

## "Ear"

- The ear consists of three main parts:
  - 1) The external ear
  - 2) The middle ear
  - 3) The internal ear
- The external and middle ear structures function for sound conduction and transmission.
- The internal ear functions for sound perception and equilibrium.
- The external ear collects airborne vibrational waveforms.
- The middle ear converts airborne waveforms into solid-borne waveforms and transmits those to the internal ear.
- The hearing part of the internal ear converts solid-borne waveforms into fluid-borne waveforms, which are translated into sound.

- The equilibrium part translates fluid dynamics into a sense of balance.

» Nerve Supply of Ear (more details later)

External Ear	EA Meatus	Tympanic Membrane	Middlle Ear
Lesser Occipital	Auriculotemporal	Auriculotemporal	Caroticotympanic
Auriculotemporal	Vagus	Vagus	Glossopharyngeal
Greater Auricular		Glossopharyngeal	

## <- EXTERNAL EAR ->

- The external ear has:

- An auricle
- An external auditory meatus

### » Auricle (Pinna)

- Has a characteristic shape and collects air vibrations.
- Consists of a thin plate of elastic cartilage covered by skin.
- Main components of the auricle:

-> Helix: The elevated margin of the auricle.

-> Tragus: A projection from the anterior margin of the auricle that extends over the opening of the external acoustic meatus.

-> Lobule: Earlobe, which does not contain cartilage.



-> Concha: The deepest depression within the auricle that leads into the external meatus.

- The auricle is an effective sound collecting and localizing device in many mammals.
- However, that function is highly questionable in humans.

### > Auricular Muscles

- Essentially vestigial in humans.
- Variably entertaining to those able to wiggle their ears.

### » External Auditory (Acoustic) Meatus

- The external auditory (acoustic) meatus is a slender curved tube.
- Leads from the concha of the auricle to the tympanic membrane

### > Function:

- Conducts sound waves from the auricle to the tympanic membrane.

## > Structure

- Outer (lateral) third:
  - Made of elastic cartilage.
- Inner (medial) two thirds:
  - Bony
  - Formed by the tympanic plate of the temporal bone.
- Lined by skin throughout.

## > Glands And Protection

- Outer third of the meatus contains:
  - Hairs
  - Sebaceous glands
  - Ceruminous glands
- These ceruminous glands:
  - Modified sweat glands
  - Secrete yellowish brown wax (cerumen: earwax)

- Function of hairs and wax:
  - Provide a sticky barrier
  - Prevent entrance of foreign bodies

## » Nerve Supply

### > Auricle Sensory Nerves

- Main sensory nerves:
  - Lesser occipital nerve
  - Great auricular nerve
- (Both are branches of the cervical plexus)

- Supplemented by small components of:

- Facial nerve
- Glossopharyngeal nerve

### > External Meatus and Tympanic Membrane Sensory Nerves

- Auriculotemporal nerve
- Auricular branch of the vagus nerve → Both are primary sensory nerves for:



- i) External meatus
- ii) External surface of tympanic membrane

## » Lymphatic Drainage

- Drains to:
  - Superficial parotid lymph nodes
  - Mastoid lymph nodes
  - Superficial cervical lymph nodes

## » Tympanic Membrane (Eardrum)

- The tympanic membrane is a thin, fibrous structure.
- Forms the interface between the external and middle ears.

### > Orientation And Shape

- Obliquely oriented:
  - Facing inferiorly, anteriorly, and laterally.

- Slightly concave laterally:
- Has a small depression called the umbo at the depth of the concavity.
- Tip of the handle of the malleus:
  - Produces the umbo.

### > Otoscopic Appearance

- When illuminated through an otoscope:
  - The concavity produces a cone of light.
  - This is a bright, light-reflecting area that radiates anteriorly and inferiorly from the umbo.

### > Dimensions And Structural Details

- The tympanic membrane is circular.
- Measures about 1 cm in diameter.
- The circumference is thickened and:
  - Slotted into a groove in the bone.



- The groove (tympanic sulcus):
  - Deficient superiorly, forming a notch.
- From the sides of the notch: Two bands pass to the lateral process of the malleus:
  - Anterior malleolar fold
  - Posterior malleolar fold
- The small triangular area on the membrane bounded by these folds:
  - Is slack and called the pars flaccida.
  - The remainder of the membrane:
    - Is tense and called the pars tensa.

