Zilong Yu
*Editor*

# Ear Diseases and CT

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# Preface

Inflammation, trauma, tumors, and congenital malformation of the ear are common diseases that frequently occur in Otolaryngology and Head & Neck Surgery, and they are also long-term questions that otologists have to resolve. The ear mainly consists of the temporal bone, which not only houses the end organs of hearing and equilibrium, the smallest isolated bone (ossicle) and articulation in the human body, but also these organ are deeply embedded in the temporal bone, making it challenging to directly observe the condition of diseases and their relationships with the surrounding structures. Numerous cranial nerves, especially the facial nerve, and large blood vessels run through the temporal bone or surround it, making the temporal bone one of the most complex bones in the human body. A detailed study of the clinical anatomy and pathological radiology of the temporal bone will provide important information for the diagnosis of ear disease, the planning of surgical strategies, and the judgment of prognosis.

High-resolution computed tomography (HRCT) offers superior spatial resolution and contrast between bone, soft tissue, and air. It can precisely demonstrate the normal structure, anatomic variations, and pathological conditions of the temporal bone. Different directional scans (such as axial, coronal, and sagittal) have their distinguishing features and advantages for displaying specific structures in the temporal bone. Multi-direction observations and comprehensive analysis will be beneficial for fully recognizing diseases and making correct conclusions. Certainly, HRCT scanning has its drawbacks in displaying soft tissue diseases (including the tumor), otogenic intracranial complications, cerebrospinal fluid ear leakage, and others. In order to mitigate this disadvantage, other examination modalities, such as magnetic resonance imaging, were also used to diagnose related diseases, aiming to improve the practicality of this book. For instructions on how to operate these modalities, please refer to the related studies.

In order to easily understand the content of this book easily and enhance the ability to read radiographic images, a progressive approach, from easy to difficult, is adopted. First, we present the clinical anatomy of the temporal bone from multiple directions, highlighting important surgical structures and providing detailed explanations. Then, we compare the sectional anatomy of the temporal bone with its corresponding CT image in axial, coronal, and sagittal views, respectively. This self-contrast can help us recognize and remember the CT images easily. Finally, we showcase typical pathological radiologic images of ear diseases from the aforementioned viewing positions, and in some cases, intraoperative findings are used to identify those conditions with their corresponding images, aiming to verify them mutually. This approach is designed to enable a comprehensive understanding of the pathological radiologic imaging of the temporal bone and assist in making correct diagnoses and surgical treatment decisions for ear diseases.

We would like to express our thanks to our colleagues in the Department of Otolaryngology and Head & Neck Surgery, as well as the Department of Radiology at Beijing Tongren Hospital and Beijing Institute of Otolaryngology for their support. We also thank People's Medical Publishing House for publishing *Ear Disease and CT* in Chinese.

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Zilong Yu

## Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this book.

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# Clinical Anatomy of Ear

1

Zilong Yu

The ear is a peripheral organ for hearing and equilibrium, it consists of the external ear, middle ear, and inner ear. The bony portion of the external auditory canal, middle ear, inner ear, and internal acoustic meatus is located in the temporal bone.

## 1.1 Clinical Anatomy of Temporal Bone

The temporal bone is a compound bone, consists of the squamous, tympanic, mastoid, petrous, and styloid portion. It is located at the both sides of the head, inlays among the sphenoid bone, parietal bone, and occipital bone, and composes a part of the lateral skull base. Numerous cranial nerves, internal carotid artery, and internal jugular vein run through or pass by the temporal bone, the end organs of the hearing and equilibrium is embedded in it, so the temporal bone is one of the most complex bones in human body, and it has important clinical significance to understand the anatomy and the relationship with the adjacent structures of the temporal bone.

### 1.1.1 Squamous Portion of Temporal Bone

The squamous (scalelike) portion is located at the anterior-superior part of the temporal bone, and forms the outer wall of the middle cranial fossa, the roof of the external auditory canal (EAC), and contributes to the glenoid fossa of the temporomandibular joint. The lateral surface of this portion is smooth with slightly bulging, and the temporal muscle attaches on it. A curved bony ridge runs from the root of zygomatic arch to the top notch over the posterior-superior area of external auditory porus, is called temporal line, which can be regarded as a reference extracranial landmark of the middle cranial fossa base, the inferior edge of the temporal muscle attaches here.

The inner aspect of the squamous portion presents slight depressions for the convolutions of the temporal lobe of the brain, and a vertical groove for the middle meninge artery. The squamous portion is connected with the petrous portion by the petrosquamous fissure (Fig. 1.1).

### 1.1.2 Tympanic Portion of Temporal Bone

The tympanic portion is a flat-curved shape bone plate, is located under the squamous portion, in front of the mastoid portion, at the lateral aspect of the petrous apex. This portion composes the bony anterior wall, base wall, and a part of the posterior wall of the external auditory canal (Figs. 1.1 and 1.2). The tympanic portion is connected with the squamous portion by the tympanosquamous fissure in front of it. The anterosuperior ridge is located at the anterosuperior aspect of the external auditory canal. Sometimes this ridge needs to be removed because it overlays the field of vision during myringoplasty. The tympanic portion is also connected with the mastoid portion by tympanomastoid fissure posteriorly, the medial aspect of this fissure, it adjoins the mastoid (vertical) segment of the facial nerve.

At the medial aspect of the tympanic portion, it is connected with the petrous portion by the petrotympanic fissure, and composes the lateral-inferior bony wall of the eustachian tube. The anteroinferior part of the tympanic portion constitutes the posterior wall of the mandibular fossa. The posterosuperior part of the tympanic portion is absent, called Rivinus notch, where no fibro-annulus exists, but the pars flaccida of tympanic membrane attaches here. At the medial end of the tympanic portion, there is a small and shallow groove, called tympanic sulcus, the fibro-annulus at the edge of tympanic membrane fits in it. If the tympanic portion is not fully developed, the congenital stenosis of the external auditory canal will take place, and if this portion is not development at all, the atresia of the external auditory canal will occur.

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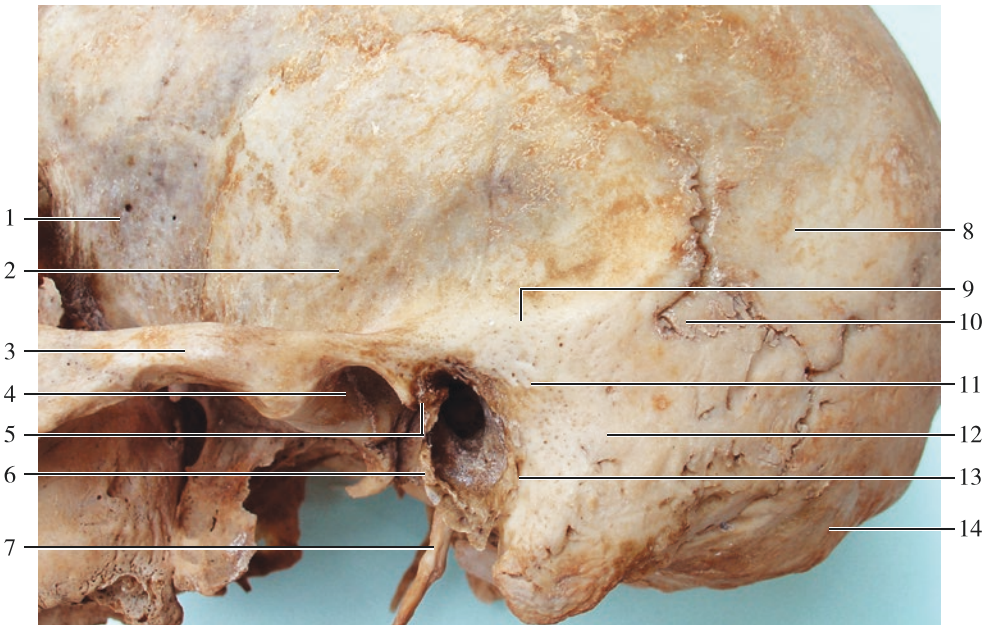


