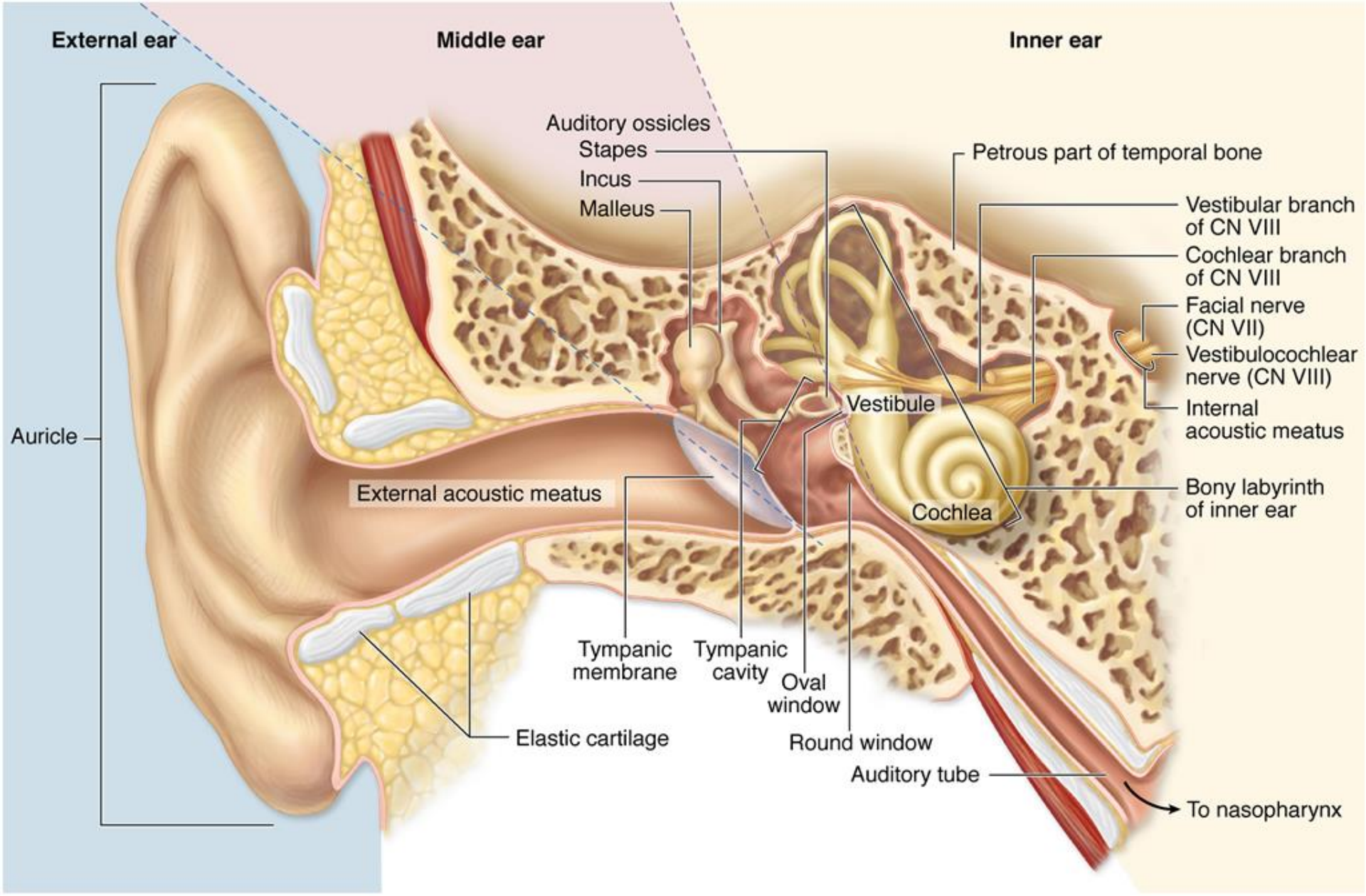
Spiral organ of Corti. Development of the auditory and vestibular system.

János Hanics M.D.

