Chapter 139: Anatomy of the Skull Base, Temporal Bone, External Ear, and Middle Ear

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Skull Base and Temporal Bone (Figs. 139-1 and 139-2)

The temporal bone contains and is surrounded by many important structures about which the otolaryngologist - head and neck surgeon must have a practical working knowledge. The bone occupies the lower middle third of the skull's side, where it articulates with five other cranial bones: the frontal, parietal, sphenoid, occipital, and zygomatic.

The sternocleidomastoid muscle and posterior belly of the digastric muscle insert onto the tip of the mastoid process. Beneath the head of the sternocleidomastoid muscle the internal jugular vein emerges from the jugular foramen accompanied by three cranial nerves: the spinal accessory (CN XI), glossopharyngeal (CN IX), and vagus (CN X). Just outside the jugular foramen CN XI is the most posterior of the three nerves, and CN X lies between it and CN IX. All three nerves are found medial to the internal jugular vein and internal carotid artery at the base of the skull, but CN X shifts to a position between and posterior to the vessels lower in the neck.

Anterolateral to the jugular foramen, the styloid process projects from the inferior surface of the temporal bone and is the bony insertion of the stylohyoid ligament and stylopharyngeal muscles. The styloid process and the posterior belly of the digastric muscle are important landmarks for the identificatio of the facial nerve (CN VII), which exits the skull via the stylomastoid foramen anterior to the digastric notch and slightly posterolateral to the styloid process. The nerve then enters the portion of the parotid gland that is associate posteriorly with the mastoid process and posterior belly of the digastric muscle, superiorly with the cartilaginous and bony portions of the external auditory meatus, and posteromedially with the styloid process and muscles, and medially with the pharynx. In addition to CN VII, the substance of the parotid gland contains the external carotid artery and its terminal branches, the posterior facial vein, the auriculotemporal branch of the mandibular division of the trigeminal nerve (CN V), and branches of the great auricular nerve from the cervical plexus.

Deep to the superficial portion of the parotid gland, the condyle of the mandible is attached via the joint capsule to the articular fossa of the temporal bone (mandibular fossa). The articular fossa is located at the root of the zygomatic arch, just anterior to the bony cartilaginous external auditory canal.

The internal carotid artery enters the carotid canal anterior to the jugular fossa and medial to the styloid process. Between the carotid canal and the styloid process, the hypoglossal nerve (CN XII) exits the skull via its own foramen, the hypoglossal canal (Fig. 139-3, A). Several important foramina lie anterior to the carotid canal within the basal portion of the greater wing of the sphenoid bone. The sphenoid's angular spine is located anterior to the carotid canal and medial to the articular fossa. Anterior to the spine is the foramen spinosum, through which the middle meningeal artery enters the middle cranial fossa (Fig. 139-3, B). Medial to the spine is the external opening of the musculotubal canal. Anterior and

medial to the foramen spinosum and lateral to the lateral pterygoid plate, the foramen ovale transmits the mandibular division of CN V as it passes from the cranial fossa to the infratemporal fossa (Fig. 139-3, C).

The meninges of the middle and posterior cranial fossae adhere to the intracranial surface of the temporal bone. The tentorium cerebelli is attached to the petrous ridge and extens from the transverse sinus to the apex of the petrous temporal bone. The tentorium overlies the dural pocket, or Meckel's cave, which contains the trigeminal ganglion. Medial to the trigeminal ganglion, the abducens nerve (CN VI) passes into the cavernous sinus via Dorello's canal within the substance of the dura. CN VI involvement within Dorello's canal is an important clinical sign for the diagnosis of Gradenigo's syndrome in cases of petrous apicitis. In the well-pneumatized mastoid bone, often only dura and a very thin layer of bone separate the intracranial contents from the pneumatic cells.

Temporal bone (Fig. 139-4)

The temporal bone can be divided into four parts: the squamous, mastoid, petrous, and tympanic.

