

## Middle Ear

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**Osteology**—The temporal bone forms the lateral side of the skull. The **external acoustic meatus** is an opening in the lateral surface of the temporal bone. It allows sound to reach the tympanic membrane. The **internal acoustic meatus** is an opening on the posteromedial surface of the petrous part of the temporal bone. It is found on the posterior slope of the petrous ridge and transmits the facial nerve (CN VII), the vestibulocochlear (CN VIII), and the labyrinthine artery. The **mastoid process** is located posteroinferior to the external acoustic meatus. It projects inferiorly from the junction of the petrous and squamous portions of the temporal bone. It contains the mastoid air cells that open into the tympanic cavity. The greater petrosal nerve passes through the canal of the greater petrosal nerve within the pterygoid canal. The **opening/hiatus** to this canal through which **the greater petrosal nerve** passes is located in the petrous part of the temporal bone. The **tegmen tympani** is a thin plate of bone that forms the roof of the tympanic cavity. It is located on the floor of the middle cranial fossa. The jugular fossa is a depression on the posterior surface of the petrous portion of the temporal bone. It forms the anterior margin of the jugular foramen. The **carotid canal** courses through the petrous part of the temporal bone. Through this canal, the internal carotid artery and plexus of nerves pass into the cranial cavity. The **stylomastoid foramen** is an opening found posterior to the base of the styloid process in the petrous portion of the temporal bone. Through it passes the facial nerve (CN VII) and the stylomastoid artery (Netter 9).

**External Ear**—The external ear is composed of the **auricle** which **collects sound** and the **external auditory meatus** which **conducts sound** to the tympanic membrane where the meatus ends.

The **auricle** is composed mainly of elastic cartilage that is covered by skin. The **helix** is the prominent outer margin of the auricle. The **antihelix** is the curved inner margin located anterior to the helix. The **tragus** is the portion of the auricle that is located closest to the face. On its inner surface, this part of the ear has hairs on it. The **lobule** of the ear lacks cartilage. It consists of fibrous tissue, fat, and blood vessels and is easily pierced for taking small samples of blood or for inserting an earring. The auricle receives cutaneous innervation from the greater auricular nerve (C2, C3) and the auriculotemporal nerve (V3). The auricle is supplied by the posterior auricular artery and superficial temporal artery (Netter 88, 20, 19).

The **external acoustic meatus** serves like a “funnel” to get sound to the middle ear. It leads inward through the tympanic portion of the temporal bone. It extends from the deepest part of the concha (deepest depression of the auricle) to the tympanic membrane. This is a distance of 2-3 cm in adults. The inner 1/3 of the external auditory meatus is bony and is continuous with the external layer of the tympanic membrane. The outer 1/3 of it is cartilaginous and is continuous with the skin of the auricle. The external auditory meatus is lined by skin that is innervated by sensory fibers that are contributed by CN V, VII, IX, and X. The skin on the outer 2/3 contains ceruminous glands that are

responsible for a waxy buildup. Buildup of wax, foreign bodies, etc. in the external auditory meatus can decrease sound transmission (Netter 87).

**Middle Ear**—The middle ear is found within the petrous part of the temporal bone and contains the auditory ossicles, muscles, and nerves. It is an air filled cavity that is covered with a mucous membrane. In some people (especially children), the mucous membrane secretions of the middle ear can buildup here b/c it doesn't drain as it should (through the auditory tube into the nasopharynx). PE tubes can be put into the posteroinferior portion of the tympanic membrane to form a drainage system for the ear. This position insures that the ossicles and nerves of the tympanic cavity are not injured by the incision of the membrane and the insertion of the tube. The middle ear has a roof, floor, and four walls (Netter 87, 88, 93, 89).

The **roof** (AKA tegmental wall) of the middle ear is formed by the **tegmen tympani**. This is a thin plate of bone that separates the tympanic cavity from the dura mater on the floor of the middle cranial fossa. The tegmen tympani overlies the epitympanic recess

The **floor** (AKA jugular wall) of the middle ear is formed by a layer of bone that separates the tympanic cavity from the IJV and jugular fossa.

