

K. J. Lee: Essential Otolaryngology and Head and Neck Surgery (IIIrd Ed)

Preface

This book is written for the young otolaryngologist who is already acquainted with the field through recent formal residency training, as well as for other physicians who are interested in concise descriptions of otolaryngologic conditions.

It is not the intent of the authors to write a complete review of otolaryngology, much less a textbook of otolaryngology. It is a discussion of many current concepts in the field. The materials in this book came from numerous sources. The first edition was compiled from the editor's notes for his own Board Examinations, with contributions from authorities in the field. This revised third edition has been updated, as well as expanded, to make it more useful to medical students and physicians in other specialties.

It is hoped that the reader will freely refer to the list of references for more in-depth dissertations.

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Chapter 1: Anatomy of the Ear

General Information

1. The temporal bone forms part of the side and base of the skull. It constitutes two-thirds of the floor of the middle cranial fossa and one-third of the floor of the posterior fossa. There are four parts to the temporal bone:

- a. Squamosa
- b. Mastoid
- c. Petrous
- d. Tympanic.

2. The following muscles are attached to the mastoid process:

- a. Sternocleidomastoid
- b. Splenius capitis
- c. Longissimus capitis
- d. Digastric
- e. Anterior, superior, posterir, auricular.

(The temporalis muscle attaches to the squamosa portion of the temporal bone and not to the mastoid process.)

3. The auricle (Fig. 1-1) is made of elastic cartilage, the cartilaginous canal of fibrocartilage. The cartilaginous canal constitutes one-third of the external auditory canal (whereas the eustachian tube is two-thirds cartilaginous); the remaining two-third is osseous.

4. The skin over the cartilaginous canal has sebaceous glands, ceruminous glands, and hair follicles. The skin over the bony canal is tight and has not subcutaneous tissue except periosteum.

5. Boundaries of the external auditory canal

Anteriorly:	mandibular fossa parotid
Posteriorly:	mastoid
Superiorly:	(medially) epitympanic recess (laterally) cranial cavity
Inferiorly:	parotid.

The anterior portion, the floor, and part of the posterior portion of the bony canal are formed by the tympanic part of the temporal bone. The rest of the posterior canal and the roof are formed by the squamosa.

6. Boundaries of the tympanum

Medially:	lateral semicircular canal and VII nerve
Superiorly:	tegmen
Anteriorly:	zygomatic arch
Laterally:	squamosa (scutum)
Inferiorly:	fossa incudis
Posteriorly:	aditus.

7. Boundaries of the tympanic cavity

Roof:	tegmen
Floor:	jugular wall and styloid prominence
Posteriorly:	mastoid, stapedius, pyramidal prominence

Anteriorly: carotid wall, eustachian tube, tensor tympani
Medially: labyrinthine wall
Laterally: tympanic membrane, scutum (latero-superior).

8. *The auricle is attached to the head by:*

a. Skin

b. An extension of cartilage to the external auditory canal cartilage

c. Ligaments:

1) Anterior ligament (zygoma to helix and tragus)

2) Superior ligament (external auditory canal to the spine of the helix)

3) Posterior ligament (mastoid to concha)

d. Muscles

1) Anterior auricular muscle

2) Superior auricular muscle

3) Posterior auricular muscle.

9. *Notch of Rivinus* is the notch on the squamosa, medial to which lies Shrapnell's membrane. The tympanic ring is not a complete ring, giving a dehiscence superiorly.

10. *Meckel's cave* is the concavity on the superior portion of the temporal bone in which the gasserian ganglion (V) is located.

11. *Dorello's canal* is between the petrous tip and the sphenoid bone. It is the groove of the VI nerve.

(Gradenigo's syndrome is characterized by:

a. Pain behind the eye

b. Diplopia

c. Aural discharge.

It is secondary to petrositis with involvement of the VI nerve.)

12. The suprameatal triangle of *Macewen's triangle* is posterior and superior to the

external auditory canal. It is bound at the meatus by the Spine of Henle, otherwise called the *suprameatal spine*. This triangle approximates the position of the antrum medially. *Tegmen mastoidei* is the thin plate over the antrum.

13. *Trautmann's triangle* is demarcated by the bony labyrinth, the sigmoid sinus, and the superior petrosal sinus or dura.