Squamous portion

The squamous portion of the temporal bone articulates with the parietal bone, frontal bone, and greater wing of the sphenoid bone. The lateral surface defines the boundary of the middle cranial fossa, and the sulcus of the middle meningeal artery scores the medial surface. As the caudal portion of the bone extends medially to join the superior surface of the petrous bone in the region of the tegment, the petrosquamous fissure is defined.

The squamous bone forms the posterosuperior portion of the external auditory meatus. Just posterior to the glenoi fossa, the squama joins the tympanic portion of the temporal bone at the tympanosquamous suture. The posterior buttress of the zygomatic process originates from the squama as a crest of bone overlying the external auditory meatus in the region of the tympanosquamous suture. In this area the hiatus between the tympanic bone and the squama corresponds to the notch of Rivinus (incisura tympanica). Posterior and caudal to the posterior buttress of the zygoma, the mastoid process projects caudally from both the squamous and petrous parts of the temporal bone.

Mastoid portion

The squama forms the anterosuperior portion of the mastoid process, and the petrous bone forms the posterior and inferior parts. Along the lateral surface of the mastoid process, in an area bounded superiorly by the temporal line and anteriorly by the posterosuperior wall of the meatus, a shallow depression exists within the cortex, the mastoid fossa or cribriform area. Anterior to this region, at the posterosuperior portion of the external auditory meatus, is the (suprameatal) spine of Henle. Caudal to the notch of Rivinus, near the middle of the posterior osseous meatal wall, the mastoid portion joins the tympanic bone at the tympanomastoid suture.

Pneumatization within the mastoid process is variable. The squama of the temporal bone forms a lateral wall of the central air-containing space, the antrum, which communicates with the middle ear by the aditus. The suprameatal spine and cribriform area provide important landmarks for surgical access to the antrum. From the region of the antrum, pneumatization may extend inferiorly into the tip of the mastoid process, where the remnant of the petrosquamous suture may persist as a thin plate of bone, Körner's septum. Pneumatization also commonly extends into the perilabyrinthine region and petrous portions of the temporal bone.

Petrous portion

The petrous portion of the temporal bone roughly assumes the configuration of a four-sided pyramid. Within the body of the petrous bone is found the labyrinth and the internal carotid artery, CN VII, and CN VIII (acoustic and vestibular portions) all penetrate the bone substance. The lateral dimension of the petrous pyramid is most interesting and important to the otologist because it defines the medial limit of the middle ear cavity. As such, this wall contains the first turn of the cochlea, or promontory; the dome of the lateral semicircular canal; an the medial wall of the antrum.

Superior and anterior surface. This portion of the petrous bone, also known as the *cerebral surface*, forms part of the middle cranial fossa. Laterally the bone is fused with the squama, and anteriorly it articulates with the sphenoid bone. The foramen lacerum is found between the apex of the petrous bone and the sphenoid bone and contains but does not transmit the internal carotid artery. Also near the apex is the hollow for the trigeminal ganglion. At the bone's anterior margin the large wing of the sphenoid bone forms the musculotubal canal. This opening contains the semicanal for the tensor tympani and the semicanal of the eustachian tube. The arcuate eminence is found near the middle of the anterior surface of the petrous bone and is the outcropping of the superior semicircular canal. The tegmen tympani is lateral to the eminence. The opening of the hiatus of the facial canal is anterior and medial to the arcuate eminence; this transmits the superficial petrosal branch of the middle meningeal artery and the greater petrosal nerve.

Posterior or cerebellar surface. The posterosuperior surface of the petrous bone forms the anterolateral wall of the cerebellar or posterior fossa. A sulcus for the superior petrosal sinus defines its superior border. Posteriorly the bone articulates with the occipital bone. Approximately midway between the apex and the anterior border of the sigmoid sulcus is the internal auditory meatus. The meatus is a short canal that begins medially at the internal acoustic pore. A bony plate, which is also part of the medial wall of the vestibule and cochlea, closes the lateral end. A horizontal ridge of bone, the transverse crest, divides the pore into upper and lower areas. The anterior portion of the superior division contains the facial nerve, which is separated from the superior vestibular nerve in the posterior portion of the upper division by a small, vertical crest of bone. Numerous foramina, which carry bunles of the cochlear nerve into the basal turn, perforate the anterior portion of the lower division. The posterior portion of the lower division accommodates the inferior vestibular nerve. The internal auditory canal also contains the internal auditory artery, a branch of the anterior inferior cerebellar artery that supplies the entire membranous labyrinth.