### > Relation To Malleus

- The handle of the malleus:
  - Bound to the inner surface of the tympanic membrane
    - By the mucous membrane

## > Innervation And Sensitivity

- The tympanic membrane is extremely sensitive to pain.
- Outer Surface Innervation
  - Auriculotemporal nerve
  - Auricular branch of the vagus nerve
- Inner Surface Innervation
  - Tympanic plexus of the glossopharyngeal nerve

## <- MIDDLE EAR ->

- The middle ear is an air-containing cavity within the petrous part of the temporal bone.

- It is lined with a mucous membrane

- The cavity is:

- Narrow, oblique, and slitlike.

- Its long axis lies approximately parallel to the plane of the tympanic membrane.

- Communications:

- Anteriorly with the nasopharynx.

- Posteriorly with the mastoid antrum.

- Main Components of the Middle Ear

- i) Tympanic cavity

- ii) Auditory ossicles and their muscles

- iii) Auditory tube

- iv) Mastoid area



- It consists of two parts:

- i) Tympanic cavity proper

- The area directly medial to the tympanic membrane.

- ii) Epitympanic recess

- The upper portion of the chamber.  
Located superior to the tympanic membrane.

- > Conceptual Structure

- The tympanic cavity can be conceptually thought of as a six-sided box with:

- Roof (superior wall)
    - Floor (inferior wall)
      - Anterior wall
      - Posterior wall
      - Medial wall
      - Lateral wall

### -> Roof (Tegmental Wall)

- The roof is a thin plate of bone, the tegmen tympani, which is part of the petrous temporal bone.
- It separates the epitympanic recess of the tympanic cavity from the dura mater lining the floor of the middle cranial fossa.
- Fracture of the tegmen tympani may cause leaking of cerebrospinal fluid into the tympanic cavity.

### -> Floor (Jugular Wall)

- The floor is a thin plate of bone, which may be partly replaced by fibrous tissue.
- It separates the tympanic cavity from the superior bulb of the internal jugular vein.
- The tympanic nerve (a branch of CN IX) pierces the floor to enter the tympanic cavity.



## -> Anterior Wall (Carotid Wall)

- Has two openings in its upper part:
  - Upper, smaller opening: conveys the tensor tympani muscle.
  - Lower, larger opening: leads into the auditory tube.
- The thin, bony septum that separates the canals is:
  - Prolonged backward on the medial wall.
    - Forms a shelflike projection.
- The carotid canal (containing the internal carotid artery) lies immediately adjacent to the thin, lower part of the anterior wall, beneath the bony wall of the auditory tube.

## -> Posterior Wall (Mastoid Wall)

- Has a large, irregular opening, the aditus ad antrum (aditus to the mastoid antrum), in its upper part.



- This opening is the entrance to the cavity (antrum) of the mastoid process and the mastoid air cells.
- It connects the epitympanic recess to the mastoid antrum.
- A small, hollow, conical projection, the pyramid (pyramidal eminence):
  - Sits below the aditus.
  - Houses the stapedius muscle.
  - The tendon of the stapedius emerges from its apex.
- The main stem of the facial nerve (CN VII):
  - Descends within the facial canal immediately adjacent to the posterior wall.
    - This relationship forms the elevated prominence of the facial canal along the posterior wall.
- A small opening inferior to the pyramid:
  - Transmits the chorda tympani nerve from the facial nerve into the tympanic cavity.

- Facial nerve divides the gland into:
  - Superficial lobe
  - Deep lobe
- Parotid duct:
  - > Medial Wall (Labyrinthine Wall)
- Separates the tympanic cavity from the internal ear.
- Thus, the medial wall of the tympanic cavity is the lateral wall of the internal ear.
- The greater part of this wall shows a rounded projection, the promontory:
- Results from the underlying first turn of the cochlea
- The fenestra vestibuli (oval window):
  - Lies above and behind the promontory.
  - Closed by the footplate of the stapes



- The fenestra cochleae (foramen tympani, round window):

- Is round and closed by the secondary tympanic membrane.
- Sits below the posterior end of the promontory.

### > Prominence of the Facial Canal

- It is an elevation above the oval window formed by the adjacent facial nerve within the facial canal.

- Appears on both the medial and posterior walls.

### • Course:

- Runs horizontally above the promontory and oval window.
- Then curves downward on the posterior wall behind the pyramid.



## > Prominence of the Lateral Semicircular Canal

- It is an elevation above the prominence of the facial canal.
- Formed by the underlying lateral semicircular canal.