The position of the inner ear



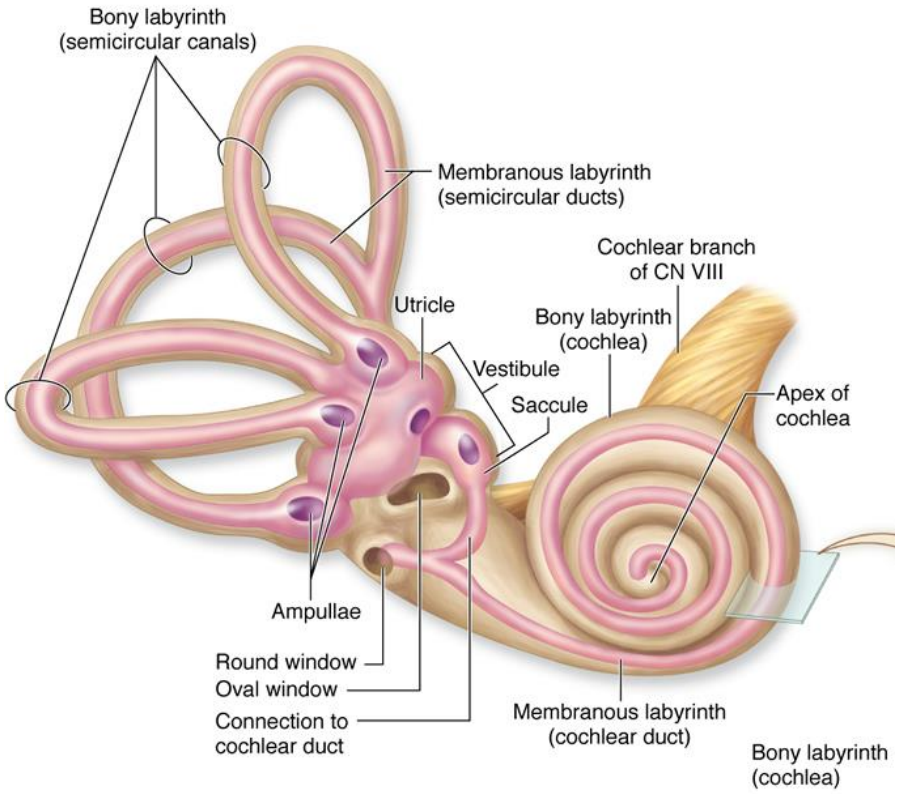
The labyrinthes of the inner ear

- Continuous cavity system in the petrous part of temporal bone

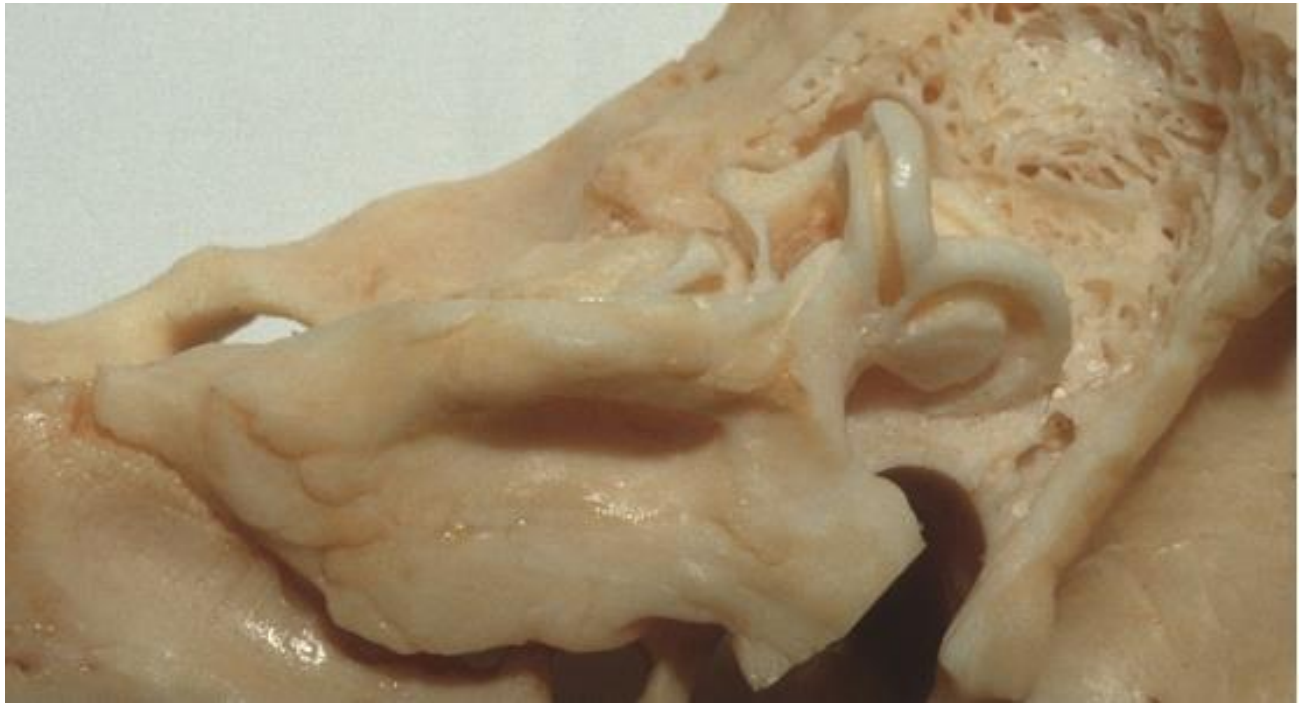
-„Cavity in cavity”:

-1) bony labyrinth - *labyrinthus osseus* – which contains the similar shape

-2) membranous labyrinth – *labyrinthus membranaceus*



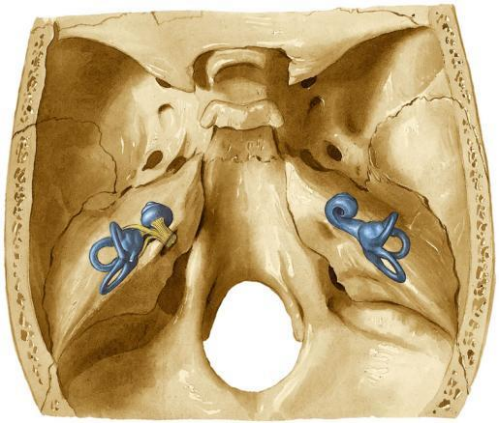
Walls of the bony labyrinth

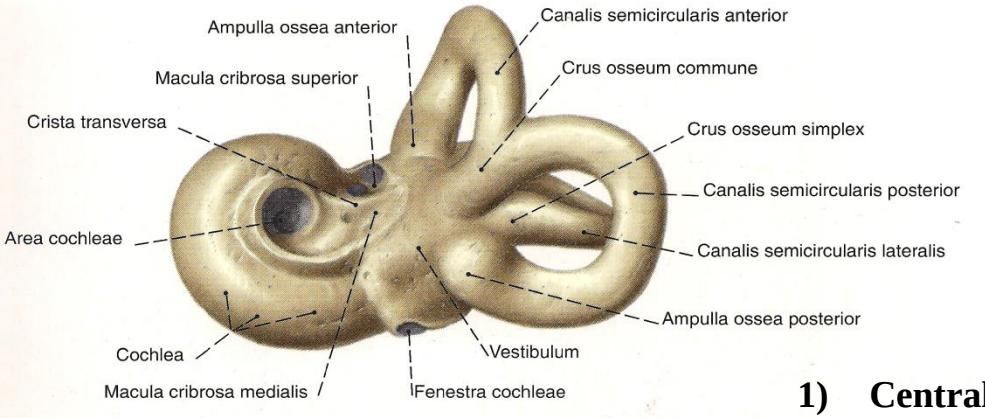


The main mass of petrous part of the temporal bone consisted from spongious bony substance.

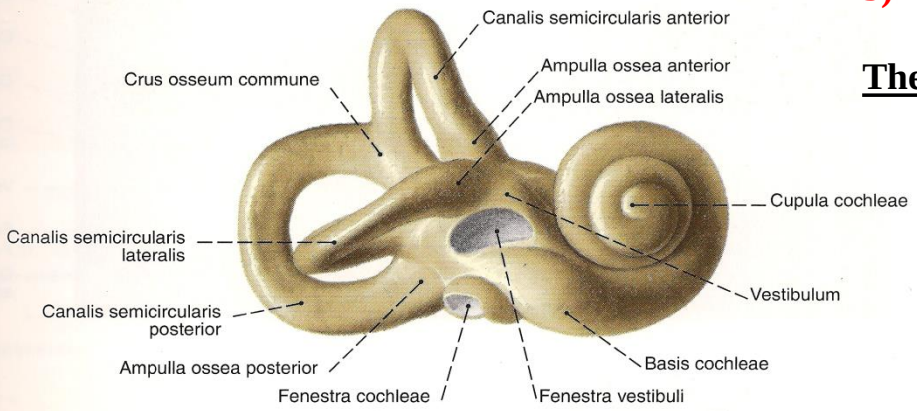
However the wall of the labyrinth formed from compact bone like a shell.

Parts of the bony labyrinth





666. ábra A csontos labyrinthus (labyrinthus osseus); a hártyás labyrinthus csontos köpenye a sziklacsontból kivésve, hátulról és felülről (jobb oldal, 300%).



667. ábra Ugyanaz, mint a fenti, oldalról és elölről (jobb oldal, 300%).

1) **Central cavity– <u>vestibule</u>**

2) **3 bony semicircular canal - <u>ant.; post.; lat.;</u>**

3) **<u>Cochlea</u>**

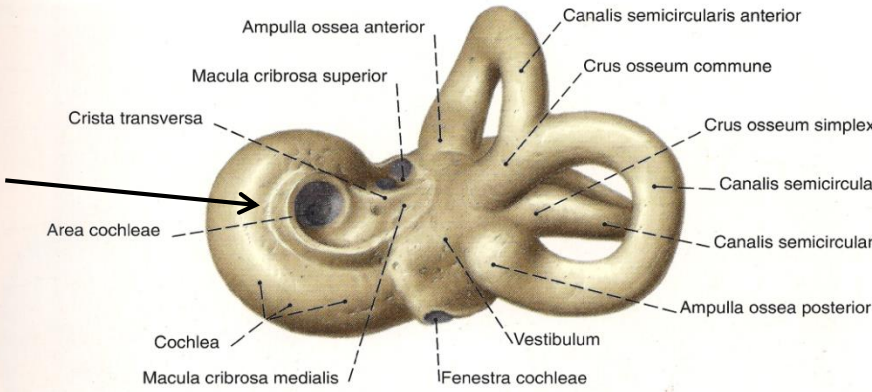
<u>They are continuous through the vestibule</u>

Cochlea

3 mm in diameter – similar to snail shell

2 and ¾ turning

Basis



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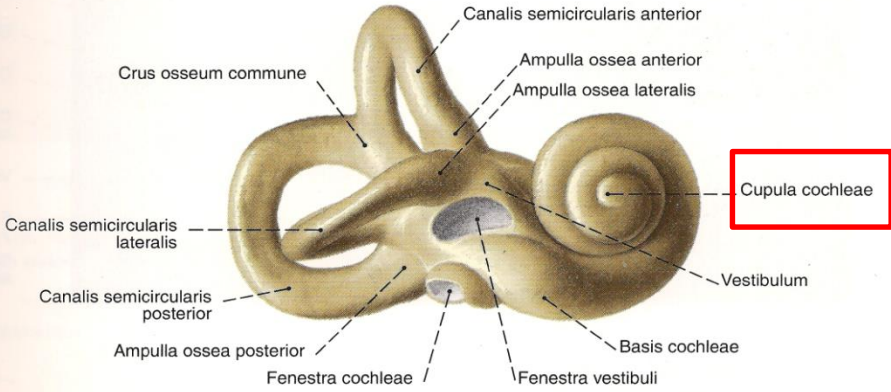