**Fig. 1.1** Lateral view of temporal bone and its adjacent structures (left). (1) Sphenoid bone. (2) Squamous portion of temporal bone. (3) Zygomatic process of temporal bone. (4) Mandibular fossa. (5) Tympanosquamous fissure. (6) Tympanic portion of temporal bone. (7) Styloid process. (8) Parietal bone. (9) Temporal line. (10) Top notch. (11) Cribriform area. (12) Mastoid process. (13) Tympanomastoid fissure. (14) Occipital bone

### 1.1.3 Mastoid Portion of Temporal Bone

The mastoid portion is located under the squamous portion, looks like a pyramid process, the so-called mastoid process. It is connected with the petrous apex medially, and forms the tympanomastoid fissure anteriorly. The lateral surface of the mastoid portion is rough, at the anterosuperior aspect of this portion, that means the posterosuperior region of the external auditory canal has a bony ridge, called the suprameatal spine. At the posterosuperior region of this spine and below the temporal line, there is an area rich in small pores which calls the cribriform area, an important surface landmark of the tympanic antrum during the tympanomastoid surgery. The sternocleidomastoid muscle is attached to the lower part of the mastoid process, and there is always a mastoid foramen penetrating inside and outside the mastoid bone near the posterior edge, which is called mastoid conducting vessel (emissarium mastoideum). This vessel connects the extracranial vein with the sigmoid sinus through this foramen. Sigmoid sinus thrombophlebitis can affect the postauricular tissue through this foramen, and can result in the postauricular subperiosteal abscess. At the medial side of the mastoid tip, there is a deep groove, named the mastoid notch, or called digastric groove, digastric muscles attach here. When air cells in the tip of the mastoid develop very well, the medial wall of it will become very thin, the cholesteatoma in the mastoid cavity can destroy the wall, the pus accumulated in the mastoid can burst into this notch, and forms the abscess between the sternocleidomastoid muscle and the deep cervical fascia, named Bezold abscess. The stylomastoid foramen is located in front of the digastric groove and at the posterolateral side of the styloid process, this is the cranial exit of the facial nerve. The shallow groove on the medial side of the notch and accompanying it is called the occipital artery groove (Fig. 1.2), the occipital artery passes through here. When the mastoid process is well pneumatized, a corresponding arc-shaped bone ridge, called the digastric crest, can be seen on the inter-surface of the mastoid cavity of the digastric groove. The intersection of the ridge and the posterior wall of the external auditory canal and the line between the incudal fossa can be used as one of the landmarks of the vertical segment of the facial nerve when the bone of the posterior wall of the external auditory canal is removed. The deep part of this line is the vertical segment of the facial nerve, and the inner side of the front end of the ridge is the stylomastoid foramen. At the junction of the medial-posterior aspect of the mastoid process and the lateral-posterior aspect of the petrous portion, there is a deep zigzag groove called sigmoid sulcus. When the mastoid air cell is poorly developed, the bone plate of the sigmoid sinus is solid, and the distance from the posterior wall of the external auditory canal is short, or very close, there is only a thin layer of bone plate, which is called the anterior displacement of the sigmoid sinus; When the sigmoid sinus is very close to the lateral bone cortex of the mastoid process, it is called the lateral displacement of sigmoid sinus. In this case, the sigmoid sinus can be damaged and cause serious bleeding when mastoid surgery is performed via the retroauricular approach, which can hinder the operation, or air embolism may occur, endangering life. When the mastoid process is well pneumatized, partial bone absence of the anterior wall of the sigmoid sulus may occasionally occur. Some patients may have pulsatile tinnitus on the ipsilateral ear. Gently pressing the carotid artery at the same mandibular angle, the tinnitus can become weaker or temporarily disappear. The tegmen of the

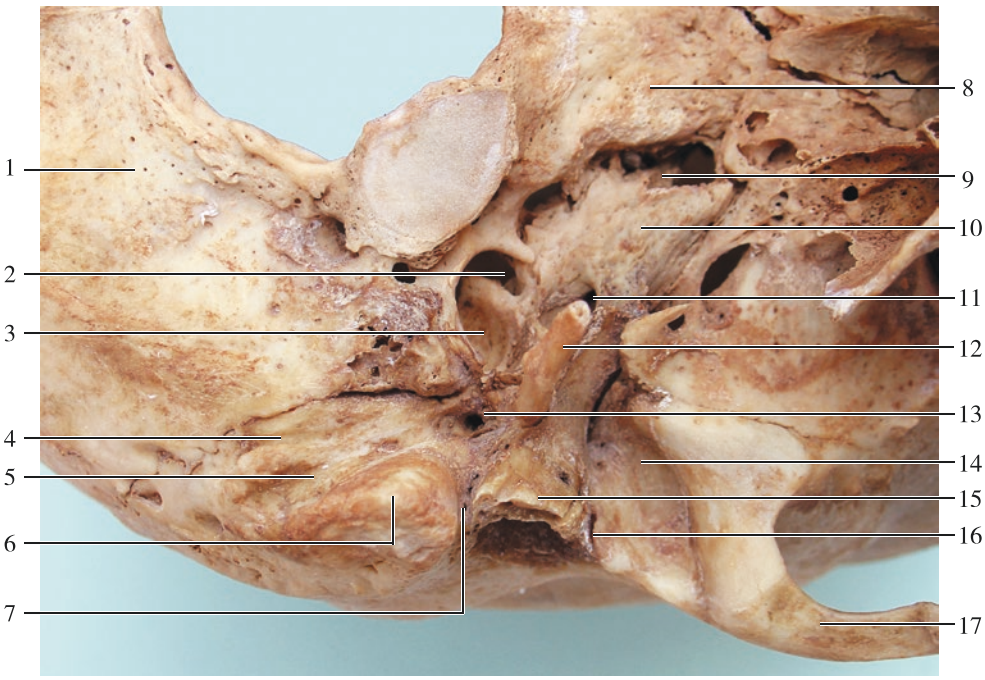


**Fig. 1.2** Skull base view of temporal bone and its adjacent structures (left). (1) Occipital bone. (2) Nerve part of jugular foramen. (3) Vascular part of jugular foramen. (4) Occipital artery groove. (5) Digastric muscle groove. (6) Mastoid tip. (7) Tympanomastoid fissure. (8) Clivus. (9) Internal orifice of carotid artery canal and foramen lacerum. (10) Petrous apex. (11) External orifice of carotid artery canal. (12) Styloid process. (13) Stylomastoid foramen. (14) Mandibular fossa. (15) Tympanic portion of temporal bone. (16) Tympanosquamous fissure. (17) Zygomatic process of temporal bone

tympanic antrum and the bone plate of the sigmoid sinus meet to form a sinodural angle. During mastoid surgery, the tympanic antrum can be found forward along this angle.