Citelli's angle is the *sinodural angle*. It is located between the sigmoid sinus and the middle fossa dura plate. Others consider the superior side of Trautmann's triangle to be Citelli's triangle.

Solid angle is the angle formed by the three semicircular canals.

Scutum is the thin plate of bone which constitutes the lateral wall of the epitympanum. It is part of the squamosa.

Mandibular fossa is bound by the zygomatic, squamosa, and tympanic bones.

Canal of Huguier transmits the chorda tympani out of the temporal bone anteriorly. It is situated lateral to the roof of the protympanum.

Foramen of Huschke is located on the anterior tympanic plate along a nonossified portion of the plate. This is near the fissures of Santorini.

Porus acusticus is the "mouth" of the internal auditory canal. The canal is divided horizontally by the *crista falciformis*.

14. There are three parts to the inner ear (Fig. 1-2):

- a. Pars superior: vestibular labyrinth (utricle and semicircular canals)
- b. Pars inferior: cochlea and saccule
- c. Endolymphatic sac and duct.

15. There are four small outpocketings from the perilymph space:

- a. Along the endolymphatic duct
- b. Fissula ante fenestram
- c. Fossula post fenestram
- d. Periotic duct.

16. There are four openings into the temporal bone:

- a. Internal auditory canal
- b. Vestibular aqueduct
- c. Cochlear aqueduct
- d. Subarcuate fossa.

17. The ponticulum is the ridge of bone between the oval window niche and sinus tympani.

18. The subiculum is a ridge of bone between the round window niche and sinus tympani.

19. Körner's septum separates the squamosa from the petrous air cells.

20. Only one-third of the population has a pneumatized petrous portion of the temporal bone.

21. Scala communis is where the scala tympani joins the scala vestibuli. The helicotrema is at the apex of the cochlea where the two join (Fig. 1-3).

22. The petrous pyramid is the strongest bone in the body.

23. The upper limits of the internal auditory canal diameter is 8 mm.

24. The cochlear aqueduct is a bony channel connecting the scala tympani of the basal turn with the subarachnoid space of the posterior cranial cavity. The average adult cochlear aqueduct is 6.2 mm long.

Middle Ear

(Tympanic plexus = V3, IX, and X)

V3 --> Auriculotemporal nerve

IX --> Jacobson's nerve

X --> Auricular nerve.

Inner Ear

Superior vestibular nerve

--> Superior and horizontal semicircular canals

--> Utricle

--> Vestibular nerve --> Sacculle

Inferior vestibular nerve

--> Sacculle

--> Posterior semicircular canal

Blood Supply

External carotid artery

- > Posterior auricular artery --> Outer ear.
- > Superficial temporal artery --> Outer ear.

External carotid artery

- > Maxillary artery --> Anterior tympanic branch --> Middle ear.
- > Maxillary artery --> Middle meningeal artery --> Superior tympanic branch --> Middle ear.
- > Maxillary artery --> Middle meningeal artery --> Superficial petrosal branch --> Middle ear.

Internal carotid artery

- > Caroticotympanic artery --> Anastomoses with branches from stylomastoid, maxillary and ascending pharyngeal arteries.

Postauricular artery

- > Posterior tympanic --> Middle ear.
- > Stylomastoid branch --> Middle ear.

Ascending pharyngeal artery

- > Inferior tympanic branch --> Middle ear.

(The long process of the incus receives the least blood supply and hence is the most frequently necrosed.)

External carotid artery

- > Occipital artery --> Meningeal branch --> Mastoid.

Internal carotid artery

- > Subarcuate vessels --> Mastoid.

External carotid artery

- > Maxillary artery --> Deep auricular branch --> Lateral surface TM.
- > Maxillary artery --> Ant tympanic branch --> Medial surface TM.
- > Posterior auricular artery --> Stylomastoid branch --> Med surf TM.

Ant inf cerebellar artery

- > Internal auditory artery --> Common cochlear artery --> Main cochlear artery --> All of cochlea except one-third of the basal turn.
- > Internal auditory artery --> Common cochlear artery --> Main cochlear artery --> Cochlear ramus --> The one-third of the basal turn.
- > Internal auditory artery --> Common cochlear artery --> Cochlear vestibular artery --> Posterior vestibular artery --> Inferior portion of utricle and saccule and posterior semicircular canal.
- > Internal auditory artery --> Anterior vestibular artery --> Cochlear vestibular artery --> Posterior vestibular artery --> Inferior portion of utricle and saccule and posterior

semicircular canal.