## > Bony Shelf for Tensor Tympani

- A bony shelf extends from the anterior wall onto the medial wall.
- This shelf supports the tensor tympani muscle.
- The posterior end of the shelf is curved upward and forms a pulley, the processus cochleariformis.
- The tendon of the tensor tympani:
  - Bends laterally around this pulley.
  - Then reaches its insertion on the handle of the malleus.



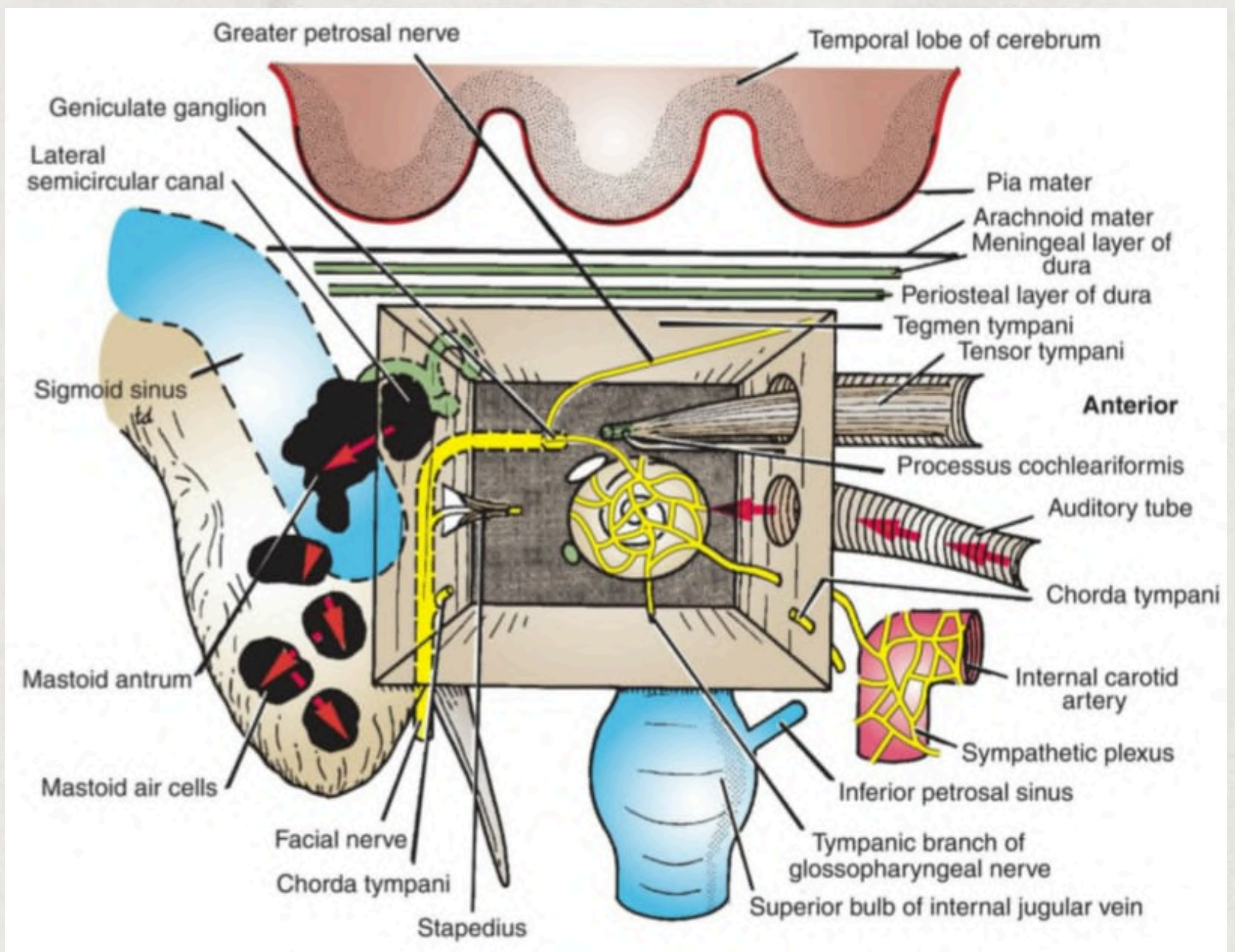
-> Lateral (Membranous) Wall

- Largely formed by the tympanic membrane
- Has two parts:

Superior part → formed by the epitympanic recess.