In the development of temporal bone, if the squamous portion extends too far to the mastoid process, the mastoid air cells can be divided by a bony plate into two parts, the inner and outer parts, this bony plate is called Korner septum. This septum can be dense, and often meets it when opening part of the mastoid air cells. If it is not noticed, it is often mistaken for having reached the inner wall of the mastoid process so that the deep condition cannot be completely cleared.

The mastoid process of infants under 2 years of age is only rudimentary, and there is no mastoid process as a barrier at the stylomastoid foramen. When the infants under this age suffer from postauricular subperiosteal abscess, do not rashly use the adult postauricular incision (that means the vertical downward incision) to perform the operation, so as to avoid damaging the facial nerve.

### 1.1.4 Petrous Portion of Temporal Bone

The petrous portion is similar to a recumbent triangular pyramid, also known as petrous pyramid. It is located at the base of the lateral skull, embedded between the great wing of the sphenoid bone and the base of the occipital bone, and houses the hearing and balance organs. There are one bottom, one tip, three faces, and three edges. The bottom faces outward and merges with the squamous and mastoid portion; The tip is rough and slightly upward, and the internal orifice of the carotid artery canal is here, and forms the posterior outside of the foramen lacerum. The three faces of the petrous portion are descripted as follows:

**Anterior surface:** It composes the rear part of the middle cranial fossa, which is connected with the intracranial surface of the squamous portion through the petrosquamous fissure. From the inside out, there are the following important structures: the trigeminal semilunar ganglion impression near the petrous apex; two small grooves parallel to the long axis of the petrous portion at the posterolateral side of the impression. The medial groove is the greater petrosal nerve groove, and the lateral groove is the lesser petrosal nerve. The posterolateral end of the greater petrosal nerve groove is a hiatus of the facial nerve canal, through which the greater petrosal nerve penetrates. There is a large bulge on the outside of the impression, the arcuate eminence, below which the anterior semicircular canal is located. In recent years, anterior semicircular canal dehiscence syndrome has become one of the research hotspots in otology, and HRCT scan can show the location and length of the fissure. In front of the arcuate eminence, there is a shallow concave thin bone plate, which are anterior tympanic tegmen and posterior tympanic antrum tegmen, they separate the tympanic cavity and tympanic sinus from the middle cranial fossa (Fig. 1.3).

**Posterior surface:** It is also the anterior to the posterior cranial fossa, which is a triangular bone surface surrounded by the superior petrosal sinus, inferior petrosal sinus, and sigmoid sinus (Fig. 1.4). The medial part of this face is the internal acoustic porus, which leads to the internal acoustic meatus. There is a fissure located at the lateral-posterior aspect of the internal acoustic porus, covered by a thin bone


**Fig. 1.3** Anterior view of petrous part of temporal bone (left). (1) Arcuate eminence. (2) Tympanic tegmen. (3) Trigeminal semilunar ganglion impression. (4) Superficial petrosal nerve groove. (5) Internal orifice of carotid artery canal. (6) Tegmen of tympanic antrum. (7) Petrosquamous fissure. (8) Squamous portion of temporal bone

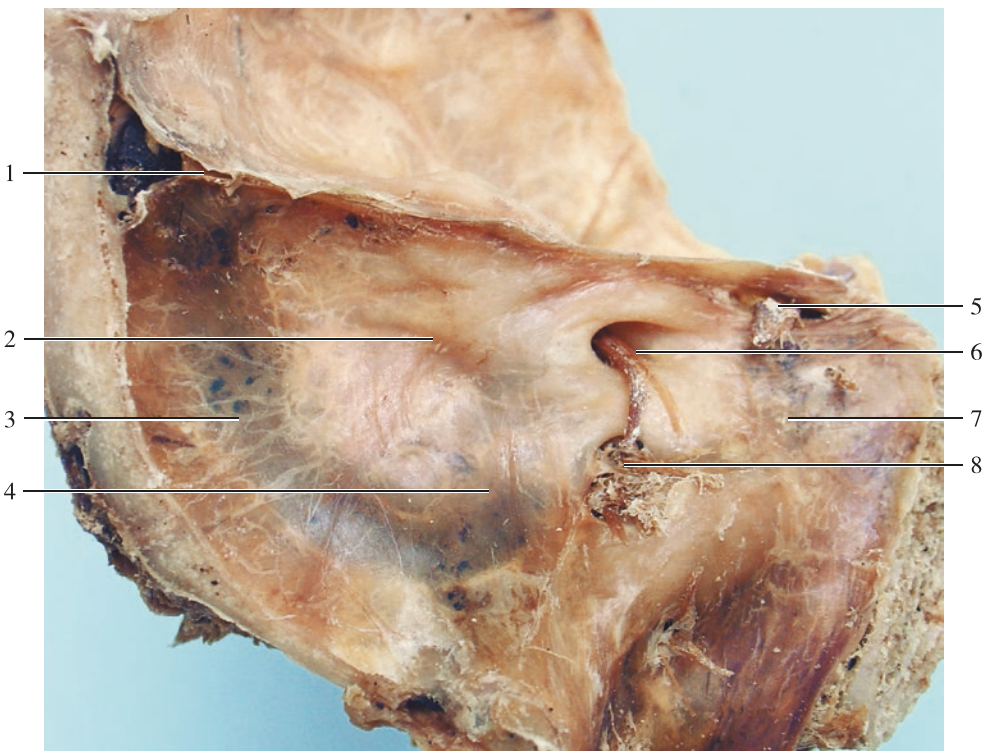


**Fig. 1.4** Posterior view of petrous part of temporal bone (left, dura mater reserved). (1) Superior petrosal sinus. (2) Endolymphatic sac fissure. (3) Sigmoid sinus. (4) Vascular part of jugular foramen. (5) Trigeminal nerve semilunar impression. (6) Internal acoustic porus and vestibulocochlear nerve. (7) Inferior petrosal sinus. (8) Nerve part of jugular foramen

plate called the endolymphatic sac fissure (Fig. 1.5), which is the outer opening of the vestibular aqueduct. The latter leads to the vestibule of the bony labyrinth through the medial side of the common crus formed by the posterior and anterior semicircular canals, through which the endolymphatic duct passes. The upper part between the internal acoustic porus.

and the endolymphatic sac and near the upper edge of the petrous portion is the subarcuate fossa. Subarcuate artery and vein pass through the petromastoid duct and enter tympanic antrum under the anterior semicircular canal arch and above the lateral(horizontal)semicircular canal, and they are the only blood vessels that communicate the posterior cranial fossa and the tympanic antrum. They provide vascular supply to the otic capsule of the vestibule, semicircular canals, the mastoid antrum, and portions of the facial nerve canal (Akyol et al. 2011). The petromastoid canal is rarely of clinical importance other than serving as an anatomic landmark. Still, radiologists should be wary of confusing it for a fracture or other pathology (Benson and Lane 2022).

