

# The Ear

The ear consists of the external, the middle ear, or tympanic cavity, and the internal ear, or labyrinth. The inner ear containing the organs of hearing and balance.

## **External Ear**

The external ear has an auricle and an external auditory meatus.

The **auricle** (pinna) has a characteristic shape and collects air vibrations. It consists of a thin plate of elastic cartilage covered by skin. The rim of the auricle is called the helix and the inferior portion is the lobule. The auricle is attached to the head by ligaments and muscles. It possesses both extrinsic and intrinsic muscles, which are supplied by the facial nerve.

The **external auditory meatus** is a curved tube that extends from the auricle to the tympanic membrane (eardrum). It conducts sound waves from the auricle to the tympanic membrane. In the adult it measures about 2.5 cm long and is narrowest about 5 mm from the tympanic membrane.

The framework of the outer third of the meatus is elastic cartilage, and the inner two-thirds is bone, formed by the tympanic plate. The meatus is lined by skin, and its outer third is provided with hairs and sebaceous and ceruminous glands. The ceruminous glands are modified sweat glands that secrete a yellowish-brown wax, the cerumen. The hairs and the wax provide a sticky barrier that prevents the entrance of foreign bodies.

The sensory nerve supply of the lining skin is derived from the auriculo-temporal nerve and the auricular branch of the vagus nerve.

The lymph drainage is to the superficial parotid, mastoid, and superficial cervical lymph nodes.

## **Middle Ear (Tympanic Cavity)**

The middle ear is an air-containing cavity in the petrous part of the temporal bone, and is lined with mucous membrane. It contains the auditory ossicles, whose function is to transmit the vibrations of the tympanic membrane (eardrum) to the perilymph of the internal ear. It is a narrow, oblique, slitlike cavity whose long axis lies approximately parallel to the plane of the tympanic membrane. It communicates in front through the auditory tube with the nasopharynx and behind with the mastoid antrum. It is separated

from the external ear by the eardrum and from the internal ear by a thin bony partition that contains two small openings, the oval window and round window.

The middle ear has a roof, floor, anterior wall, posterior wall, lateral wall, and medial wall.

The **roof** (or tegmental wall) is formed by a thin plate of bone, the tegmen tympani, which is 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.

The **floor** (or jugular wall) is narrow. It is formed by a thin plate of bone, which may be deficient and may be partly replaced by fibrous tissue. It separates the tympanic cavity from the superior bulb of the internal jugular vein.

The **anterior wall** (or carotid wall) 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 of two canals. The upper and the smaller is the entrance into the canal for tensor tympani muscle, and the lower and larger of these leads into the auditory tube. The thin bony septum, which separates the two canals, is prolonged backward on the medial wall, where it forms a shelflike projection, the processus cochleariformis, the posterior end of this forms a pulley around which the tendon of the tensor tympani turns laterally through 90 degree to run to the malleus.

The **posterior wall** (or mastoid wall) has in its upper part a large, irregular opening, the aditus to the mastoid antrum. Below this is a small, hollow, conical projection, the pyramid, from whose apex emerges the tendon of the stapedius muscle. Lateral to the pyramid, there is an opening through which the chorda tympani nerve enters the middle ear from the facial nerve.

The **lateral wall** is largely formed by the tympanic membrane.

The **tympanic membrane** is a thin, fibrous membrane that is pearly gray. The membrane is obliquely placed, facing downward, forward, and laterally. It is concave laterally, and at the depth of the concavity is a small depression, the **umbo**, produced by the tip of the handle of the malleus.

The tympanic membrane is circular and measures about 1 cm in diameter. The circumference is thickened and is slotted into a groove in the bone. The groove or the tympanic sulcus, is deficient superiorly, which forms a notch. From the sides of the notch, two bands termed the **anterior** and **posterior malleolar folds**, pass to the lateral process of the malleus. Small triangular area on the tympanic membrane that is bounded by the folds is slack and is called **pars flaccida**. The remainder of the membrane is tense and is

called the **pars tensa**. The handle of the malleus is bound to the inner surface of the tympanic membrane by the mucous membrane.

The tympanic membrane is externally sensitive to pain and is innervated on its outer surface by the auriculotemporal nerve and the auricular branch of the vagus.

The **medial wall** (or labyrinthine wall) is formed by the lateral wall of the inner ear. The greater part of the wall shows a rounded projection, called the promontory, which results from the underlying first turn of the cochlea. Above and behind the promontory lies the **fenestra vestibuli** (oval window), which is oval shaped and closed by the base of the stapes. On the medial side of this window is the perilymph of the scala vestibuli of the inner ear. Below the posterior end of the promontory lies the **fenestra cochleae** (round window), which is rounded and closed by the secondary tympanic membrane. On the medial side of this window is the perilymph of the blind end of the scala tympani.

