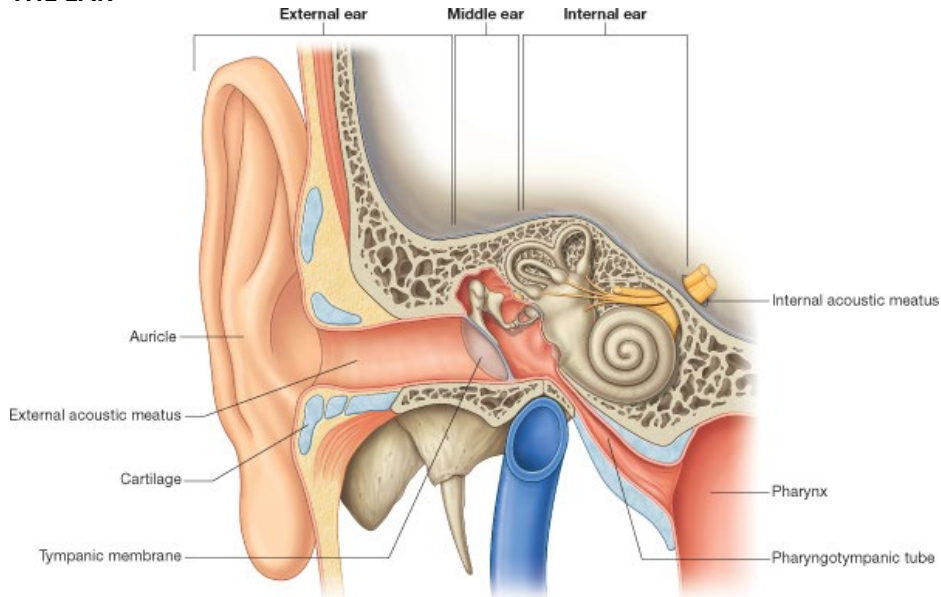


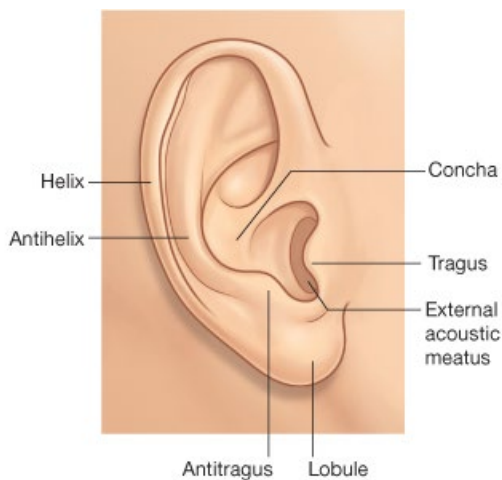
THE EAR



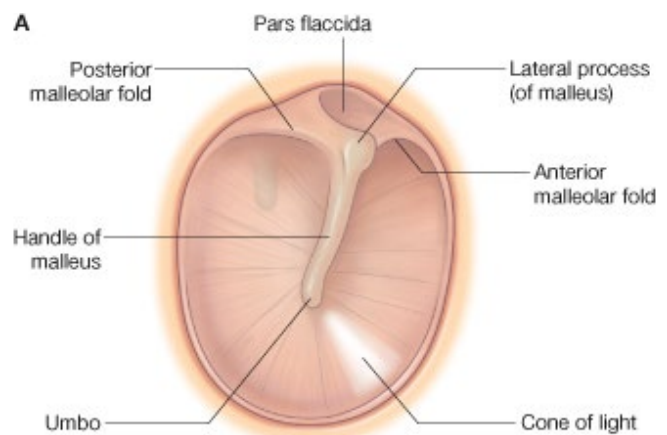
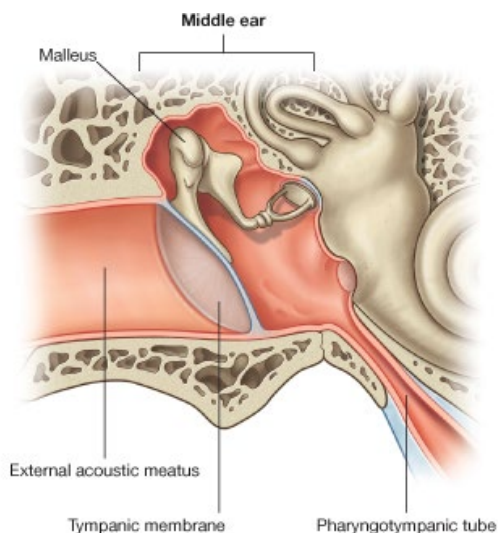
THE EXTERNAL EAR:

- External ear consists of 2 parts:
 - **Auricle / pinna**
 - **External acoustic/auditory meatus**
- **Auricle** has a fibroelastic cartilage framework, with skin firmly attached.
- The surface of the auricle is thrown into numerous complex depressions & folds – allows collection of soundwaves and detection of their direction
- Outermost crest of the ear = the **helix**
- Helix runs down to the **lobule**
- Lobule is fleshy and has no fibrocartilaginous support
- Inner rim of the ear = **antihelix**
- Antihelix encircles a deeper concave region of the ear – the **concha**
- Hearing aid is moulded to fit the concha & external meatus with an airtight seal.
- Anteriorly, the entrance to the external auditory meatus projects laterally as a small spur of elastic fibrocartilage – the **tragus**
- The **external auditory meatus** and **tympanic membrane** (at its inner end), can be examined with an auriscope
- In a newborn child, the external auditory meatus is very short (Δ must be careful when using auriscope).
- In adults:
 - Outer 1/3 of external auditory meatus is composed of cartilage
 - Inner 2/3 is walled by bone – **tympanic plate** of temporal bone
- External auditory meatus forms an S-shaped curve:
 1. Curves anteriorly
 2. Curves posteriorly
 3. Curves anteroinferiorly \rightarrow tympanic membrane

- Tympanic membrane is *not* perpendicular to the meatus: angled obliquely
- Means that the anterior wall and floor of the meatus is longer than the posterior wall and roof.
- The auricle must be pulled upwards and backwards to straighten the meatus for examination.