**Inferior surface:** It composes a part of the lateral skull base with uneven surface. The bone surface of the anterior medial part is rough, which is the attachment of the petrostaphylinus (levator veli palati muscle), tensor tympani muscle, and the cartilage of the eustachian tube. The posterior lateral part has two deep concaves adjacent to the anterior medial and the posterior lateral part. The anterior medial part is the external orifice of the carotid artery canal, through which the internal carotid artery and the carotid artery nerve plexus pass. The carotid artery canal first rises vertically along the anterior wall of the tympanic cavity, and then bends forward and runs horizontally in front of the cochlea, opening at the internal orifice of the carotid artery canal at the petrous apex. The posterior and outer part of the external carotid artery orifice is the jugular fossa, which is the top of the Glomus jugular (Figs. 1.2 and 1.6). The jugular foramen is the place where the internal jugular vein exits, it is composed of the jugular notch of the occipital bone and the petrous portion of the temporal bone and it is divided into the posterior external vascular area (Glomus jugular) and the anteromedial nerve area (glossopharyngeal nerve, vagus nerve, accessory nerve). The tumor in the jugular foramen area can cause the expansion of the foramen area and bone destruction. On the thin bone ridge between the external opening of the carotid artery canal and the jugular fossa, there is the inferior opening of the tympanic canaliculus, and the tympanic branch of the glossopharyngeal nerve-the Jacobson nerve, passes through. There is a triangular impression on the anteromedial side of the jugular fossa and close to the jugular interphysis (arteriovenous ridge), which is the location of the petroganglion of the glossopharyngeal nerve. There is a small hole at the bottom of the concave, which is the external aperture of the cochlear canaliculus. The cochlear canaliculus leads outward to the beginning of the scala tympani of the modiolus, containing the perilymph.

**Three margins of petrous portion:** The upper margin of the petrous part is the longest, with a superior petrosal groove containing the superior petrosal sinus; At the medial part of the inferior margin of the petrous portion, there is a

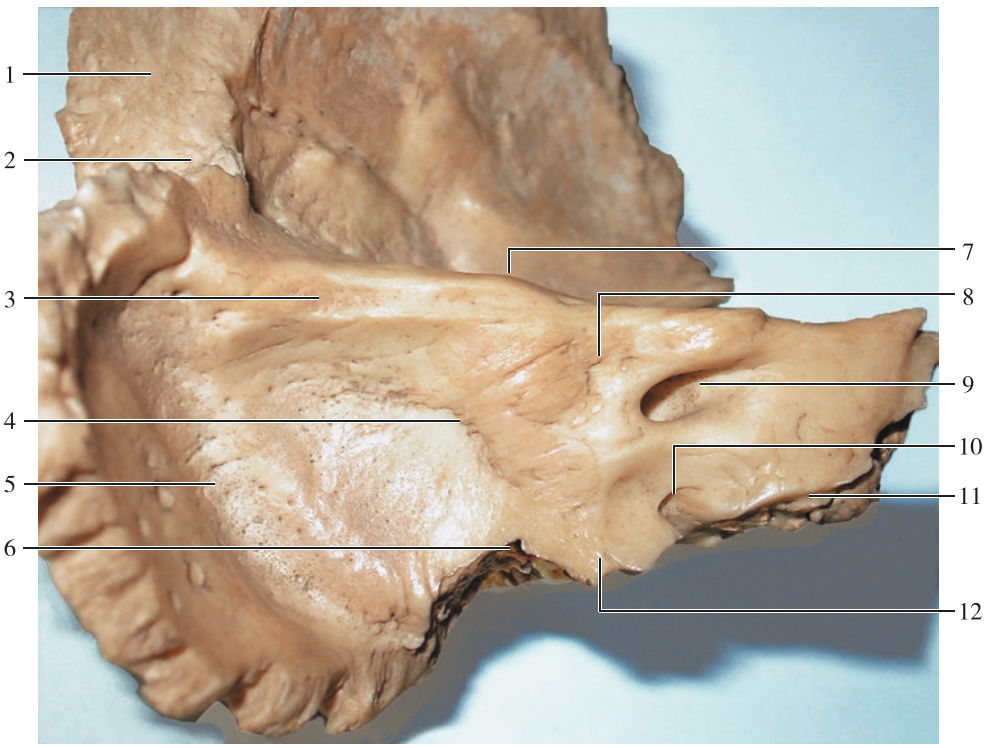


**Fig. 1.5** Posterior view of petrous part of temporal bone (left). (1) Squamous portion of temporal bone. (2) Top notch. (3) Superior petrosal groove. (4) Fissure of endolymphatic sac. (5) Sigmoid sulus. (6) Vascular part of jugular foramen. (7) Arcuate eminence. (8) Subarcuate fossa (outer opening of petrolacteal canal). (9) Internal acoustic porus. (10) Nerve part of jugular foramen and external opening of cochlear canaliculus. (11) Inferior petrosal sinus. (12) Jugular interphysis

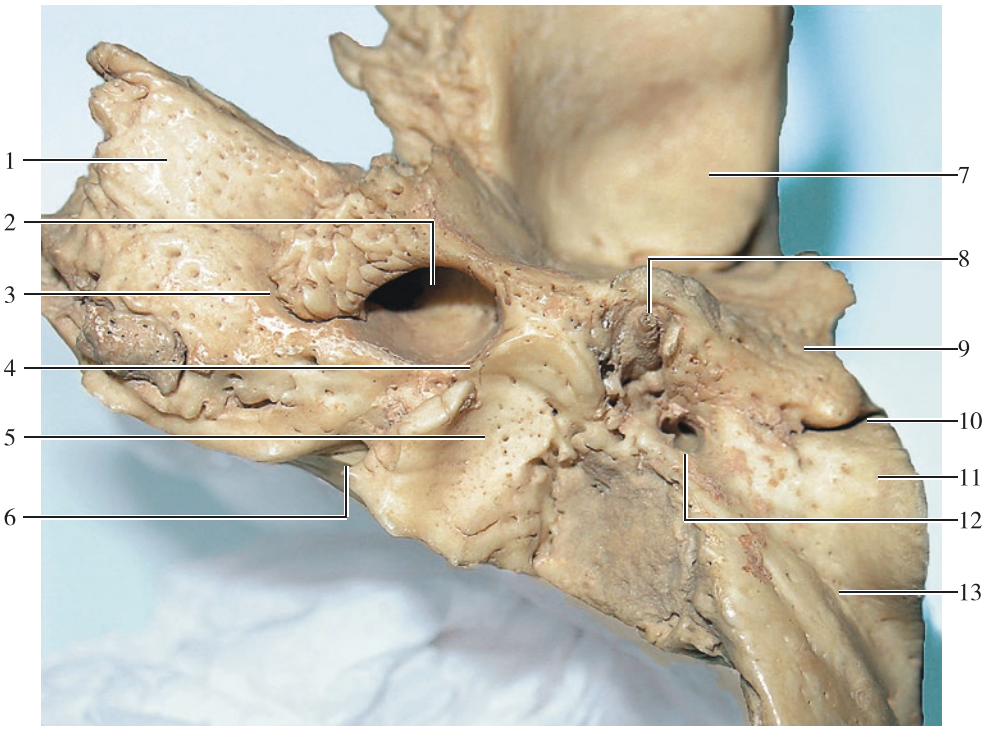


**Fig. 1.6** Inferior view of petrous portion of temporal bone (left). (1) Attachment part of levator veli palatine muscle. (2) External orifice of carotid artery canal. (3) Petrotympanic fissure. (4) Arteriovenous ridge. (5) Jugular fossa. (6) Nerve area of jugular foramen (external opening of cochlear canaliculus). (7) Mandibular fossa. (8) Styloid process. (9) Tympanic portion of temporal bone. (10) Tympanomastoid fissure. (11) Mastoid process. (12) Stylomastoid foramen. (13) Digastric groove