Between the internal auditory meatus and the superior petrosal sulcus is a small channel, the subarcuate fossa, that transmits small veins to the dura. Caudal and lateral to the fossa, midway between the meatus and the sigmoid sulcus, is the vestibular aqueduct, which transmits the endolymphatic duct and sac. The external aperture of the vestibular aqueduct is overhung by a thin rim of bone, and the foveate impression lies distal to the aperture and contains the intradural portion of the endolymphatic sac.

Inferior surface. This is the most irregular of the petrous bone's surfaces. The oval opening of the carotid canal is about midway between the apex and the base; this is the entrance for the internal carotid artery and its plexus of veins and sympathetic nerves. The canal courses in a cephalad direction along the anterior wall of the tympanic cavity to the bony wall of the eustachian tube and then bens horizontally, ending at the apex of the petrous bone. Posterior to the carotid foramen is the jugular foramen, which is formed between the inferior surface of the petrous bone and the occipital bone. The carotid ridge is a sharp outcrop of bone separating the carotid and jugular foramen. The lateral part of the foramen contains the sigmoid portion of the transverse sinus; the medial part contains the inferior petrosal sinus and the glossopharyngeal, vagus, and accessory nerves. Anterior to the lateral compartment is the broad fossa for the jugular bulb. Medial to the fossa, between the petrous and occipital bones, is the funnel-shaped opening of the cochlear canaliculus. Posterior and lateral to the jugular foramen is a cylindrically shaped bony spur, the styloid process, and just lateral to its base is the stylomastoid foramen, which transmits the facial nerve and, in some individuals, the auricular branch of the vagus nerve.

Tympanic portion

The tympanic part of the temporal bone forms the anterior and inferior walls and part of the posterior wall of the external auditory meatus. It is separated anteriorly from the squamous bone by the tympanosquamous suture, more medially from the petrous bone by the petrotympanic fissure, and posteriorly from the mastoid portion of the petrous bone by the tympanomastoid fissure. In the infant the bone is ring-shaped, open above and anteriorly. In the adult the inner part of the tympanic ring is grooved and is called the *tympanic sulcus;* it accommodates the tympanic membrane annulus. The inferior aspect of the tympanic bone is elongated into the vaginal process immediately anterior to the styloid process.

Venous sinuses

The lateral (transverse sinus) is the largest of the venous sinuses. It extens horizontally from the occipital protuberance within the tentorium cerebelli to the cerebellar surface of the petrous bone, where it courses in a caudal direction as the sigmoid portion, to end in the jugular bulb. At the jugular bulb the sigmoid sinus receives the inferior petrosal sinus, which courses along the inferior portion of the cerebellar surface of the petrous pyramid. The superior petrosal sinus enters the sigmoi sinus at its junction with the horizontal portion of the lateral sinus. Both the superior and the inferior petrosal sinuses contain blood from the cavernous sinus. The inferior petrosal sinus also contains blood from the basilar plexus. The vein of the cochlear aqueduct is transmitted by a separate bony channel that parallels the cochlear aqueduct and terminates in the inferior petrosal sinus. The vein of the vestibular aqueduct accopanies the endolymphatic duct and drains together with numerous smaller veins that drain the endolymphatic sac into the lateral sinus.

External Ear

The external ear includes the auricle and the external auditory meatus.

Auricle (Fig. 139-5)

An irregular framework of yellow elastic fibrocartilage, covered by perichondrium and skin, makes up the auricle, or pinna. The lateral surface generally is concave, with each concavity represented on the medial side by a corresponding convexity. The skin overlying the lateral surface adheres firmly to the perichondrium; however, the medial surface is attached more loosely with areolar tissue beneath the epidermis. The crus of the helix divides the largest concavity, or auricular concha, into the cymba conchae superiorly and the cavum conchae inferiorly. The cartilage of the cavum conchae extends into the cartilaginous external auditory canal, which is incomplete superiorly in the auricular notch, or incisura terminalis. Inferior to the incisura is the prominent cartilaginous process, the tragus, and more inferior, lying opposite and inferior to the tragus, is the antitragus. The posterosuperior rim of the conchal cartilage is a prominent ridge, the anthelix, which is divided superiorly into two ridges that define a shallow depression, the triangular fossa. The external rim of the auricle is the helix, which is continuous with the crus of the helix superiorly and the lobule inferiorly.