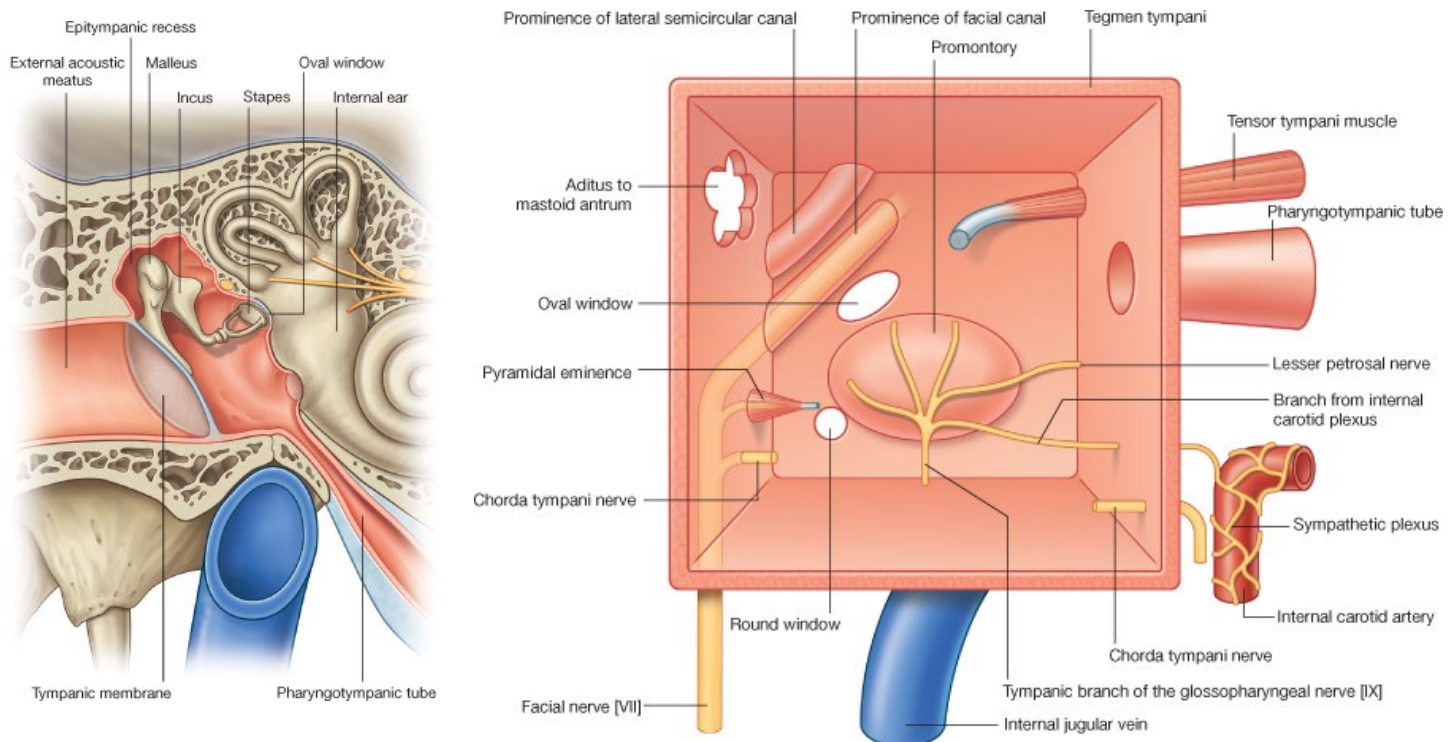


- The tympanic membrane has a characteristic appearance:
- Part of the **malleus** (one of middle ear ossicles) shines through the membrane
- **Long handle** of the malleus is attached to the inner surface of the membrane – visible as a streak passing downwards and backwards to a point just below its centre.
- At the upper end of the handle a small **lateral process** of the malleus creates a prominence on the membrane.
- **Anterior & posterior folds** extend from the handle, upwards and around the periphery of the membrane.
- Between the folds is a **flaccid** part of the membrane, which is highly vascular.
- The membrane is drawn inwards towards the handle of the malleus → outer surface of the membrane is concave.
- Light reflected from the auroscope is reflected in anteroinferior quadrant of the membrane – the **cone of light**
- The external auditory meatus and tympanic membrane receive sensory nerve fibres from the:
 - Vagus nerve (X)
 - Trigeminal nerve (V)



THE MIDDLE EAR:

- Middle ear can also be called the **tympanic cavity**
- It is a small, air-filled space within the petrous temporal bone
- Communicates with the pharynx in front through the **auditory tube** (aka **eustachian tube / pharyngotympanic tube**)
- Communicates with the antrum behind
- Upper part of the cavity is expanded into **epitympanic recess**
- Middle ear contains chain of 3 ossicles (small bones)
- The ossicles connect the tympanic membrane to the membrane of the inner ear; Δ transmit vibrations across the tympanic cavity from external ear \rightarrow inner ear.
- Δ mechanic coupling between vibrations of tympanic membrane & vibrations of fluid of inner ear.



- **Tympanic cavity** is irregular in shape, but it can be thought of as having lateral, medial, anterior, posterior walls, and a roof and floor.
- Cavity has the same dimensions & size as a watch battery.
 - Lateral wall: tympanic membrane
 - Medial wall: bone of inner ear (which has several eminences and grooves)

Medial wall:

- Composed of bone of the inner ear.
- **Promontory** is a rounded elevation of the medial wall produced by the underlying **cochlea**
- Behind the promontory are 2 openings in the bone of the inner ear which lead onto the bony cavities of the inner ear:
 - Upper opening: fenestra vestibuli / oval window
 - Closed in life by part of **stapes** (a middle ear ossicle)
 - Lower window: fenestra cochleae / round window
 - Closed by a secondary tympanic membrane

Anterior wall:

- Leads to 2 canals:
 - **Eustacian tube**
 - **Canal for tensor tympani muscle**
- **Eustacian (auditory) tube** is the lower and larger tube, and connects with the pharynx
- Initially the tube is within the petrous temporal bone
- Continues as a cartilaginous tube.
- Auditory tube protects middle ear by allowing pressure to be equalised on the 2 sides of the tympanic membrane at all times.
- Tube opens on swallowing / yawning
- Cartilaginous part is attached to several muscles which are active during these actions.
- Mucus membrane of auditory tube is supplied by **glossopharyngeal nerve (IX)**
- **Canal for tensor tympani muscle** is above the auditory tube
- **Tensor tympani muscle** is small and gives rise to a tendon within the tympanic cavity which changes direction to insert into the handle of the malleus
- Changes direction by passing through a small bony pulley – the **processus trochleariformis**
- The canal for the **internal carotid artery** through the skull base is related to the anterior wall of the middle ear – separated from it only by a thin lamina of bone.

Posterior wall:

- **Aditus** = opening in posterior wall of tympanic cavity which leads from the epitympanic recess → **mastoid antrum**
- **Pyramidal eminence** containing the **stapedius muscle** is found on the posterior wall below the aditus.
- Tendon of the **stapedius muscle** arises from the summit of the pyramid → inserts into the stapes.

