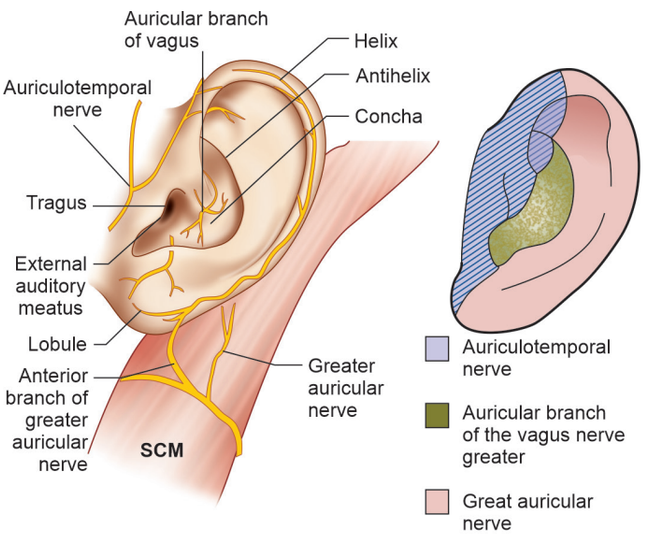


Fig. 1.6: Nerve supply of pinna (*SCM: Sternocleidomastoid muscle*)

Blood supply: The posterior auricular artery is the major artery supplying the medial surface of the pinna. The anterior auricular branch of the superficial temporal artery supplies the lateral surface of pinna, which has the helix, antihelix, triangular fossa, tragus and lobule. The superficial temporal artery is assisted by a small auricular branch from the occipital artery (Fig. 1.7).

Lymphatic drainage: The upper part of the anterior surface of pinna drains into the preauricular nodes and the rest of it drains to the upper deep cervical nodes. The posterior surface and lower part of pinna drains into lymph nodes at the mastoid tip.

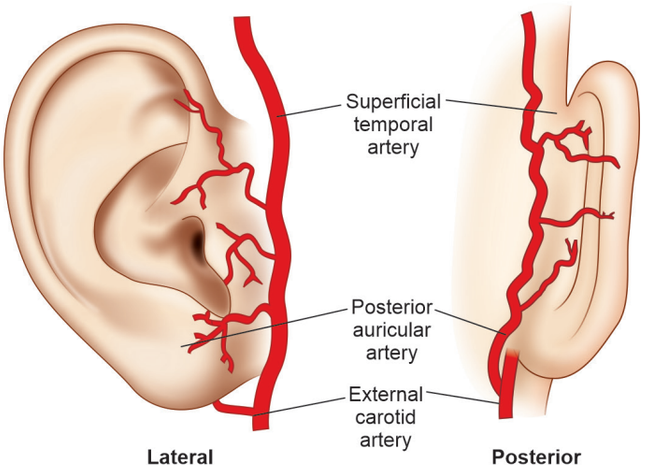


Fig. 1.7: Blood supply of pinna

Surgical considerations

1. The **incisura terminalis** (between the crus of helix and tragus) is an area where the pinna lacks cartilage. The vertical limb of Lempert's incision is made in this area during an endaural approach (Fig. 1.8).
2. The **'conchal stitch'** is placed through the concha while performing the endoscopic ear surgeries. It helps to straighten the external auditory canal, thereby leading to better visualization of tympanic membrane and middle ear.
3. The conchal cartilage is a good graft for attic reconstruction following an atticotomy or as a graft for revision tympanoplasty.
4. The tragal cartilage and perichondrium are ideal grafts for permeatal tympanoplasty.
5. Ear lobule is devoid of any cartilage and hence it is an ideal site for ear piercing. Remember the cosmetic ear piercing through the pinna cartilage is not recommended because it predisposes to keloid formation.

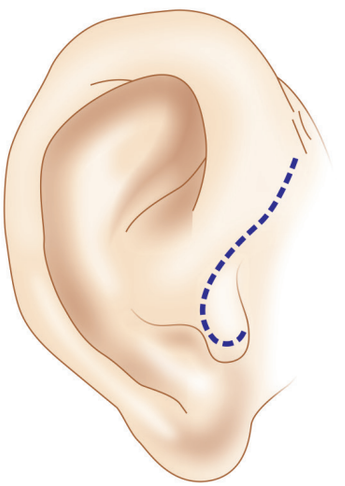


Fig. 1.8: Blue line shows the inter-cartilaginous limb of endaural incision (Lempert's incision)

EXTERNAL AUDITORY CANAL (EAC)

External auditory canal extends from the concha to the tympanic membrane. Its length is 24 mm, of which lateral 8 mm (1/3rd) is cartilaginous and medial 16 mm (2/3rd) is bony. The direction of the cartilaginous part in adults is downward, inward and forwards. Therefore, on pulling the pinna *upwards and backwards* the canal can be straightened for visualization of the tympanic membrane. In neonates the bony EAC is not developed, therefore it is more horizontal. Hence, gentle *downward and backward* movement of the pinna is required to visualise the tympanic membrane.

The bony cartilaginous junction of EAC has natural openings called **fissures of Santorini**, which form a communication for the infections and tumours to spread to and from the parotid gland.

The bony EAC has two suture lines, namely the **tympanosquamous suture** anteriorly and **tympanomastoid suture** posteriorly. These are difficult areas for tympanomeatal flap elevation during surgery because the periosteum is strongly adhered at the suture lines.

There are two constrictions in EAC: First constriction is at the bony-cartilaginous junction and the second constriction at a point 5 mm from the tympanic membrane, which is formed due to the prominence of the anterior canal wall, and is called the **isthmus**. This is the narrowest portion of the EAC. Medial to the isthmus is the **anterior recess** which is a difficult area to access clinically and is a common site for foreign body impaction.

The EAC is lined by keratinizing squamous epithelium. The skin of the cartilage shows ceruminous and sebaceous glands. The ceruminous glands are modified apocrine glands which produce watery white secretions in the roots of the hair follicles. The sebaceous glands produce oily secretion called *sebum*.

Wax is the combined secretions of ceruminous glands and sebaceous glands along with desquamated epithelial cells. It is either of dry or wet type, which is decided by Mendelian traits. The wet wax gene being the dominant gene phenotypically. The wet wax is yellowish brown in colour, sticky and wet and on the other hand the dry wax is yellowish or grey in colour, dry and flaky. Wax contains lysozymes, amino acids, fatty acids and immunoglobulins, which have some bactericidal effects.

The **arterial supply** to the EAC is via the auricular branch of the superficial temporal artery and posterior auricular artery. Deep auricular branches of the first part of the maxillary artery also supply the EAC.