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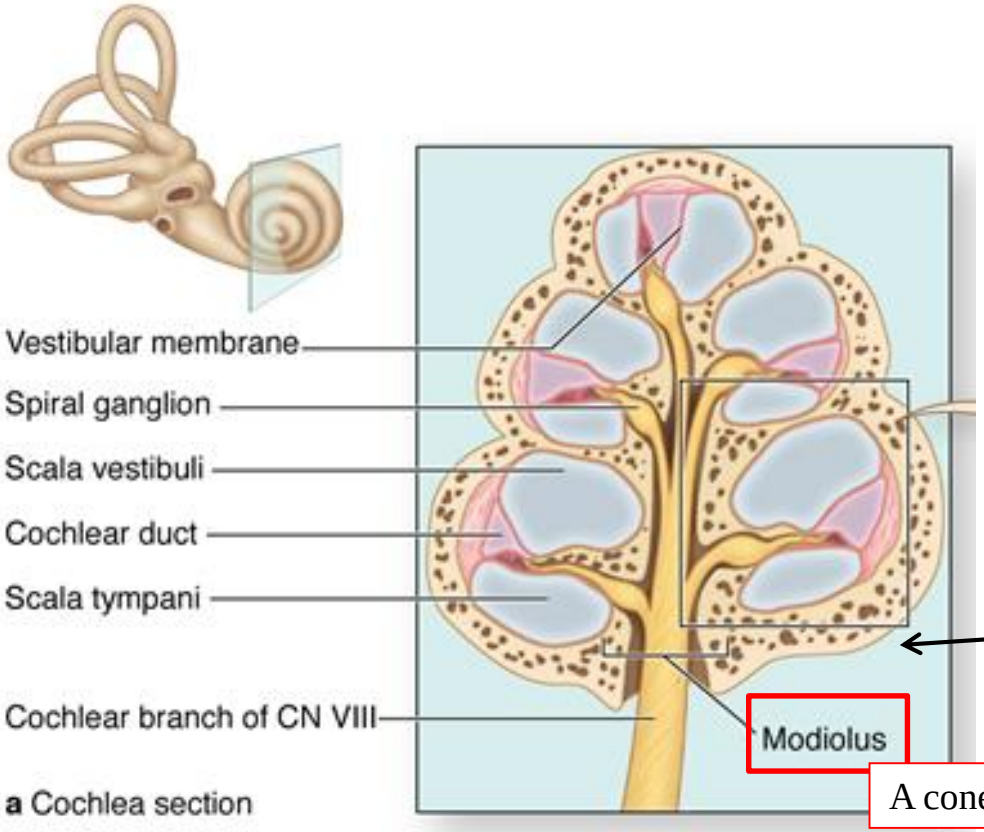
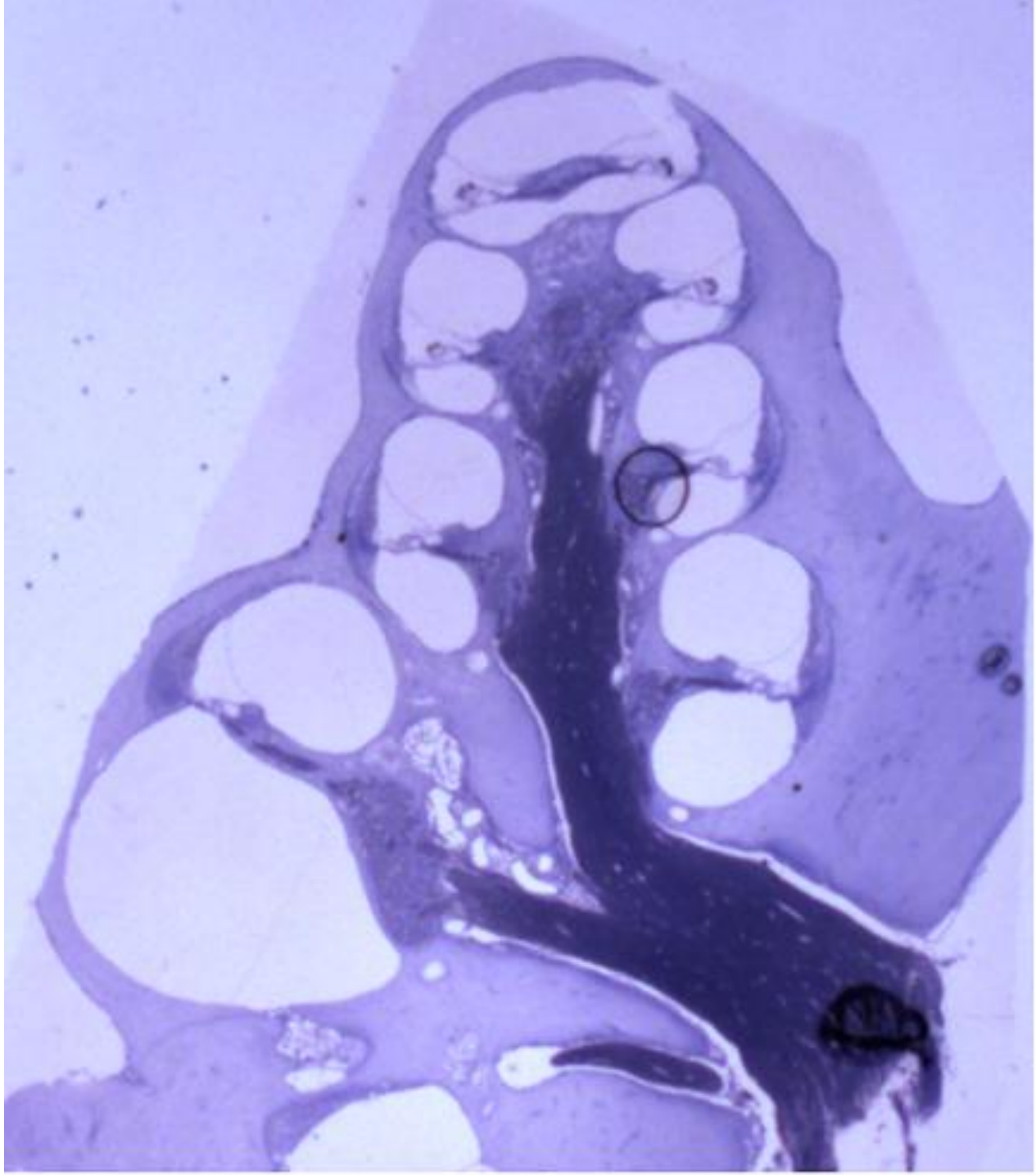