The **lateral wall** (AKA membranous wall) is formed by the convex tympanic membrane. The **tympanic membrane** is obliquely oriented in an inferolateral position and is composed of intermediate fibers interposed between modified skin and an internal mucous membrane. It has a centrally located concavity depression called the **umbo**. The **manubrium (handle) of the malleus** is embedded in the wall of the tympanic membrane toward the umbo. The lateral wall also contains the **chorda tympani** which crosses the medial surface of the neck of the malleus.

The **medial wall** (AKA labyrinth wall) separates the tympanic cavity from the inner ear. It features the **promontory**, which is the rounded bony eminence formed by the basal turn of the cochlea. The oval and round windows are also found in this wall. The **round window** (AKA fenestra cochleae) is located below and behind the promontory. It is closed by a membrane. The **oval window** (AKA fenestra vestibuli) is covered by the base of the stapes. Above the oval window, the facial nerve bulges out and descends vertically behind the promontory. Superior and posterior to this is the lateral semicircular canal which also produces a bulge in the medial wall. Also beneath the mucous membrane in the medial wall is the tympanic plexus which carries both sensory (CN IX) and autonomic fibers.

The **anterior wall** (AKA carotid wall) separates the tympanic cavity from the carotid canal. It is an incomplete wall due to its **opening of the pharyngotympanic (auditory) tube** and due to the fact that it contains the tendon of the tensor tympani muscle. The auditory tube is directed anteriorly in an inferior and medial direction. It provides ventilation (equilibrates the air from outside and the air inside the ears). It also facilitates drainage and protects against the spread of infection. The proximal 1/3 of the auditory tube is bony and the distal 2/3 is cartilaginous. The auditory tube is lined with a mucous

membrane that is continuous with the middle ear and nasopharynx. Normally the auditory tube is closed. It is opened by contraction of the tensor veli palatine and levator veli palatine muscles. These muscles take origin in part of the auditory tube cartilage, so they tug on it and open it when you are doing something such as swallowing or yawning.

The **posterior wall** (AKA mastoid wall) contains an opening in its superior part that connects the epitympanic recess to the mastoid antrum which contains the mastoid air cells. This opening is called the **aditus ad antrum**. The facial nerve descends medial to this aditus. The posterior wall also contains a hollow, cone-shaped prominence called the **pyramidal eminence**. The tip of the pyramid is filled with the **stapedius** muscle.

The **auditory ossicles** are found within the middle ear. They are a chain of small bones that travel from the tympanic membrane to an oval opening on the medial wall of the tympanic cavity called the **oval window**. The oval window leads to the bony labyrinth of the inner ear. The ossicles are the first bones to be fully ossified during development and are basically mature by the time of birth. The **malleus** (“hammer”) attaches to the tympanic membrane. Its handle, or **manubrium**, is embedded in the tympanic membrane with its tip located at the umbo. The malleus moves with the tympanic membrane and acts as a lever. The head of the malleus articulates with the incus in a saddle joint. The **incus** (“anvil”) is the middle ossicle of the middle ear. It articulates with the head of the malleus and with the head of the stapes. The joint between the incus and stapes is a ball and socket joint. The malleus and incus are found within an **epitympanic recess** of the temporal bone. The **stapes** (“stirrup”) is the medial ossicle of the middle ear. It is the smallest of the ossicles and its **base** or footplate fills the oval window on the medial wall of the tympanic cavity. The stapes articulates with the long process of the incus. The ossicles of the middle ear are suspended by ligaments from the roof and bony walls. They concentrate sound energy as it is converted to mechanical energy, increasing force by 10 times. They also decrease amplitude of the sound.

There are two muscles which serve a protective function in helping stiffen the chain of ossicles and in helping dampen vibrations.

**Stapedius muscle**—This the smallest voluntary/striated muscle in the body. It **originates** on the walls of the pyramidal eminence. Its tendon exits at the apex to **insert** onto the neck of the stapes. Its **action** is to pull the stapes posteriorly and tilt its base. It is **innervated** by the facial nerve (CN VII) and is **supplied** by the anterior tympanic artery. With the exception of its tendon, this muscle is entirely enclosed in bone.