The **nerve supply** of EAC is from the trigeminal, facial, glossopharyngeal and vagus nerves (Fig. 1.9). The floor of the EAC is supplied by auricular branch of the vagus nerve which is also called the **Arnold's nerve**. Stimulation of this nerve while cleaning the EAC can produce a cough reflex. Small part of the posterosuperior canal wall is supplied by the sensory branch of the facial nerve*. The anterior part of the EAC is supplied by the auriculotemporal branch of the mandibular division of the trigeminal nerve.

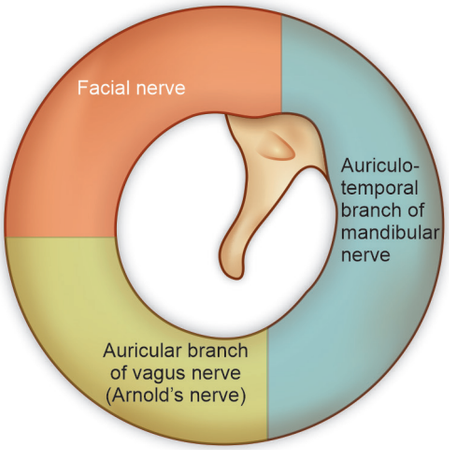


Fig. 1.9: Nerve supply of the external auditory canal

*__Note:__ In cases of vestibular schwannoma there occurs anaesthesia of the posterosuperior canal wall due to involvement of facial nerve at internal acoustic meatus and is called ***Hitselberger sign.***

MIDDLE EAR CLEFT

It consists of the tympanic cavity or middle ear space, Eustachian tube and the mastoid air cell system.

The middle ear is connected anteriorly to the Eustachian tube and posteriorly to the mastoid air cell system. It is laterally bounded by the tympanic membrane and medially by the osseous labyrinth.

EN4.4: Demonstrate the correct technique to hold visualize and assess the mobility of the tympanic membrane and interpret and diagrammatically represent the findings.

TYMPANIC MEMBRANE

It lies at the medial end of the external auditory canal. It is oval in shape and positioned at an angle of 55 degree with the floor of the external auditory canal. The handle of the malleus draws the tympanic membrane slightly inward, producing a flattened cone shape. Its longest diameter is from posterosuperior to anteroinferior and is 9–10 mm, while the diameter perpendicular to this and is 8–9 mm.

The peripheral part of the tympanic membrane is thick and fibrocartilaginous in nature and is called **tympanic annulus**. The annulus sits in the groove in the tympanic bone, which is called the tympanic sulcus. This sulcus is deficient superiorly where it forms the **notch of Rivinus**. The anterior and posterior malleal folds arise from the tympanic sulcus at the junction of the notch of Rivinus and are attached to the lateral process of the malleus.

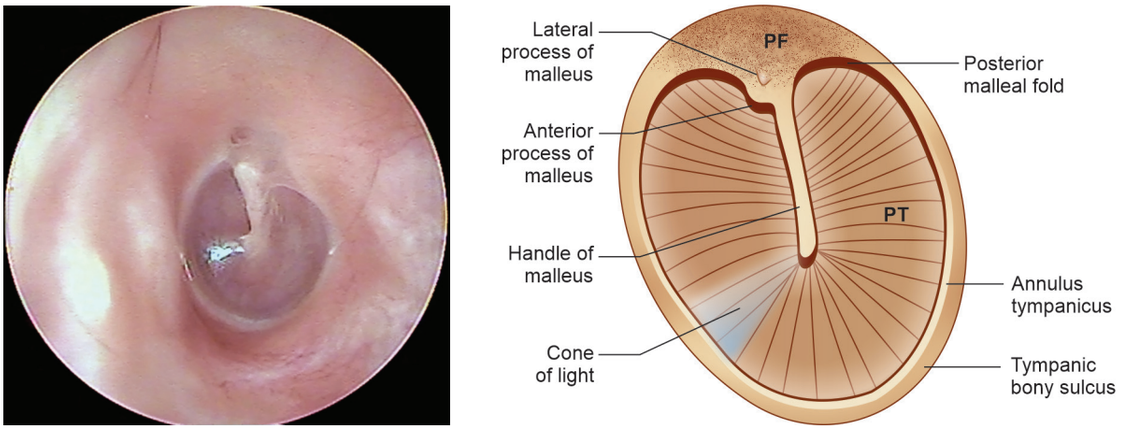


Fig. 1.10: Structure of tympanic membrane

The tympanic membrane can be divided into two parts, **pars tensa** and **pars flaccida**. The area between malleolar folds and the notch of Rivinus, is the pars flaccida. The rest of the tympanic membrane is called the pars tensa. The tip of the malleus attaches to the centre of the membrane, which is called the *umbo* (Fig. 1.10). The tympanic membrane has three layers: outer epithelial, middle fibrous (lamina propria) and inner mucosal. In pars tensa, the fibrous layer has radially oriented outer fibres, circular, parabolic and transversely arranged deeper fibres. These well-arranged fibres give rigidity to this part of the tympanic membrane and therefore is called pars tensa. In case of pars flaccida, the fibrous layer is less marked and the arrangement of the fibres is also random, hence the term pars flaccida.

Blood supply

- Epidermal surface of the tympanic membrane is supplied by the deep auricular branch of the maxillary artery.
- Mucosal surface of the membrane is supplied by the anterior tympanic branch of maxillary and stylomastoid branch of the posterior auricular artery.

Nerve supply: It is supplied by the branches of auriculotemporal nerve (V3), auricular branch of vagus and tympanic branches of IX nerve.

MIDDLE EAR SPACE

The tympanic cavity or the middle ear space is classically divided into 3 parts but with the advent of the ear endoscopes it has now been divided into 5 parts (Fig. 1.11).

The parts of the tympanic cavity are:

1. Epitympanum
2. Mesotympanum
3. Hypotympanum
4. Retrotympanum
5. Protympanum.

- The epitympanum or attic is the portion of the middle ear above the level of malleal folds.

