EAR

The ear is the organ of hearing and balance. It has three parts (Fig. 8.113):

- The first part is the **external ear** consisting of the part attached to the lateral aspect of the head and the canal leading inward.
- The second part is the **middle ear**—a cavity in the petrous part of the temporal bone bounded laterally, and separated from the external canal, by a membrane and connected internally to the pharynx by a narrow tube.
- The third part is the **internal ear** consisting of a series of cavities within the petrous part of the temporal bone between the middle ear laterally and the internal acoustic meatus medially.

The internal ear converts the mechanical signals received from the middle ear, which start as sound captured by the external ear, into electrical signals to transfer information to the brain. The internal ear also contains receptors that detect motion and position.

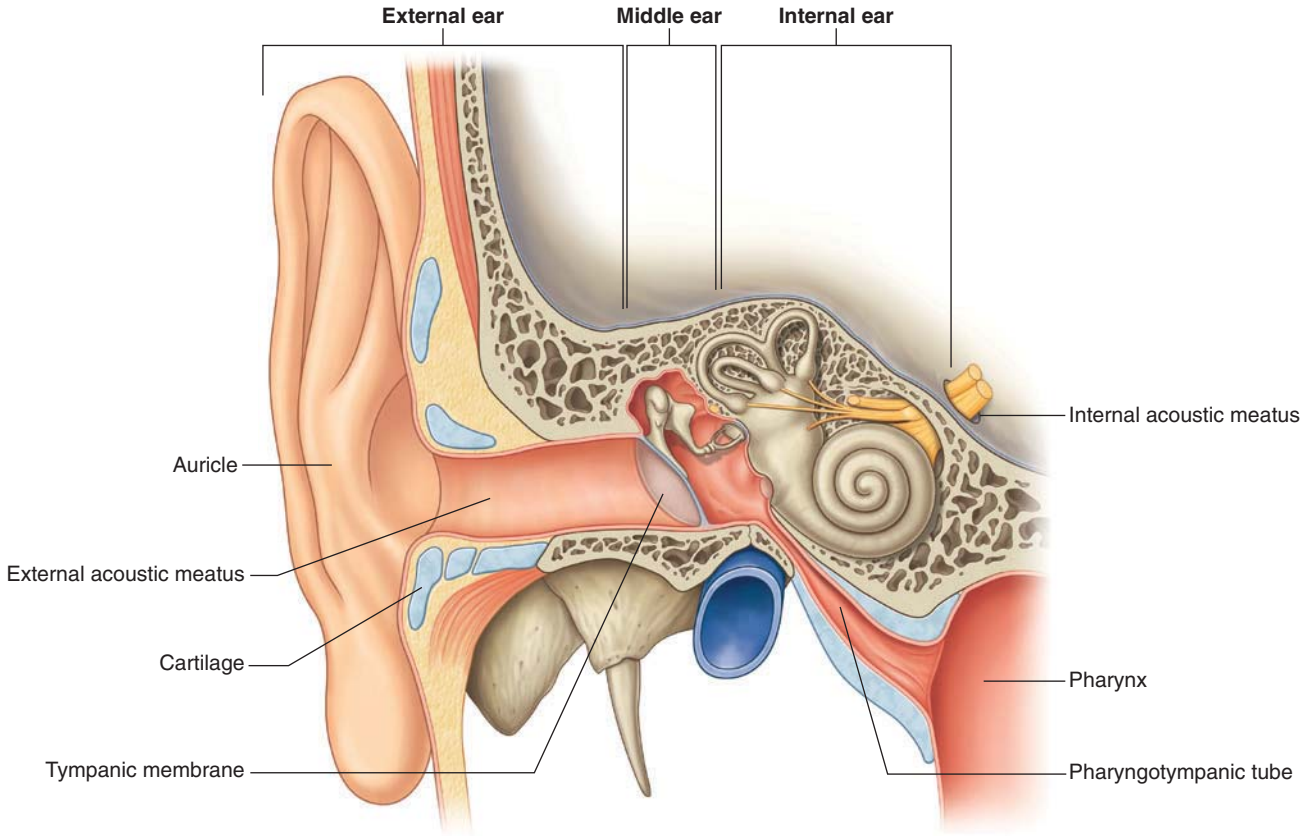

Fig. 8.113 Right ear.

External ear

The external ear consists of two parts. The part projecting from the side of the head is the **auricle** (**pinna**) and the canal leading inward is the **external acoustic meatus**.

Auricle

The auricle is on the side of the head and assists in capturing sound. It consists of cartilage covered with skin and arranged in a pattern of various elevations and depressions (Fig. 8.114).

The large outside rim of the auricle is the **helix**. It ends inferiorly at the fleshy lobule, the only part of the auricle not supported by cartilage.

The hollow center of the auricle is the **concha of the auricle**. The external acoustic meatus leaves from the depths of this area.

Just anterior to the opening of the external acoustic meatus, in front of the concha, is an elevation (the **tragus**). Opposite the tragus, and above the fleshy **lobule**, is another elevation (the **antitragus**). A smaller curved rim, parallel and anterior to the helix, is the **antihelix**.

Muscles

Numerous intrinsic and extrinsic muscles are associated with the auricle:

- The intrinsic muscles pass between the cartilaginous parts of the auricle and may change the shape of the auricle.
- The extrinsic muscles, the anterior, superior, and posterior auricular muscles, pass from the scalp or skull to the auricle and may also play a role in positioning of the auricle (see Fig. 8.56).

Both groups of muscles are innervated by the facial nerve [VII].

Innervation

Sensory innervation of the auricle is from many sources (Fig. 8.115):

- The outer more superficial surfaces of the auricle are supplied by the great auricular nerve (anterior and

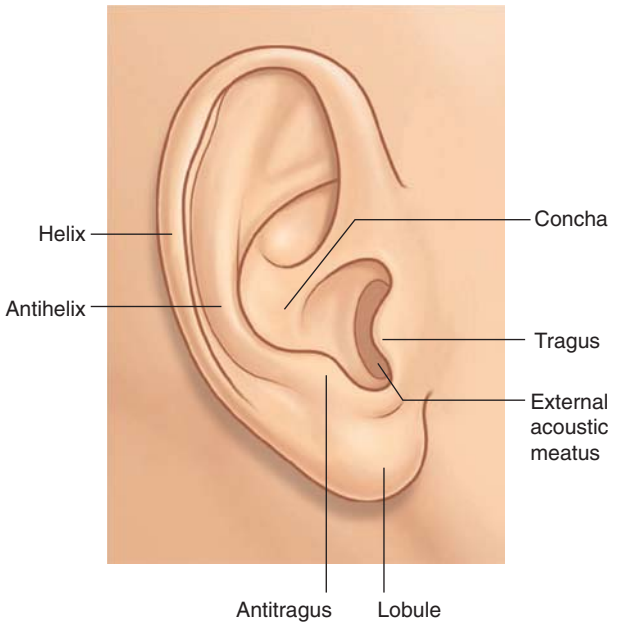

Fig. 8.114 Auricle.