Basis – It looks to the fundus of the internal acoustic meatus

A cone like cavity in the axis



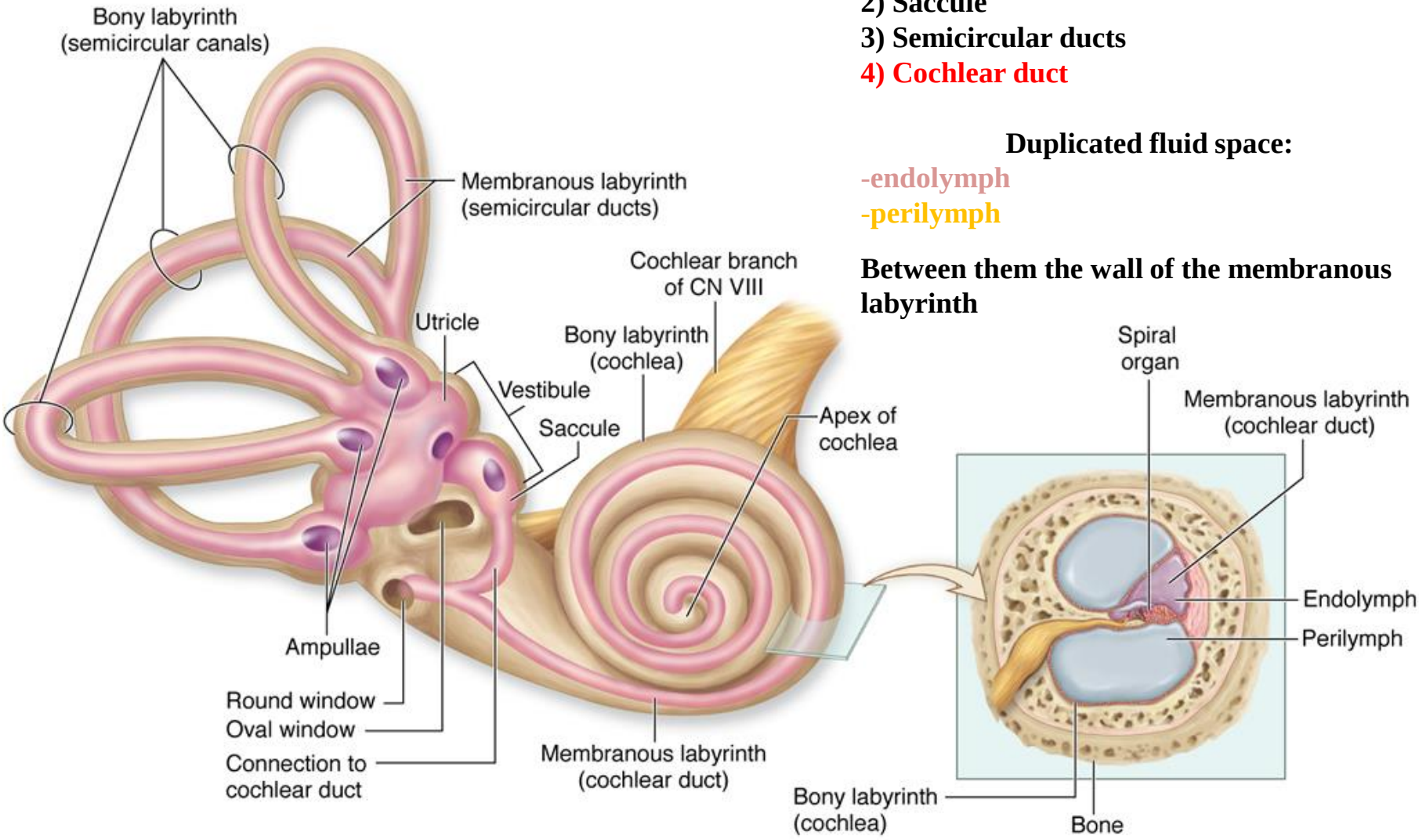
Parts of the membranous labyrinth

1) Utricle
2) Saccule
3) Semicircular ducts
4) Cochlear duct

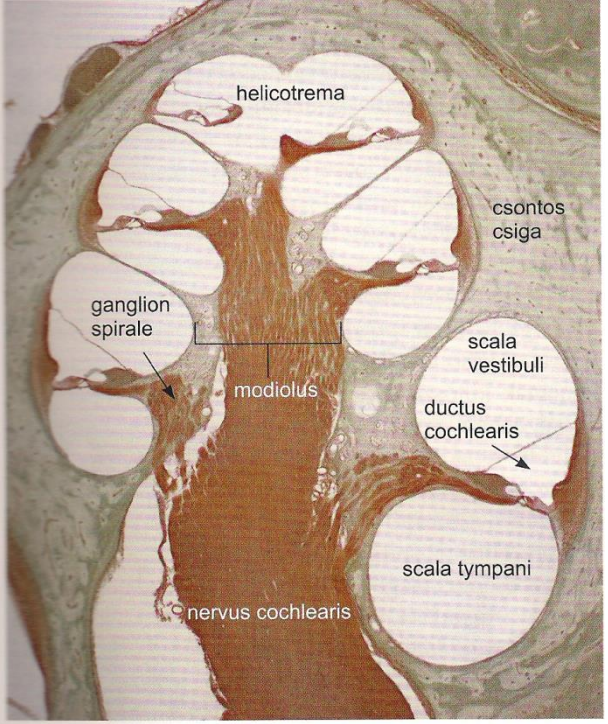
Duplicated fluid space:

-endolymph
-perilymph

Between them the wall of the membranous labyrinth



Borders of the cochlear duct

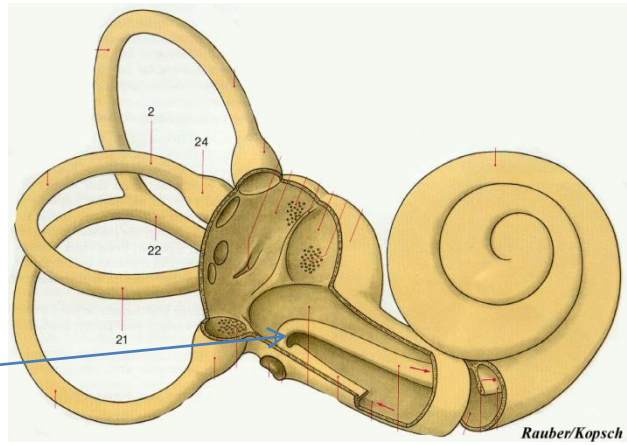


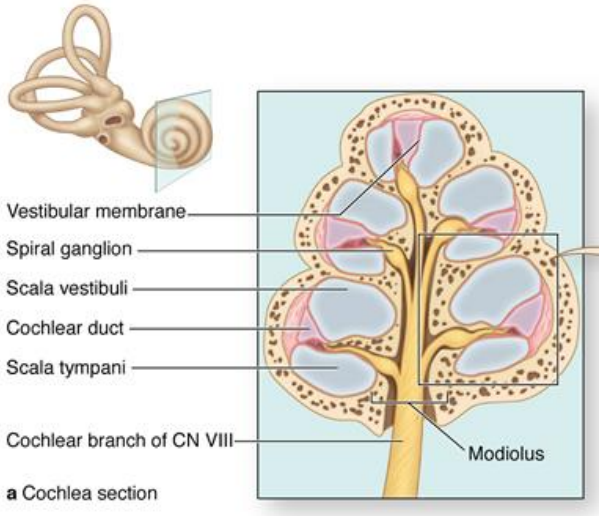
23-8. ábra

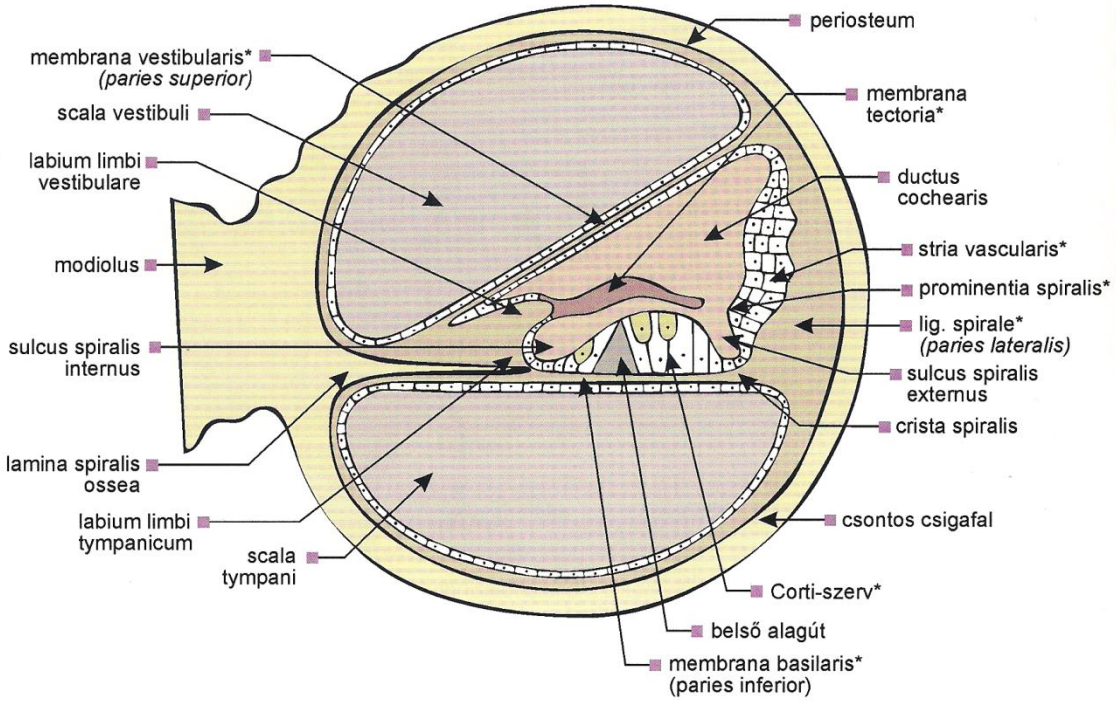
A csiga hosszmetszeti képe (macska belső fül, HE, 23×).