The auricle is attached firmly to the tympanic bone by its contribution to the fibrocartilaginous canal and more loosely by the anterior, superior, and posterior auricular ligaments and six poorly developed intrinsic muscles.

Cranial nerves V, VII, and X and the third cervical nerve provide the sensory nerve supply to the auricle and meatus. The great auricular nerve originates from the third cervical nerve and provides sensory innervation to skin overlying the mastoid process and the medial and lateral aspects of the pinna. The auriculotemporal nerve originates from the third division of CN V and provides innervation to the cartilaginous and bony meatus adjacent to the mandibular fossa and the anterior part of the pinna. The auricular branch of CN X exits the temporal bone at the stylomastoid foramen and supplies the floor of the external auditory meatus and a small part of the auricle together with branches of CN VII, which also contribute to the sensory innervation of the posterosuperior meatus.

The external carotid artery supplies all the bloo to the pinna and external auditory canal. The posterior auricular artery courses along the anterior surface of the mastoid process and provides blood to this region of the mastoid and the auricle. The superficial temporal artery supplies blood to the external auditory canal and auricle from its position anterior to the structures.

External acoustic meatus

The external acoustic meatus consists of a lateral cartilaginous meatus and a medial osseous meatus. The canal extends from the conchal cartilage to the tympanic membrane and is approximately 25 mm long in its superior and posterior dimension. As the meatus extends medially, it courses in an anterior and inferior direction and is slightly S-shaped.

The cartilaginous portion of the meatus makes up a little less than one-half the length of the canal and is incomplete posteriorly and superiorly. In the anterior wall of the cartilage are two slits called the incisurae santorini.

The anterior and inferior walls and lower portion of the posterior walls of the osseous canal are developed from the tympanic ring. The upper portion of the posterior wall and the superior wall develop from the squamous portion of the temporal bone. The superior wall is separated medially from the attic of the tympanic cavity by thin bone, and more laterally a thicker wall of bones separates the canal from the middle fossa. The posterior wall is sloce to the mastoid cells and the descending portion of the facial canal. The inferior wall is composed of dense bone, but in some instances it may be thin, exposing an enlarged or dehiscent jugular bulb. The anterior wall defines the posterior limit of the glenoid fossa, is close to the condule of the mandible, and may be thin or even dehiscent.

Middle Ear

The middle ear consists of the tympanic cavity and the osseous eustachian tube.

Confines of tympanic cavity (Figs. 139-6 to 139-8)

The tympanic cavity contains the sound-pressure transformer mechanism, the tympanic segment of the facial nerve, and a complex of vessels and nerves. The tympanic cavity is a cleft within the temporal bone between the tympanic membrane laterally and the osseous labyrinth medially. The roof of the tympanic cavity is the tegmen, a thin plate of bone separating the space from the middle cranial fossa. The floor of the tympanic cavity is a thin layer of bone over the bulb of the internal jugular vein and an irregular collection of air cells. The posterior boundary is more complex and contains many important anatomic landmarks. The posterior wall is close to the mastoid air cell system; the pyramidal eminence, a bony elevation that transmits the tendon of the stapedius muscle, is attached to the superior aspect of this wall. Part of the muscle is contained within the pyramidal process itself. The chorda tympani nerve enters the tympanic cavity lateral to the pyramidal process through its foramen, the tympanic opening of the canal for the chorda tympani. The posterior sinus, or facial recess, is between the pyramidal process and the chorda tympani nerve (see Fig. 139-6). The incudal fossa, where the posterior ligament of the incus is attached, is cephalad to the facial recess. The anterior boundary of the tympanic cavity partly consists of the wall of the carotid canal, which may be very thin. The tensor tympani muscle and its semicanal are found superiorly, and the eustachian tube orifice is found more inferiorly along the anterior wall. The medial wall consists of the promontory, or basal turn of the cochlea; the oval and round windows; and the fallopian canal. A ridge of bone found superiorly, the ponticulus, and a ridge of bone found inferiorly, the subiculum, divide the medial wall into three main depressions. The round window niche is inferior to the subiculum, the oval window niche superior to the ponticulus, and the tympanic sinus medial to the facial nerve between the subiculum and ponticulus (see Fig. 139-7). Inferior to the subiculum in the round window niche, or fossula of the cochlear window, is the cochlear window or round window orifice, which is closed by a fibrous mucosal-covered membrane. Superior to the ponticulus is the oval window niche, or fossula of the vestibular window, which leads to the vestibular or oval window. The footplate of the stapes closes the window. The prominent ridge of bone posterior and superior to the fossulae contains the facial nerve, and posterosuperior to this structure is