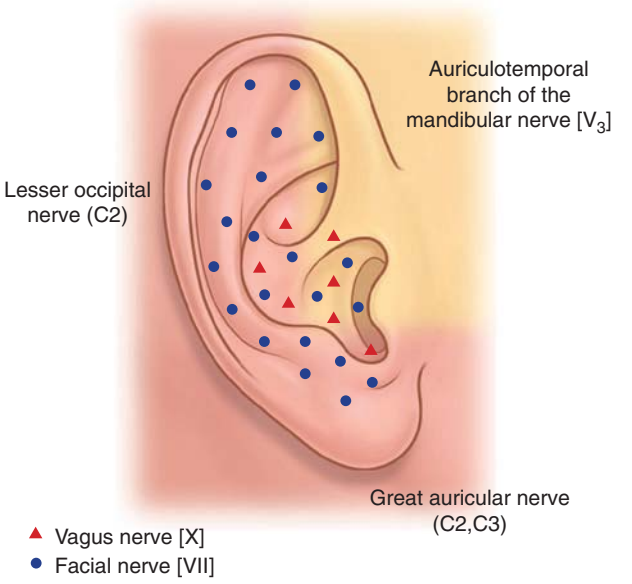

Fig. 8.115 Sensory innervation of the auricle.

posterior inferior portions) and the lesser occipital nerve (posterosuperior portion) from the cervical plexus and the auriculotemporal branch of the mandibular nerve [V_3] (anterosuperior portion).

- The deeper parts of the auricle are supplied by the vagus nerve [X] (the auricular branch) and the facial nerve [VII] (which sends a branch to the auricular branch of the vagus nerve [X]).

Vessels

The arterial supply to the auricle is from numerous sources. The external carotid artery supplies the posterior auricular artery, the superficial temporal artery supplies anterior auricular branches, and the occipital artery supplies a branch.

Venous drainage is through vessels following the arteries.

Lymphatic drainage of the auricle passes anteriorly into parotid nodes and posteriorly into mastoid nodes, and possibly into the upper deep cervical nodes.

External acoustic meatus

The external acoustic meatus extends from the deepest part of the concha to the **tympanic membrane** (eardrum), a distance of approximately 1 inch (2.5 cm) (Fig. 8.116). Its walls consist of cartilage and bone. The lateral one-third is formed from cartilaginous extensions from some of the auricular cartilages and the medial two-thirds is a bony tunnel in the temporal bone.

Throughout its length the external acoustic meatus is covered with skin, some of which contains hair and modified sweat glands producing **cerumen** (earwax). Its diameter varies, being wider laterally and narrow medially.

The external acoustic meatus does not follow a straight course. From the external opening it passes upward in an anterior direction, then turns slightly posteriorly still passing upward, and finally, turns again in an anterior direction with a slight descent. For examination purposes, observation of the external acoustic meatus and tympanic membrane can be improved by pulling the ear superiorly, posteriorly, and slightly laterally.

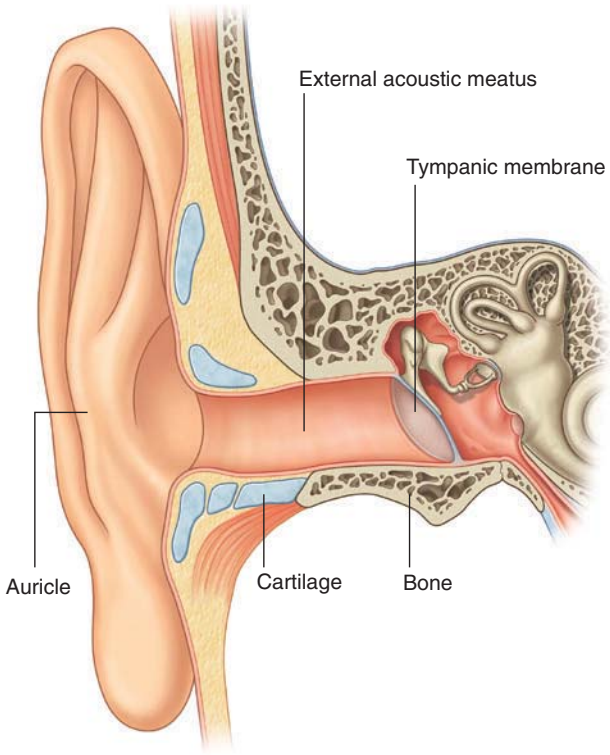

Fig. 8.116 External acoustic meatus.

Innervation

Sensory innervation of the external acoustic meatus is from several of the cranial nerves. The major sensory input travels through branches of the auriculotemporal nerve, a branch of the mandibular nerve [V_3] (anterior and superior walls), and in the auricular branch of the vagus nerve [X] (posterior and inferior walls). A minor sensory input may also come from a branch of the facial nerve [VII] to the auricular branch of the vagus nerve [X].

Tympanic membrane

The tympanic membrane separates the external acoustic meatus from the middle ear (Figs. 8.117 and 8.118). It is at an angle, sloping medially from top to bottom and posteriorly to anteriorly. Its lateral surface therefore faces inferiorly and anteriorly. It consists of a connective tissue core lined with skin on the outside and mucous membrane on the inside.

Around the periphery of the tympanic membrane a **fibrocartilaginous ring** attaches it to the tympanic part of the temporal bone. At its center, a concavity is produced

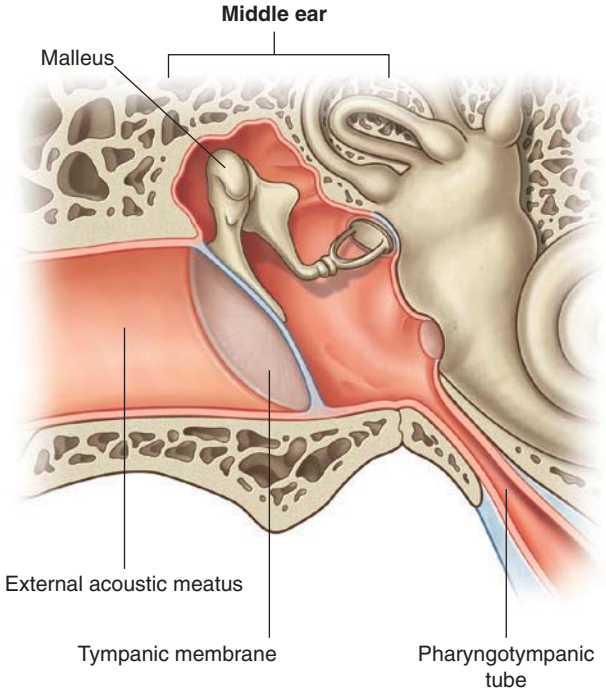

Fig. 8.117 Middle ear.