--> Internal auditory artery --> Anterior vestibular artery --> Superior portion of utricle and saccule, superior and horizontal semicircular canals.

Basilar artery (occasionally)

--> Internal auditory artery --> Common cochlear artery --> Main cochlear artery --> All of cochlea except one-third of the basal turn.

--> Internal auditory artery --> Common cochlear artery --> Main cochlear artery --> Cochlear ramus --> The one-third of the basal turn.

--> Internal auditory artery --> Common cochlear artery --> Cochlear vestibular artery --> Posterior vestibular artery --> Inferior portion of utricle and saccule and posterior semicircular canal.

--> Internal auditory artery --> Anterior vestibular artery --> Cochlear vestibular artery --> Posterior vestibular artery --> Inferior portion of utricle and saccule and posterior semicircular canal.

--> Internal auditory artery --> Anterior vestibular artery --> Superior portion of utricle and saccule, superior and horizontal semicircular canals.

Figure 1-4. Sensory Innervation of the Auricle

Posterior surface:

--> C3 via greater auricular nerve

--> C2,3 via lesser occipital nerve

--> X auricular branch

--> VII sensory twigs.

Anterior surface:

--> V3 auriculotemporal nerve

--> X auricular branch

--> VII sensory twigs.

Figure 1-5. Cross-Section of Internal Auditory Canal

Anterior - VII - "Bill's Bar" - Sup vestibular nerve - Posterior
- Cochlear nerve - Inferior vestibular nerve.

Figure 1-6. Measurements of the Tympanic Membrane

Vertical 9-10 mm

Horizontal 8-9 mm.

The tympanic membrane has four layers:

1. Squamous epithelium

2. Radiating fibrous layer

3. Circular fibrous layer

4. Mucosa layer.

Average total layer of tympanic membrane: 70-80 mm².

Average vibrating surface of tympanic membrane: 55 mm².

Venous Drainage

Vertebral	Cavernous	External jugular
I	I	I
Occipital	Superior petrosal	Mastoid emissary veins
I	I	I
Lateral sinus	Sigmoid sinus	Sigmoid sinus
	I	
	Internal jugular vein <--	Inf petrosal sinus

Ossicles

Malleus

1. Head
2. Neck
3. Manubrium
4. Anterior process
5. Lateral or short process.

Stapes

1. Head
2. Posterior crus
3. Anterior crus
4. Footplate (average 1.41 mm x 2.99 mm).

Incus

1. Body
2. Short process

3. Long process (lenticular process).

Ligaments

Malleus

1. Superior malleal ligament (head to roof of epitympanum)
2. Anterior malleal ligament (neck near anterior process to sphenoid bone through the petrotympanic fissure)
3. Tensor tympani (medial surface of upper end of manubrium to cochleariform process)
4. Lateral malleal ligament (neck to tympanic notch).

Incus

1. Superior incudal ligament (body to tegment)
2. Posterior incudal ligament (short process to floor of incudal fossa).

Stapes

1. Stapedial tendon (apex of the pyramidal process to the posterior surface of the neck of the stapes).
2. Annular ligament (footplate to margin of vestibular fenestrum).

Malleal:Incudal joint is a diarthroidal joint.

Incudo:Stapedial joint is a diarthroidal joint.

Stapedial:Labyrinthal joint is a syndesmotic joint.

Middle Ear Folds of Significance

1. Anterior malleal fold: neck of the malleus to anterosuperior margin of the tympanic sulcus.
2. Posterior malleal fold: neck to posterosuperior margin of the tympanic sulcus.
3. Lateral malleal fold: neck to neck in an arch form and to Shrapnell's membrane.
4. Anterior pouch of von Tröltsch: Lies between the anterior malleal fold and the portion of the tympanic membrane anterior to the handle of the malleus.
5. Posterior pouch of von Tröltsch: Lies between the posterior malleal fold and the

portion of the tympanic membrane posterior to the handle of malleus.