the prominence of the lateral semicircular canal. The lateral boundary of the tympanic cavity is the membranous wall formed by the tympanic membrane and its annulus, the bony tympanic sulcus and the lateral wall of the epitympanic recess, the tympanic scutum. The epitympanic recess is a space defined superiorly by the tegmen tympani, medially by the prominence of the facial cranial and semicircular canal, laterally by the scutum, and posteriorly by the incudal fossa.

The tympanic cavity is lined with a mucous membrane that also invests the contents of the cavity. The epithelium consists of flat, cuboial, and columnar cell types. Each type may bear cilia (see Fig. 139-8). The epithelium extends from the eustachian tube orifice over the promontory to invest the muscles and tendons within the middle ear cleft and form several pouches in the superior aspect of the cavity. One such space is the superior recess of the tympanic membrane, or Prussak's space, which is found between the pars flaccida of the tympanic membrane and the neck of the malleus. Two other blind pouches, the anterior and the posterior recesses of the tympanic membrane, or the pouches of von Troltsch, are formed from reflections of the anterior and posterior mallear folds between the ossicles, their ligaments, and the tympanic membrane.

The middle ear cleft communicates with the tympanic antrum via the aditus ad antrum in the posterosuperior wall of the epitympanic recess. It is by this route that cholesteatoma extends from the middle ear cleft into the mastoid cavity. The membranous folds and pouches may influence the direction and location of spread.

Vascular system of tympanic cavity and ossicles (Figs. 139-9 and 139-10)

The blood supply of the middle ear and mastoid cavity originates from both the internal and the external carotid arteries. The anterior tympanic artery is a terminal branch of the internal maxillary artery. Two of its branches supply the bone and mucosa of the superior and lateral walls of the epitympanic cavity, and a third branch provides the main blood supply for the malleus and incus (see Fig. 139-9). Another branch of the internal maxillary artery, the deep auricular artery, provides two branches to the vascular ring of the tympanic membrane. A posterior branch supplies the majority of the tympanic membrane, whereas the anterior branch supplies a lesser portion of the anterior and inferior region.

Two arteries originate from the middle meningeal artery: the superior petrosal and the superior tympanic. The superficial petrosal artery enters the facial hiatus and divides into two main branches. Both branches pass within the fallopian canal to provide a major blood supply to the geniculate ganglion and the facial nerve. The blood supply to the incudostapedial joint area is derived from the superior and inferior arteries of the stapedius tendon and posterior crural artery (see Fig. 139-10). These arteries in turn originate from the arterial plexus, supplied by the superficial petrosal artery within the fallopian canal and its anastomosis with a stylomastoid artery. The superior tympanic artery enters the middle ear adjacent to the lesser petrosal nerve. The artery supplies the tensor tympani and a portion of the epitympanic space. It also forms an anastomotic plexus with the inferior tympanic artery, which gives rise to the anterior stapedial artery and ultimately the anterior crural (femoral) artery (See Fig. 139-10).