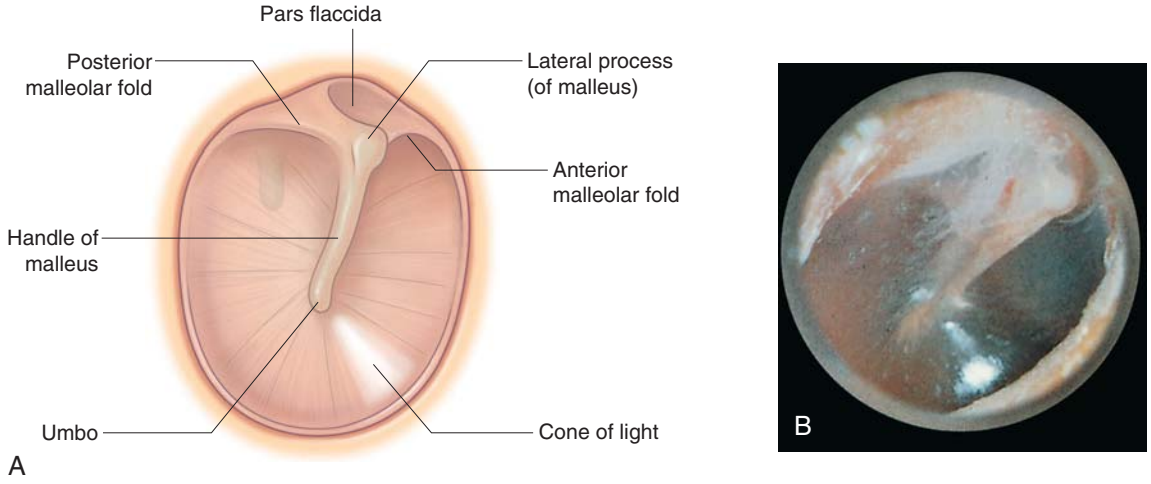

Fig. 8.118 Tympanic membrane (right ear). **A.** Diagram. **B.** Otoscopic view.

by the attachment on its internal surface of the lower end of the **handle of the malleus**, part of the malleus bone in the middle ear. This point of attachment is the **umbo of the tympanic membrane**.

Anteroinferior to the umbo of the tympanic membrane a bright reflection of light, referred to as the cone of light, is usually visible when examining the tympanic membrane with an otoscope.

Superior to the umbo in an anterior direction is the attachment of the rest of the handle of the malleus (Fig. 8.118). At the most superior extent of this line of attachment a small bulge in the membrane marks the position of the **lateral process** of the malleus as it projects against the internal surface of the tympanic membrane. Extending away from this elevation, on the internal surface of the membrane, are the **anterior** and **posterior malleolar folds**. Superior to these folds the tympanic membrane is thin and slack (the **pars flaccida**), whereas the rest of the membrane is thick and taut (the **pars tensa**).

Innervation

Innervation of the external and internal surfaces of the tympanic membrane is by several cranial nerves:

- Sensory innervation of the skin on the outer surface of the tympanic membrane is primarily by the auriculotemporal nerve, a branch of the mandibular nerve [V_3] with additional participation of the auricular branch of the vagus nerve [X], a small contribution by a branch of the facial nerve [VII] to the auricular branch of the vagus nerve [X], and possibly a contribution from the glossopharyngeal nerve [IX].
- Sensory innervation of the mucous membrane on the inner surface of the tympanic membrane is carried entirely by the glossopharyngeal [IX] nerve.

In the clinic

Otitis media

The eustachian tube links the middle ear and pharynx and balances the pressure between the outer and middle ear. Colds and allergies, particularly in children, can result in swelling of the lining of the eustachian tube, which can then impair normal drainage of fluid from the middle ear. The fluid then builds up behind the tympanic membrane, providing an attractive environment for bacteria and viruses to grow and cause otitis media. Left untreated, otitis media can lead to perforation of the tympanic membrane, hearing loss, meningitis, and brain abscess.

In the clinic

Examination of the ear

The ear comprises three components—the external, middle, and internal ear.

Clinical examination is carried out to assess hearing and balance. Further examination involves use of an otoscope or other imaging techniques.

External ear

The external ear is easily examined. The external acoustic meatus and the tympanic membrane require otoscopic examination (Fig. 8.118B). An otoscope is a device through which light can be shone and the image magnified to inspect the external acoustic meatus and the tympanic membrane.

The examination begins by grasping the posterosuperior aspect of the ear and gently retracting it to straighten the external auditory meatus. The normal tympanic membrane is relatively translucent and has a gray–reddish tinge. The handle of the malleus is visible near the center of the membrane. In the 5 o'clock position a cone of light is always demonstrated.

Middle and inner ears

The middle ear is investigated by CT and MRI to visualize the malleus, incus, and stapes. The relationship of these bones to the middle ear cavity is determined and any masses identified.

The inner ear is also assessed by CT and MRI.

In the clinic

Swimmer's ear
Swimmer's ear, often called otitis externa, is a painful condition resulting from an infection in the external acoustic meatus. It frequently occurs in swimmers.

In the clinic

Surfer's ear
Surfer's ear, which is prevalent among individuals who surf or swim in cold water, results from the development of a "bony lump" in the external acoustic meatus. Growth of the lump eventually constricts the meatus and reduces hearing in the affected ear.

In the clinic

Tympanic membrane perforation
Although perforation of the tympanic membrane (eardrum) has many causes, trauma and infection are the most common.

Ruptures of the tympanic membrane tend to heal spontaneously, but surgical intervention may be necessary if the rupture is large.

Occasionally, it may be necessary to enter the middle ear through the tympanic membrane. Because the chorda tympani runs in the upper one-third of the tympanic membrane, incisions are always below this level. The richer blood supply to the posterior aspect of the tympanic membrane determines the standard surgical approach in the posteroinferior aspect.