**Fig. 1.7** Petrous apex view of petrous portion of temporal bone (right). (1) Semicanal of tensor tympani muscle. (2) Eustachian tube. (3) Arcuate eminence. (4) Hiatus of facial nerve. (5) Internal opening of carotid artery canal

petrosal groove containing the inferior petrosal sinus; its lateral end is located nearby the jugular foramen. The inner part of the front edge of the petrous portion is connected with the great wing of the sphenoid bone to form the petrosphenoidal fissure. The outer part and the corresponding parts of the squamous and tympanic portion form the petrosquamous fissure and the petrotympanic fissure, respectively. Between the petrous portion and the squamous portion, there are two bony canals parallel up and down that enter the tympanic cavity. The upper part is the semicanal of the tensor tympanic muscle, and the lower part is the eustachian tube (Fig. 1.7).

**Internal acoustic meatus:** Internal acoustic meatus is located in the petrous portion of the temporal bone, it is a

bony canal containing the facial nerve, the vestibular nerve, the cochlear nerve, and the labyrinthine artery and vein. The internal acoustic porus in the medial part of the back of the petrous part is oblate, the rear edge is sharp and protruding, and the front edge is flat without obvious edge. The average length of the internal acoustic meatus is about 10 mm, and its lateral end is closed by a vertical osseous plate with a cribriform hole. This plate is the fundus of internal acoustic meatus, which constitutes the majority of the inner wall of the vestibule and the cochlea, and this fundus is divided into two areas with different sizes by a transverse crest (Fig. 1.8). The superior area is small and is divided into two parts by a vertical crest (Bill's bar), which is usually located on the lateral side of the transverse crest; Therefore, the fundus is divided into four quadrants: anterosuperior, posterosuperior, anteroinferior, and posteroinferior quadrant. The anterosuperior quadrant is a small hole, called the facial nerve area, that is, the entrance of the facial nerve canal, which is the narrowest part of the facial nerve bone canal in the temporal bone; From then on, the facial nerve enters the bone canal (fallopian canal) as a labyrinthine segment and reaches the geniculate ganglion forward and outward; the posterosuperior quadrant, called the superior vestibular area, has a larger hole that pass through the upper terminal branch of the vestibular nerve. The anteroinferior quadrant is the cochlear area, a relatively large area compared with the others, numerous small spiralis foraminosus arrange in this quadrant, it is the place where the cochlear nerve fibers pass through. The length of the cochlear nerve canal is about 1–2 mm. It moves forward and outward, as a result, when observing from the internal acoustic porus, the cochlear area cannot be seen completely due to the obstruction of the anterior wall of the internal acoustic meatus. The vestibular end of the basal turn of the cochlea is close to the inferior vestibular area (Fig. 1.9), therefore, the cochlear nerve foramen and the fine holes (cribriform) of the cochlear nerve fibers around the basal turn of the cochlea occupy most of the area below the transverse crest; behind the cochlear quadrant is the inferior vestibular area in posteroinferior quadrant, with several small holes, which are passed by the inferior terminal branch of the vestibular nerve that innervates the saccule. There is a singular foramen in the posterior part of the inferior vestibular quadrant and the posterior inferior wall of the internal acoustic meatus, through which the posterior ampullary nerve (also called the singular foramen nerve) passes, which is the terminal branch of the inferior vestibular nerve. The singular canal is rarely of radiologic interest, though it does serve as a landmark during some procedures (Agirdir et al. 2001). Sometimes a small foramen can be seen at the posterior part of the transverse crest, known as the transverse crest foramen, whose significance is still unclear (Kozerska and Skrzat 2015; Schart-Moren et al. 2018).

The internal acoustic meatus is the thin part of the temporal bone. Transverse fractures of the temporal bone can often penetrate the internal acoustic meatus, causing damage to the inner ear and the facial nerve.

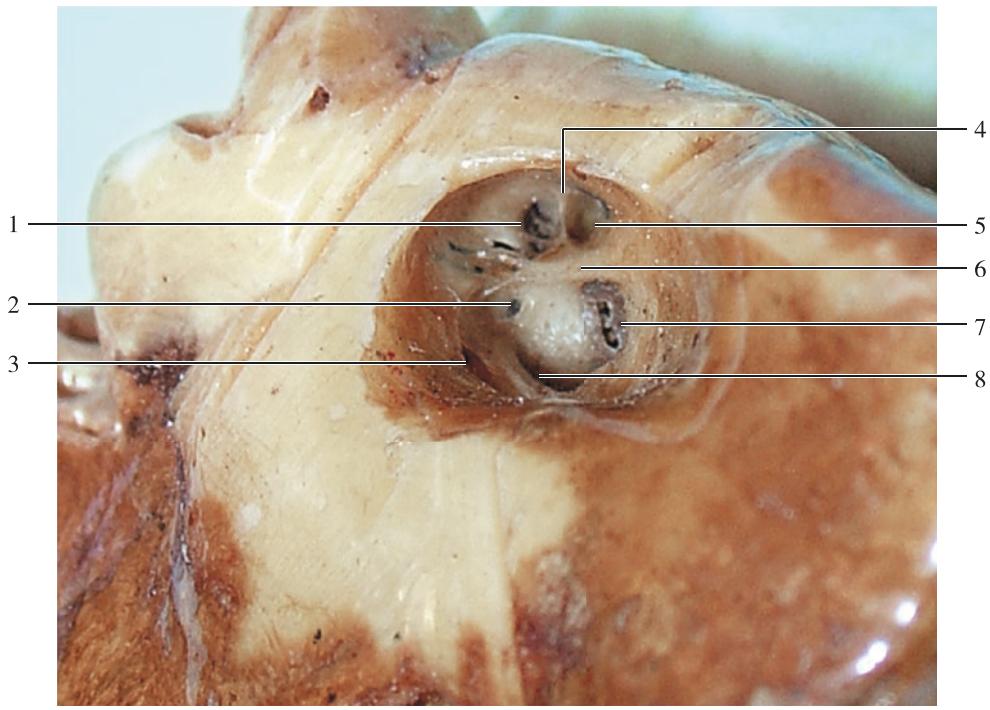


**Fig. 1.8** Fundus of internal acoustic meatus (left). (1) Superior vestibular nerve foramen area. (2) Inferior vestibular nerve foramen area. (3) Singular foramen. (4) Bill's crest. (5) Facial nerve foramen area. (6) Transverse crest. (7) Cochlear nerve foramen area. (8) Cochlear nerve fiber (vestibular end) foramen area of base turn of cochlea