Prussak's space (Fig. 1-7) is bound:

1. Anteriorly by the lateral malleolar fold
2. Posteriorly by the lateral malleolar fold
3. Superiorly by the lateral malleolar fold
4. Inferiorly by the lateral process of the malleus
5. Medially by the neck of the malleus
6. Laterally by Shrapnell's membrane.

The *oval window* sits in the sagittal plane.

The *round window* sits in the transverse plane and is protected by an anterior lip from the promontory. It faces posteroinferiorly as well as laterally.

The *tensor tympani* inserts from the cochleariform process onto the medial surface of the upper end of the manubrium. It supposedly pulls the tympanic membrane medially, thus tensing it. It also draws the malleus medially and upward. It raises the resonant frequency and attenuates low frequencies.

The *stapedius muscle* most frequently attaches to the posterior neck of the stapes. Occasionally it is attached to the posterior crus or head and rarely to the lenticular process. It is attached posteriorly at the pyramidal process. It pulls the stapes posteriorly, supposedly raises the resonant frequency of the ossicular chain and attenuates sound.

Eustachian Tube

1. It is 17-18 mm at birth and grows to about 35 mm in adult life.
2. At birth the tube is horizontal and grows to be at an incline of 45° in adult life. Thus the pharyngeal orifice is about 15 mm lower than the tympanic orifice.
3. It can be divided into an anteromedial cartilaginous portion (24 mm) and a posterolateral bony (11 mm) portion. The narrowest part of the tube is at the junction of the bony and the cartilaginous portions. (Reminder: The external auditory canal is one-third cartilaginous and two-thirds bony.)
4. The cartilaginous part of the tube is lined by pseudostratified columnar ciliated epithelium but toward the tympanic orifice it is lined by ciliated cuboidal epithelium.
5. It opens by the action of the tensor palati (innervated by the third division of the V nerve) acting synergistically with the levator veli palatini (innervated by the vagus). In

children the only muscle that works is the tensor palati because the levator palati is separated from the eustachian tube cartilage by a considerable distance. Therefore, a cleft palate child with poor tensor palati function is expected to have eustachian tube problems until the levator palati starts to function.

6. In a normal individual a pressure difference of 200-300 mm H₂O is needed to produce air flow.

7. It is easier to expel air from the middle ear than to get it into the middle ear (reason for more tubal trouble with descent in an airplane).

8. A pressure of -30 mm Hg or lower for 15 minutes can produce a transudate in the middle ear. A pressure differential of 90 mm Hg or greater may "lock" the eustachian tube preventing opening of the tube by the muscles. This is called the "critical pressure difference".

9. If the pressure differential exceeds 100 mm Hg, the tympanic membrane may rupture.

10. A Valsalva maneuver generates about 20-40 mm Hg pressure.

11. The lymphoid tissues within the tube have been referred to as the tonsil of Gerlach.

12. The tympanic ostium of the tube is at the anterior wall of the tympanic cavity about 4 mm above the most inferior part of the floor of the cavity. The diameter of the ostium is 3-5 mm. The size of the pharyngeal ostium varies from 3-10 mm in its vertical diameter and 2-5 mm in its horizontal diameter.

Embryology of the Ear

The Auricle

On the *sixth week* of gestation, condensation of the *mesoderm* of the *first and second arches* occurs to give rise to six hillocks called the Hillocks of His. The first three hillocks are derived from the first arch while the second arch contributes to the last three (Fig. 1-9).

First arch:	First hillock --> tragus (1). Second hillock --> helical crus (2). Third hillock --> helix (3).
Second arch:	Fourth hillock --> antihelix (4). Fifth hillock --> antitragus (5). Sixth hillock --> lobule and lower helix (6).

On the seventh week: Formation of cartilage is in progress.

On the twelfth week: The auricle is formed by fusion of the hillocks.

On the twentieth week: It has reached adult shape although it does not reach adult size till one is 9 years old.

The concha is formed by three separate areas from the *first groove (ectoderm)* (see Fig. 1-9).

- a. Middle part of the first groove: Concha cavum.
- b. Upper part of the first groove: Concha cymba.
- c. Lower part of the first groove: Intertragus incisura.