The caroticotympanic arteries are branches of the internal carotid artery that pass through the bony partition between the carotid canal and middle ear cleft and eventually anastomose with branches of the inferior tympanic and tubal arteries. The inferior tympanic artery is a branch of the ascending pharyngeal artery that enters the middle ear cleft with the tympanic (Jacobson's) nerve. This artery, along with the caroticotympanic arteries, provides the major blood supply to the mucosa of the promontory and the lower tympanic cavity (hypotympanum).

The venous drainage from the middle ear cleft is principally via the lateral sinus, jugular bulb, the petrosal sinuses, the pterygoid plexus of veins, and the middle meningeal veins.

Sensory nerves of tympanic cavity

The sensory root of the facial nerve is the intermediate nerve. Fibers from this nerve either pass anteriorly from the geniculate ganglion as the greater petrosal nerve or posteriorly within the facial nerve to exit as the chorda tympani nerve. After exiting the facial hiatus, the greater petrosal nerve enters the foramen lacerum, where it joins the deep petrosal nerve to form the nerve of pterygoid canal (vidian nerve). This nerve traverses the pterygoid (vidian) canal and then the sphenopalatine ganglion, where the sensory fibers have their cell bodies. These fibers are distributed to the soft palate and tongue. Preganglionic secretory fibers from the cell bodies in the superior salivatory nucleus also end in the sphenopalatine ganglion. Their corresponding postganglionic fibers innervate the lacrimal gland and provide secretory innervation to the nasal cavity. Sensory fibers of the chorda tympani nerve have their cell bodies in the geniculate ganglion and provide taste sensation to the anterior two thirds of the tongue. The chorda tympani nerve also carries preganglionic secretory fibers from cell bodies within the superior salivatory nucleus, which synapse within the submaxillary ganglion and then provides secretory motor impulses to the submaxillary and sublingual glands.

The tympanic nerve (Jacobson's nerve) provides sensory innervation to the mucosa of the middle ear cleft and eustachian tube region. This nerve originates from the inferior ganglion of the glossopharyngeal nerve, and after entering the tympanic cavity through the inferior tympanic canaliculus, branches repeatedly within shallow bony channels overlying the promontory. Branches of the tympanic nerve join branches of the caroticotympanic nerve at the level of the cochleariform process to form the lesser petrosal nerve. The lesser petrosal nerve provides preganglionic secretory motor fibers to the parotid gland via the otic ganglion. Small branches from the tympanic nerve and lesser petrosal nerve appear to anastomose with the facial nerve and greater petrosal nerve, respectively, as they course close to each other within the middle ear cleft and substance of the petrous bone.

A branch of the vagus nerve and a smaller branch from the inferior ganglion of the glossopharyngeal nerve join to form Arnold's nerve (auricular ramus of the vagus). This nerve and branches of the facial nerve provide cutaneous innervation to the posterior surface of the external auditory canal.

Tympanic membrane (Fig. 139-11)

The tympanic membrane is found at the en of the osseous external auditory meatus and forms the lateral wall of the tympanic cavity. The membrane is eliptic in shape, approximately 8 mm wide, 9 to 10 mm high, and about 0.1 mm thick. The inferior pole of the membrane lies further medially than the superior pole, at an inclination of about 40 degrees relative to the inferior wall of the auditory meatus. The drum is funnel shaped, with the umbo corresponding to the tip of the manubrium at its apex. The handle of the malleus shines through the tympanic membrane, and in the upper anterior part of this bony process is a protuberance, the short process of the malleus or mallear prominence. The anterior and posterior mallear fols extend from this process to the tympanic sulcus and define the inferior extent of the flaccid portion of the membrane, or Shrapnell's membrane. This portion of the membrane appears thinner than the inferior larger portion of the tympanic membrane, the pars tensa. The pars tensa inserts into a small bony groove in the tympanic bone, the tympanic sulcus, and is attached by a fibrocartilaginous ring. Shrapnell's membrane is attached directly to the squama of the temporal bone at the notch of Rivinus.