Inferior part → formed by the eardrum.

» Diagram



## » Auditory Ossicles And Associated Muscles

### > General Features

- The three auditory ossicles:
  - Malleus
  - Incus
  - Stapes
- They form a mobile osseous bridge from the tympanic membrane to the oval window.
- The joints between the ossicles are of the synovial type.



# 1) Malleus (Largest Ossicle)

- Parts:

-> Head: Rounded, articulates posteriorly with the incus.

-> Neck: Constricted part below the head.

-> Handle (long process)

- The head:

- Passes downward and backward.

- Firmly attached to the medial surface of the tympanic membrane.

- Visible through the tympanic membrane on otoscopic examination.

- Anterior process:

- A spicule of bone.

- Connects to the anterior wall of the tympanic cavity via a ligament.

- Lateral Process of Malleus

- Projects laterally.
- Attaches to the anterior and posterior malleolar folds of the tympanic membrane.

## 2) Incus

- Body:

- Large and rounded.
- Articulates anteriorly with the head of the malleus.
- Head of malleus + body of incus occupy most of the epitympanic recess.

- Long Process:

- Descends behind and parallel to the handle of the malleus.
- Lower end bends medially → articulates with head of the stapes.
- Shadow of the long process can sometimes be seen through the tympanic membrane during otoscopy.

- Short Process:

- Projects backward.
- Attaches to the posterior wall of the tympanic cavity by a ligament.

### 3) Stapes

- Head:

- Small, articulates with the long process of the incus.

- Neck:

- Narrow, receives insertion of stapedius muscle.

- Two Limbs:

- Diverge from the neck.
- Attach to the oval base (footplate).



- Base (Footplate):
  - Oval-shaped.
  - Attached to the margin of the oval window via the annular ligament (ring of fibrous tissue).

## > Associated Muscles of The Ossicles

- Tensor Tympani
  - Inserts on the handle of the malleus (detailed earlier).

- Stapedius
    - Inserts on the neck of the stapes.
- Smallest skeletal muscle in the human body.

MUSCLE	ORIGIN	INSERTION	NERVE SUPPLY	ACTION
Tensor tympani	Wall of auditory tube and wall of its own canal	Handle of malleus	Mandibular division of the trigeminal nerve	Dampens down vibrations of tympanic membrane
Stapedius	Pyramid of the middle ear	Neck of stapes	Facial nerve	Dampens down vibrations of stapes

## > Auditory Ossicle Movement

- Axis of Rotation
  - Malleus and incus rotate on an anteroposterior axis.

- Axis passes through:
  - Ligament connecting anterior process of malleus to the anterior wall of the tympanic cavity.
  - Anterior process of malleus itself.
  - Short process of incus.
- Ligament connecting short process of incus to the posterior wall of the tympanic cavity.
- Movement During Medial Displacement of Tympanic Membrane
  - Tympanic membrane moves medially → so does the handle of the malleus.
  - Head of malleus + body of incus move laterally.
  - Long process of incus + stapes move medially.
  - Base (footplate) of stapes is pushed medially into the fenestra vestibuli.
  - Perilymph in scala vestibuli is displaced → initiates wave transmission in the internal ear.



## > Perilymph Dynamics

- Perilymph is incompressible.
- So, inward stapes movement → outward bulging of secondary tympanic membrane at the fenestra cochleae.
- This lies at the lower end of the scala tympani.

## > Reverse Movement

- If tympanic membrane moves laterally, all movements are reversed:
  - Handle of malleus → lateral
  - Head of malleus + body of incus → medial
  - Stapes pulled laterally

## > Protective Mechanism



- Excessive lateral movement of malleus head:
- Causes temporary separation of articulation between malleus and incus.
- Prevents the base of stapes from being pulled laterally out of fenestra vestibuli.

### > Force Amplification

- Leverage ratio of ossicles: 1.3 : 1
- Area ratio:
- Tympanic membrane is 17x larger than stapes footplate.
- Combined pressure amplification on perilymph: 22 : 1

## » Auditory (Pharyngeotympanic) Tube

### > Anatomical Course & Position

- Connects anterior wall of tympanic cavity to the nasopharynx.
- Descends and passes over the upper border of the superior constrictor muscle.

## > Functions

- Equalizes air pressure in middle ear with atmospheric pressure:
- Balances pressure on both sides of tympanic membrane.
- Ensures free movement of eardrum.
- Provides drainage route for serous secretions of middle ear mucosa.

