Physiology of hearing and equilibrium

The **ear** functions as the sensory organ for both **hearing** and **equilibrium (balance)** . These two modalities rely on specialized mechanoreceptors located within distinct regions of the ear.

Ear Structure

The ear is anatomically divided into three major regions:

1. **External (outer) ear**
2. **Middle ear**
3. **Internal (inner) ear**

Each section plays a unique role in detecting and transmitting sensory information to the brain.

1. External Ear (Outer Ear)

The external ear includes:

- **Auricle (pinna)** – A cartilaginous structure covered by skin, shaped to collect and direct sound waves into the ear canal.
- **External auditory canal (meatus)** – A slightly curved tunnel within the temporal bone lined by skin and **ceruminous glands** , which secrete protective earwax.

The **tympanic membrane (eardrum)** marks the boundary between the external and middle ear. It vibrates in response to sound waves and transmits these vibrations to the ossicles of the middle ear.

2. Middle Ear

The middle ear is an air-filled cavity that contains three small bones known as the **auditory ossicles** :

- **Malleus** (hammer)
- **Incus** (anvil)
- **Stapes** (stirrup)

These ossicles amplify and transmit vibrations from the tympanic membrane to the **oval window** of the inner ear.

Also present is the **Eustachian tube (auditory tube)** , which connects the middle ear to the nasopharynx. It equalizes pressure on both sides of the tympanic membrane, maintaining optimal vibration sensitivity.

3. Inner Ear (Labyrinth)

The inner ear contains the sensory organs for both hearing and equilibrium. It is housed within the petrous part of the temporal bone and consists of two major components:

A. Cochlea (Organ of Hearing)

- The **cochlea** is a spiral-shaped, fluid-filled structure responsible for converting mechanical sound vibrations into electrical signals.
- Within the cochlea lies the **organ of Corti**, which contains **hair cells** embedded in the **basilar membrane**.
- These hair cells are mechanoreceptors that transduce sound vibrations into nerve impulses.
- Movements of the **basilar membrane** in response to specific sound frequencies displace the hair cells, triggering action potentials in the **cochlear branch of the vestibulocochlear nerve (cranial nerve VIII)**.

B. Vestibular Apparatus (Organ of Equilibrium)

The vestibular system consists of:

- **Semicircular canals** – Detect **rotational (angular) acceleration** of the head. Each of the three canals is oriented in a different plane to sense motion in all directions.
- **Utricle** – Detects **linear acceleration in the horizontal plane**, such as forward or backward motion.
- **Saccule** – Detects **linear acceleration in the vertical plane**, such as moving up or down.

Each of these structures contains specialized **hair cells** embedded in gelatinous membranes:

- In the semicircular canals, the hair cells reside in **ampullae** and are associated with a structure called the **cupula**.
- In the utricle and saccule, the hair cells are embedded in the **macula**, which contains **otoliths** (calcium carbonate crystals) that shift in response to gravity or motion.

Sensory Receptors

Each inner ear contains six groups of hair cells:

- **Three in the semicircular canals** (one per canal)
- **One in the utricle**
- **One in the saccule**
- **One in the cochlea**

These **mechanoreceptors** respond to movement of endolymph (fluid) and initiate nerve impulses through cranial nerve VIII to appropriate regions of the brain:

- **Auditory cortex** in the temporal lobe (for hearing)

- **Cerebellum and brainstem** (for balance)

Functional Roles of the Ear

Structure	Primary Function
Auricle	Collects and directs sound waves
Tympanic membrane	Converts sound waves to mechanical vibrations
Ossicles	Amplify and transmit vibrations
Cochlea	Converts mechanical vibrations to electrical signals (hearing)
Semicircular canals	Detect rotational movement (angular acceleration)
Utricle	Detects linear acceleration (horizontal)
Saccule	Detects linear acceleration (vertical)