Otitis media (infection of the middle ear) is common and can lead to perforation of the tympanic membrane. The infection can usually be treated with antibiotics. If the infection persists, the chronic inflammatory change may damage the ossicular chain and other structures within the middle ear to produce deafness.

Middle ear

The middle ear is an air-filled, mucous membrane–lined space in the temporal bone between the tympanic membrane laterally and the lateral wall of the internal ear medially. It is described as consisting of two parts (Fig. 8.119):

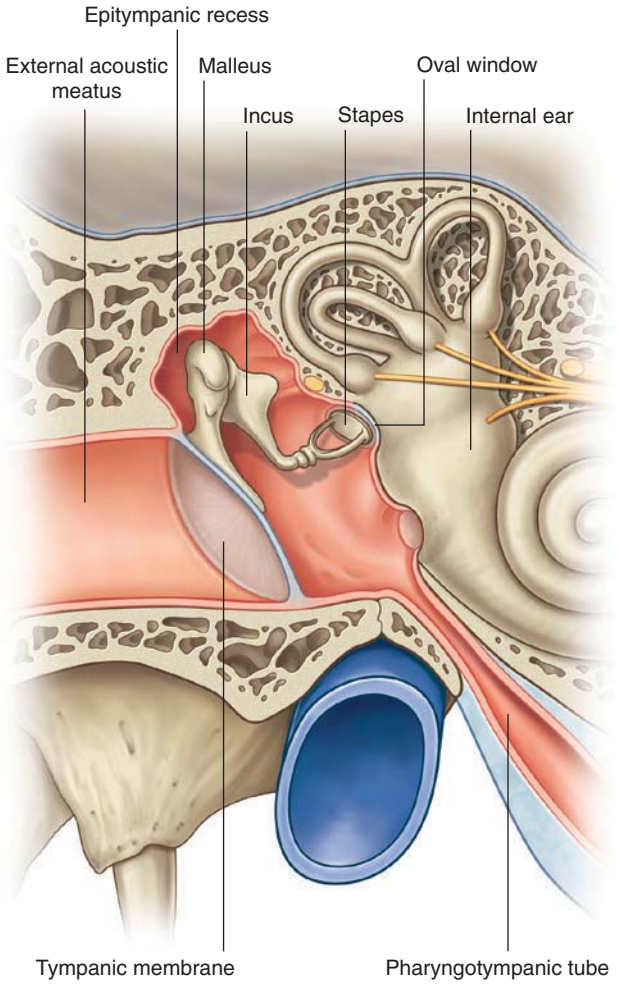

Fig. 8.119 Parts of the middle ear.

- the **tympanic cavity** immediately adjacent to the tympanic membrane, and
- the **epitympanic recess** superiorly.

The middle ear communicates with the mastoid area posteriorly and the nasopharynx (via the pharyngotympanic tube) anteriorly. Its basic function is to transmit vibrations of the tympanic membrane across the cavity of the middle ear to the internal ear. It accomplishes this through three interconnected but movable bones that bridge the space between the tympanic membrane and the internal ear. These bones are the malleus (connected to the tympanic membrane), the incus (connected to the malleus by a synovial joint), and the stapes (connected to the incus by a synovial joint, and attached to the lateral wall of the internal ear at the oval window).

Boundaries

The middle ear has a roof and a floor, and anterior, posterior, medial, and lateral walls (Fig. 8.120).

Tegmental wall

The tegmental wall (roof) of the middle ear consists of a thin layer of bone, which separates the middle ear from the middle cranial fossa. This layer of bone is the tegmen tympani on the anterior surface of the petrous part of the temporal bone.

Jugular wall

The jugular wall (floor) of the middle ear consists of a thin layer of bone that separates it from the internal jugular vein. Occasionally, the floor is thickened by the presence of mastoid air cells.

Near the medial border of the floor is a small aperture, through which the tympanic branch from the glossopharyngeal nerve [IX] enters the middle ear.

Membranous wall

The membranous (lateral) wall of the middle ear consists almost entirely of the tympanic membrane, but because the tympanic membrane does not extend superiorly into the epitympanic recess, the upper part of the membranous wall of the middle ear is the bony lateral wall of the epitympanic recess.