Roof:

- Thin
- Formed by part of the **petrous temporal bone** – the **tegmen tympani**
- Above the roof is the temporal lobe of the brain

Floor:

- Related to the jugular foramen & internal jugular vein

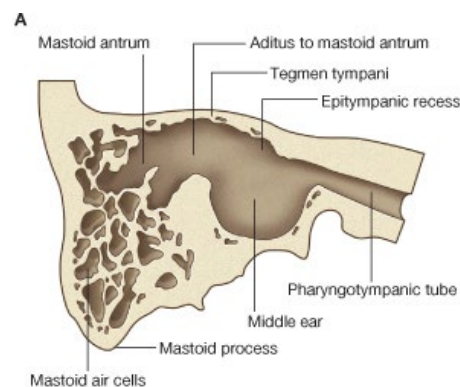
Ossicles of the tympanic cavity:

- **Malleus**
- **Incus**
- **Stapes**
- Contained within tympanic cavity
- Linked by synovial joints
- **Malleus:**
 - Looks like a 'hammer'
 - Head lies in epitympanic recess, held in place by 3 ligaments

- 'Handle' of the malleus is firmly attached to the inner surface of the tympanic membrane
- **Incus:**
 - Head of the incus articulates with the malleus at saddle-shaped synovial joint
 - Short process of the incus attaches to wall of epitympanic recess
 - Long process of incus articulates with the head of the stapes – a tiny ball & socket joint.
 - Long process runs downwards and backwards through the cavity in parallel with the handle of the malleus.
- **Stapes:**
 - Articulates with incus at a synovial ball and socket joint
 - Footplate of the stapes fits into and closes the oval window of inner ear
 - The stapedius muscle attaches to the neck of the stapes

Mastoid process and mastoid antrum:

- Mastoid antrum lies behind the middle ear
- It is an air sinus within the petrous temporal bone
- It is the only air sinus which is well formed at birth
- BUT the mastoid *process* is not formed at birth.
- Infection can spread from middle ear into the mastoid antrum.
- Aditus is in the posterior wall of the epitympanic cavity, and leads into the mastoid antrum
- Relations of the mastoid antrum:
 - Posterior wall: related to the sigmoid sinus by a thin layer of bone.
 - Roof: related to the brain
 - Medial wall: related to posterior semicircular canal
- Mastoid process does not develop till the 2nd year of life
- Air cells gradually extend into it
- Cavities in the mastoid process are continuous with the air-containing mastoid antrum and tympanic cavity.
- Air cavities are occasionally found in other parts of the petrous temporal bone
- Air cells can extend as far as the apex of the petrous temporal bone.
- Mucus membrane of the mastoid air cells are supplied by the:
 - **Mandibular division of trigeminal nerve (V)**
 - Via the **nervus spinosus** which passes through the foramen spinosum
 - **Glossopharyngeal nerve (IX)** fibres from middle ear



INNER EAR

- **Boney labyrinth** is a series of cavities and canals within the deep part of the petrous temporal bone.
- Boney cavities are filled with a fluid called **perilymph**
- Within the boney labyrinth the organs of balance and hearing form the **membranous labyrinth**
- The membranous labyrinth contains **endolymph**
- The membranous labyrinth is anchored to the boney labyrinth at several points – Δ it does not float around.

BONEY LABYRINTH:

- Centrally placed cavity – the **vestible**
- Vestible communicates behind with 3 boney **semicircular canals**
- In front, the vesible is curled into a boney canal – the **cochlea**
- Contains perilymph, which is similar in composition to CSF
- **Aquaduct of the cochlea** passes through the petrous temporal bone from the cochlea → jugular foramen and subarachnoid space.
- CSF may flow along this aquaduct to the cochlea.
- Perilymph is also likely formed as a transudate from the blood vessels in the walls of the boney labyrinth.
- Perilymph may be removed through the aquaduct, or by other mechanisms.
- **Fenestra vesibuli (oval window)** is a hole in the lateral wall of the vestibule, opening onto middle ear.
- The footplate of the stapes plugs this hole.
- Movement of the stapes Δ transmits pressure waves to the perilymph.

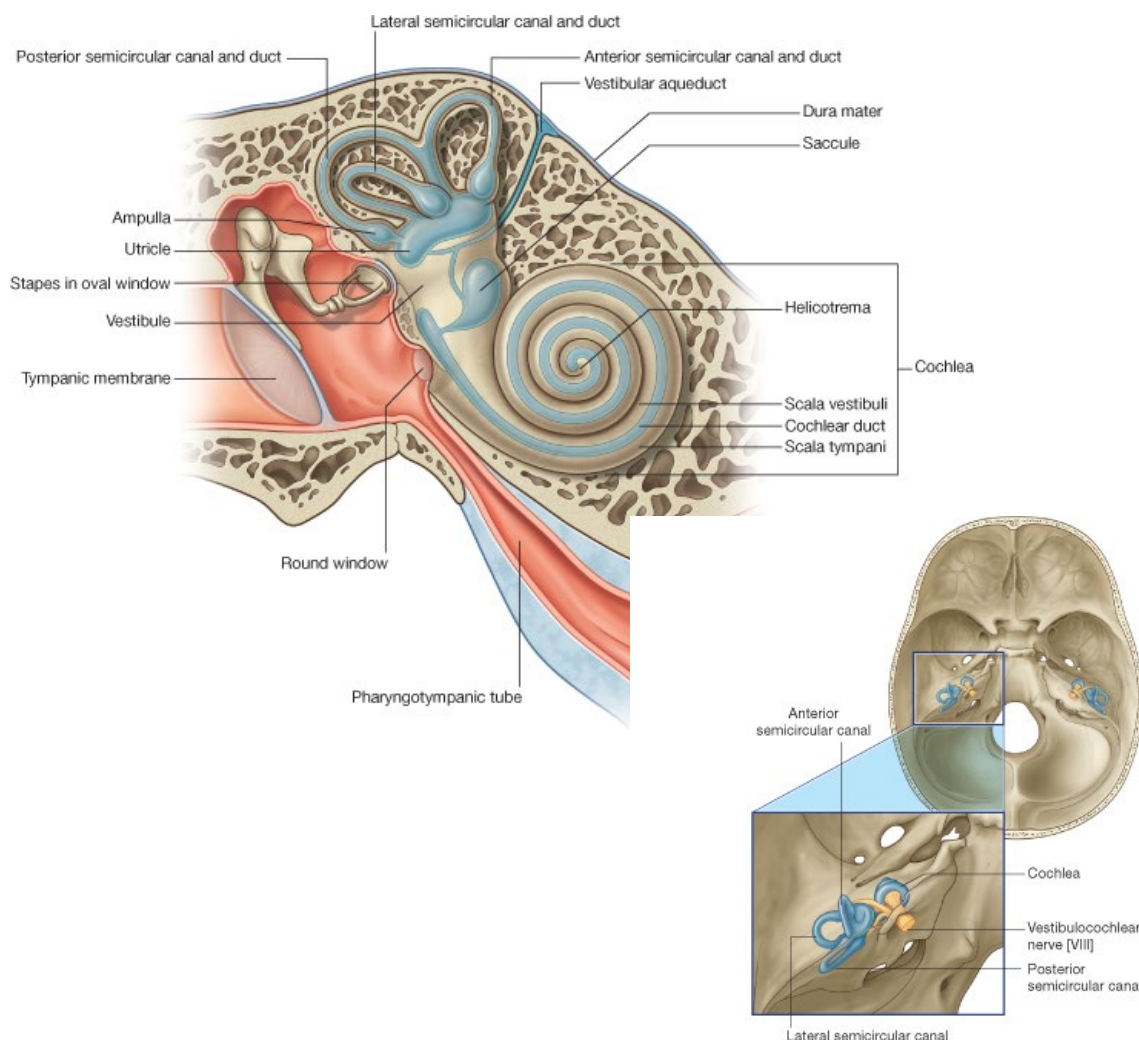
Cochlea:

- Sinuous tunnel
- Runs forward from cavity of vestibule
- Looks like shell of snail
- 2 ¾ turns
- Apex of cochlea – **cupula** – lies deep to the medial wall of the tympanic cavity
- First turn of the cochlea raises a bulge called the **promontary** on the medial wall of the middle ear cavity.
- Cochlea is wound around a central axis called the **modiolus**
- The canal is partly divided by a **boney spiral lamina**
 - Projects from the central column into the canal
- Division of the canal of the cochlea is completed by the **basilar membrane** stretching from the edge of the spiral lamina → outer wall of the canal.
- The boney spiral lamina and basilar membrane Δ completely divide the canal into:
 - Above: **scala vestibuli**
 - Below: **scala tympani**
- The 2 canals are continous at the apex of the cochlea through a hole called the **helicotrema**.