Both the pars tensa and pars flaccida consist of three layers: a lateral epidermis continuous with the skin of the external auditory meatus, a middle layer or lamina propria, and a medial mucosal layer continuous with the mucosa of the tympanic cavity. Originally it was believed that Shrapnell's membrane possessed no lamina propria layer because it appears thinner and more distensible than the pars tensa. This is, however, not the case, and the appearance of this membrane more likely is caused by the organization and content of the connective tissue within the lamina propria. The lamina propria of the pars tensa consists of connective tissue fibers arranged in two basic layers. Outer radial fibers originate from the inferior four-fifths of the handle of the malleus and the umbo and insert into the tympanic sulcus (Fig. 139-11, A). An inner layer of circular fibers originates primarily from the short process of the malleus. Transversely and parabolically oriented fibers intertwine these two layers. The exact nature of the fibers is unknown; they probably are neither pure collagen nor elastin (Fig. 139-11, B).

Vessels within the mucosal and epidermal surfaces that communicate through anastomoses within the lamina propria provide the blood supply to the tympanic membrane. The epidermal vessels originate from the deep auricular branch of the internal maxillary artery, and the mucosal vessels originate from the anterior tympanic branch of the internal maxillary artery, and from the stylomastoid branch of the posterior auricular artery.

The tympanic nerve and the auricular branch of the vagus nerve provide part of the nerve supply to the tympanic membrane. The auriculotemporal branch of the mandibular nerve provides additional sensory innervation.

Auditory ossicles (Fig. 139-12)

The three major auditory osssicles are the malleus, incus, and stapes. Together with the tympanic membrane and the ligamentous attachments, the ossicular chain forms the sound-pressure transformer mechanism of the middle ear. The malleus is the most lateral of the three ossicles and is attached to the tympanic membrane, whereas the stapes is attached to the vestibular window.

The malleus bones consist of two main parts: the head and the handle, or manubrium. The head of the malleus occupies a portion of the upper tympanic space and has a toothlike process that articulates with the body of the incus. Between the head and the elongated handle is the neck of the malleus. The anterior process projects from the anterior surface of the neck. Opposite an just inferior to the short process is a roughened area on the handle of the malleus for the attachment of the tendon of the tensor tympani muscle. The handle of the malleus is firmly attached to the tympanic membrane on its lateral surface, giving rise to the mallear stripe (stria mallearis). Medially the handle is covered with middle ear mucosa.

The incus resembles a molar tooth. The crown of the tooth, or the body, articulates with the head of the malleus. The short and long processes of the incus correspond to the roots of the tooth. The short process rests in the incudal fossa and is attached by a ligament. The long process is thinner and more tapered than the short process and articulates with the head of the stapes. A flattened bony platform, the lenticular process, sits at the end of the long process at the point of articulation.

The stapes bone is shaped like a stirrup and consists of two legs, the anterior and posterior crura, and a footplate, which is attached by an annular ligament to the margins of the vestibular window. The two crura are joined superiorly at the head, which articulates with the lenticular process of the incus. Each leg resembles a through, with the concave surfaces facing each other. Of the two legs, the anterior crus is more delicate and less curved. On the posterior crus is a roughened area in the region of the head for the attachment of the tendon of the stapedius muscle. Cartilage covers the articulating surface of the head.

Six ligaments support the ossicles within the tympanic cavity. The anterior ligament of the malleus extends from the angular spine of the sphenoid bone through the petrotympanic fissure to insert on the neck of the malleus. The superior mallear ligament extends from the upper tegmen tympani to insert on the head of the malleus. The lateral mallear ligament extends from the neck of the malleus to the upper edge of the notch of Rivinus. The superior incudal ligament passes from the tegment tympani to the body of the incus, whereas the ligament of the short process passes from the incudal fossa to the floor of the antrum. The annular ligament of the stapes attaches the footplate to the margins of the vestibular window.

The stapedius muscle lies within the pyramidal process and originates along the ascending part of the fallopian canal. Contraction of this muscle drives the anterior aspect of the stapes base laterally. The stapedial branch of the facial nerve innervates the muscle. The tensor tympani muscle is about four times as long as the stapedius muscle, or 2 cm, and originates from the cartilaginous portion of the eustachian tube, the adjacent part of the cartilaginous portion of the eustachian tube, the adjacent part of the sphenoid bone, and the bony semicanal of the petrous pyramid. The tensor tympani tendon exits the bone from the cochleariform process, a bony prominence overlying the first genu of the facial nerve. From here the tendon extends laterally to attach to the handle of the malleus. The motor supply to the tensor tympani muscle is the trigeminal nerve.