## > Structural Composition

- Lateral one-third: Bony
- Medial two-thirds: Cartilaginous:
  - Cartilage is C-shaped
  - Open side of "C" normally collapsed → mucosa of open part is in apposition with mucosa lining the cartilage.



## > Mucous Membrane Continuity

- Lined with mucous membrane continuous with:
  - Tympanic cavity
  - Nasopharynx
- This continuity allows infections to spread from nasopharynx to middle ear (e.g., in upper respiratory infections).

## v> Mechanism of Opening the Tube

- At rest → tube remains closed.
- Requires active opening
- Done by muscles of soft palate:
  - Tensor veli palatini
  - Levator veli palatini
- These muscles separate the mucosa from the cartilage wall.

## > Timing of Tube Opening

- Tube opens during palatal activity:

- Swallowing
- Yawning

- These actions are optimal for:

- Equalizing pressure
- Draining secretions

## > Clinical Relevance

- You “pop” your ears during altitude changes by:

- Swallowing or yawning, which opens the auditory tube.

- Infection pathway:

- Tube acts as a route for spread of infection from nasopharynx to middle ear → can result in otitis media.



## » Mastoid Area

### > Main Components

- Mastoid Antrum – Main cavity within the mastoid process
- Mastoid Air Cells – Honeycomb-like network of air-filled spaces

### 1) Mastoid Antrum

- Located within the mastoid process of the temporal bone.
- Communicates with epitympanic recess via:
  - Aditus ad antrum in the posterior wall of tympanic cavity.
- Important for understanding infection spread.