**Tensor tympani muscle**—This muscle **originates** on the cartilaginous auditory tube and the greater wing of the sphenoid bone. It courses from the anterior wall above the auditory tube and becomes tendinous and turns laterally to **insert** onto the manubrium of the malleus. Its action is to draw the handle of the malleus and the membrane medially. It is **innervated** by the pterygoid branch of the mandibular nerve (V3) and is **supplied** by the superior tympanic branch of the middle meningeal artery.

**Internal Ear**—The inner ear is involved with the reception of sound and with maintaining balance. It is found within the petrous portion of the temporal bone within the otic capsule which is hollow and is filled with the fluid bony labyrinth. Within the bony labyrinth is the membranous labyrinth (Netter 89, 90, 91, 92).

The **membranous labyrinth** is a series of sacs and ducts that communicate with each other. It contains a watery fluid called endolymph and is composed of two portions. The vestibular labyrinth and the cochlear labyrinth. Within the *vestibular labyrinth*, there are two small communicating sacs called the **utricle** and **sacculle** which are concerned with maintaining balance. The oval window opens into a space called the vestibule. This is where the saccule and utricle are found. These two sacs have specialized sensory epithelium that is innervated by the vestibular division of the vestibulocochlear nerve (CN VIII). The *cochlear labyrinth* contains the **cochlear duct** which opens into the cochlea.

The **bony labyrinth** is composed of the cochlea, vestibule, and semicircular canals. It is not actually bone, but is a fluid filled system called perilymph. The **cochlea** is the shell-shaped structure within the bony labyrinth. It makes approximately 2 ½ turns and contains the cochlear duct which is the portion of the inner ear concerned with hearing. The **vestibule** is a small oval chamber which contains the utricle and saccule. The vestibule is continuous with the cochlea anteriorly and the semicircular canals posteriorly. The **semicircular canals** are found posterosuperior to and open into the vestibule. They are set up at right angles to each other. The lateral semicircular canal is oriented in a horizontal plane. The anterior and posterior semicircular canals are oriented vertically and are at angles to each other. The posterior semicircular canal is oriented parallel to the petrous ridge. The anterior semicircular canal is perpendicular to the petrous ridge.

**Nerves of the Ear**—The **facial nerve** (CN VII) exits the cranial cavity through the internal acoustic meatus. It courses anteriorly between the cochlea and three semicircular canals within the facial canal. It then turns posteriorly and courses along the medial wall and then descends along the posterior wall of the tympanic cavity. Here it gives off a **nerve to the stapedius muscle**. The motor root of the facial nerve (CN VII) exits the skull through the stylomastoid foramen. The intermediate portion of the facial nerve includes the greater petrosal nerve and the chorda tympani nerve. The **chorda tympani nerve** carries preganglionic parasympathetic fibers to the submandibular ganglion. It also carries taste fibers from the geniculate ganglion. The **geniculate ganglion** contains the cell bodies for taste fibers destined for the anterior 2/3 of the tongue. The **greater petrosal nerve** begins at the geniculate ganglion and emerges at the hiatus for the greater petrosal nerve. It carries preganglionic parasympathetic fibers toward the pterygopalatine ganglion.

The **vestibulocochlear nerve** (CN VIII) passes into the internal auditory meatus. It provides sensory innervation to the vestibule and the cochlea. In the vestibule, the

**vestibular nerve** is responsible for balance and proprioception. In the cochlea, the **cochlear nerve** is responsible for hearing (Netter 98, 118).

**Conductive vs. Sensorineural Hearing Loss**—Conductive hearing loss occurs in the conducting portion of the ear. It can happen due to an obstruction, perforation, inflammation, infection, or arthritis of the ossicles. Sensorineural hearing loss is often due to things such as head injury, tumors, or birth defects.