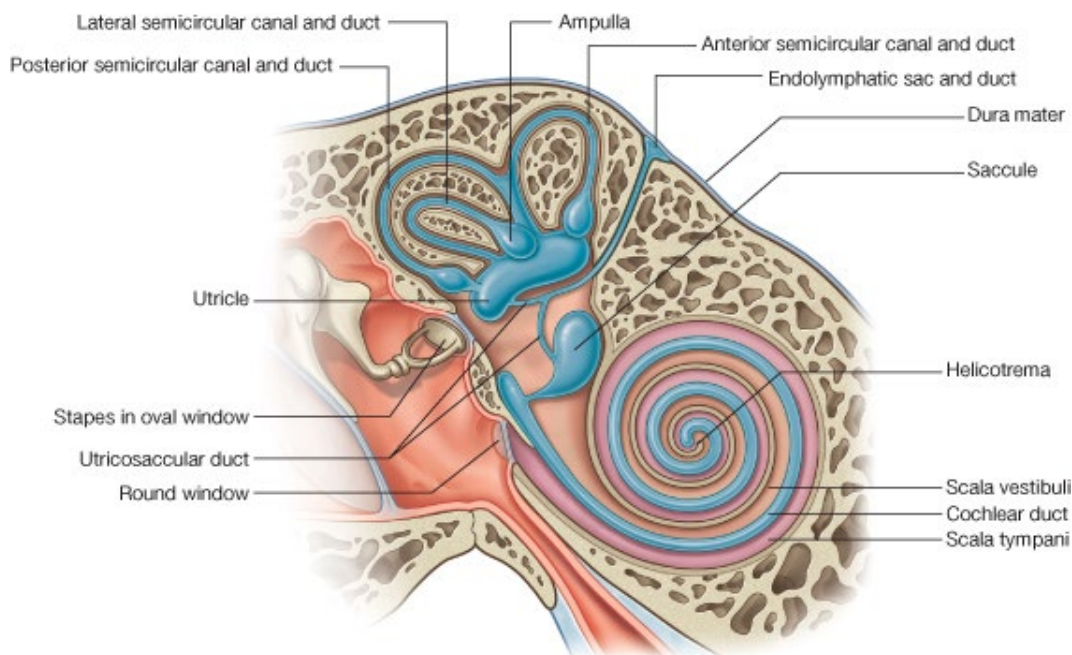
- Vibrations in the perilymph created by movement of the footplate of the stapes in the oval window travel along the scala vestibuli → apex of the cochlea.
- Vibrations then pass through the helicotrema → scala tympani → downwards to base of cochlea.
- Reach fenestra cocleae (round window), closed over by secondary tympanic membrane.
- This route ensures that vibrations at the secondary tympanic membrane are in the opposite direction to those of the footplate of the stapes.
- Δ pressure in the perilymph does not become excessive.

Semicircular canals:

- Lead from posterior of the vestibule cavity.
- There are 3 semicircular canals:
 - **Anterior** (aka superior)
 - **Posterior**
 - **Lateral**
- There is an **ampulla** at one end of each semicircular canal, which contains organs sensitive to body movement.
- Anterior & posterior canals are vertically placed:
 - Posterior lies in long axis of temporal bone
 - Anterior lies perpendicular to the long axis
- Anterior canal lies at higher level than posterior canal (hence it is aka 'superior')
- Anterior canal raises bony eminence on anterior aspect of petrous temporal bone in middle cranial fossa – the **arcuate eminence**
- The lateral canal lies horizontally.



MEMBRANOUS LABYRINTH:

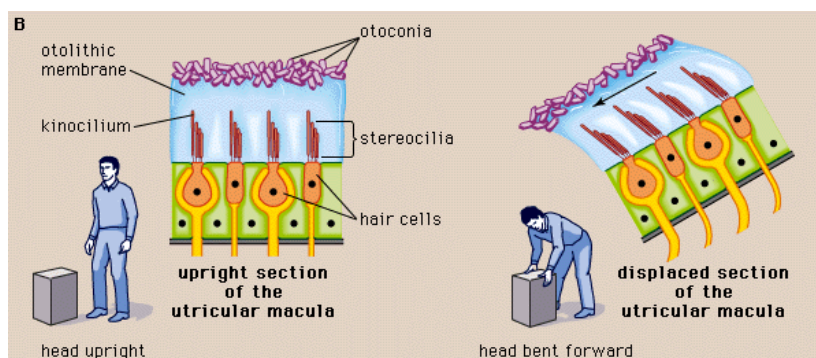


- Canals & cavities of bony labyrinth contains a series of sacs & tubes filled with endolymph
- The membranous labyrinth is smaller than the bony labyrinth.
- Within the vestibule there are 2 sacs of endolymph:
 - Posteriorly: **utricle**
 - Anteriorly: **saccule**
- **Semicircular ducts** lie within the bony semicircular canals, and are continuous with the utricle in front.
- **Cochlea duct** is continuous with the saccule in front.
- Cochlea duct lies within the bony cochlea canal.
- **Endolymphatic duct** is a blind-ending sac arising from the utricle and saccule
- Extends through the petrous bone in the **bony aquaduct of the vestibule**
- Comes to lie against dura in the posterior cranial fossa at posterior aspect of the petrous temporal bone.
- The dura covers over a hole in the bone here.
- A vascular network in the specialised epithelial cells at this termination of the endolymphatic duct is responsible for the reabsorption of endolymph into the bloodstream.