**Fig. 1.9** Fundus of internal acoustic meatus (left, attaching soft tissue). (1) Superior vestibular foramen area. (2) Transverse crest foramen. (3) Inferior vestibular foramen area. (4) Singular foramen. (5) Bill's crest. (6) Facial nerve foramen area. (7) Transverse crest. (8) Cochlear nerve foramen area. (9) Cochlear nerve fiber (vestibular end) foramen area of base turn of cochlea

### 1.1.5 Styloid Process

The styloid process originates from the lower part of the tympanic portion of the temporal bone and extends forward and downward. It is a thin and long bone with average length about 25 mm; The stylopharyngeus, styloglossus, stylohyoideus, et al. attach at the distal end of the styloid process. There is a stylomastoid foramen (Fig. 1.2) between the styloid process and the mastoid process, which is the inferior opening of the facial nerve canal, that is, the cranial exit of the facial nerve.

## 1.2 Anatomy of External Ear

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

### 1.2.1 Auricle

The auricle is attached to both sides of the skull with the aid of auricle cartilage, muscles, ligaments, and skin, with an angle of 30–45° to the squamous portion of temporal bone. The auricle is mainly composed of auricle cartilage. The surface is covered with skin. The front skin is directly connected with the perichondrium, there is less subcutaneous connective tissue, which is prone to frostbite, and the subcutaneous hematoma is not easy to absorb during trauma. Auricular trauma or cartilage injury during surgery can cause perichondritis, cartilage necrosis, and easily lead to auricle deformation. The part of the lobule is composed of fat and connective tissue, without cartilage. The outer edge of the auricle is a convoluted ear ring (helix), and the antihelix is located the medial side of the helix and parallels with the helix. The fossa between the helix and the antihelix is called scaphoid fossa or scapha, the upper end of the antihelix is divided into two crura, between the two crura is a triangular fossa, and the front of the antihelix is a deep concave concha, which is the most common site of pseudocyst of the auricle. The concha is divided into the upper cymba concha and the lower cavum concha by the crus of helix (Fig. 1.10). In front of the concha cavity is the external auditory canal opening. The protrusion in front of the external auditory canal is the tragus, which contains cartilage to partially overlap the external auditory canal opening. The depression between the tragus and the crus of the helix is the incisura anterior auris (Figs. 1.11 and 1.12), where there is no cartilage, and the incision here can directly reach the bone of the external auditory canal. Auricular cartilage is continuous with that of external audi-

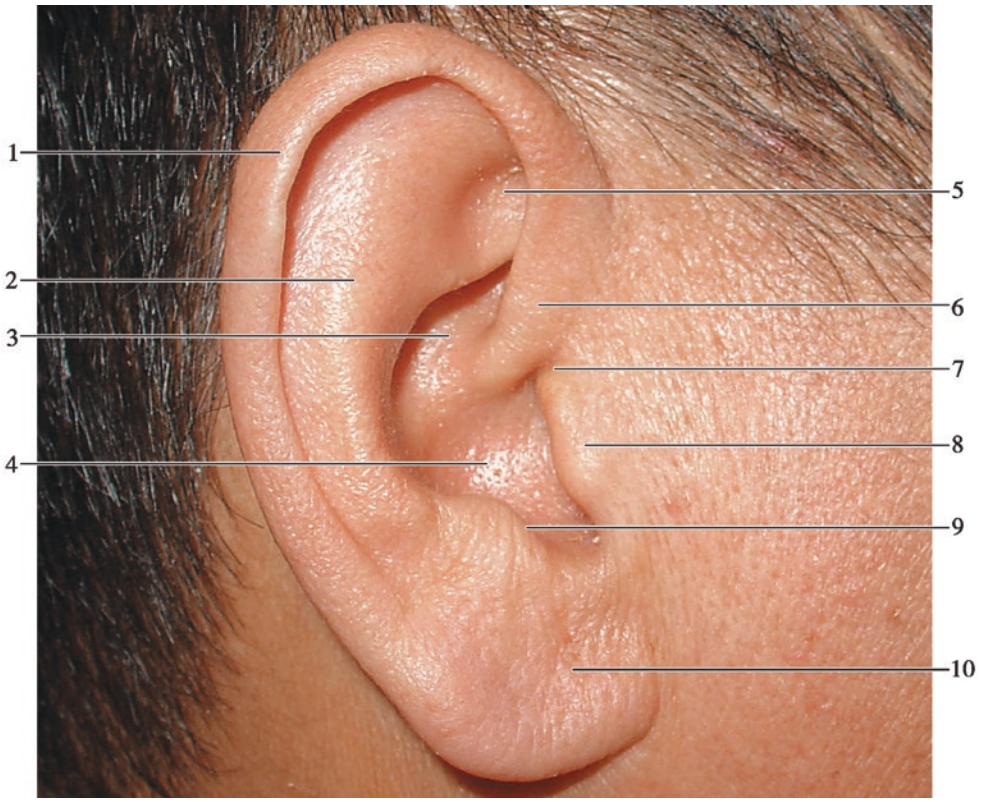


**Fig. 1.10** Surface landmark of auricle (right). (1) Helix. (2) Antihelix. (3) Cymba conchae. (4) Cavum conchae. (5) Triangular fossa. (6) Helix crus. (7) Incisura anterior auris. (8) Tragus. (9) Antitragus. (10) Lobule