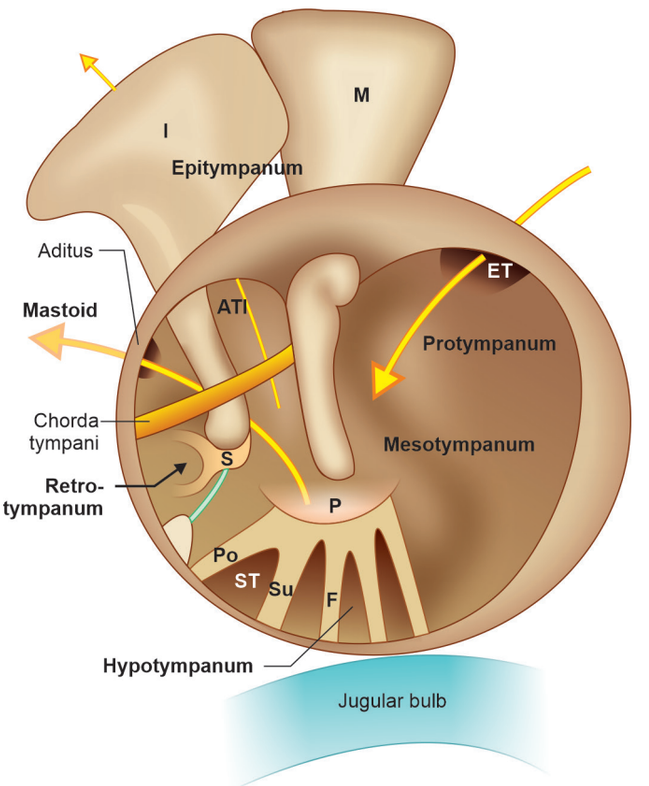


Fig. 1.11: Parts of the middle ear cavity and the ventilation pathways of middle ear cleft (*ATI: Anterior tympanic isthmus; I: Incus, M: Malleus; S: Stapes; ET: Eustachian tube; C: Chorda tympani; ST: Sinus tympani; P: Promontory; F: Funiculus; Su: Subiculum; Po: Ponticulus; J: Jugular bulb*)

- The mesotympanum lies below the level of malleal folds and is separated from the epitympanum by a series of mucosal folds and membranes. It is part of the tympanic cavity which corresponds to the pars tensa of the tympanic membrane. The mesotympanum is part of the tympanic cavity which can be seen via the external auditory canal by otoscope or microscope.
- The hypotympanum is the portion of the middle ear cavity below the level of tympanic sulcus.

- The retrotympanum includes the posterior wall and posteromedial portion of the tympanic cavity which can be seen only by using angled endoscopes via the large perforation or after elevation of tympanomeatal flap. This part of the middle ear cavity can sometimes be visualised through a large pars tensa perforation).
- The protympanum is the part anterior to the promontory which joins with the tympanic portion of the Eustachian tube. Recent studies, physiologically consider protympanum to be lateral most part of the Eustachian tube.

WALLS OF THE TYMPANIC CAVITY

The tympanic cavity resembles a cube with six sides.

1. **Lateral wall:** It is formed by the tympanic membrane and outer attic/epitympanic wall (scutum). The scutum erosion is a sign squamosal type of chronic otitis media.
2. **Roof:** The roof of the epitympanum is formed by the bony plate called the *tegmen tympani*. This separates the middle ear from the middle cranial fossa. **Cog or spur** is a bony projection from the tegmen which divides the epitympanum into a smaller anterior epitympanic space (AES) and the larger posterior epitympanic space (PES). The anterior epitympanic space may be the site for residual cholesteatoma (one of the *hidden areas* of microscopic ear surgery) (Fig. 1.12).
3. **Floor:** The floor separates the hypotympanum from the dome of the jugular bulb. It may sometimes be absent leading to dehiscent jugular bulb, which can increase risk of jugular bulb injury at the time of middle ear surgery (Fig. 1.13).
4. **Anterior wall:** The anterior wall is narrow because of convergence of the medial and the lateral walls anteriorly. The lower 1/3rd of the anterior wall is separated from the carotid artery by a thin plate. The