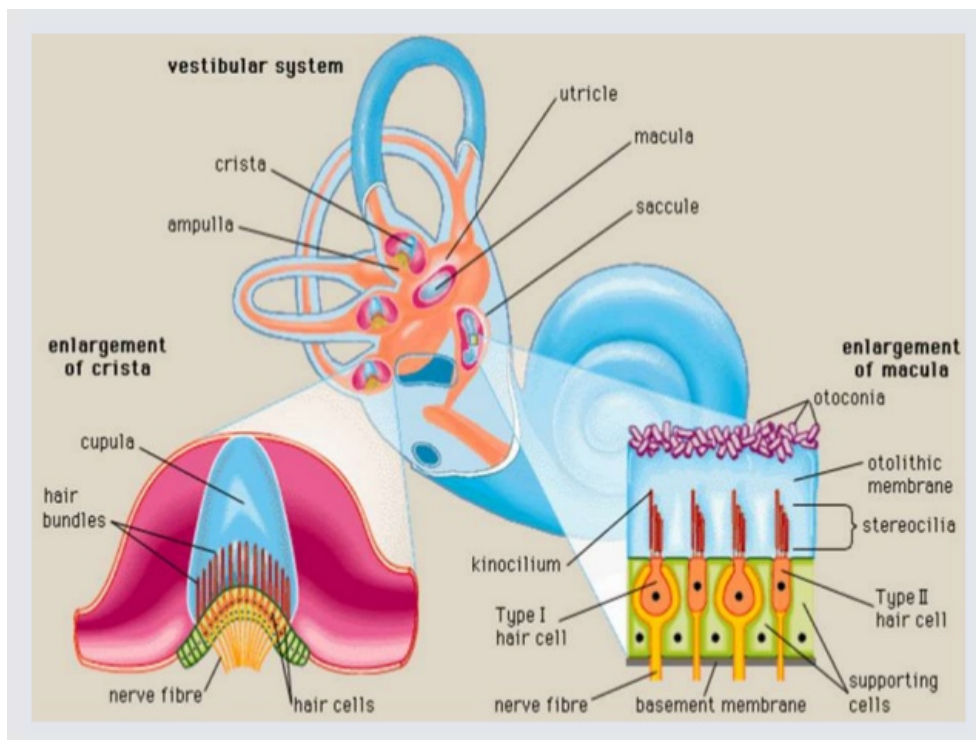
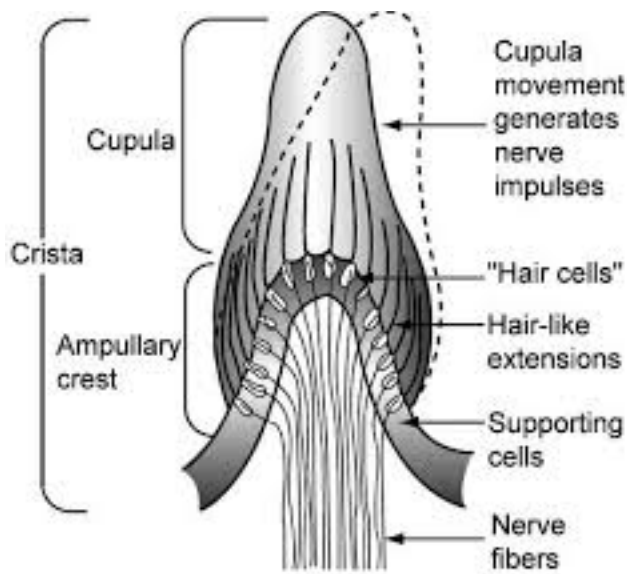
Saccule, utricle & semicircular canals:

- **Saccule** is joined to the duct of the cochlea in front by the **ductus reuniens**
- 3 **semicircular ducts** occupy the semicircular canals, and are continuous with the utricle.
- Near the orifices the semicircular ducts are dilated into **ampullae**, each of which contains a projection – the **ampullary crest**.

- Both **utricle** and **saccul**e contain specialised neuroepithelium which is sensitive to the pull of gravity.
- The **macula of the utricle** is a thickening of the wall of the utricle formed from this neuroepithelium.
- Similar thickening in wall of the saccul – the **macula of the saccul**e
- The macula of the saccul is at right angles to the macula of the utricle
- The macula of the utricle and saccul signal alterations in the position of the head with reference to the pull of gravity.
- This information is used to change muscle tone in the body, esp:
 - Supporting muscles
 - Muscles of neck
 - Muscles concerned with eye movement
- Macula are Δ known as the **organs of static balance**.
- Epithelium of both the macula and ampullary crests are composed of:
 - Hair cells
 - Supporting cells
- The bases of the hair cells are associated with nerve terminals afferent fibres of **vestibular nerve**
- **Otolithic membrane** is a gelatinous mass which overlies each macula
- Otolithic membrane contains crystalline bodies – **otoconia**
- Alterations in position of head in relation to line of gravity is detected as it causes the otolithic membrane to drag over the sensitive hair cells.



- The **ampullary crests** of the semicircular ducts signal **angular acceleration** of the head (rather than static balance).
- The ampullary crests are covered with minute **stereocilia** of sensitive hair cells
- Ampullary crests are covered with gelatinous, dome-shaped **cupula**
- The cupula rests on the surface of each ampullary crest
- The stereocilia are completely embedded into the cupula
- The cupula completely occludes the flow of endolymph through the semicircular ducts
- But movement of the head sets up current and drag in the endolymph, which moves the cupula over the stereocilia – stimulating the hair cells
- → change in discharge in **vestibular nerve (branch of VIII)**
- Vestibular nerve has a basal level of discharge
- Movement of the cupula in one direction → ↑ discharge
- Movement of the cupula in opposite direction → ↓ discharge

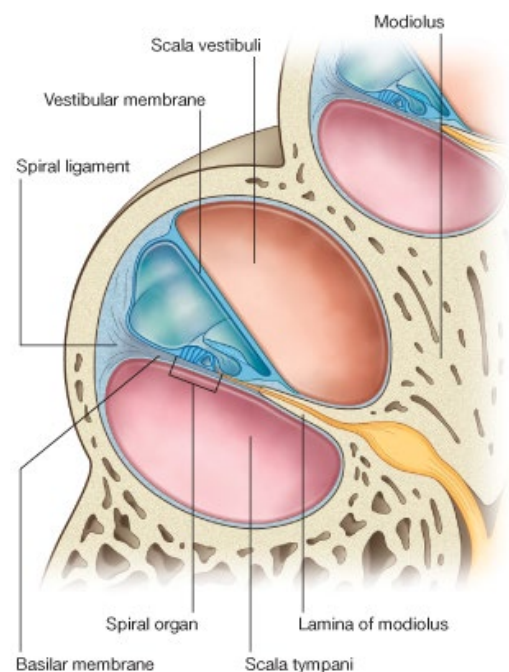
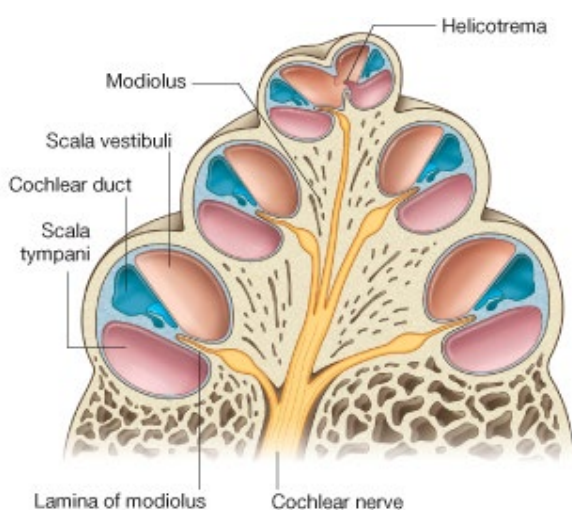
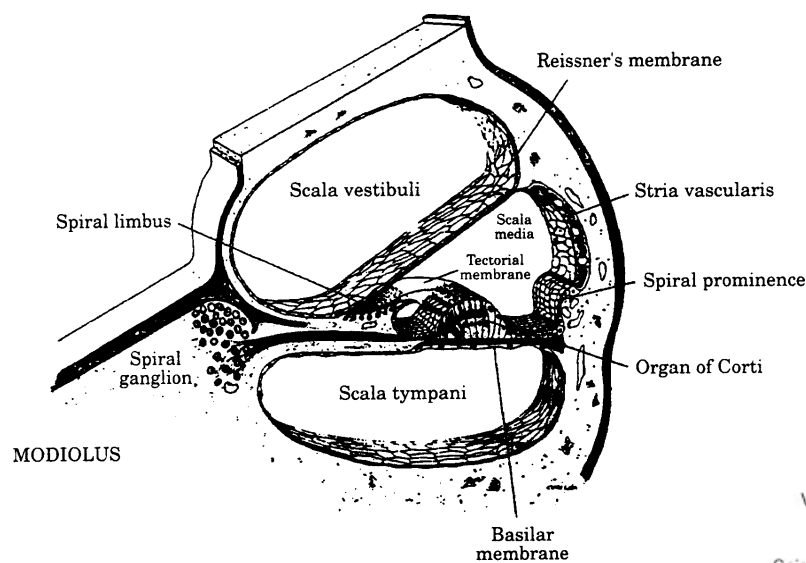