The External Auditory Canal

On the *eight week of gestation*, the surface *ectoderm* in the region of the upper end of the *first pharyngeal groove* (dorsal) thickens. This solid core of epithelium continues to grow toward the middle ear. Simultaneously, the concha cavum deepens to form the outer one-third of the external auditory canal. By the *twenty-first week* this core begins to resorb and "hollow out" to form a channel. The innermost layer of ectoderm remains to become the superficial layer of the tympanic membrane. Formation of the channel is completed by the twenty-eight week. At birth, the external auditory canal is neither ossified nor of adult size. Completion of ossification occurs around *age 3* and *adult size* is reached at *age 9*.

The Eustachian Tube and the Middle Ear

During the third week of gestation, the first and second pharyngeal pouches lie laterally on either side of what is to become the oral and pharyngeal tongue. As the third arch enlarges, the space between the second arch and the pharynx (first pouch) is compressed and becomes the *eustachian tube*. The "outpocketing" at the lateral end becomes the *middle ear space*. Because of the proximity to the first, second, and third arches, the V, VII, and IX nerves are found in the middle ear. By the *tenth week*, pneumatization begins. The antrum appears on the *twenty-third week*. However, it is of interest that the middle ear is filled with mucoid connective tissue until the time of birth. The *twenty-eight week* marks the apparition of the tympanic membrane which is derived from all three origins.

- a. Ectoderm --> squamous layer.
- b. Mesoderm --> fibrous layer.
- c. Entoderm --> mucosal layer.

Between the twelfth and the 28th week, four primary mucosal sacs emerge, each becoming a specific anatomic region of the middle ear.

- a. Saccus anticus --> anterior pouch of von Trölsch.
- b. Saccus medius --> epitympanum and petrous area.
- c. Saccus superior --> posterior pouch of von Trölsch, part of the mastoid, inferior

incudal space.

d. Sacculus posterior --> round window and oval window niches, sinus tympani.

At birth, the embryonic subepithelium is resorbed and pneumatization continues in the middle ear, antrum and mastoid. Pneumatization of the petrous portion of the temporal bone, being the last to arise, continues until puberty.

The middle ear is well formed at birth and enlarges only slightly postnatally. At age 1, the mastoid process appears. At age 3, the tympanic ring and osseous canal are calcified.

The eustachian tube measures approximately 17 mm at birth and continues to grow to 35 mm in adulthood.

The Malleus and Incus

On the *sixth week* of embryonic development, the malleus and the incus appear as a single mass. By the *eighth week* they are separated and the *malleoincudal joint* is formed. The *head and neck of the malleus* are derived from *Meckel's cartilage* (first arch mesoderm), the *anterior process* from the *process of Folius* (mesenchyme bone) and the *manubrium* from the *Reichert's cartilage* (second arch mesoderm). The *body and short process of the incus* originate from *Meckel's cartilage* (first arch mesoderm) and the *long process* from *Reichert's cartilage* (second arch mesoderm). By the *sixteenth week*, the ossicles reach adult size. On the *sixteenth week*, ossification begins and appears first at the long process of the incus. On the *seventeenth week*, the ossification center becomes visible on the medial surface of the neck of the malleus and spreads to the manubrium and the head. *At birth, the malleus and incus are of adult size and shape.* The ossification of the malleus is never complete so that part of the manubrium remains cartilaginous. (The lenticular process is also known as "sylvian apophysis" or "os orbiculare").

The Stapes

At *4.5 weeks* the mesenchymal cells of the *second arch* condense to form the blastema. The VII nerve divides the blastema into *stapes, interhyale* and *laterohyale*. On the *seventh week*, the stapes ring emerges around the stapedial artery. The *lamina stapedialis*, which is of the otic mesenchyme, appears to become the footplate and annular ligament. At 8.5 weeks, the incudalstapedial joint develops. The interhyale becomes the stapedial muscle and tendon, the laterohyale becomes the posterior wall of the middle ear. Together with the otic capsule, the laterohyale also becomes the pyramidal process and facial canal. The lower part of the facial canal is said to be derived from Reichert's cartilage.

On the *tenth week*, the stapes changes its ring shape to "stirrup" shape. On the *nineteenth week*, ossification begins and starts at the obturator surface of the stapedial base. The ossification is completed by the 28th week except for the vestibular surface of the footplate which remains cartilaginous throughout life. At birth the stapes is of *adult size and form*.