### **Clinical Correlations**—

**External Ear Injury**—Bleeding within the auricle from trauma can produce an auricular hematoma. Blood collects between the perichondrium and auricular cartilage and as it enlarges it compromises the blood supply to the cartilage. If left untreated, fibrosis develops in the skin and results in a malformed ear.

**Otoscopic Examination**—This begins by straightening the meatus by pulling the helix up, out and back in adults. This reduces the curvature of the meatus. In an infant the meatus is straightened by pulling the auricle down and back. These maneuvers can also help indicate inflammation of the auricle or external meatus. When looking with an otoscope, the tympanic membrane is translucent and pearly gray. The malleus handle is usually visible and from the inferior end of it, there is often a reflection of light from the otoscope's illuminator (light reflex).

**Otitis Externa**—This is a bacterial infection of the skin of the external auditory meatus. It often develops in swimmers who don't dry their ears properly after swimming. The infection causes itching and pain in the external ear. Pulling on the auricle increases the pain felt.

**Perforation of the Tympanic Membrane**—A “ruptured eardrum” may result from otitis media and can cause middle ear deafness. It can also be caused by foreign bodies, trauma, or excessive pressure in the external ear. Minor ruptures heal spontaneously, but larger ruptures can require surgery to repair the tear. The superior half of the tympanic membrane is more vascular than the inferior half, so incisions to release pus from an abscess of the middle ear must be made posteroinferiorly through the membrane. This also avoids injury to the chorda tympani and auditory ossicles.

**Otitis Media**—A bulging red tympanic membrane may indicate pus or fluid in the middle ear. An infection here is often due to upper respiratory infections. As the tympanic membrane becomes red and bulges, a person may complain of their ear “popping.” If untreated, otitis media can produce impaired hearing b/c it can cause scarring of the auditory ossicles. This limits their ability to respond to sound.

**Mastoiditis**—This is an infection of the mastoid antrum and mastoid cells resulting from a middle ear infection that causes inflammation of the mastoid process. This is not a common occurrence since antibiotics have been widely used.

**Earache**—This is a common symptom with many causes. Earaches may be caused by otitis externa, otitis media, or dental abscesses.

**Blockage of the Pharyngotympanic Tube**—This tube forms a route for infection to pass from the nasopharynx to the tympanic cavity. It is easily blocked by swelling of its mucous membrane or as a result of mild infections. When the tube is occluded, residual air in the tympanic cavity is absorbed into the mucosal blood vessels. This causes lower pressure and retraction of the tympanic cavity and its membrane. Hearing is also affected. The tubes can be subject to temporary pressure changes (due to things like flying in an airplane). This pressure difference can be alleviated by swallowing or yawning to open the pharyngotympanic tubes.

**Paralysis of the Stapedius**—The tympanic muscles have a protective action in dampening large vibrations on the tympanic membrane due to loud noises. Movement of the stapes can be uninhibited by something that causes paralysis of the stapedius (for example, a lesion of the facial nerve).

**Motion Sickness**—The maculae of the membranous labyrinth are static organs with small otoliths embedded among the hair cells. The otoliths are under the influence of gravity. They cause the hair cells to bend. This stimulates the vestibular nerve and provides awareness of position of the head. They also respond to quick tilting movements and to linear acceleration and deceleration. A fluctuating stimulation of the maculae results in motion sickness.

**Dizziness and Hearing Loss**—Injuries to the peripheral auditory system can cause hearing loss, vertigo (dizziness), and tinnitus (buzzing or ringing).

**Meniere Syndrome**—This condition involves blockage of the cochlear aqueduct. It is characterized by recurrent attacks of tinnitus, hearing loss, and vertigo. The symptoms are accompanied by a sense of pressure within the ear, distortion of sounds, and sensitivity to noises.

**High Tone Deafness**—This is due to the persistent exposure to excessively loud sounds which causes degenerative changes to the spiral organ. This condition often occurs in people who do not wear protective ear wear when exposed to loud noises.

**Otic Barotrauma**—An injury to the ear caused by an imbalance in pressure between the ambient air and the air in the middle ear drum is called otic barotraumas. It is usually seen in fliers and divers.