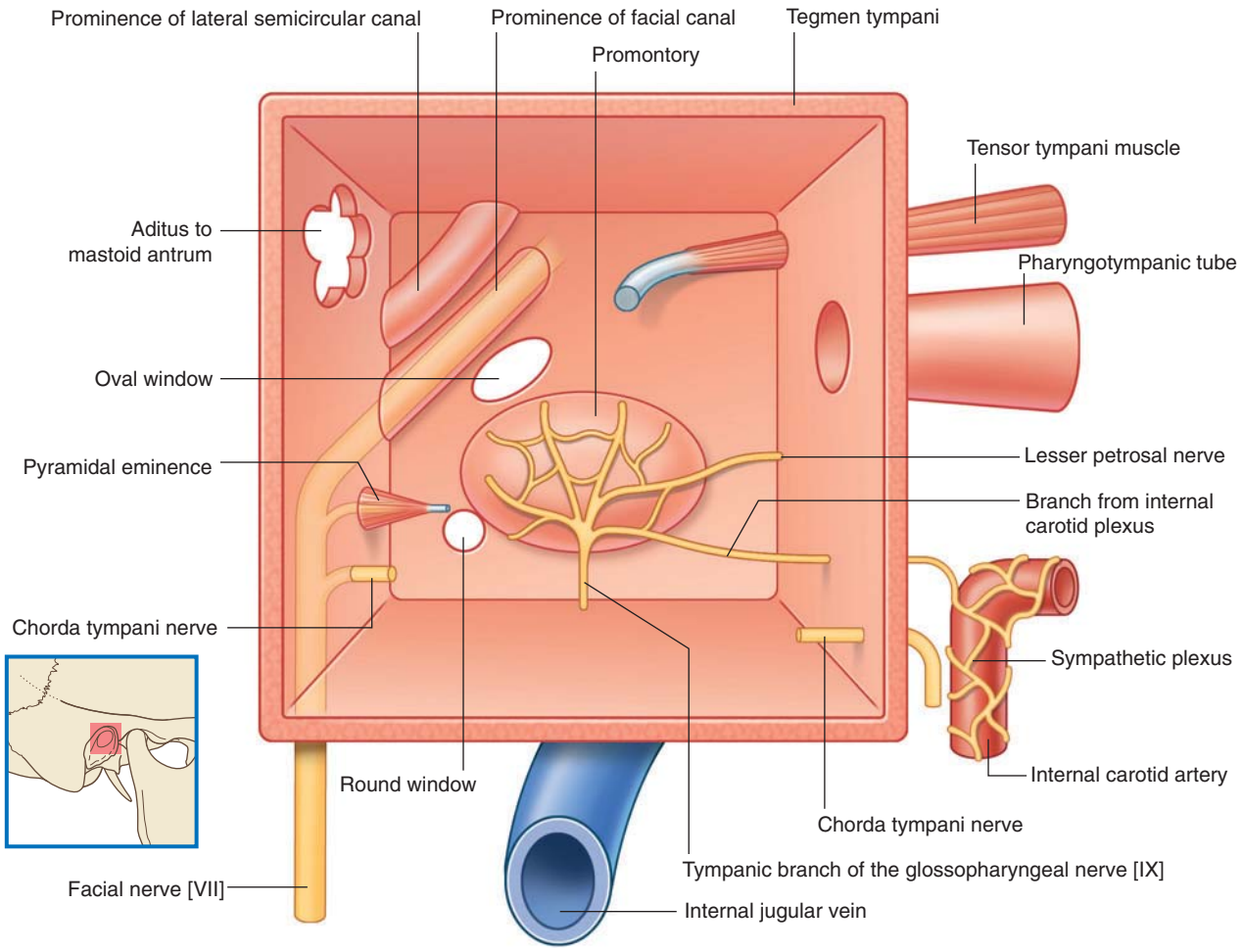

Fig. 8.120 Boundaries of the right middle ear.

Mastoid wall

The mastoid (posterior) wall of the middle ear is only partially complete. The lower part of this wall consists of a bony partition between the tympanic cavity and mastoid air cells. Superiorly, the epitympanic recess is continuous with the **aditus to the mastoid antrum** (Figs. 8.120 and 8.121).

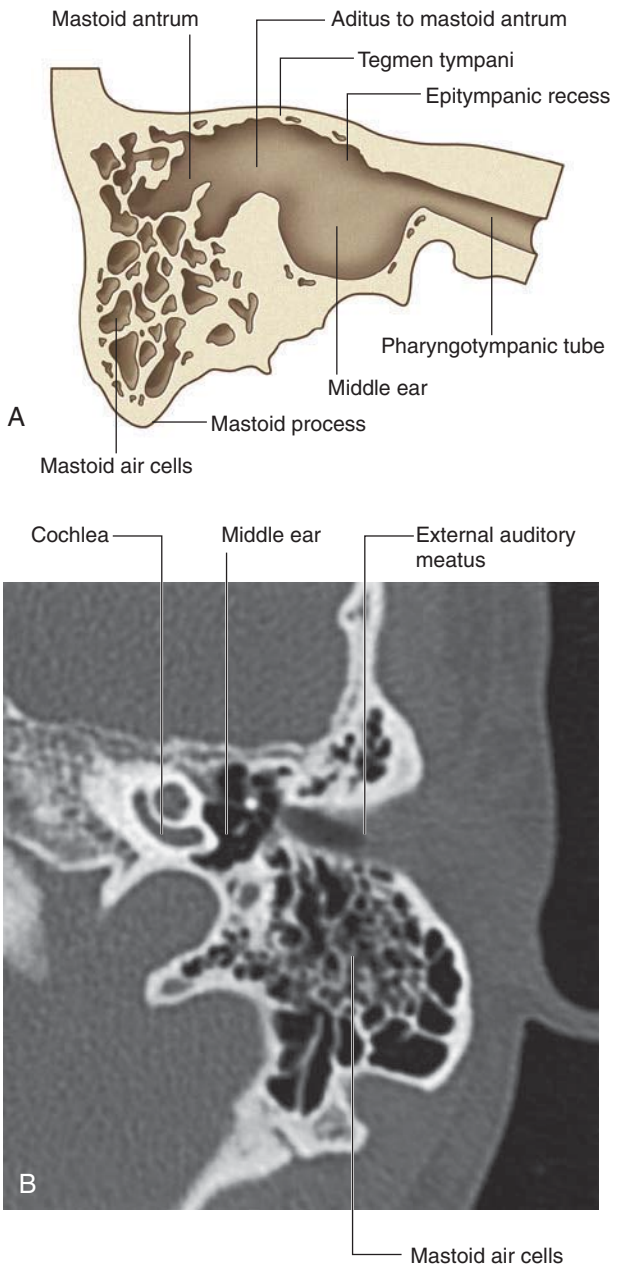

Fig. 8.121 Mastoid antrum and surrounding bone. **A.** Diagram. **B.** High-resolution CT scan of left ear (petrous temporal bone).

Associated with the mastoid wall are:

- the pyramidal eminence, a small elevation through which the tendon of the stapedius muscle enters the middle ear; and
- the opening through which the chorda tympani nerve, a branch of the facial nerve [VII], enters the middle ear.

Anterior wall

The anterior wall of the middle ear is only partially complete. The lower part consists of a thin layer of bone that separates the tympanic cavity from the internal carotid artery. Superiorly, the wall is deficient because of the presence of:

- a large opening for the entrance of the pharyngotympanic tube into the middle ear, and
- a smaller opening for the canal containing the tensor tympani muscle.

The foramen for the exit of the chorda tympani nerve from the middle ear is also associated with this wall (Fig. 8.120).

Labyrinthine wall

The labyrinthine (medial) wall of the middle ear is also the lateral wall of the internal ear. A prominent structure on this wall is a rounded bulge (the **promontory**) produced by the basal coil of the **cochlea**, which is an internal ear structure involved with hearing (Fig. 8.120).

Associated with the mucous membrane covering the promontory is a plexus of nerves (the **tympanic plexus**), which consists primarily of contributions from the tympanic branch of the glossopharyngeal nerve [IX] and branches from the internal carotid plexus. It supplies the mucous membrane of the middle ear, the mastoid area, and the pharyngotympanic tube.

Additionally, a branch of the tympanic plexus (the lesser petrosal nerve) leaves the promontory and the middle ear, travels across the anterior surface of the petrous part of the temporal bone, and leaves the middle cranial fossa through the foramen ovale to enter the otic ganglion. Other structures associated with the labyrinthine wall are two openings, the oval and round windows, and two prominent elevations (Fig. 8.120):

- The **oval window** is posterosuperior to the promontory, is the point of attachment for the **base of the stapes** (**footplate**), and ends the chain of bones that transfer vibrations initiated by the tympanic membrane to the cochlea of the internal ear.