Both end is blind!!!
Through the reuniens duct connects with saccule

Vestibular crest



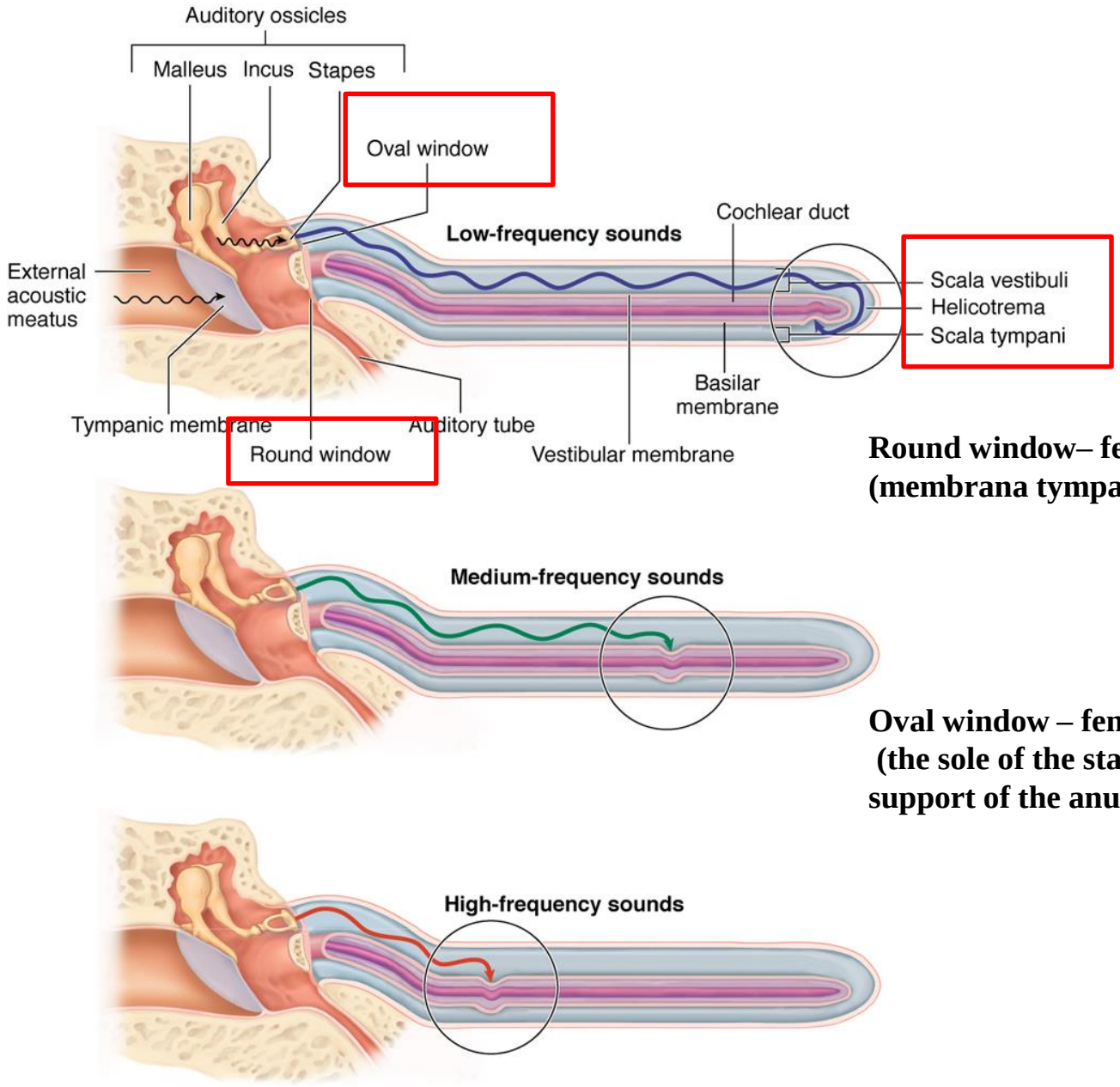




23-9. ábra

A csigajárat keresztmetszete. Az endolymphatér rózsaszín, a perilympha-tér halványkék. Az alagutat kitöltő folyadék (cortilympha) összetétele a perilymphához hasonló, ezért szintén kék színnel van feltüntetve. A ductus cochlearis falát alkotó képletek neveit csillaggal jelöltük meg.