### > Anatomical Relations of Mastoid Antrum

- Anterior wall:
  - Related to tympanic cavity
  - Contains aditus ad antrum

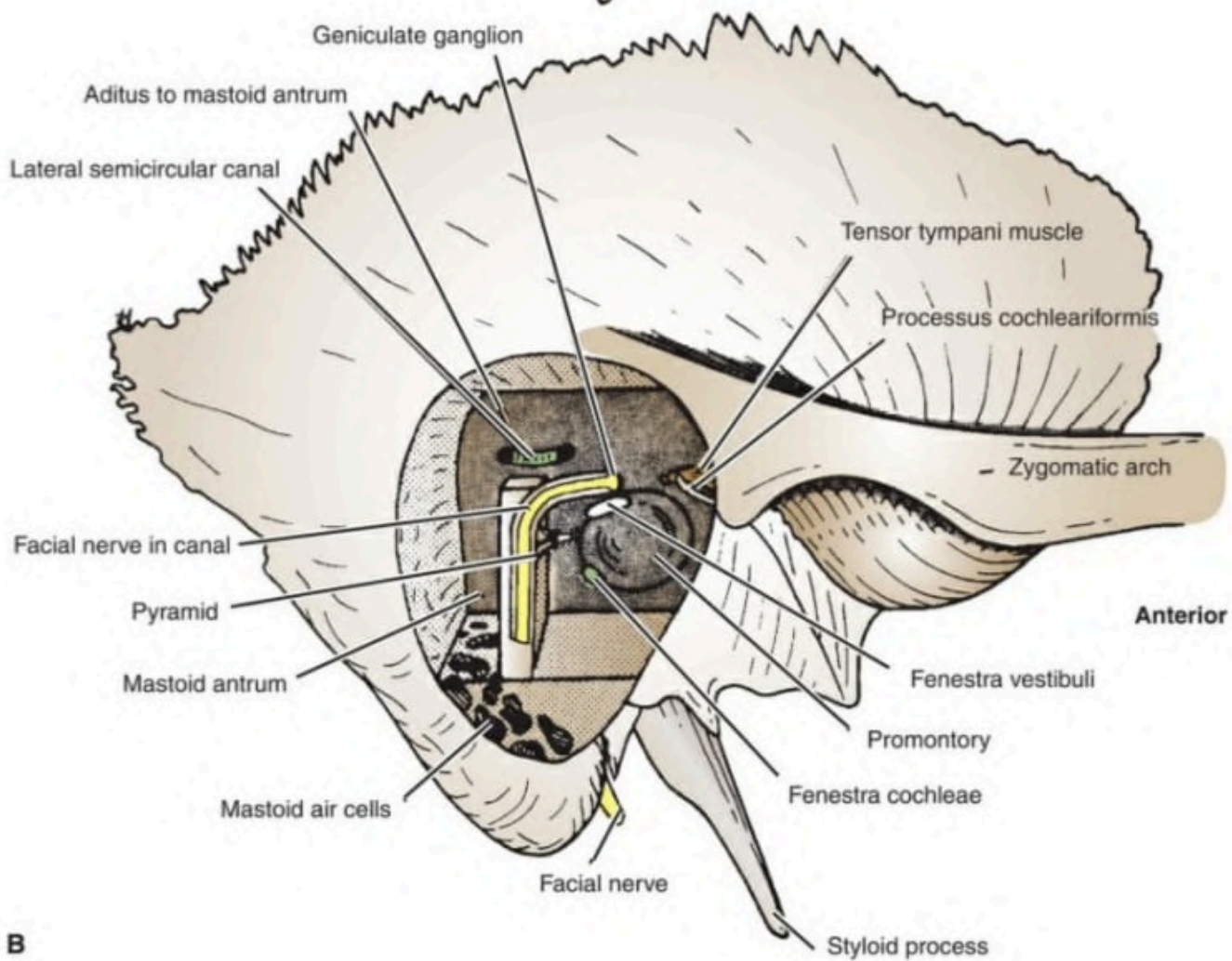
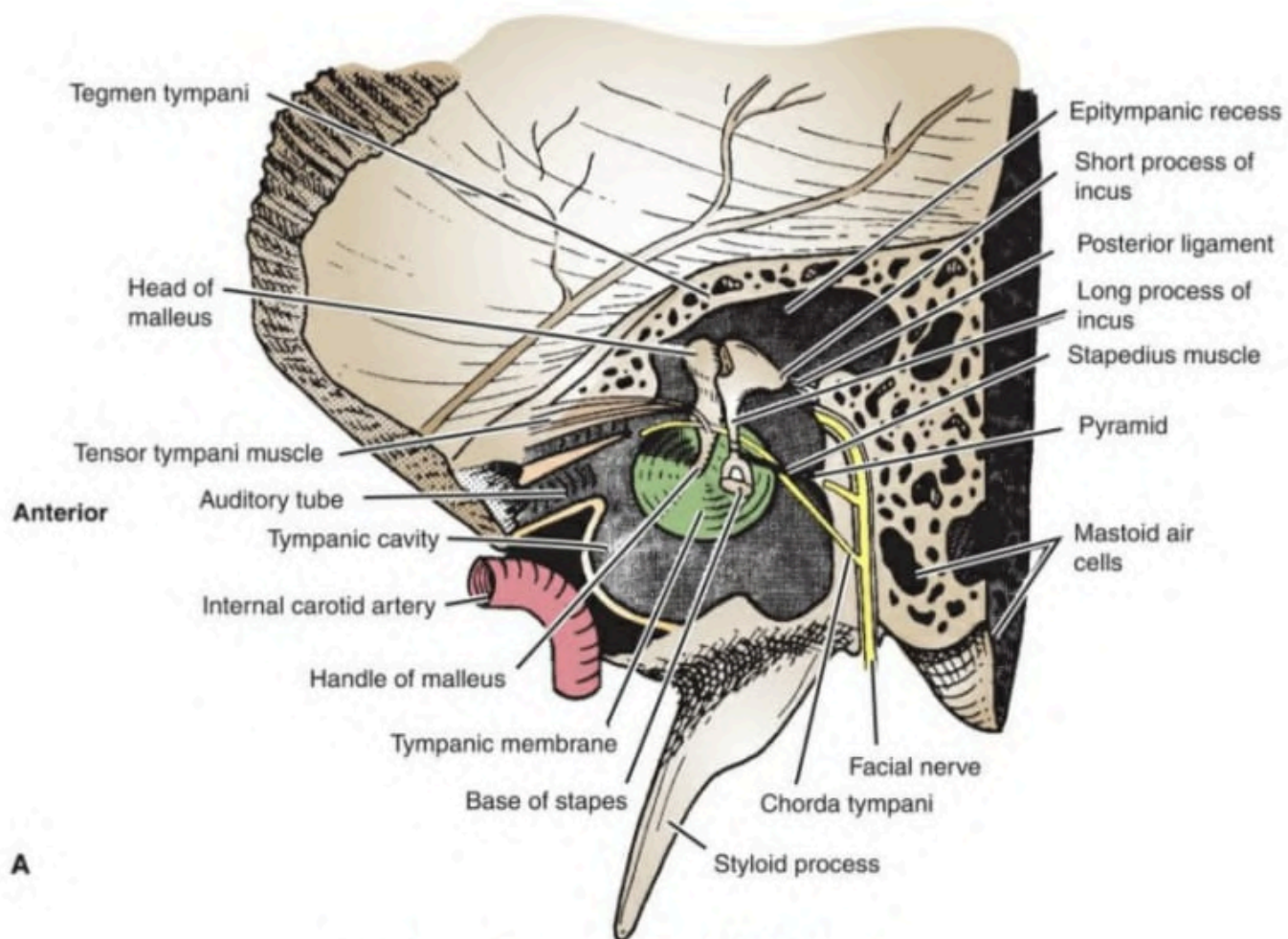
- Posterior wall: Separates antrum from:
  - Sigmoid venous sinus
  - Cerebellum
- Lateral wall:
  - Forms floor of suprameatal triangle
    - 1.5 cm thick
- Medial wall:
  - Related to posterior semicircular canal
- Superior wall:
  - Formed by tegmen tympani (thin bone plate)
- Related to:
  - Meninges of middle cranial fossa
    - Temporal lobe of brain
- Inferior wall:
  - Perforated with holes
- Allows communication with mastoid air cells