### **Auditory Ossicles**

The auditory ossicles are the malleus, incus, and stapes.

The **malleus** is the largest ossicle and possesses a head, a neck, a long process or handle, an anterior process, and a lateral process.

The **head** is rounded and articulates posteriorly with the incus. The **neck** is the constricted part below the head. The **handle** passes downward and backward and is firmly attached to the medial surface of the tympanic membrane. It can be seen through the tympanic membrane on the otoscopic examination. The **anterior process** is a spicule of bone that is connected to the anterior wall of the tympanic cavity by a ligament. The **lateral process** projects laterally and is attached to the anterior and posterior malleolar folds of the tympanic membrane.

The **incus** possesses a large body and two processes.

The **body** is rounded and articulates anteriorly with the head of the malleus. The **long process** descends behind and parallel to the handle of the malleus. Its lower end bends medially and articulates with the head of the stapes. Its shadow on the tympanic membrane can sometimes be recognized on otoscopic examination. The **short process** projects backward and is attached to the posterior wall of the tympanic cavity by a ligament.

The **stapes** has a head, a neck, two limbs, and a base.

The head is small and 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. The edge of the base is attached to the margin of the fenestra vestibuli by a ring of fibrous tissue, the annular ligament.

## **Muscles of the Ossicles**

### **Tensor Tympani**

- **Origin:** From the cartilage of the auditory tube and the bony walls of its own canal.
- **Insertion:** The slender muscle passes backward and ends in a rounded tendon, which turns laterally around the processus cochleariformis and is inserted into the handle of the malleus.
- **Nerve supply:** A branch from the nerve to the medial pterygoid muscle, which is a branch of the mandibular division of the trigeminal nerve.
- **Action:** Reflexly damps down the vibrations of the malleus by making the tympanic membrane more tense.

### **Stapedius**

- **Origin:** From the internal walls of the hollow pyramid.
- **Insertion:** The tendon emerges from the apex of the pyramid and is inserted into the neck of the stapes.
- **Nerve supply:** From the facial nerve, which lies behind the pyramidal.
- **Action:** Reflexly damps down the vibrations of the stapes by pulling on the neck of the bone.

## **Auditory Tube**

The auditory tube extends from the anterior wall of the tympanic cavity downward, forward, and medially to the nasal pharynx. Its posterior third is bony, and its anterior two-thirds is cartilaginous. It joins the nasal pharynx by passing over the upper border of the superior constrictor muscle. It serves to equalize air pressures in the tympanic cavity and the nasal pharynx.

## **Mastoid Antrum**

This air-filled extension from the middle ear cavity lies behind the middle ear in the petrous part of the temporal bone. It communicates with the middle ear cavity through an opening called aditus, which may be as large as 1 cm in diameter.

The **anterior wall** is related to the middle ear and contains the aditus to the mastoid antrum.

The **posterior wall** separates the antrum from the sigmoid venous sinus and the cerebellum.

The **lateral wall** is 1.5 cm thick and forms the floor of the suprameatal triangle ( the small triangular area on the surface of the skull immediately posterosuperior to the bony external auditory meatus).

The **medial wall** is related to the posterior semicircular canal.

The **superior wall** is the thin plate of bone, the tegmen tympani, which is related to the meninges of the middle cranial fossa and the temporal lobe of the brain.

The **inferior wall** is perforated with holes, through which the antrum communicates with the mastoid air cells.

### **Mastoid Air Cells**

The mastoid process begins to develop during the second year of life. The mastoid air cells are a series of communicating cavities within the process that are continuous above with the antrum and the middle ear. They are lined with mucous membrane.

### **Facial Nerve**

At the bottom of the internal acoustic meatus, the facial nerve enters the facial canal. The nerve runs laterally above the vestibule of the internal ear until it reaches the medial wall of the middle ear. Here the nerve expands to form the sensory geniculate ganglion. The nerve then bends sharply above the promontory.

The facial nerve descends in the posterior wall of the middle ear, behind the pyramid, and finally emerges through the stylomastoid foramen. The important branches of its intrapetrous part are:

1. The **greater petrosal nerve** arises from the facial nerve at the geniculate ganglion. It emerges on the superior surface of the petrous part of the temporal and runs forward in a groove. It runs below the trigeminal ganglion and enters the foramen lacerum. It is here joined by the deep petrosal nerve from the sympathetic plexus on the internal carotid artery and forms the nerve of the pterygoid canal. This passes forward and enters the pterygopalatine fossa, where it ends in the pterygopalatine ganglion.

2. The **nerve to the stapedius** arises from the facial nerve as it descends in the facial canal behind the pyramid. It supplies the muscle within the pyramid.
3. The **chorda tympani** arises from the facial nerve just above the stylomastoid foramen. It enters the middle ear close to the posterior border of the tympanic membrane. The nerve leaves the middle ear through the petrotympanic fissure and enters the infratemporal fossa, where it joins the lingual nerve.