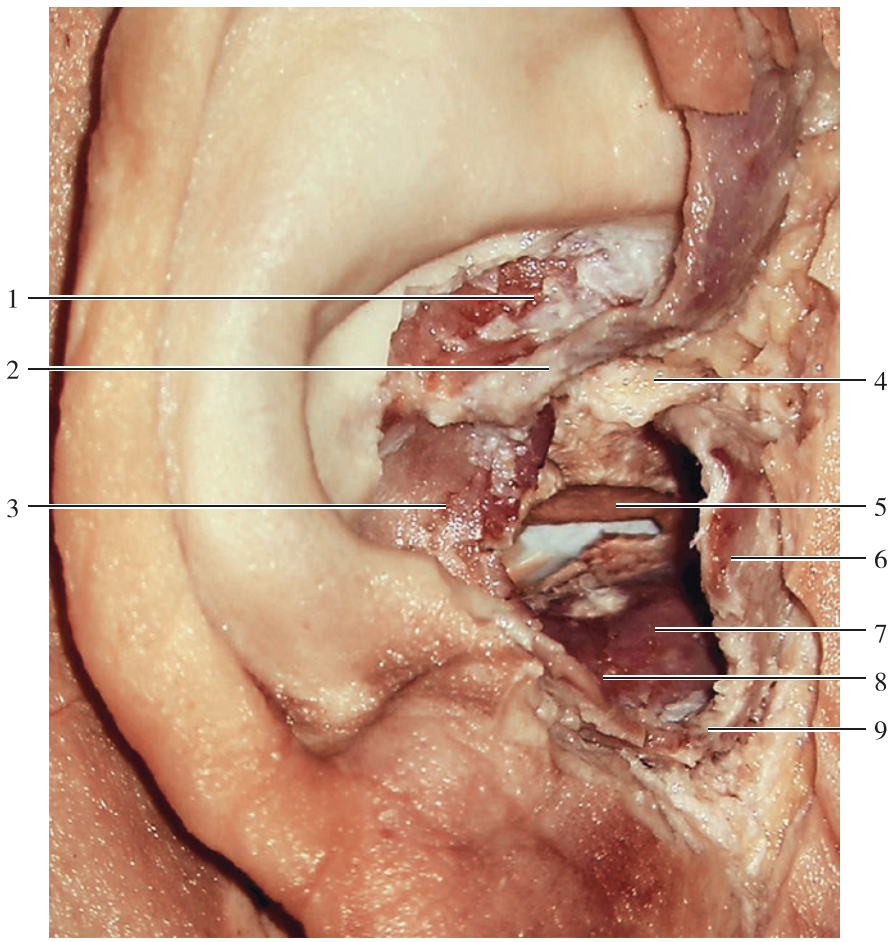


**Fig. 1.11** Anatomy of concha and external auditory canal opening (right). (1) Cymba conchae. (2) Helix crus. (3) Cavum conchae. (4) Incisura anterior auris. (5) Skin of external auditory canal. (6) Auricular cartilage. (7) External auditory canal cartilage. (8) Cartilage of antitragus. (9) Intertragic notch

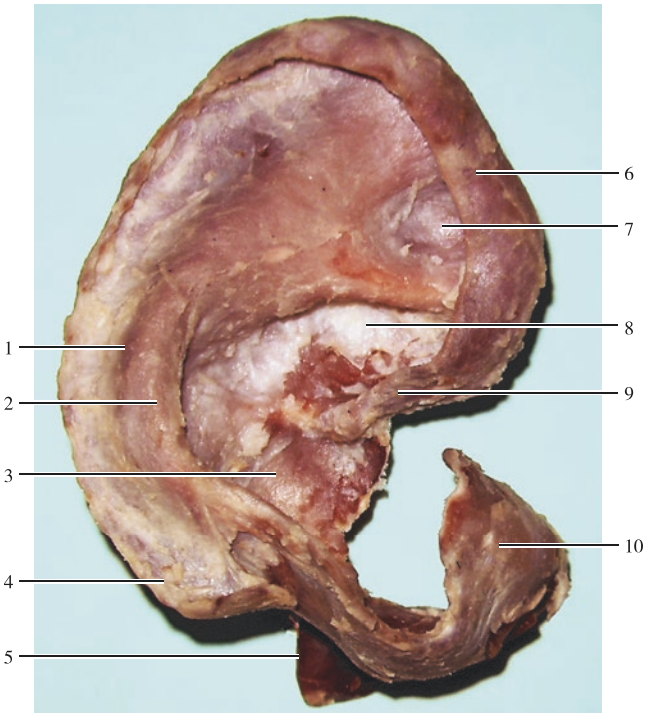


**Fig. 1.12** Anterior view of external ear cartilage (right). (1) Scaphoid fossa (2) Antihelix. (3) Concha. (4) Free edge of helix. (5) Posterior wall cartilage of external auditory canal. (6) Helix. (7) Triangular fossa. (8) Cymba conchae. (9) Helix crus. (10) Tragus

tory canal (Figs. 1.12 and 1.13). One site infection can cause the entire external ear cartilage infection.

### 1.2.2 External Auditory Canal

The external auditory canal starts from the bottom of the concha cavity and reaches the tympanic membrane inwards. It is a slightly S-shaped blind tube with a length of 2.5–3.5 cm, outer 1/3 of the external auditory canal is cartilage and the inner 2/3 is bony (Fig. 1.14). There are two constrictions in external auditory canal, one is the junction of cartilage and bone, the other is about 0.5 cm far away from the tympanic membrane, the latter is called isthmus. The skin of cartilaginous part contains cerumen glands similar to sweat glands, which can secrete cerumen, and is rich in hair follicles and sebaceous glands. It is a common site of furuncle. The bony external auditory canal is composed of the tympanic portion of temporal bone, the lower edge of the squamous portion of the temporal bone and the anterior upper part of the mastoid process. The lower position of the middle cranial fossa is common when the upper wall of the external auditory canal is poorly developed, and the cholesteatoma of the external auditory canal is common in the bony part of this canal.

**Fig. 1.13** Posterior view of external ear cartilage (right). (1) Triangular fossa. (2) Concha. (3) Tragus. (4) Inferior wall cartilage of external auditory canal. (5) Posterior wall Cartilage of external auditory canal. (6) Helix

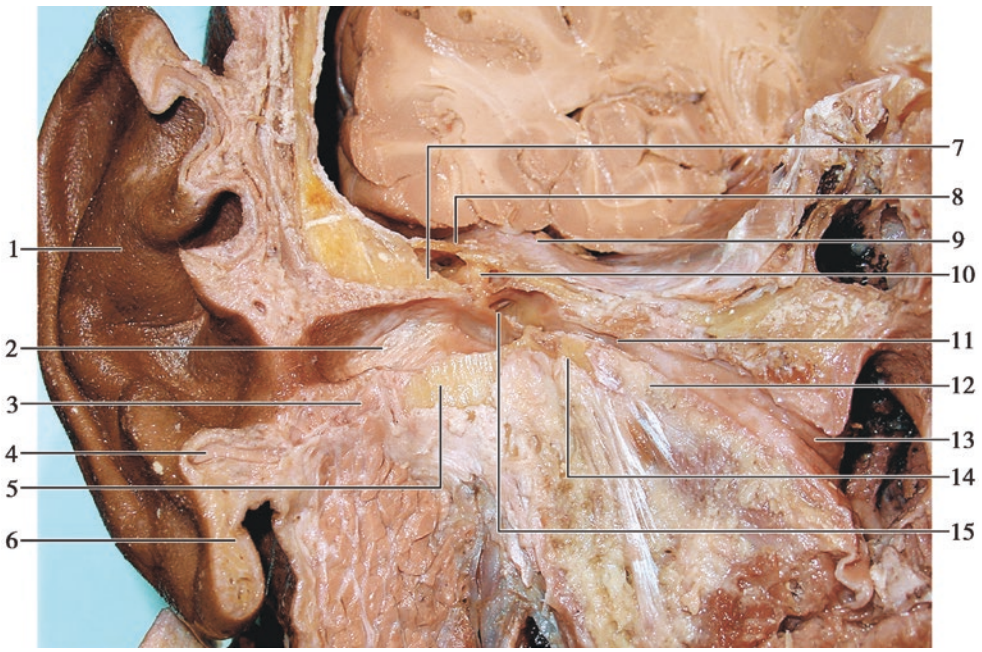


**Fig. 1.14** Anatomy of ear in coronal view (right). (1) Auricle. (2) External auditory canal. (3) Cartilaginous part of external auditory canal. (4) Concha cartilage. (5) Bony part of external auditory canal. (6) Lobule. (7) Tympanic scutum. (8) Tegmen tympani. (9) Arcuate eminence. (10) Malleus. (11) Isthmus of eustachian tube. (12) Cartilaginous part of eustachian tube. (13) Pharyngeal orifice of eustachian tube. (14) Bony part of eustachian tube. (15) Tympanic membrane

## 1.3 Anatomy of Middle Ear

The middle ear consists of four parts: tympanic cavity, eustachian tube, tympanic antrum, and mastoid process (Figs. 1.14 and 1.15).

