The Ear

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The ear consists of the external ear; the middle ear (tympanic cavity); and the internal ear (labyrinth), which contains the organs of hearing and balance.

Sound is captured by the external ear

Mechanical signals in the middle ear

The internal ear converts the mechanical signals into electrical signals to transfer information to the brain

The internal ear also contains receptors that detect motion and position
External Ear

**Auricle (pinna)**

- The auricle has a characteristic shape
- It collects air vibrations
- It consists of a thin plate of elastic cartilage covered by skin

**External auditory meatus**

- The external auditory meatus is a curved tube that leads from the auricle to the tympanic membrane
- It conducts sound waves from the auricle to the tympanic membrane
Anotia is complete absence of the external ear, and is most likely caused by a developmental disturbance between the seventh and eighth gestational week.

Prominent ears (also known as ‘bat’ ears) are caused by the absence or inadequacy of an antihelical fold.

The cartilage of the auricle is arranged in a pattern of elevations and depressions.

1. **Helix.**
2. Crus of helix
3. Auricular tubercle.
4. **Antihelix.**
5. Crura of antihelix.
6. Triangular fossa.
7. Scaphoid fossa.
8. **Concha of auricle.**
9. **Tragus.**
10. **Antitragus.**
11. Intertragic notch.
12. **Lobule of auricle.**

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Note that the Auricular branches of vagus and facial nerves supply deeper parts of the auricle.

Auriculotemporal nerve:
- upper part of the outer surface

Great auricular nerve:
- the lower part of both inner and outer surfaces

Lesser occipital nerve:
- the upper part of the inner surface

The cough reflex via the vagus nerve
The external auditory meatus

✓ The framework of the outer third of the meatus is elastic cartilage, and the inner two thirds is bone
✓ The meatus is lined by skin
✓ The outer third is provided with hairs and sebaceous and ceruminous glands

**Ceruminous glands** are modified sweat glands that secrete a yellowish brown wax (cerumen = earwax)

The hairs and the wax provide a sticky barrier that prevents the entrance of foreign bodies

Cerumen is produced in the outer third of the cartilaginous portion of the ear canal. pH is acidic in normal healthy canals. Contains a bactericidal enzyme.

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Otoscopic examination of the tympanic membrane is facilitated by first straightening the external auditory meatus by gently pulling the auricle \textbf{upward and backward} in the adult.

This straightens the ear canal and improves visualization.
In the adult the external meatus is about 1 in. (2.5 cm) long and is narrowest about 0.2 in. (5 mm) from the tympanic membrane.
The Tympanic membrane (ear drum) is a thin, fibrous membrane.

- The membrane is obliquely placed, facing downward, forward, and laterally.
- The inner surface of tympanic membrane is fixed to handle of Malleus.
- The membrane is concave laterally.
- Umbo is a small depression produced by the tip of the handle of the malleus.

Is formed of:
1. Outer layer: Skin
2. Middle layer: Fibrous tissue
3. Inner layer: Mucous membrane
Remember that the middle fibrous layer is present in the major parts of the ear drum which called **pars tensa**

However, this layer is **absent** in the upper part of the ear drum which is called **pars flaccida** (Shrapnell's membrane) (Rivinus’ ligament)

The pars tensa and flaccida are separated from each other by two folds called the **anterior and posterior malleolar folds**

The tympanic membrane is extremely sensitive to pain
Otoscopic Examination
When the membrane is illuminated through an otoscope, the concavity produces a cone of light, which radiates anteriorly and inferiorly from the umbo.

Clinical application
The tympanic membrane is a relatively thin connective tissue structure, and is susceptible to perforation (usually by trauma or infection).

An infection of the middle ear (otitis media) causes pus and fluid to build up behind the tympanic membrane. This causes an increase in pressure within the middle ear, and eventually the eardrum can rupture.

 ✓ The tympanic membrane is pearly white or light gray, and you can see through it.
 ✓ You can see the tiny bones of the middle ear pushing on the tympanic membrane.
The cone of light is at the 5 o'clock position in the right ear and at the 7 o'clock position in the left ear.
Lateral surface of tympanic membrane

Note the tympanic membrane is translucent, concave laterally.