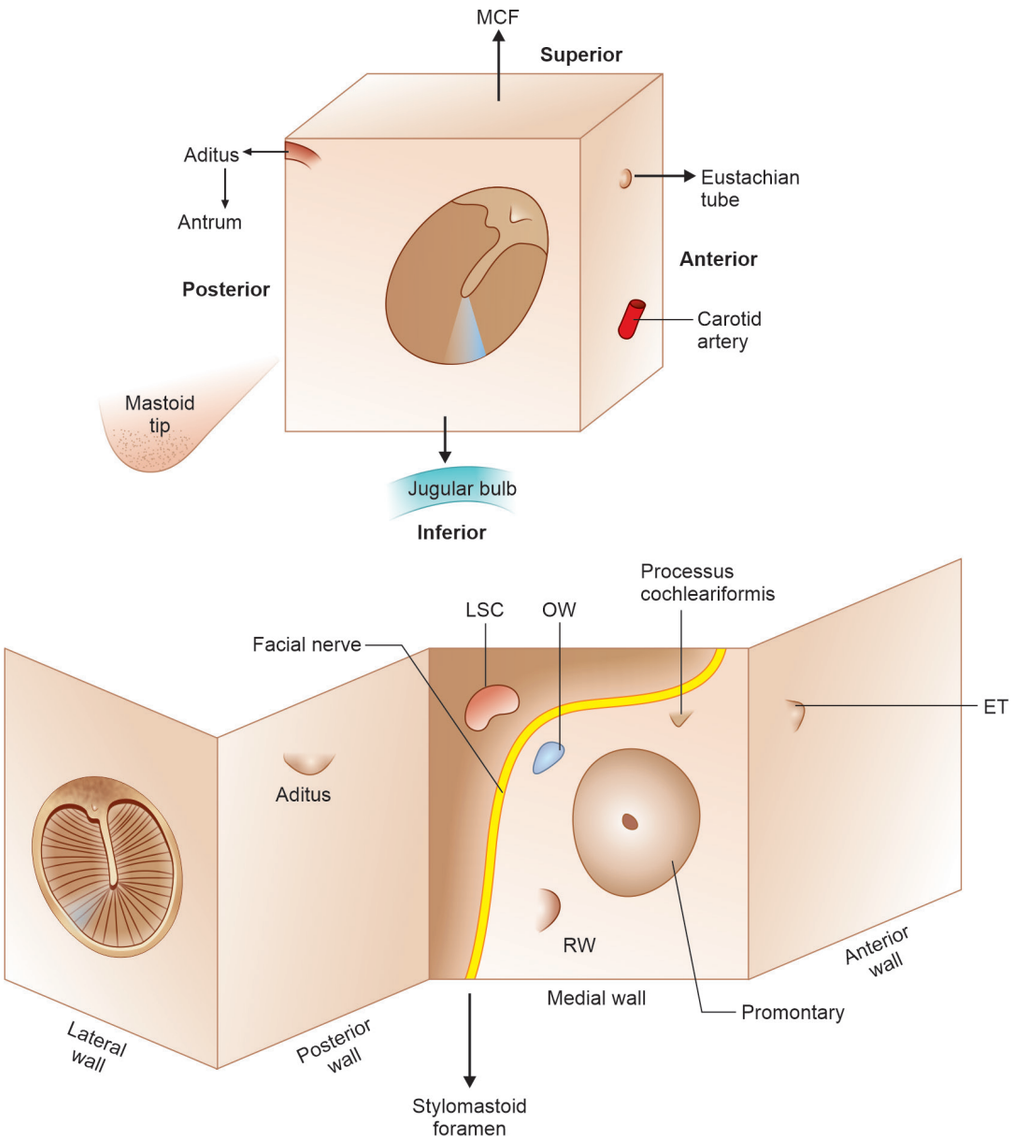


Fig. 1.12: Relation of middle ear with surrounding important structures

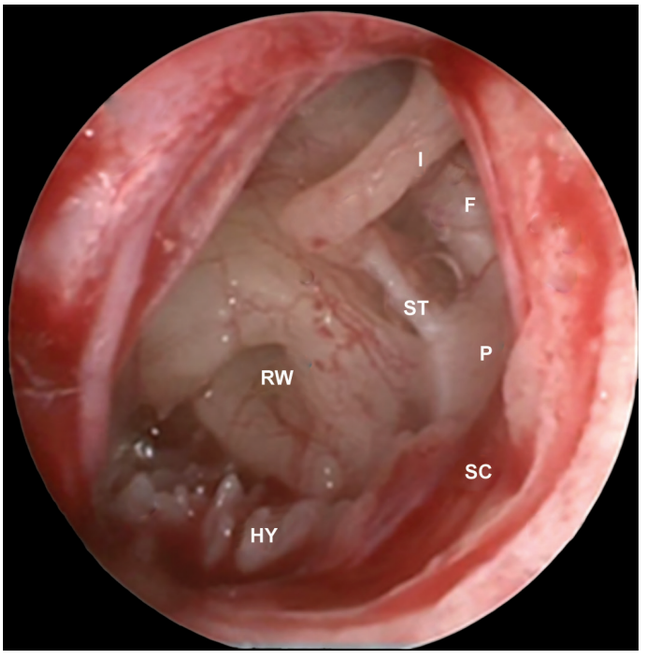


Fig. 1.13: Endoscopic view of hypotympanic cells and floor
I: Incus; ST: Stapedial tendon; F: Facial nerve; P: Pyramid; SC: Styloid complex; HY: Hypotympanic cells; RW: Round window

middle part of the anterior wall has the Eustachian tube orifice. The canal for the tensor tympani muscle lies above the Eustachian tube orifice.

5. **Medial wall:** It shows a rounded bulge of the basal turn of the cochlea called **promontory**. It has numerous grooves for the nerves of the tympanic plexus derived from the glossopharyngeal nerve and the sympathetic fibers along the carotid artery.

   Above and behind the promontory is the **oval window** niche which has a kidney shape. It is closed by the footplate of the stapes. Its average size is 3.25 mm in length × 1.75 mm in width.

   A triangular niche called the **round window** lies inferior and posterior to the oval window. **Subiculum** is a bony ridge, which extends posteriorly from the round window, outward to the styloid eminence region. Another bony ridge called the **ponticulus** extends from the pyramidal process towards the promontory. Ponticulus lies above the subiculum and area between the two is called the **sinus tympani**. **Funiculus** ('meaning borderline') is a bony ridge extending from the promontory to the jugular dome, which separates the retrotympanum from the hypotympanum (Fig. 1.14).

   The bony canal of facial nerve which is also called as **fallopian canal** runs above the promontory and oval window from anterior to posterior direction. Anteroinferior to the first genu of the facial nerve, the medial wall of the middle ear is marked by a bony projection called as **processus cochleariformis**. The tendon of the tensor tympani muscle takes a turn here

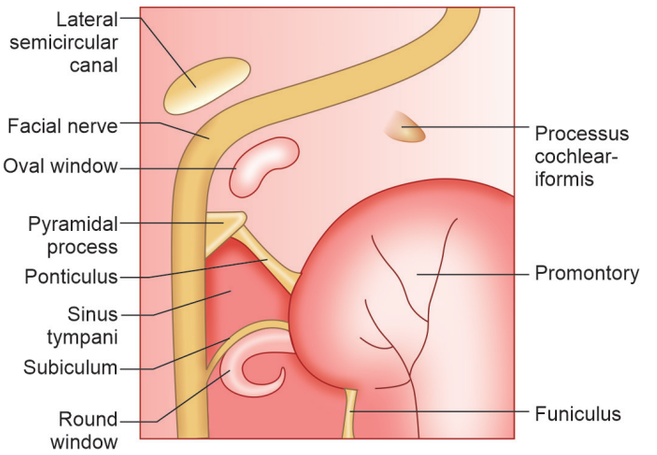


Fig. 1.14: Structures over the medial wall

and gets inserted on the medial aspect of the neck of the malleus. Posteriorly, behind the oval window the nerve turns inferiorly and progresses in the posterior wall of the tympanic cavity.

6. **Posterior wall:** The superior aspect of the posterior wall of the middle ear cavity communicates with the mastoid air cell system through an opening called the **aditus.** Just below the aditus lies the **fossa incudis**, which lodges the short process of incus. Just below the fossa incudis, the posterior wall has a bony projection called **pyramid**. It gives rise to the tendon of the stapedius muscle.

Facial recess is a triangular space bounded by the facial nerve medially, chorda tympani laterally and fossa incudis superiorly. This recess is utilized for the **posterior tympanotomy approach** to the middle ear especially retrotympanum (Fig. 1.15).

Sinus tympani is the posterior extension of the mesotympanum into the posterior canal wall. It is bounded by ponticulus superiorly and subiculum inferiorly. It lies medial to the facial nerve and can be deep up to 9 mm. It is one of the hidden areas and a common sites for the residual disease in cholesteatoma surgery. It can be best visualised by the use of angled endoscopes.

Contents

Ossicles

1. **Malleus** is the most lateral and the largest ossicle. It resembles a 'hammer'. It has a head, neck and handle or manubrium. The head of malleus articulates with the body of the incus in the epitympanum. Below the neck there are two processes called the anterior and lateral process. The anterior and posterior malleal folds which arise from the annulus tympanicus, are attached to the lateral process of malleus. The upper part of the manubrium receives the tendon of tensor tympani muscle (Fig. 1.16).