The chorda tympani contains many taste fibers from the mucous membrane covering the anterior two-thirds of the tongue ( not from the vallate papillae) and the floor of the mouth. The taste fibers are the peripheral processes of the cells in the geniculate ganglion.

The nerve also contains preganglionic parasympathetic secretomotor fibers that reach the submandibular ganglion and are there relayed to the submandibular and sublingual salivary glands.

### **Tympanic Nerve**

The tympanic nerve arises from the glossopharyngeal nerve, just below the jugular foramen. It passes through the floor of the middle ear onto promontory. Here it splits into branches, which form the tympanic plexus. The tympanic plexus supplies the lining of the middle ear and gives off the lesser petrosal nerve.

The **lesser petrosal nerve** contains secretomotor fibers for the parotid gland. Having entered the skull it leaves through the foramen ovale. The nerve joins the otic ganglion.

### **The Internal Ear, or Labyrinth**

The labyrinth is situated in the petrous part of the temporal bone, medial to the middle ear. It consists of (1) the bony labyrinth, comprising a series of cavities within the bone, and (2) the membranous labyrinth, comprising a series of membranous sacs and ducts contained within the bony labyrinth.

### **Bony Labyrinth**

The bony labyrinth consists of three parts, the vestibule, the semicircular canals, and the cochlea. These are cavities situated in the substance of dense bone. They are lined by endosteum and contain a clear fluid, the perilymph, in which is suspended the membranous labyrinth.

The **vestibule**, the central part of the bony labyrinth, lies posterior to the cochlea and anterior to the semicircular canals. In its lateral wall are the fenestra vestibuli, which is

closed by the base of the stapes and its annular ligament, and the fenestra cochleae, which is closed by the secondary tympanic membrane. Lodged within the vestibule are the saccule and utricle of the membranous labyrinth.

The three **semicircular canals** ( superior, posterior, and lateral ), open into the posterior part of the vestibule. Each canal has a swelling at one end called ampulla. The canals open into the vestibule by five orifices, one of which is common to two of the canals. Lodged within the canals are the semicircular ducts.

The superior canal is vertical and placed at right angle to the long axis of the petrous bone. The posterior canal is also vertical but is placed parallel with the long axis of the petrous bone. The lateral canal is set in a horizontal position, and it lies in the medial wall of the aditus to the mastoid antrum, above the facial nerve canal.

The **cochlea** resembles a snail shell. It opens into the anterior part of the vestibule. Basically, it consists of a central pillar, the **modiolus**, around which a hollow bony tube makes two and one-half spiral turns. Each suture is conical. The apex faces anterolaterally and the base faces posteromedially. The first basal turn of the cochlea is responsible for the promontory seen on the medial wall of the middle ear.

The modiolus has a broad base, which is situated at the bottom of the internal acoustic meatus. It is perforated by branches of the cochlear nerve. The **spiral lamina** is a thin, narrow, plate of bone, which winds around the modiolus and projects into the interior of the canal and partially divides it. The basilar membrane stretches from the free edge of the spiral lamina to the outer bony wall, thus dividing the cochlear canal into **scala vestibuli** above and the **scala tympani** below. The perilymph within the scala vestibuli is separated from the middle ear by the base of the stapes and the annular ligament at the fenestra vestibuli. The perilymph in the scala tympani is separated from the middle ear by the secondary tympanic membrane at the fenestra cochleae.

### **Membranous Labyrinth**

The membranous labyrinth is lodged within the bony labyrinth. It is filled with endolymph and surrounded by perilymph. It consists of utricle and saccule, which are lodged in the bony vestibule; the three semicircular ducts, which lie within the bony semicircular canals; and the duct of the cochlea, which lies within the bony cochlea. All these structures freely communicate with one another.

The **utricle** is the larger of the two vestibular sacs. It is indirectly connected to the saccule and the endolymphatic duct by the utriculosaccular duct.

The **saccule** is globular and is connected to the utricle as described above. The endolymphatic duct, after being joined by the utriculosaccular duct, passes on to end in a small blind pouch, the endolymphatic sac. This lies beneath the dura on the posterior surface of the petrous part of the temporal bone.

Located on the walls of the utricle and saccule are specialized sensory receptors, which are sensitive to the orientation of the head to gravity or other acceleration forces.

The **semicircular ducts**, although much smaller in diameter than the semi-circular canals, have the same configuration. They are arranged at right angles to each other. They open into the utricle and have ampullae in the same position as the ampullae of the canals. The ampullae of the ducts contain a fold of their lining ( crista ampullaris) which extends transversely across ampulla. It is surrounded by hair cells embedded in a gelatinous cupula, and is the sensory organ of the duct. It is innervated by the vestibular part of the vestibulocochlear nerve, which ends on the hair cells of the epithelium of the crista.