The antero-inferior quadrant of the ear drum is called the **cone of light** (because it reflects the light coming from the otoscope).
Otitis media

The light reflex on the tympanic membrane is dull or absent. The tympanic membrane is red and bulging. You can often see amber liquid or bubbles behind the eardrum.
Middle Ear (Tympanic Cavity)

- Is an air-containing cavity in the petrous part of the temporal bone
- Is lined with mucous membrane
- It contains the auditory ossicles, whose function is to transmit the vibrations of the tympanic membrane (eardrum) to the inner ear

The middle ear has
- ROOF
- FLOOR
- ANTERIOR WALL
- POSTERIOR WALL
- LATERAL WALL
- MEDIAL WALL
Tympanic cavity (middle ear) is a narrow, oblique, slitlike cavity whose long axis lies approximately parallel to the plane of the tympanic membrane.
Walls of middle ear

- Roof
- Medial wall
- Anterior wall
- Posterior wall
- Floor
Roof

Is formed by **tegmen tympani** (part of the petrous temporal bone)

It separates the tympanic cavity from the **meninges and the temporal lobe** of the brain in the middle cranial fossa.

Floor

It separates the tympanic cavity from the **internal jugular vein**
➢ Is formed below by a thin plate of bone that separates the tympanic cavity from the **internal carotid artery**

➢ At the upper part of the anterior wall are the openings into two canals
   The lower and larger leads into **the auditory tube**
   The upper and smaller is the entrance into **the canal for the tensor tympani muscle**
Opening of Eustachian tube into nasopharynx
EUSTACHIAN TUBE:

It connects the anterior wall of the tympanic cavity to the nasopharynx.

It serves to equalize air pressures in the tympanic cavity and the nasopharynx.

Its posterior inner third is bony. Its anterior two thirds are cartilaginous.

Normally, the Eustachian tube is collapsed, but it opens with swallowing.

Pharyngo-tympanic tube
Auditory tube
Eustachian tube
**Oval window:**
Above and behind the promontory, oval shaped and closed by the base of the stapes *(Fenestra vestibuli)*

**Round window:**
Below the posterior end of the promontory, round and closed by the secondary tympanic membrane *(Fenestra cochleae)*

**Promontory** is a rounded projection (results from the underlying first turn of the cochlea)

The medial wall is formed by the lateral wall of the inner ear.

Fenestra means window
The base of stapes closes the oval window of the internal ear.
Internal acoustic meatus

Brain stem

Stylomastoid foramen

7th

8th
1- Has in its upper part a large, irregular opening, the **aditus** to the mastoid

2- Below, a small conical projection, the **pyramid**, from its apex emerges the tendon of the stapedius muscle

3- The **vertical part of the facial nerve**
Mastoid Antrum
The mastoid antrum lies behind the middle ear in the petrous part of the temporal bone
It communicates with the middle ear by the aditus
The horizontal part of the facial nerve

Stylomastoid foramen

Anterior

Posterior

The vertical part of the facial nerve
Infections and Otitis Media

The posterior wall of the mastoid antrum is related to the **sigmoid venous sinus**. If the infection spreads in this direction, a *thrombosis in the sigmoid sinus* may take place.

Medial wall: A spread of the infection in this direction can cause a *facial nerve palsy and labyrinthitis with vertigo*.

Although rare, complications of OM are commonly encountered given its high prevalence. Complications of OM are classified as extracranial or intracranial. Brain abscess are commonly considered the second most common intracranial complication of OM after meningitis.
Groove for the **sigmoid sinus**
**CONTENTS OF THE MIDDLE EAR**

A-3 Auditory Ossicles
B-2 muscles
C-2 nerves (tympanic plexus and chorda tympani)
D-air

- It contains the auditory ossicles, whose function is to transmit the vibrations of the tympanic membrane (eardrum) to the perilymph of the internal ear
Ossicles

A
- Incus articulation
- Head of malleus
- Neck of malleus
- Lateral process
- Anterior process
- Handle of malleus

B
- Body of incus
  - Short limb
  - Long limb
- Base of stapes

C
- Posterior limb
- Anterior limb
- Head of stapes
1-The malleus is the largest ossicle and possesses head, a neck, a long process or handle, an anterior process, and a lateral process. Its head is rounded and articulates posteriorly with the **incus**.