- The **round window** is posteroinferior to the promontory.
- Posterior and superior to the oval window on the medial wall is the **prominence of the facial canal**, which is a ridge of bone produced by the facial nerve [VII] in its canal as it passes through the temporal bone.
- Just above and posterior to the prominence of the facial canal is a broader ridge of bone (**prominence of the lateral semicircular canal**) produced by the lateral semicircular canal, which is a structure involved in detecting motion.

Mastoid area

Posterior to the epitympanic recess of the middle ear is the aditus to the mastoid antrum, which is the opening to the mastoid antrum (Fig. 8.121).

The **mastoid antrum** is a cavity continuous with collections of air-filled spaces (the **mastoid cells**), throughout the mastoid part of the temporal bone, including the mastoid process. The mastoid antrum is separated from the middle cranial fossa above by only the thin tegmen tympani.

The mucous membrane lining the mastoid air cells is continuous with the mucous membrane throughout the middle ear. Therefore infections in the middle ear can easily spread into the mastoid area.

In the clinic

Mastoiditis

Infection within the mastoid antrum and mastoid cells is usually secondary to infection in the middle ear. The mastoid cells provide an excellent culture medium for infection. Infection of the bone (osteomyelitis) may also develop, spreading into the middle cranial fossa.

Drainage of the pus within the mastoid air cells is necessary and there are numerous approaches for doing this. When undertaking this type of surgery, it is extremely important that care is taken not to damage the mastoid wall of the middle ear to prevent injury to the facial nerve [VII]. Any breach of the inner table of the cranial vault may allow bacteria to enter the cranial cavity and meningitis will ensue.

Pharyngotympanic tube

The pharyngotympanic tube connects the middle ear with the nasopharynx (Fig. 8.122) and equalizes pressure on both sides of the tympanic membrane. Its opening in the middle ear is on the anterior wall, and from here it extends forward, medially, and downward to enter the nasopharynx just posterior to the inferior meatus of the nasal cavity. It consists of:

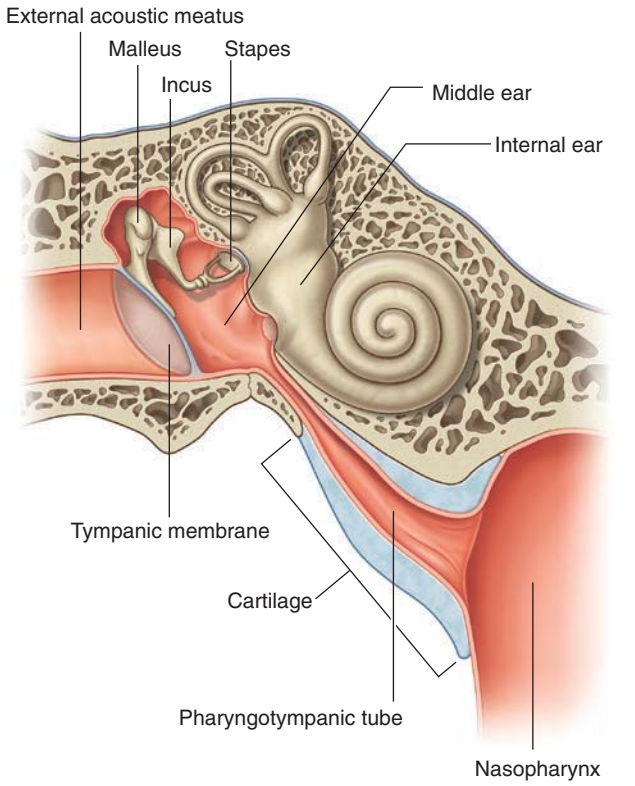

Fig. 8.122 Pharyngotympanic tube.

- a **bony part** (the one-third nearest the middle ear); and
- a **cartilaginous part** (the remaining two-thirds).

The opening of the bony part is clearly visible on the inferior surface of the skull at the junction of the squamous and petrous parts of the temporal bone immediately posterior to the foramen ovale and foramen spinosum.

Vessels

The arterial supply to the pharyngotympanic tube is from several sources. Branches arise from the **ascending pharyngeal artery** (a branch of the external carotid artery) and from two branches of the maxillary artery (the middle meningeal artery and the artery of the pterygoid canal).

Venous drainage of the pharyngotympanic tube is to the pterygoid plexus of veins in the infratemporal fossa.

Innervation

Innervation of the mucous membrane lining the pharyngotympanic tube is primarily from the tympanic plexus because it is continuous with the mucous membrane lining the tympanic cavity, the internal surface of the tympanic membrane, and the mastoid antrum and mastoid cells. This plexus receives its major contribution from the tympanic nerve, a branch of the glossopharyngeal nerve [IX].

Auditory ossicles

The bones of the middle ear consist of the malleus, incus, and stapes. They form an osseous chain across the middle ear from the tympanic membrane to the oval window of the internal ear (Fig. 8.123).

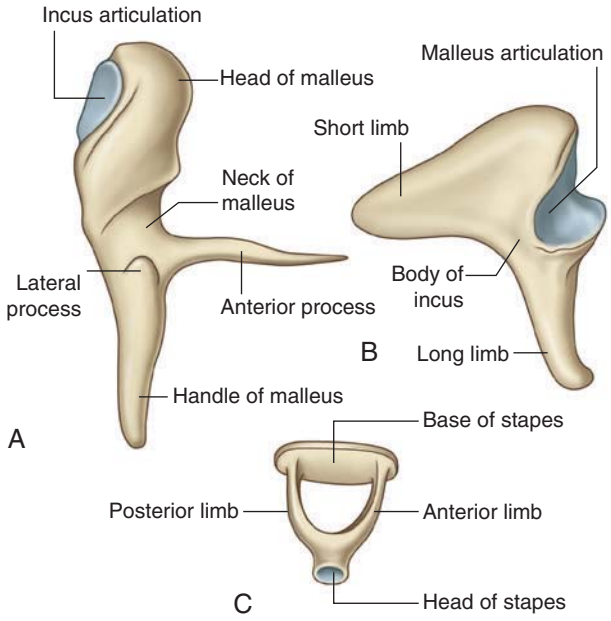

Fig. 8.123 Auditory ossicles. **A.** Malleus. **B.** Incus. **C.** Stapes.

Muscles associated with the auditory ossicles modulate movement during the transmission of vibrations.

Malleus

The malleus is the largest of the auditory ossicles and is attached to the tympanic membrane. Identifiable parts include the **head of the malleus**, **neck of the malleus**, **anterior and lateral processes**, and **handle of the malleus** (Fig. 8.123). The head of the malleus is the rounded upper part of the malleus in the epitympanic recess. Its posterior surface articulates with the incus.