The Inner Ear

On the *third week* neuroectoderm and ectoderm lateral to the first branchial groove condense to form the *otic placode*. The latter invaginates until completely submerged and surrounded by mesoderm to become the *otocyst* or *otic vesicle* by the *fourth week*. The *fifth week* marks the appearance of a wide dorsal and a slender ventral part of the otic vesicle. Between these two parts, the endolymphatic duct and sac develop. On the *sixth week*, the semicircular canals take shape and by the eight week, together with the utricle, they are fully formed. Formation of the basal turn of the cochlea takes place on the *seventh week* and by the *twelfth week* the complete two and a half turns are developed. Development of the saccule follows that of the utricle. Evidently, the pars superior (semicircular canals and utricle) is developed before the pars inferior (sacculus and cochlea). Formation of the membranous labyrinth without the end organ is said to be complete by the *fifteenth week* of gestation.

Concurrent with the formation of the membranous labyrinth, the precursor of the otic capsule emerges on the eight week as a condensation of mesenchyme precartilag. The 14 centers of ossification can be identified on the *fifteenth week* and ossification is completed on the 23rd week of gestation. The last area to ossify is the fissula ante fenestram which may remain cartilaginous throughout life. Other than the endolymphatic sac which continues to grow until adulthood, the membranous and bony labyrinth are of *adult size at the 23rd week of embryonic development*. The endolymphatic sac is the first to appear and the last to stop growing.

At the third week, the common macula first appears. Its upper part differentiates into the utricular macula and the cristae of the superior and lateral semicircular canals, whereas its lower part becomes the macula of the saccule and the cristae of the posterior semicircular canal. On the *eighth week*, two ridges of cells as well as the stria vascularis are identifiable. On the *eleventh week*, the vestibular end organs complete with sensory and supporting cells are formed. On the *twentieth week*, development of the stria vascularis and the tectorial membrane is completed. On the *23rd week*, the two ridges of cells divide into inner ridge cells and outer ridge cells. The inner ridge cells become the spiral limbus, the outer ones become the hair cells, pillar cells, Hensen's cells, and Deiters' cell. On the *26th week*, the tunnel of Corti and canal of Nuvel are formed.

The neurocrest cells lateral to the rhombencephalon condense to form the acoustic-facial ganglion which differentiates into the facial geniculate ganglion, superior vestibular ganglion (utricle, superior and horizontal semicircular canals) and inferior ganglion (saccule, posterior semicircular canal and cochlea).

At birth, four elements of the temporal bone are distinguishable: petrous, squamous, tympanic ring, and styloid process. The mastoid antrum is present but the mastoid process is not formed until the end of the second year of life and pneumatization of the mastoid soon follows. The tympanic ring extends laterally after birth forming the osseous canal.

Clinical Information

1. Congenital microtia occurs about 1:20.000 births.

2. The auricle is formed early. Therefore, malformation of the auricle implies malformation of the middle ear, mastoid, and VII nerve. On the other hand, a normal auricle with canal atresia indicates development in the 28th week, by which time ossicles and middle ear are already formed.

3. Improper fusion of the first and second branchial arches results in a preauricular sinus tract (epithelial lined).

4. Malformation of first branchial arch and groove results in:

- a. Auricle abnormality (first and second arches)
- b. Bony meatus atresia (first groove)
- c. Abnormal incus and malleus (first and second arches)
- d. Abnormal mandible (first arch).

When the maxilla is also malformed, this constellation of findings is called Treacher-Collins syndrome (mandibular-facial dysostosis).

- a. Outward-downward slanted eyes (antimongoloid)
- b. Notched lower lid
- c. Short mandible
- d. Bony meatal atresia
- e. Malformed incus and malleus
- f. Fishmouth

5. Abnormalities of the otic capsule and labyrinth are rare because they are phylogenetically ancient.

6. An incidence of 20-30% dehiscent tympanic portion of the VII nerve has been reported.

7. The incidence of absent stapedius tendon, muscle, and pyramidal eminence is estimated at 1%.

8. Twenty percent of preauricular cysts are bilateral.

9. In the very young infants, Hyrtl's fissure affords a route of direct extension of infection from the middle ear to the subarachnoid spaces. The fissure closes as the infant grows. Hyrtl's fissure extends from the subarachnoid space near the glossopharyngeal ganglion to the hypotympanum just inferior and anterior to the round window. (Eggston, 1947.)