The ossicles obtain their blood supply from submucosal vessels within the tympanic cavity. Blood vessels passing through the mucosal folds that invest the ossicles provide the blood supply to the malleus and incus. Many vessels pass through the ossicular complex along the tendon of the stapedius muscle, first to the stapes and then laterally to the incus and

malleus. Other vessels pass directly from the facial canal to the stapes.

Eustachian tube

Anatomy of the eustachian tube is discussed in Chapter 142.

Facial nerve (Fig. 139-13)

The facial nerve (CN VII) occupies an anterior cephalad position within the internal auditory canal and remains anterior to the superior vestibular nerve and cepahalad to the cochlear nerve. As the nerve leaves the internal acoustic meatus, it separates from the statoacoustic nerves and passes cephalad to the transverse crest and anterior to a vertical crest of bone known to surgeons as "Bill's bar". In the region of Bill's bar the nerve leaves the longitudinal axis of the temporal bone and curves anteriorly around the basal turn of the cochlea between the basal turn and the vestibule in its labyrinthine segment. The nerve expands at the geniculate ganglion and then proceeds in a posterior direction. At the acute right-angle bend (external genu) the greater petrosal nerve leaves the facial nerve at the anterior edge of the geniculate ganglion and proceeds anteriorly through the hiatus of the facial canal. At the hiatus the facial nerve proceeds posteriorly and enters the tympanic cavity, where it runs transverse to the lognitudinal axis of the temporal bone in the horizontal or tympanic segment. This segment extends from the geniculate ganglion to a point just anterior and caudal to the lateral semicircular canal. The cochleariform process overlaps the beginning of the tympanic segment of the nerve. For most of its length, the horizontal segment of the fallopian canal defines the superior boundary of the entrance to the oval window niche.

As it curves around the oval window niche, the nerve begins its vertical segment anterior and inferior to the lateral semicircular canal. In the region of the oval window niche, the facial nerve lies within the medial wall of the tympanic cavity, where the bone of the facial canal is very thin. The nerve may be in direct contact with the mucosa of the tympanic cavity by dehiscences in the facial canal in 50% to 60% of normal petrous bones. As the nerve begins its vertical segment, it passes lateral to the tympanic sinus, which extends a variable distance medial to the nerve.

As the facial nerve enters its vertical portion, it is medial to the short process of the incus and lateral to the stapedius muscle. Inferior to the short process of the incus, the facial sinus cells are delineated superiorly by the incudal fossa, medially by the facial canal, and laterally by the chorda tympani nerve. The facial recess within the posterior wall of the tympanic cavity also may be called the suprapyramial process because of its relationship to the pyramidal eminence.

A complex relationship exists within the vertical segment of the facial canal between the nerve and its perineural investments, the stapedius muscle and nerve, and the tympanic vascular plexus. The stapedius muscle is medial to the facial nerve in its vertical course, where it may or may not occupy compartments separate from the facial canal. The nerve to the stapedius muscle branches from the adjacent facial nerve, where it is juxtaposed to the muscle. In addition to the stapedius muscle, the facial canal also is occupied partly by a circumneural investment of vessels and connective tissue, which may occupy more than 50% of the bony canal.

In addition to the vascular plexus, two other connective tissue investments make up the circumneural sheath. Within the facial canal, just peripheral to the vascular plexus, is the periosteum. The periosteal leayer is less well developed than a second connective tissue investment, the epineurium, which lies deep to the vascular plexus and is the chief component of the perineural sheath (Fig. 139-13, A). No well-defined perineurium exists. Individual connective tissue fibers course through the nerve fibers and make up the endoneurium (Fig. 139-13, B). The facial nerve sheath therefore consists of three layers: the periosteum, the vascular plexus, and the epineurium.