Inferior to the head of the malleus is the constricted neck of the malleus, and below this are the anterior and lateral processes:

- The anterior process is attached to the anterior wall of the middle ear by a ligament.
- The lateral process is attached to the anterior and posterior malleolar folds of the tympanic membrane.

The downward extension of the malleus, below the anterior and lateral processes, is the handle of the malleus, which is attached to the tympanic membrane.

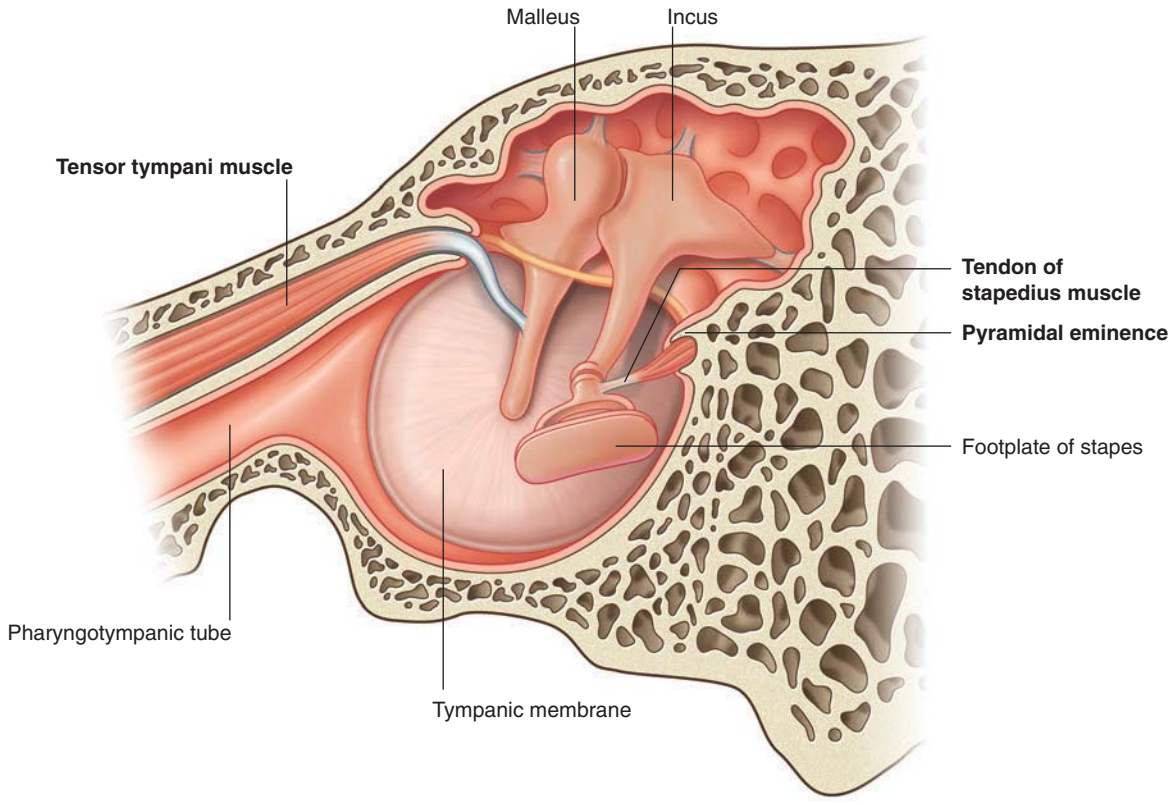

Fig. 8.124 Muscles associated with the auditory ossicles (right ear).

Incus

The second bone in the series of auditory ossicles is the incus. It consists of the **body of the incus** and **long** and **short limbs** (Fig. 8.123):

- The enlarged body of the incus articulates with the head of the malleus and is in the epitympanic recess.
- The long limb extends downward from the body, paralleling the handle of the malleus, and ends by bending medially to articulate with the stapes.
- The short limb extends posteriorly and is attached by a ligament to the upper posterior wall of the middle ear.

Stapes

The stapes is the most medial bone in the osseous chain and is attached to the oval window. It consists of the **head of the stapes**, **anterior** and **posterior limbs**, and the **base of the stapes** (Fig. 8.123):

- The head of the stapes is directed laterally and articulates with the long process of the incus.
- The two limbs separate from each other and attach to the oval base.
- The base of the stapes fits into the oval window on the labyrinthine wall of the middle ear.

Muscles associated with the ossicles

Two muscles are associated with the bony ossicles of the middle ear—the tensor tympani and stapedius (Fig. 8.124 and Table 8.10).

Tensor tympani

The tensor tympani muscle lies in a bony canal above the pharyngotympanic tube. It originates from the cartilaginous part of the pharyngotympanic tube, the greater wing of the sphenoid, and its own bony canal, and passes through its canal in a posterior direction, ending in a rounded tendon that inserts into the upper part of the handle of the malleus.

Innervation of the tensor tympani is by a branch from the mandibular nerve [V_3].

Contraction of the tensor tympani pulls the handle of the malleus medially. This tenses the tympanic membrane, reducing the force of vibrations in response to loud noises.

Stapedius

The stapedius muscle is a very small muscle that originates from inside the pyramidal eminence, which is a small projection on the mastoid wall of the middle ear (Fig. 8.124). Its tendon emerges from the apex of the pyramidal eminence and passes forward to attach to the posterior surface of the neck of the stapes.

The stapedius is innervated by a branch from the facial nerve [VII].

Contraction of the stapedius muscle, usually in response to loud noises, pulls the stapes posteriorly and prevents excessive oscillation.

Vessels

Numerous arteries supply the structures in the middle ear:

- the two largest branches are the **tympanic branch** of the maxillary artery and the **mastoid branch** of the occipital or posterior auricular arteries;
- smaller branches come from the middle meningeal artery, the ascending pharyngeal artery, the artery of the pterygoid canal, and tympanic branches from the internal carotid artery.

Venous drainage of the middle ear returns to the pterygoid plexus of veins and the superior petrosal sinus.