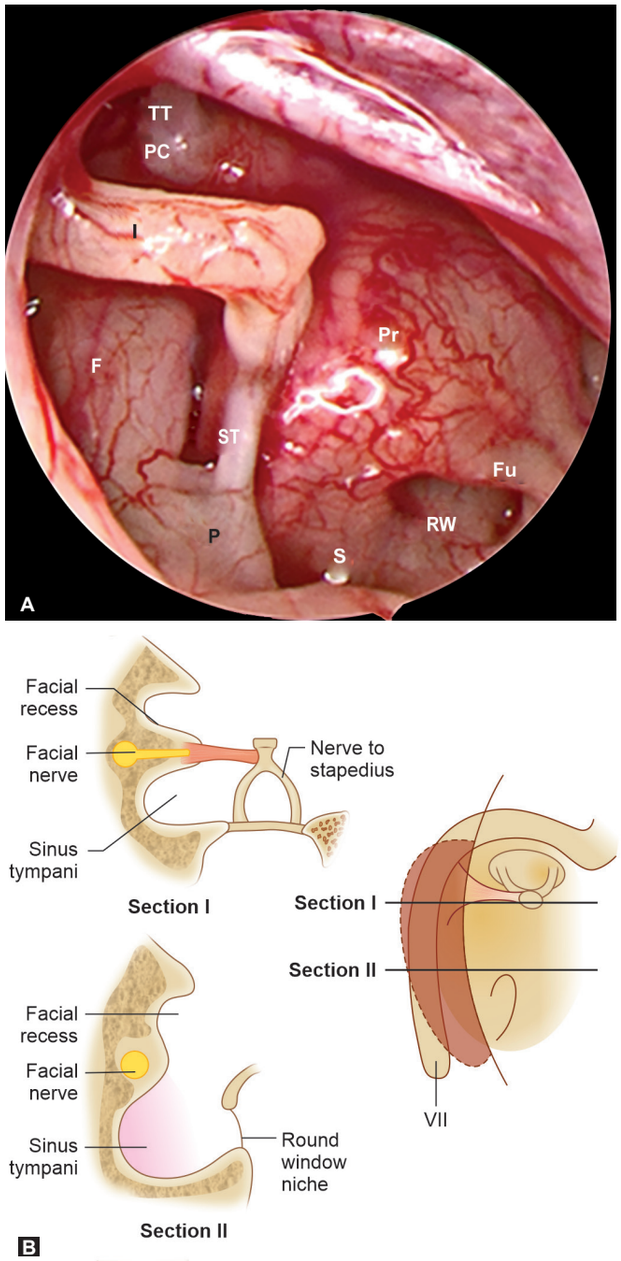


Fig. 1.15: Relationship of facial recess, facial nerve and sinus tympani. (A) Endoscopic view; (B) Diagrammatic representation
F: Facial nerve; P: Pyramid; RW: Round window; PR: Promontory; I: Incus; ST: Sinus tympani; PC: Processus cochleariformis; FI: Funiculus; S: Subiculum

2. **Incus** resembles an 'anvil'. It has a body, short process and long process. The long process has a slender lenticular process at its end, to which articulates the stapes head. The lenticular process is sometimes called the *fourth ossicle* or a sesamoid bone (Fig. 1.17).
3. **Stapes** resemble a 'stirrup'. It has a head, neck, anterior and posterior crura and the footplate. The stapedial tendon is attached to the posterior part of the neck and posterior part of posterior crura. The dimensions of the foot plate are 3 mm × 1.4 mm. The footplate is surrounded by the annular ligament (Figs 1.18 and 1.19).

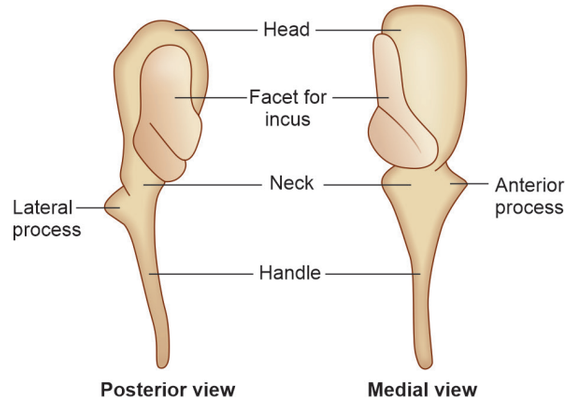


Fig. 1.16: Parts of malleus

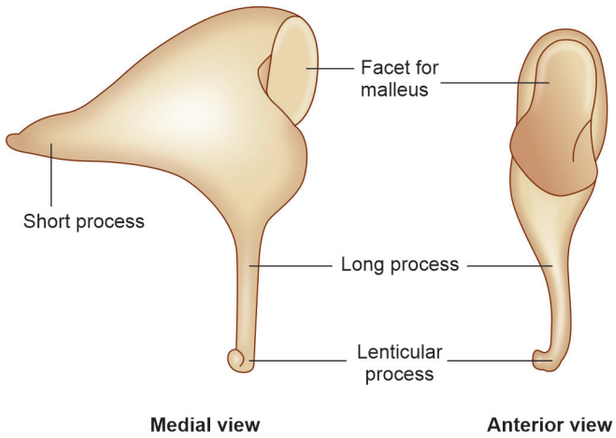


Fig. 1.17: Parts of incus

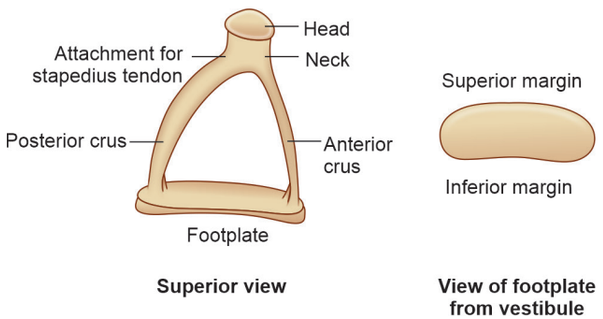


Fig. 1.18: Parts of stapes

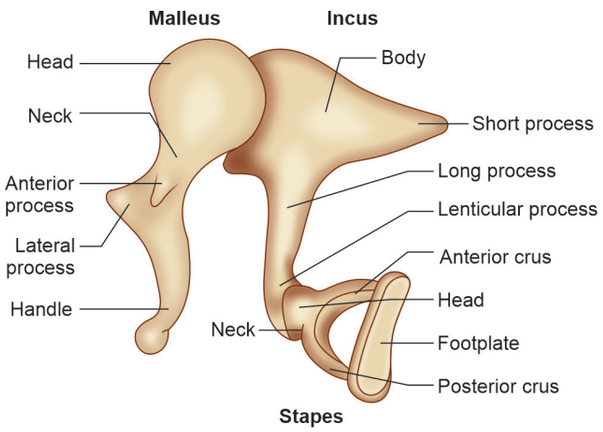


Fig. 1.19: Ossicular chain

MASTOID AIR CELL SYSTEM

The mastoid air cell system causes the pneumatization of the bony cortex of the mastoid bone. The pneumatization of mastoid is variable and is of three types:

1. *Cellular type or well pneumatized*: It has well-developed mastoid air cells with thin intervening septi (Fig. 1.20).
2. *Diploic*: There are few air cells with thick septa in-between.
3. *Sclerotic or acellular*: There is lack of pneumatization; therefore, no cells are seen apart from mastoid antrum. The mastoid antrum is always present though it may be contracted in size. A **'contracted antrum'** usually associated with low-lying dura and forwardly placed sigmoid sinus (Fig. 1.21).