### 1.3.1 Tympanic Cavity

The tympanic cavity (or tympanum) is an **air-containing** space lined with the mucosa, most of which is located between the tympanic membrane and the lateral wall of the inner ear. It is connected with the downward and medial nasopharynx through the eustachian tube anteriorly (Fig. 1.14), and the tympanic cavity is also connected with the tympanic antrum and the mastoid cavity through the entrance of the tympanic antrum (aditus ad antrum) (Fig. 1.15). The tympanic cavity can be divided into three parts according to the upper and lower margins of the pars tensa of the tympanic membrane: (1) The epitympanum, or the attic, is the tympanic cavity located above the level of the upper margin of the pars tensa; (2) The mesotympanum is located between the upper and lower edge level of pars tensa, that means the tympanic cavity is located between the pars tensa of tympanic membrane and the inner wall of the tympanic cavity; (3) Hypotympanum, a small part of the middle ear, lies below the level of the lower margin of the pars tensa of the tympanic membrane, reaches the tympanic floor. The upper and lower length of the tympanic cavity is about 15 mm, and the anterior and posterior length is about 13 mm; The inner and outer length is about 6 mm in the epitympanum and about 4 mm in the hypotympanum. The distance between the mesotympanum and the promontory is the shortest, only about 2 mm. There are ossicles, nerves, muscles and ligaments in the tympanic cavity.

#### 1.3.1.1 Six Walls of Tympanic Cavity

The tympanic cavity is like a roughly oblong space with six walls: lateral, medial, anterior, posterior, top, and bottom wall.

**Lateral wall** is composed of bone and membrane. The bony part is small, which is the lateral wall of the attic above the tympanic membrane, also known as the tympanic scutum (Fig. 1.14). The bony part is composed of the squamous portion of the temporal bone and the medial part of the tympanic portion. The obtuse or disappearance of the tympanic scutum is one of the characteristic changes of the epitympanic cholesteatoma on the CT image of the temporal bone. The membrane part is large, that is tympanic membrane. The tympanic membrane is between the tympanic cavity and the external auditory canal, which is an inward concave, elliptical, and translucent membrane (Fig. 1.16); the tympanic membrane is about 9 mm high, 8 mm wide, and 0.1 mm thick. The front and lower part of the tympanic membrane inclines inward and forms an angle of 45–50° with the bottom of the external auditory canal. Therefore, the anterior inferior wall of the external auditory canal is longer than the posterior-superior wall. The edge of the tympanic membrane is slightly thick, most of them are embedded in the tympanic sulcus by fibrocartilage annulus, which is the pars tensa. At the tympanic notch where the upper tympanic sulcus is absent, the tympanic membrane is directly attached to the temporal bone, which is relatively loose, and is called the pars flaccida. The main signs of the tympanic membrane are the short process


**Fig. 1.15** Eustachian tube, tympanic cavity, tympanic antrum and mastoid process (left). (1) Tegmen tympani. (2) Aditus ad antrum. (3) Head of malleus. (4) Neck of malleus. (5) Manubrium. (6) Tympanic orifice of eustachian tube. (7) Promontory. (8) Tegmen tympanic sinus. (9) Tympanic antrum. (10) Body of incus. (11) Short crus of incus. (12) Long crus of incus. (13) Mastoid process. (14) Chorda tympani. (15) Cochlear window niche

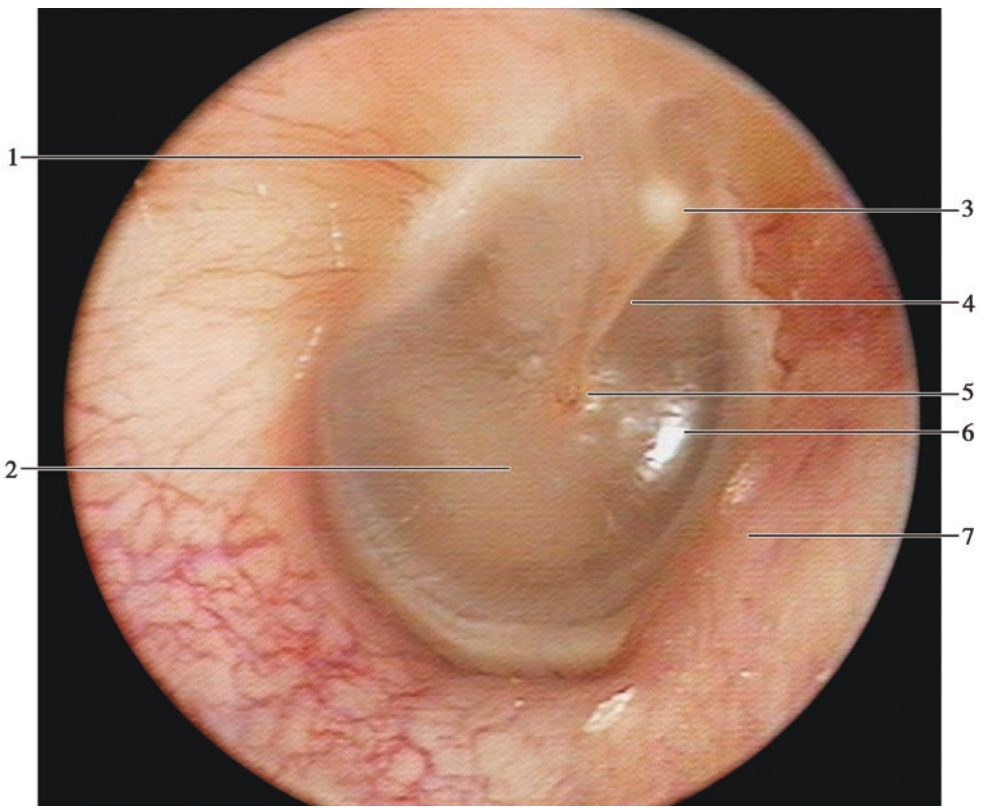


**Fig. 1.16** Surface landmark of tympanic membrane (right). (1) Pars flaccida. (2) Pars tensa. (3) Short process of malleus. (4) Manubrium. (5) Umbo. (6) Cone of light. (7) Anterior inferior wall of external auditory canal

of the malleus located at the upper front, the light cone is located at the anteroinferior part of the tympanic membrane and the malleus handle is located between the two. The structure of the tympanic membrane can be divided into three layers: the outer layer is the epithelial layer, which is a stratified squamous epithelium continuous with the skin of the external auditory canal; The middle is the fibrous layer, which contains the shallow radial fibers and the deep annular