Macula of utricle / saccule	Organs of static balance	Macula: hair cells with stereocilia embedded in otolithic membrane with otoconia
Crista of ampulla (semicircular canals)	Organs of angular acceleration	Crista: hair cells embedded in cupula
Spiral organ of corti	Hearing	Organ of corti: stereocilia of inner and outer hair cells sat on basilar membrane, embedded in tectorial membrane

Cochlear duct:

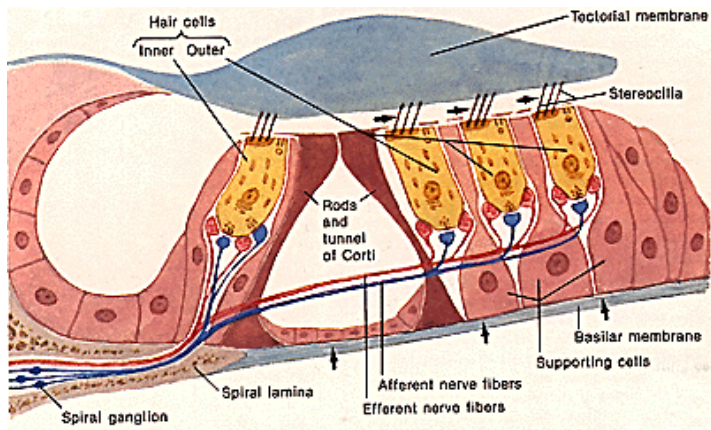
- Spirally arranged within the bony cochlea
- Concerned with hearing
- Begins as ductus reuniens (from saccule)

- Spirals to a close near apex of the cochlea
- Floor of the duct is the **basilar membrane** that stretches from the **spiral bony lamina** → outer wall of cochlea canal.
- Roof of the duct is the **vestibular membrane** that also stretches from the **spiral bony lamina** → outer wall of cochlea canal.
- Cochlear duct Δ has a triangular cross-section.
- Above the attachment of the basilar membrane, the outer wall of the cochlea duct represents a **spiral prominence**.
- The epithelium above the prominence is highly vascular & called **stria vascularis**
- The stria vascularis is responsible for:
 - **Production of endolymph**
 - Maintenance of ionic composition



- Specialised organ of hearing is the **spiral organ of Corti**
- Lies on the **basilar membrane** of cochlea duct.
- Spiral organ of Corti consists of several parts:

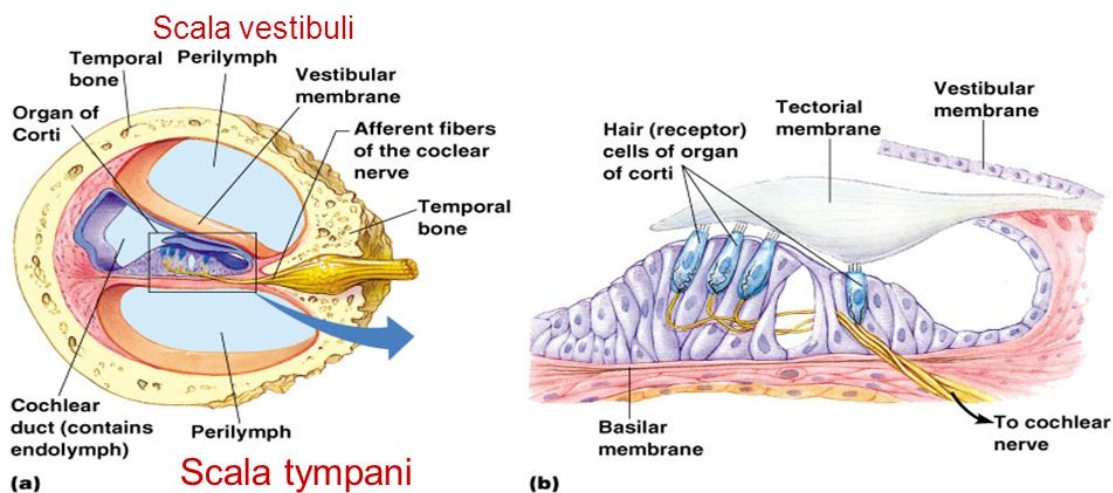
- Inner and outer hair cells sit on the basilar membrane
- These cells form columns which slope towards each other – creating a triangular **tunnel of Corti** between them
- ‘Hairs’ or stereocilia of the outer hair cells are embedded in a fibrogelatinous membrane – **tectorial membrane**
- The stereocilia fo the inner hair cells are free of the tectorial membrane



Note: the stereocilia of the inner hair cells in the picture should not be in contact with the tectorial membrane

Cochlea

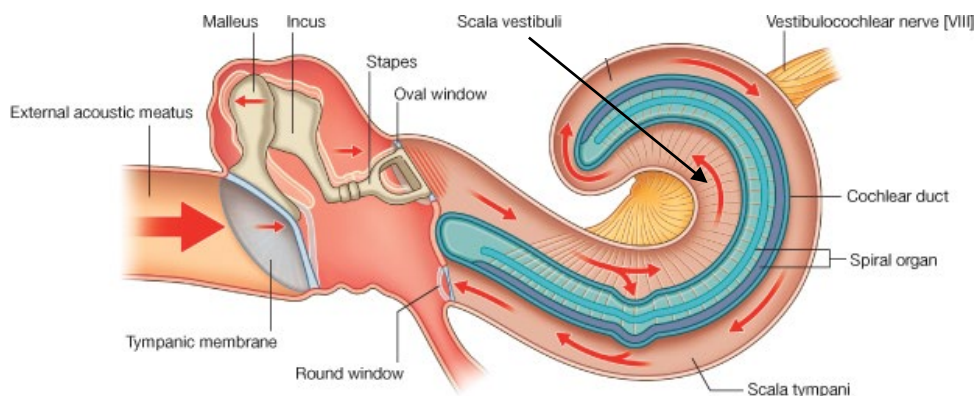
- Spiral organ of Corti
- Receptors = hair cells on the basilar membrane