There are various groups of air cells found in the mastoid and have been named according to their location:

Mastoid antrum*: It is the largest mastoid air cell and communicates with the middle air directly via the aditus. It is present at the depth of 1.5 mm from the mastoid cortex externally. It is a surface marked by the **suprameatal triangle (McEwen's triangle).** The volume of the antrum is approximately 2 ml. Its roof is formed by the *tegmen antri* (which separates it from the middle cranial fossa) and medial wall relates to lateral and posterior semicircular canals. While performing mastoidectomy, sometimes Korner's septum is encountered which gives a false impression of reaching the antrum but the actual antrum is still deeper and is found only after its removal.*

Boundaries of the Supramental Triangle (Fig. 1.22)

Anteriorly: The posterosuperior border of the bony external auditory canal along with the suprameatal spine of Henle.

Superiorly: The supramastoid crest or superior temporal line.

Posteriorly: A vertical line drawn tangent to the posterior margin of the external auditory canal.

Various Cells in the Mastoid Air Cell System

1. Periantral cell
2. Tegmen cells
3. Perisinus cells
4. Retrofacial cells
5. Perilabrynthine cells
6. Peritubal cells
7. Tip cells
8. Marginal cells
9. Zygomatic cells
10. Squamosal cells.

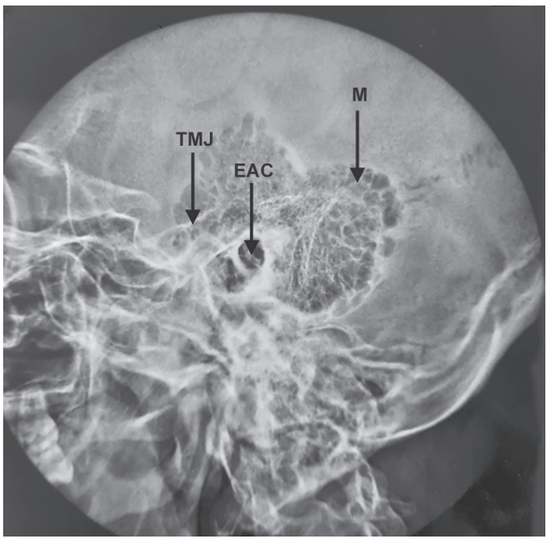


Fig. 1.20: X-ray mastoid—well pneumatized mastoid

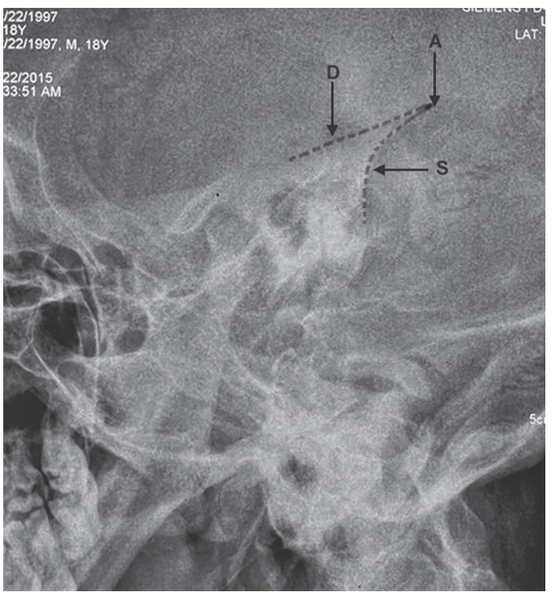


Fig. 1.21: X-ray mastoid—sclerosed mastoid
(EAC: External auditory canal; M: Mastoid; TMJ: Temporomandibular joint; D: Dural plate; S: Sinus plate; A: Sinodural angle)

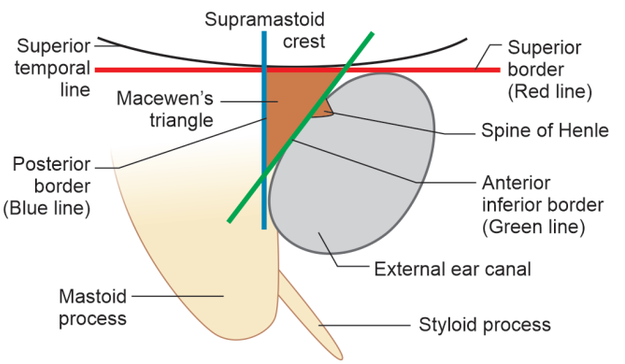


Fig. 1.22: Boundaries of the suprameatal triangle

**Korner's septum* is formed due to the persistence of petrosquamosal lamina. This bony lamina is seen during embryological stages at the junction of saccus superior (mastoid pneumatization) with saccus medius (petrous pneumatization). The persistence of this bony lamina forms the Korner's septum.

Mucosa of the Middle Ear Cleft

The middle ear cavity is lined by ciliated columnar epithelium in the anterior, inferior parts and cuboidal epithelium in the posterior part. The epitympanum and the mastoid air cell system are lined by flat non-ciliated epithelium without goblet cells and mucous glands. The lining of the nasopharynx is continuous with the middle ear cleft. The middle ear mucosa also covers the ossicles, muscles, nerves and ligaments in a manner similar to the peritoneum lining the abdominal viscera. Thus it forms various mucosal folds connecting the middle ear structures. The **epitympanic diaphragm** separates the epitympanum from mesotympanum. The ventilation of the epitympanum comes from the mesotympanum is via two openings called—anterior tympanic isthmus (ATI) and posterior tympanic isthmus (PTI).

The Eustachian tube is lined by ciliated epithelium near the nasopharyngeal end, pseudostratified columnar in the middle and columnar with mucous glands near the middle ear end.

Tympanic Plexus

The tympanic plexus is formed by the tympanic branch of the glossopharyngeal nerve **(Jacobson's nerve)** and the branches from the sympathetic plexus around the internal carotid artery. The plexus provides branches to the tympanic membrane and mucosal lining of the middle ear cleft.