**The incus possesses:**
- a large body and two processes:
  - The body articulates with the head of the malleus.
  - The long process articulates with the head of the stapes.

**The stapes** has a head, a neck, two limbs, and a base.
- **The head** articulates with the long process of the **incus**.
- The neck is narrow and receives the insertion of the **stapedius** muscle. The two limbs diverge from the neck and are attached to the **oval base** which closes the **oval window** of the internal ear.
Malleus

The handle is firmly attached to the medial surface of the tympanic membrane.
Incus
**Stapes**

The base of stapes closes the **oval window** of the internal ear.

The **Annular stapedial ligament** is a ring of fibrous tissue that connects the base of the stapes to the oval window of the inner ear.

Calcification and hardening of the annular ligament of the stapes (Otosclerosis) is a common cause of adult deafness.
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<td>Mandibular division of trigeminal nerve</td>
<td>Dampens down vibrations of tympanic membrane</td>
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<tr>
<td>Stapedius</td>
<td>Facial nerve</td>
<td>Dampens down vibrations of stapes</td>
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Muscles of middle ear

Tensor tympani muscle

Stapedius muscle

Anterior

Hyperacusis

Hypoacusis
Chorda tympani
Chorda tympani
**The chorda tympani**

- It arises from the facial nerve just above the stylomastoid foramen
- It enters the middle ear close to the posterior border of the tympanic membrane.
- It then runs forward over the tympanic membrane and crosses the root of the handle of the malleus
- It leaves the middle ear through the petrotympanic fissure and enters the infratemporal fossa, where it joins the lingual nerve

The chorda tympani contains:

1. Taste fibers from the mucous membrane covering the anterior two-thirds of the tongue and the floor of the mouth.
2. Carries preganglionic parasympathetic fibers to the submandibular and sublingual glands via the submandibular ganglion
The **petrotympanic fissure** is a fissure in the temporal bone.

The chorda tympani runs through the fissure to join with the lingual nerve in the infratemporal fossa.

The **chorda tympani** is a branch of the facial nerve.

The **chorda tympani** passes medial to the tympanic membrane and the handle of the malleus, and again enters the temporal bone. It exits the skull through the petrotympanic fissure and descends in the infratemporal fossa.

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The tympanic nerve arises from the glossopharyngeal nerve, just below the jugular foramen.

It passes through the floor of the middle ear and onto the promontory.

Here it splits into branches, which form the tympanic plexus.

The tympanic plexus supplies the lining of the middle ear and gives off: **Lesser petrosal nerve**

It leaves the skull through the foramen ovale.

Carries preganglionic parasympathetic fibers to the parotid gland via the **otic ganglion**.
Foramen ovale transmits:
- Mandibular nerve
- Accessory meningeal artery
- Lesser petrosal nerve
- Emissary vein

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Pterygoid venous plexus in Infratemporal fossa

Cavernous sinus

Foramen ovale

Emissary vein

Pterygoid venous plexus in Infratemporal fossa
Inner Ear (labyrinth)
Inner ear is situated in the petrous part of the temporal bone.