The **duct of the cochlea** is triangular in cross section and is connected to the saccule by the reuniens duct. The highly specialized epithelium that lies on the basilar membrane forms the spiral organ of Corti and contains the sensory receptors for hearing.

### **The Vestibulocochlear Nerve (Eighth Cranial Nerve)**

At the bottom of the internal acoustic meatus, the nerve divides into vestibular and cochlear portions.

The **vestibular nerve** is expanded to form the vestibular ganglion. The branches of the nerve then pierce the lateral end of the internal acoustic meatus and gain entrance to the membranous labyrinth, where they supply the utricle, the saccule, and the ampullae of the semicircular ducts.

The **cochlear nerve** divides into branches, which enter foramina at the base of the modiolus. The sensory ganglion of this nerve takes the form of an elongated spiral ganglion that is lodged in a canal winding around the modiolus in the base of the spiral lamina. The peripheral branches of this nerve pass from the ganglion to the spiral organ of Corti.

### **Maxillary Nerve**

The maxillary nerve arises from the trigeminal ganglion in the middle cranial fossa. It passes forward in the lateral wall of the cavernous sinus and leaves the skull through the foramen rotundum to enter the pterygopalatine fossa. The nerve crosses the fossa and enters the orbit by passing through the inferior orbital fissure.

The nerve is now called the infraorbital nerve, and it runs forward on the floor of the orbit, first in the infraorbital groove and then in the infraorbital canal. It appears on the face by emerging through the infraorbital foramen.

### **Branches**

- A **meningeal branch** supplies the dura in the middle cranial fossa.
- The **ganglionic branches** are two short nerves that hold the pterygopalatine ganglion in the pterygopalatine fossa. They contain sensory fibers that without interruption have passed through the ganglion from the nose, palate, and pharynx. They also contain postganglionic parasympathetic fibers that are going to the lacrimal gland.
- The **Posterior superior alveolar nerve** arises in the pterygopalatine fossa. It passes downward on the back of the maxilla and pierces its posterior surface. It supplies the maxillary sinus, the upper molar teeth, and the adjoining parts of the gum and cheek.
- The **zygomatic nerve** arises in the pterygopalatine fossa and enters the orbit through the inferior orbital fissure. It ascends on the lateral wall of the orbit and divides into the zygomaticotemporal and zygomaticofacial nerves, which are distributed to the skin of the face.
- The **middle superior alveolar nerve** arises from the infraorbital nerve as it lies in the infraorbital groove. It descends in the lateral wall of the maxillary sinus and supplies the upper premolar teeth and the adjoining parts of the gum and cheek.
- The **anterior superior alveolar nerve** arises from the infraorbital nerve as it lies in the infraorbital canal. It descends in the lateral wall of the maxillary sinus and supplies the upper canine and incisor teeth. A small terminal branch supplies part of the lateral wall and floor of the nose.

### **Pterygopalatine Ganglion**

The pterygopalatine ganglion is a parasympathetic ganglion that is deeply placed in the pterygopalatine fossa.

The preganglionic secretomotor fibers arise in the **lacrimal nucleus** of the facial nerve. They run in the sensory root of the facial nerve, then in the greater petrosal branch, and then in the nerve of the pterygoid canal, which enters the posterior surface of the ganglion. The postganglionic fibers reach the maxillary nerve by one of its ganglionic branches. They then run in the zygomatic, the zygomaticotemporal nerve, and the lacrimal nerve to reach the lacrimal gland. Other postganglionic fibers run in the palatine nerves and nasal nerves to the palatine and nasal glands.

Sympathetic postganglionic fibers reach the ganglion via the internal carotid plexus, the deep petrosal nerve, and the nerve of the pterygoid canal. They pass without interruption through the ganglion and emerge in the orbital branches of the ganglion. They supply the orbital muscles.

### **Branches**

The branches are composed mainly of sensory fibers derived from the maxillary nerve. They reach the ganglion by way of ganglionic branches of the nerve.

- Orbital branches enter the orbit through the inferior orbital fissure.
- The greater and lesser palatine nerves supply the mucous membrane of the palate, tonsil, and nasal cavity.
- The nasal branches enter the nose through the sphenopalatine foramen and supply the mucous membrane of the nasal cavity.
- The pharyngeal branch supplies the mucous membrane of the root of the nasal part of the pharynx.

### **Maxillary Artery**

The maxillary artery leaves the infratemporal fossa by passing through the pterygomaxillary fissure into the pterygopalatine fossa. Here, it splits into branches that accompany the branches of the maxillary nerve.