## 2) Mastoid Air Cells

- Honeycomb-like network within the mastoid process.
- Lined with mucous membrane
- This mucous Membrane is continuous with:
  - Mastoid antrum
  - Middle ear
- Allow bidirectional spread of infection:
  - Tympanic cavity ↔ Mastoid air cells
- > Developmental Aspect
  - Not present at birth.
  - Begin to develop during 2nd year of life.
  - Development influenced by:
    - Pull of sternocleidomastoid muscle.

# » Diagram





## <- INTERNAL EAR (LABYRINTH) ->

### » Location

- Situated in the petrous part of the temporal bone
- Lies medial to the middle ear

### » Divisions

- i) Bony Labyrinth - Series of cavities in bone
- ii) Membranous Labyrinth - Series of membranous sacs and ducts suspended within the bony labyrinth

### » Bony Labyrinth

- Contains perilymph (clear fluid)
- Lined by endosteum
- Surrounds the membranous labyrinth

- Composed of three parts:

- Vestibule
- Semicircular Canals
- Cochlea

i) Vestibule (Central part)

- Lies:

- Posterior to cochlea
- Anterior to semicircular canals

- Lateral wall:

- Contains fenestra vestibuli (closed by base of stapes + annular ligament)

- Contains fenestra cochleae (closed by secondary tympanic membrane)

- Contains:

- Sacculle and utricle of the membranous labyrinth



## ii) Semicircular Canals

- Three canals:
  - Superior
  - Posterior
  - Lateral
- Open into posterior part of vestibule via five orifices:
  - One is common to two canals
  - Each canal has an ampulla (swelling at one end)
  - Semicircular ducts are located inside these canals
- Orientation of Canals
  - > Superior canal:
    - Vertical
    - At right angles to long axis of petrous bone
  - > Posterior canal:
    - Vertical
    - Parallel to long axis of petrous bone

-> Lateral canal:

- Horizontal
- Lies in medial wall of aditus to mastoid antrum
- Located above facial nerve canal

### iii) Cochlea (Part of Bony Labyrinth)

#### > General Description

- Spiral-shaped structure resembling a snail shell
- Opens into the anterior part of the vestibule
- Consists of a central pillar: modiolus
- A hollow bony tube spirals around the modiolus making  $2\frac{1}{2}$  turns

#### > Spiral turns:

- Decrease in radius progressively
- Whole cochlea appears conical
- Apex: Faces anterolaterally



- Base: Faces posteromedially

#### > Clinical Surface Landmark

- The first basal turn of the cochlea produces the promontory seen on the medial wall of the middle ear

#### > Modiolus

- Central pillar of the cochlea
- Has a broad base at the bottom of the internal acoustic meatus
- Perforated by branches of the cochlear nerve

#### > Spiral Lamina

- A bony spiral ledge winding around the modiolus
- Projects partially into the cochlear canal
- Supports the basilar membrane

## > Basilar Membrane

- Extends from:
  - Free edge of spiral lamina → to → outer bony wall
- Divides the cochlear canal into two chambers:
  - i) Scala vestibuli (upper)
  - ii) Scala tympani (lower)