SUMMARY OF THE MECHANISMS OF HEARING:

- Sound vibrations are collected by the pinna
- Transmitted through external acoustic meatus → tympanic membrane
- Movement of the ossicle transmits the vibrations to the inner ear (oval window)
- Force per unit area of the footplate of the stapes is amplified 20 times

- Stapedius and tensor tympani muscles help by dampening excess vibrations – by stiffening the chain of ossicles.
- Vibration of stapes sets up pressure waves in the fluid of vestibule
- Waves are conducted via the perilymph of the scala vestibuli → helicotrema → scala tympani → basilar & vestibular membranes between them.
- Cannot Δ close off the cochlea system, or the pressure would rise to excess.
- To dissipate the pressure:
 - Inward excursion of oval window
 - → pressure wave through scala vestibuli
 - → apex of cochlea
 - → through the helicotrema
 - → into scala tympani
 - → dissipated as outward movement of secondary tympanic membrane in round window.
- Vibrations in the perilymph of the scala vestibuli set up vibrations in the basilar membrane
- → organ of corti (sitting on the basilar membrane), moves with respect to the tectorial membrane.
- → shear/deflection of the stereocilia of the hair cells of the organ of corti
- → change in membrane potential of the hair cells
- → AP discharge in the nerves supplying the hair cells.
- Larger movements → greater movement of basilar membrane → greater neuronal firing.
- Sensory nerves pass from the hair cells → towards the modiolus where they have their cell bodies in the spiral ganglion within the modiolus.
- From here neurons pass outwards as the cochlear part of the VIII cranial nerve



THE VESTIBULOCOCHLEAR NERVE:

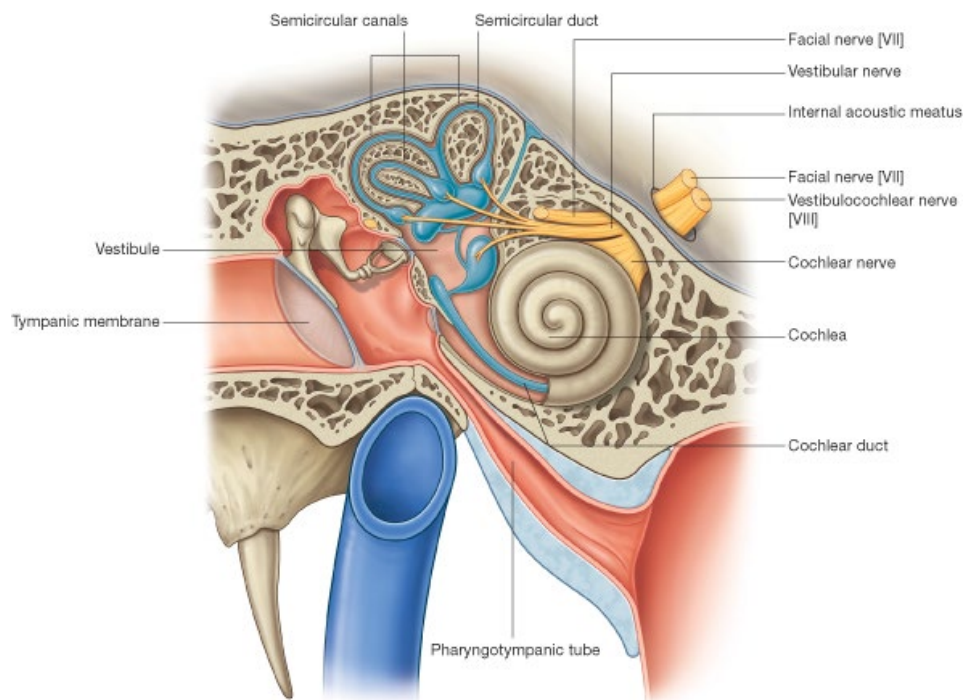
- Cranial nerve VIII = **vestibulocochlear nerve**
- Carries sensory impulses from the organs of balance and hearing to the brain

Cochlear branch

- Hair cells in the cochlear duct are deformed by vibrations → impulses → transmitted in cochlear fibres of the vestibulocochlear nerve.
- The sensory cell bodies of these cochlear fibres are found in the spiral ganglion within the modiolus (remember, every sensory nerve must have a ganglion at some point in its course).

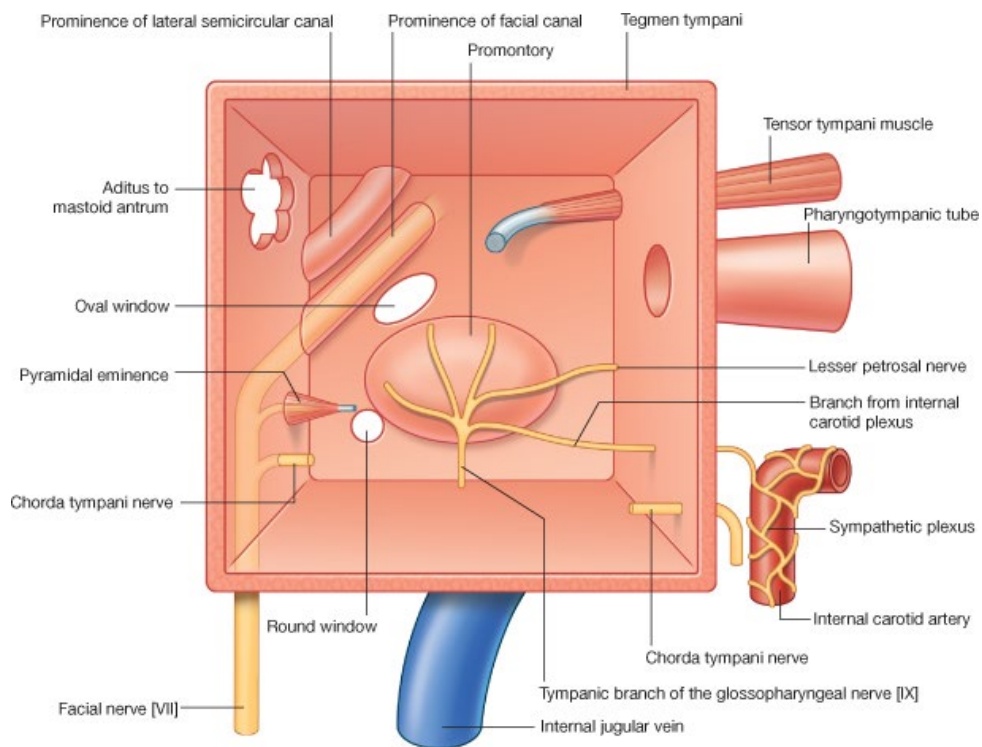
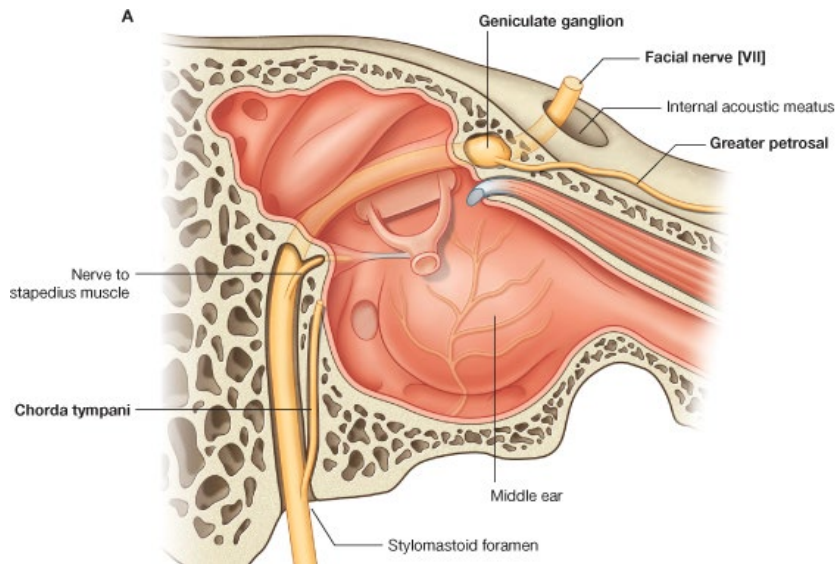
Vestibular branch