Blood Supply of Middle Ear Cleft

The main blood supply of the middle ear cleft is derived from branches of the maxillary artery with some contributions from the internal carotid artery.

Lymphatic Drainage of Middle Ear

Middle ear and Eustachian tube drain into the retropharyngeal and level V lymph nodes.

> ***Note:*** The inner ear does not have lymphatics.

INNER EAR (LABYRINTH)

It has mainly two parts, namely the bony and membranous labyrinth. The bony labyrinth houses the membranous labyrinth containing the sensory portion of cochlea and vestibular structures.

Bony Labyrinth

It is the dense bony shell surrounding the vestibule, the semicircular canals and the cochlea.

The **vestibule** is the central portion of the bony labyrinth, which lies between the middle ear and the internal auditory meatus. It is 5 mm long, 5 mm high and 3 mm deep. **Fenestra vestibuli** is an opening on the lateral wall of vestibule, which is closed by the footplate of stapes.

The posterior wall of the vestibule has the five openings of the semicircular canals. The anterior wall of the vestibule contains the elliptical opening for the scala vestibuli of the cochlea. On the medial wall, anteriorly is the spherical recess for **saccule** from where starts the inferior vestibular nerve. Behind the saccule is the ridge called vestibular crest, lower end of which has the cochlear nerve fibres. Above and behind the crest is the elliptical recess for the **utricle**. The vestibular aqueduct opens below the elliptical recess. The aqueduct passes through the temporal bone to open into the posterior cranial fossa.

The semicircular canals (SCCs) are three in number—superior, posterior and lateral SCCs. Situated behind and above the vestibule, each SCC forms two-third turns of a circle with a diameter 0.8 mm. One end of each canal is dilated to form the **ampulla**. Each ampulla contains the vestibular sensory epithelium. Each ampullated end opens independently into the vestibule.

The non-ampullated ends of the superior and posterior SCC join to form the **crus commune**. The non-ampullary end of the lateral SCC opens into the vestibule independently below the crus commune. The lateral SCC bulges into the posteromedial wall of epitympanum. The apex of superior SCC lies close to the floor of the middle cranial fossa and the petrous bone over it is called the *arcuate eminence* and is important landmark during middle cranial fossa surgeries.

The cochlea is placed anterior to the vestibule and appears like a snail shell having approximately *two and half turns*. The cochlea coils about a central cone called the *modiolus*, tapering from the base to the apex.

The apex of the cochlea points laterally and forwards positioned at the upper part of the medial wall of the tympanic cavity. The basal turn of the cochlea forms the bulge of **promontory**. A thin bone arises from a modiolus spiral upwards in the lumen of cochlea as the spiral bony lamina. The membranous spiral lamina arises from this thin bone and divides the cochlea into *scala vestibuli*, *scala tympani* and *scala media* as part of membranous cochlea (Fig. 1.23).

The scala tympani is a blind tube having **fenestra cochleae** at its base, which is called *round window* and is closed by secondary tympanic membrane. It is also connected with the subarachnoid space through the *aqueduct of cochlea*. The scala vestibuli is closed at the oval window by the footplate of the stapes. The scala tympani and vestibule are both filled with perilymph and have communication with each other at the apex of cochlea called the *helicotrema*.

Membranous Labyrinth

It consists of a series of sacs filled with endolymph. It consists of utricle, saccule, cochlear duct (scala media) and semicircular canals.

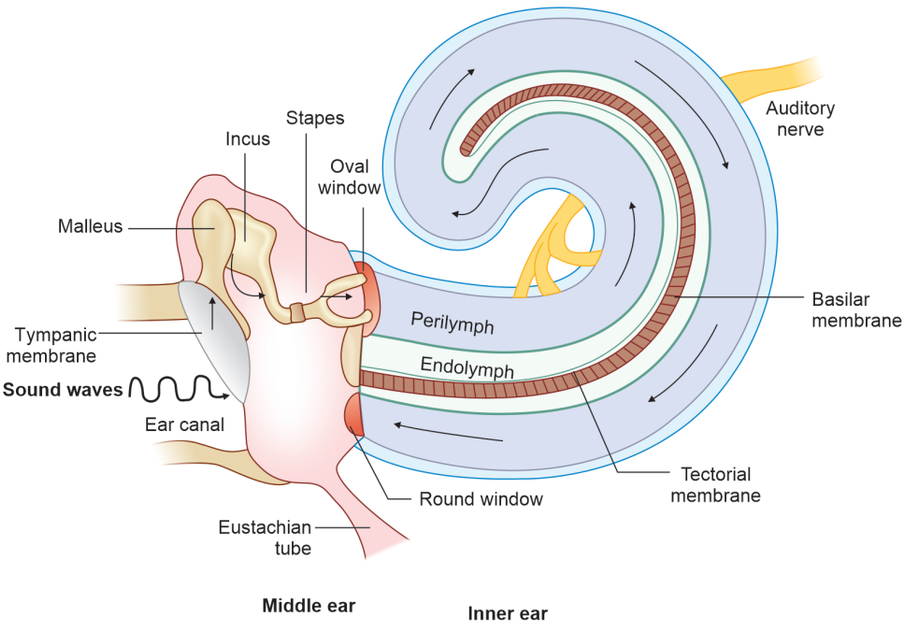


Fig. 1.23: Structure of cochlea

Scala Media (Cochlear Duct)

The cochlear duct is a tube within the bony cochlea. Its average length is around 34 mm. It is triangular in section and has three walls:

1. Basilar membrane which supports the organ of Corti.
2. Reissner's membrane which separates it from scala vestibuli.
3. Stria vascularis contains the vascular epithelium which contributes to the secretion of the endolymph.

Organ of Corti

On the floor of the cochlear duct, two ridges, the upper ridge supports the tectorial membrane and the lower ridge giving rise to membranous spiral lamina with fibres of acoustic nerve going to the organ of Corti.