## > Perilymph Compartments

- i) Scala Vestibuli:
  - Contains perilymph
- Separated from middle ear by:
  - Base of stapes
  - Annular ligament
  - Located at fenestra vestibuli



## ii) Scala Tympani:

- Contains perilymph
- Separated from middle ear by:
  - Secondary tympanic membrane
  - Located at fenestra cochleae

## » Membranous Labyrinth

### > General Features

- Lodged within the bony labyrinth
  - Filled with: Endolymph
  - Surrounded by: Perilymph

### • Components:

- Utricle and Saccule → in bony vestibule
- Three semicircular ducts → in bony semicircular canals
- Duct of the cochlea → in bony cochlea
- All components communicate freely with each other

## > Utricle

- Larger of the two vestibular sacs
  - Location: Bony vestibule
    - Connected to:
      - Sacculle via ductus utriculosaccularis
      - Ductus endolymphaticus indirectly

## > Sacculle

- Globular in shape
- Located in bony vestibule
  - Connected to:
    - Utricle (via ductus utriculosaccularis)
    - Duct of cochlea via ductus reuniens



## > Ductus Endolymphaticus

- Formed by union of:
  - Ductus utriculosaccularis
  - Ends as a blind pouch: Saccus endolymphaticus
- Location: Beneath the dura on posterior surface of petrous temporal bone

## > Sensory Receptors (Static Equilibrium)

- Located in walls of utricle and saccule

### • Detect:

- Head orientation to gravity
- Linear acceleration and deceleration

## > Semicircular Ducts

- Contained within bony semicircular canals
- Smaller in diameter than canals but same configuration

- Arranged at right angles to each other (representing all 3 planes)
  - Each has:
    - Ampulla (dilated end)
    - Contains sensory receptors for dynamic equilibrium
  - Function:
    - Detect angular acceleration/deceleration
    - Movement of endolymph within ducts stimulates receptors in ampullae
- > Duct of the Cochlea
  - Lies within bony cochlea
  - Triangular in cross-section
  - Connected to sacculle via ductus reuniens
    - Contains:
      - Basilar membrane
      - Spiral organ of Corti
    - Contains sensory receptors for hearing



## "Clinical Notes"

### » Tympanic Membrane Examination

- Otoscopic technique:

- > Adults: Pull auricle upward and backward

- > Infants: Pull auricle straight backward or backward and downward

- Normal appearance:

- > Color: Pearly gray

- > Shape: Concave

- Length of external auditory meatus: ~1 inch (2.5 cm)

- Narrowest point: ~5 mm (0.2 inch) from tympanic membrane

## » Tympanic Membrane Perforation (Ruptured Eardrum)

- Causes:

- Otitis media
- Penetrating foreign objects
- Excessive pressure

- Clinical consequence:

- Conduction deafness

## » Otitis Media (Middle Ear Infection)

- Definition: Acute infection of the middle ear

- Cause:

- Spread from upper respiratory tract infection via the auditory (Eustachian) tube

- Due to common mucous membrane continuity with nasopharynx



- Pathology:

- Inflamed mucosa → auditory tube obstruction

Increased pressure/fluid in tympanic cavity

- Otoscopic signs:

- Bulging & red tympanic membrane

- Clinical outcome:

- Impaired hearing

## » Complications of Otitis Media

### > Acute Mastoiditis:

- Spread to mastoid antrum and air cells
- Intracranial Spread – Superior Direction:
  - Structures involved:
    - Meninges
  - Temporal lobe of brain

- Complications:

- Meningitis
- Temporal lobe cerebral abscess

> Medial Spread:

- Structures involved:

- Facial nerve

- Internal ear

- Complications:

- Facial nerve palsy

- Labyrinthitis → Vertigo

> Posterior Spread:

- Related structure: Sigmoid venous sinus

- Complication: Sigmoid sinus thrombosis

» Ossicle Disruption

> Otosclerosis

- Definition: Abnormal bone formation around the footplate of stapes

- Result: Fixation of stapes into the oval window



- Consequence:

- Restricted stapes movement
- Conduction deafness

» Hyperacusis

- Definition: Abnormally increased sensitivity to sound

- Cause:

- Paralysis of stapedius muscle
- Typically due to facial nerve (CN VII) lesion

- Pathophysiology:

- Inability of stapes and ossicular chain to dampen loud sounds

- Result:

- Sounds appear excessively loud or painful