- Carry impulses from hair cells in the maculae and ampullary crests (balance)

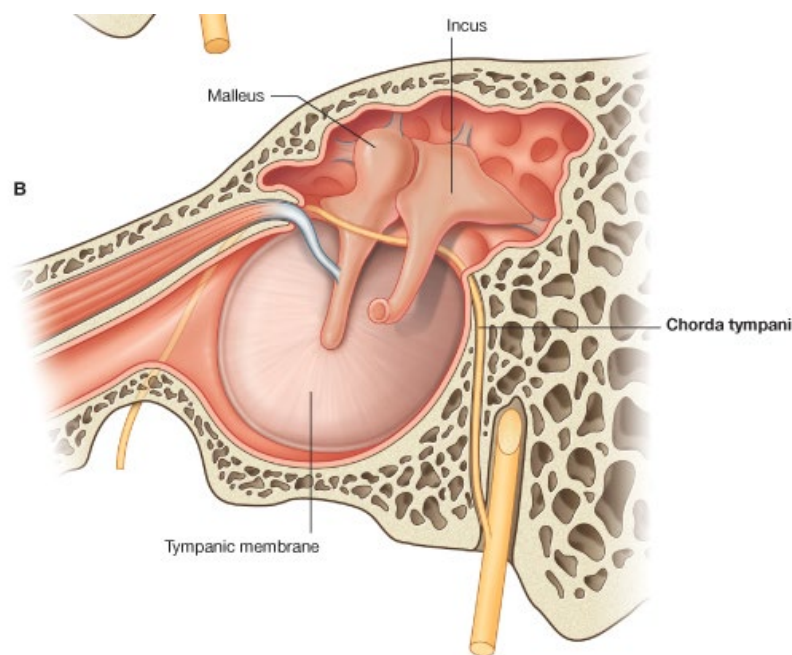


FACIAL NERVE IN THE PETROUS TEMPORAL NERVE

- The **facial nerve (VII)** also uses the **internal acoustic meatus** as a means of entering the petrous temporal bone.
- Then bypasses the ear cavities within its own tunnel.
- Means that for a short distance VII & VIII cranial nerves travel together.
- Facial nerve (VII) is on its way to supply the muscles of the face.
- Facial nerve passes laterally along the internal acoustic meatus until it reaches the medial wall of the middle ear cavity. It does this in conjunction with:
 - Vestibulocochlear nerve (VIII)
 - Labyrinthine artery
- Here, the sensory fibres of the facial nerve have a ganglion – the **geniculate ganglion**
- Nerve then turns a right angle backwards and runs along the top of the medial wall of the middle ear cavity **in its own boney canal**
- On reaching the back of the medial wall of the middle cavity it turns another right-angle downwards in its canal.
- Eventually runs out of the petrous temporal bone and skull through **stylomastoid foramen**



- While in its tunnel in the petrous temporal bone, the facial nerve gives off several branches:
- **2 x petrosal nerve** run forward through the petrous temporal bone
- **Nerve to stapedius** is a nerve supplying the stapedius muscle in the middle ear.
- The stapedius and the tensor tympani are both muscles which attach to the ossicles in the middle ear and stabilise the excursions of the ossicles.
- I.e. they prevent dislocation of the ossicles when very loud noises.
- **Stapedius: supplied by facial nerve (VII)**
- **Tensor tympani: supplied by trigeminal nerve (V)**
- Paralysis of stapedius → **hyperacusia** – an excessive acuteness of hearing.
- **Chorda tympani** branch
- Given off from facial nerve in the bony facial canal as the the nerve reaches the stylomastoid foramen.
- Runs up over the tympanic membrane and handle of the malleus → leaves the skull.
- Carries:
 - Taste fibres from the tongue
 - Parasympathetic secretor motor fibres to salivary glands in floor of mouth



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APPLIED ANATOMY OF THE EAR:

- The external auditory meatus can be affected by:
 - Minor infections
 - Logged foreign bodies
 - Accumilation of wax
- Can cause pain and may progress to more serious complications
- Infections of the middle ear occur frequently, esp in children
- May progress to mastoid air cells

- May originate in the pharynx and track up the auditory tube to the middle ear.
 - Δ children with cleft palate are particularly susceptible to middle ear infection.
- Persistent infection may lead to deafness.
- Tympanic membrane becomes red and swollen, and cone of light is not visible.
- May be necessary to incise the tympanic membrane so as to drain the middle ear cavity.

- The superior half of the tympanic membrane:
 - Is very vascular
 - Has the chorda tympani running over it
 - Has the handle of the malleus attached to it.
- The posteroinferior quadrant is least vascular, and has not important structures attached - Δ would incise here to drain the middle ear.

- **Vertigo** can be caused by:
 - Labyrinthitis (inflammation of membranous labyrinth)
 - Excess endolymph production \rightarrow \uparrow pressure \rightarrow degeneration of macula hair cells (**Meniere's disease**)
- Syringing wax out of the external auditory meatus with water which is significantly different from body temperature \rightarrow movement of endolymph \rightarrow dizziness

- **Deafness** may result from:
 - A. Damage to vestibulocochlear nerve (VIII)
 - B. Mechanical disruption to sound transmission through the chain of ossicles (between tympanic membrane and oval window).
 - E.g. congenital fixation of the stapes to the oval window.