The membranous spiral lamina has three layers:

1. Flattened epithelium of scala tympani (below).
2. Middle fibrous layer
3. Upper surface of the organ of Corti.

The organ of Corti is a complex arrangement of auditory sensory cells and supporting cells sitting on the basilar membrane. The parts of the organ of Corti are (Fig. 1.24):

1. **Sensory hair cells:** These cells have clusters of fine filaments projecting from the upper surface, called stereocilia. They are distinctively of two types:

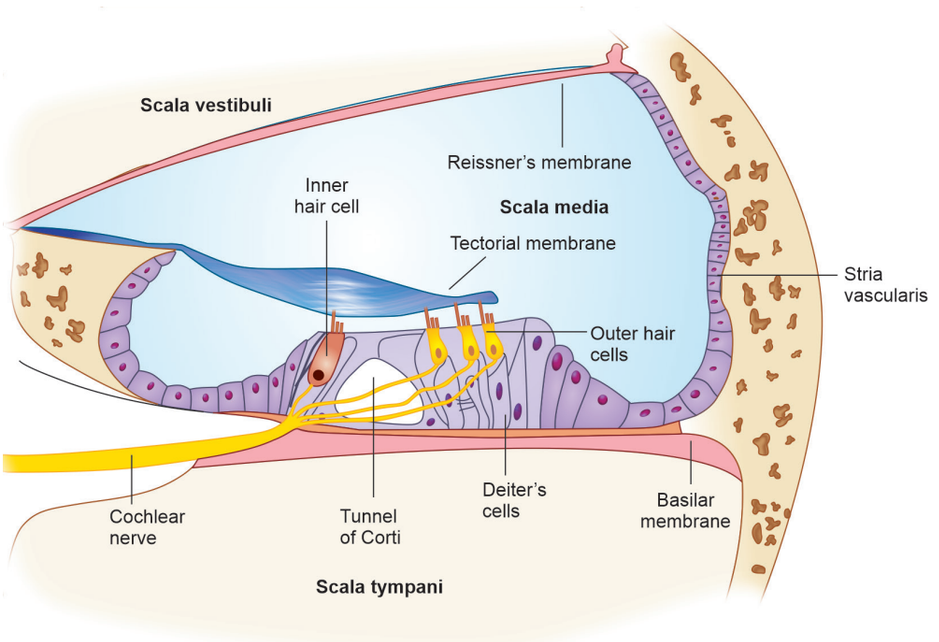


Fig. 1.24: Structure of organ of Corti

The ***inner hair cells (IHC)*** are a single row of cells on the inner or medial side of the spiral. The inner hair cells are flask shaped with a small apex and large cell body. They are richly supplied by afferent cochlear nerve fibres.

The ***outer hair cells (OHC)*** are cylindrical in shape and are arranged in 3–4 rows. They are present on the outer or lateral side of the spiral. The outer hair cells modulate the function of the inner hair cells.

2. **Extracellular spaces:** These are spaces within the organ of Corti, namely **spaces of Nuel** (around the OHC) and **tunnel of Corti** (between the OHC and IHC).
3. **Tectorial membrane:** It is an a highly hydrated extracellular matrix which lies over the mechanosensory hair cells in the cochlea. It has three main constituents: water (97%), glycosaminoglycans (GAG), collagenous and noncollagenous proteins. Recent studies show that mutations in genes controlling the constituent proteins lead to significant hearing losses. It is extremely sensitive to distortion and shrinkage. The tips of the longest stereocilia of OHC are embedded or attached to the tectorial membrane. The relative movement of hair cells and tectorial membrane generate stimulus for the hair cells.
4. **Supporting cells:** These are highly specialised and differentiated cells which provide support to the outer hair cells. These are the Pillar cells, Deiter's cells and Hensen's cells.

Nerve Supply of Cochlea

The nerve supply to the cochlea is from the brainstem via the afferent and efferent fibres.

Afferent nerve fibres that innervate the OHC and IHC are of mainly two types. Majority are type 1 myelinated neurons that innervate IHCs. The remaining 5–10% fibres are unmyelinated type 2 neurons which innervate the OHCs. All fibres collect in the spiral ganglion enclosed within the *Rosenthal canal*. The efferent neurons which innervate the cochlea have their cell bodies in the mid-brain regions.

Labyrinthine Fluids

1. **Perilymph:** It fills the space between the membranous and bony labyrinth. Its exact source is not known. Though it has been suggested to be a filtrate of blood serum from capillaries of spiral ligament or due to direct communication from CSF via the aqueduct of cochlea. It resembles plasma, interstitial fluid and CSF in composition (high in Na^+ and low in K^+ ions).
2. **Endolymph:** It fills the membranous labyrinth and it resembles the intracellular fluids. It is rich in K^+ ions and low in Na^+ ions. It is secreted by the stria vascularis of cochlea and the dark cells of the utricle and ampullated ends of SCC.

Blood Supply of Labyrinth

The main blood supply of the inner ear is from the labyrinthine artery which is a branch of the anterior inferior cerebellar artery (AICA). Labyrinthine arteries may sometimes arise directly from the basilar artery or even vertebral artery (Fig. 1.25).

The venous drainage is via anterior, posterior spiral vein and vestibular vein. These finally form the vein of cochlea which drains into the jugular bulb.

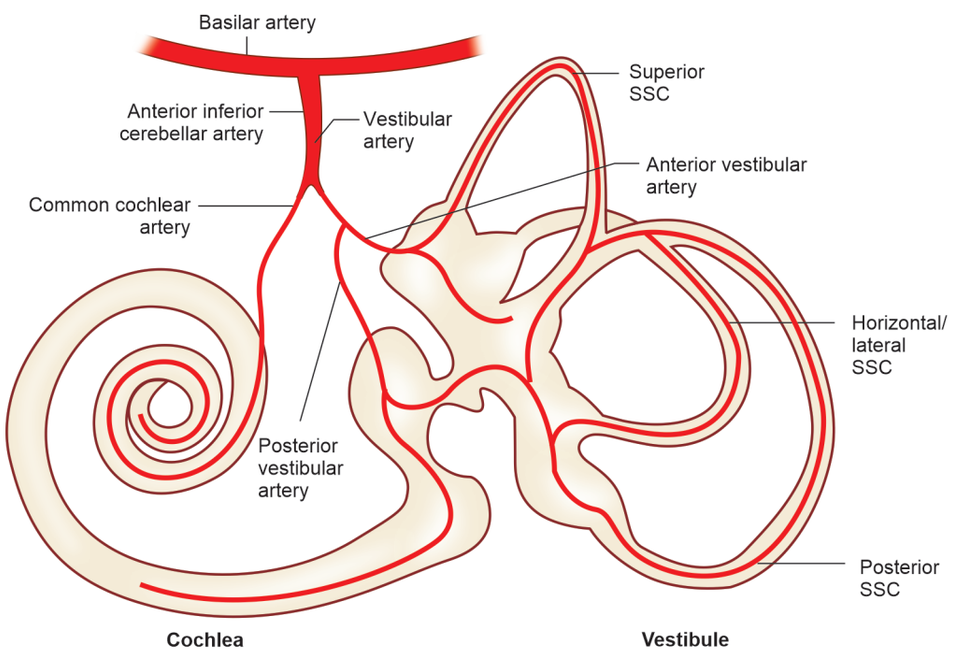


Fig. 1.25: Blood supply of membranous labyrinth