Innervation

The tympanic plexus innervates the mucous membrane lining the walls and contents of the middle ear, which includes the mastoid area and the pharyngotympanic tube. It is formed by the **tympanic nerve**, a branch of the glossopharyngeal nerve [IX], and from branches of the internal carotid plexus. The tympanic plexus occurs in the

Table 8.10 Muscles of the middle ear

Muscle	Origin	Insertion	Innervation	Function
Tensor tympani	Cartilaginous part of pharyngotympanic tube, greater wing of sphenoid, its own bony canal	Upper part of handle of malleus	Branch from mandibular nerve [V_3]	Contraction pulls handle of malleus medially, tensing tympanic membrane
Stapedius	Attached to inside of pyramidal eminence	Neck of stapes	Branch of facial nerve [VII]	Contraction pulls stapes posteriorly, preventing excessive oscillation

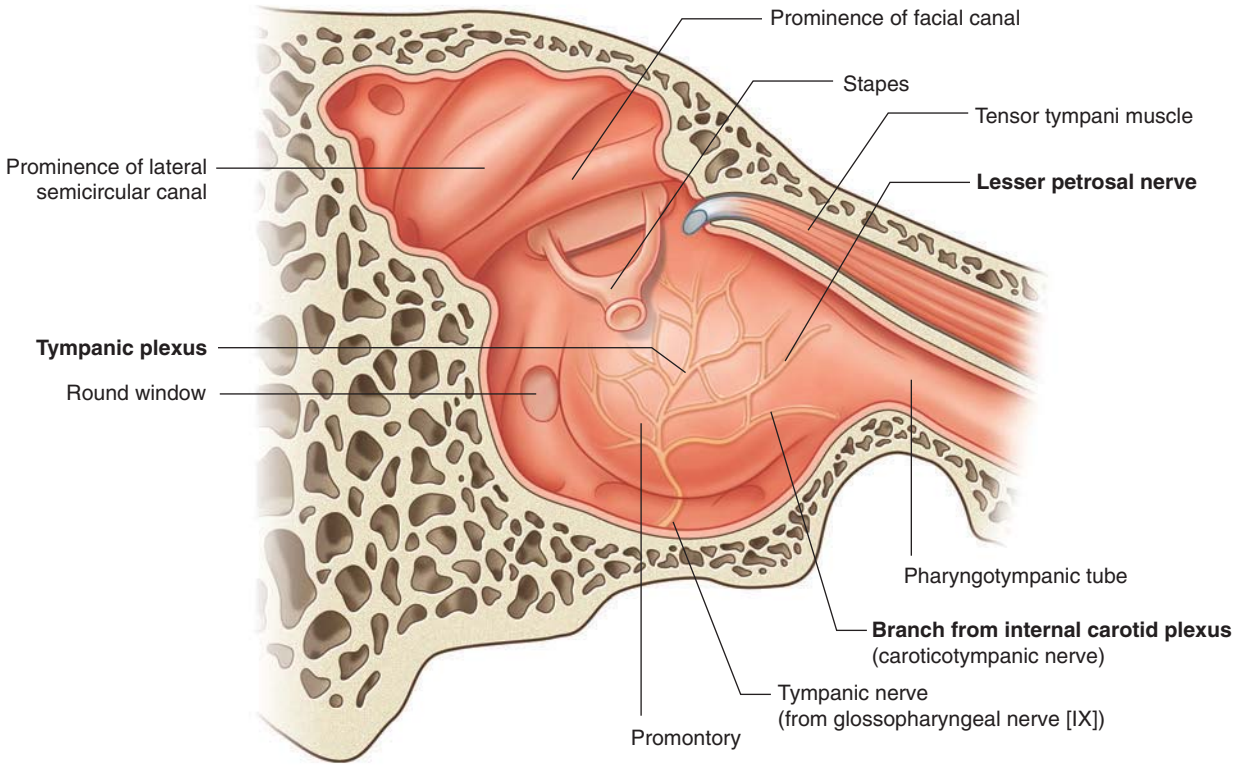

Fig. 8.125 Innervation of the middle ear.

mucous membrane covering the promontory, which is the rounded bulge on the labyrinthine wall of the middle ear (Fig. 8.125).

As the glossopharyngeal nerve [IX] exits the skull through the jugular foramen, it gives off the tympanic nerve. This branch reenters the skull through a small foramen and passes through the bone to the middle ear.

Once in the middle ear, the tympanic nerve forms the **tympanic plexus**, along with branches from the plexus of nerves surrounding the internal carotid artery (**caroticotympanic nerves**). Branches from the tympanic plexus supply the mucous membranes of the middle ear, including the pharyngotympanic tube and the mastoid area.

The tympanic plexus also gives off a major branch (the lesser petrosal nerve), which supplies preganglionic parasympathetic fibers to the otic ganglion (Fig. 8.125).

The lesser petrosal nerve leaves the area of the promontory, exits the middle ear, travels through the petrous part of the temporal bone, and exits onto the anterior surface of the petrous part of the temporal bone through a hiatus just below the hiatus for the greater petrosal nerve (Fig. 8.126). It continues diagonally across the anterior surface of the temporal bone before exiting the middle cranial fossa through the foramen ovale. Once outside the skull it enters the otic ganglion.

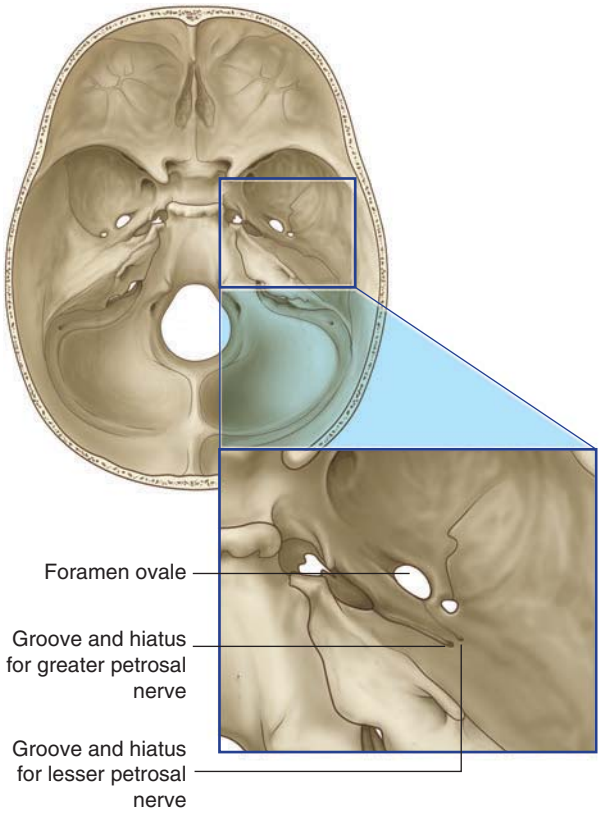

Fig. 8.126 Grooves and hiatuses for the greater and lesser petrosal nerves.