- Anterior semicircular canal
- Cochlea
- Vestibulocochlear nerve [VIII]
- Posterior semicircular canal
- Internal acoustic meatus
- Lateral semicircular canal
The inner ear is divided into:
1- Bony labyrinth
2- Membranous labyrinth

The vestibule, the central part of the bony labyrinth
Bony labyrinth

- Semicircular canals
- Vestibule
- Cochlea

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The membranous labyrinth is lodged within the bony labyrinth. It is filled with **endolymph** and surrounded by **perilymph**.
The duct of the cochlea lies within the bony cochlea.
Posterior semicircular canal
Lodged within the canals are the semicircular ducts.
Superior semicircular canal
Superior semicircular duct

Lodged within the canals are the semicircular ducts
Lateral semicircular canal
Lateral semicircular duct

Lodged within the canals are the semicircular ducts
Bony ampullae

Each canal has a swelling at one end called the **ampulla**.
Membranous ampullae

Membranous ampullae are lodged in the bony ampullae
Utricle and Saccule are lodged in the bony vestibule.
Saccule

Utricle and Saccule are lodged in the bony vestibule.
Vestibulo-cochlear nerve

Vestibular nerve

Cochlear nerve
The inner ear contains sensory receptors for hearing and balance. Mechanoreceptors/Hair cells (Columnar cells)

- Two maculae of the utricle and saccule,
- Three cristae ampullares in the ampullae of each semicircular duct
- The organ of Corti in the cochlear duct.
Vestibular nerve carries impulses from the utricle, the saccule, and the ampullae of the semicircular ducts (contain the sensory receptors for balance)
Cochlear nerve carries impulses from organ of Corti in cochlea (contains the sensory receptors for hearing)
✓ The cochlear duct itself forms the middle compartment, or scala media, filled with endolymph. It is continuous with the saccule and ends at the apex of the cochlea.
✓ The larger scala vestibuli contains perilymph and is separated from the scala media by the very thin vestibular membrane (Reissner membrane).
✓ The scala tympani also contains perilymph and is separated from the scala media by the basilar membrane.
The scalae tympani and vestibuli communicate with each other at the apex of the cochlea via the **helicotrema**.
The cochlea is about 35 mm long and makes $2\frac{3}{4}$ turns around a bony core called the **modiolus**.
The **organ of Corti**, or spiral organ, where sound vibrations of different frequencies are detected, consists of hair cells and other epithelial structures supported by the basilar membrane.

Note: Cell Bodies of cochlear Nerve (CN VIII) located in the Modiolus (**Spiral ganglion**)
Section through cochlea

- Scala vestibuli
- Cochlear duct (Scala media)
- Scala tympani
- Lamina of modiolus
- Cochlear nerve
- Spiral ganglion
- Modiolus
- Helicotrema
The auditory nerve (cochlear) carries the electrical signal to the brain, which turns it into a sound that we recognize and understand.
With the tectorial membrane removed, SEM shows the apical plate of the rat spiral organ through which rigid stereocilia bundles project into endolymph.
The auditory hair cells are located within the spiral organ of Corti on the basilar membrane in the cochlea of the inner ear.

Stereocilia (hair bundles) protrude from the apical surface of the cell into the fluid-filled cochlear duct.

The inner hair cells transform the sound vibrations in the fluids of the cochlea into electrical signals that are then relayed via the auditory nerve to the auditory brainstem and to the auditory cortex.

The deflection of the hair-cell stereocilia opens mechanically gated ion channels that allow positively charged ions (primarily potassium) to enter the cell.

The influx of positive ions from the endolymph in the scala media depolarizes the cell, resulting in a receptor potential.

Damage to these hair cells results in decreased hearing sensitivity, and because the inner ear hair cells cannot regenerate, this damage is permanent.

Note: hair cells detect movement.
Problems of the vestibular system can result in **vertigo, or dizziness**, a sense of bodily rotation and lack of equilibrium. Spinning the body produces vertigo due to overstimulation of the cristae ampullares of the semicircular ducts. Overstimulation of the maculae of the utricle caused by repetitive changes in linear acceleration and directional changes can normally lead to motion sickness (sea sickness/ car sickness).
Supporting cells

Gelatinous layer

Columnar hair cells

Sensory epithelium of saccule, utricle and semicircular ducts

Depolarization

Hyperpolarization

Bending of these stereocilia change membrane potential
Facial nerve

Internal acoustic meatus

Horizontal part of facial canal

Vertical part of facial canal

N to stapedius

Chorda tympani

Stylomastoid foramen

Posterior auricular n

Parotid gland

Stylohyoid

Post belly of digastric