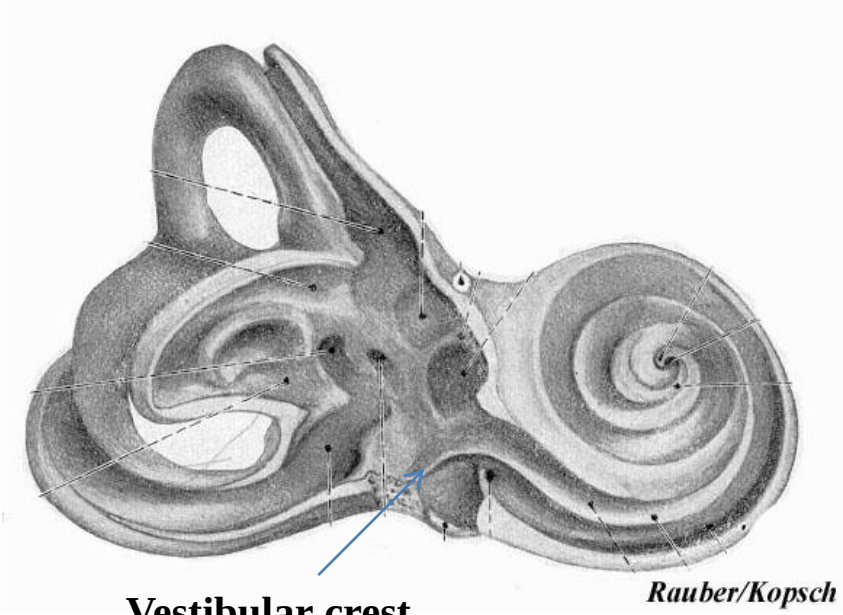
Scala vestibuli and scala tympani



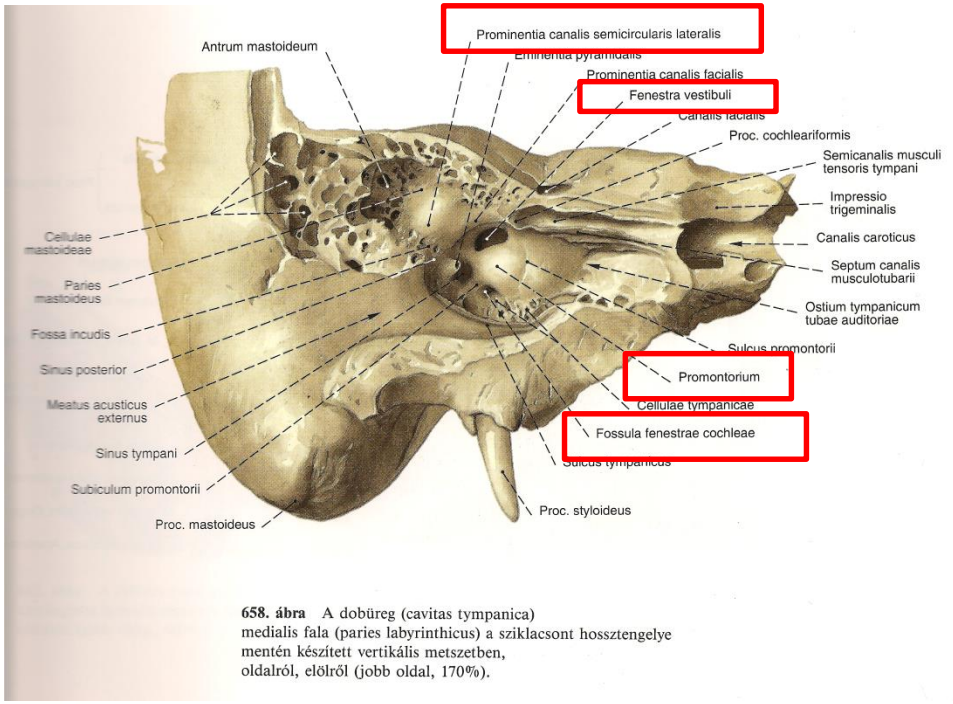
Round window– fenestra cochleae (membrana tympani secundaria close it)

Oval window – fenestra vestibuli (the sole of the stapes fit it with the support of the anular ligament)

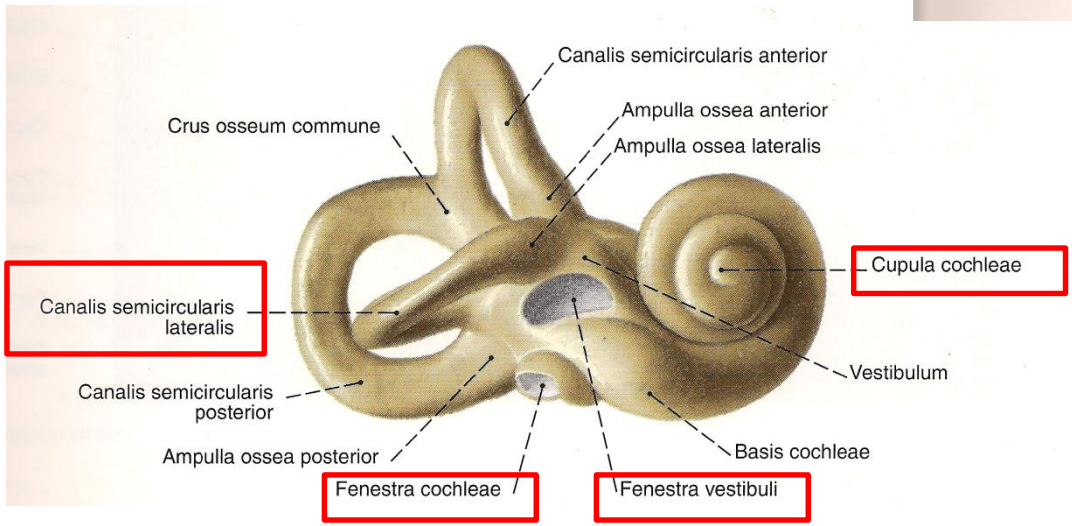
From the middle ear



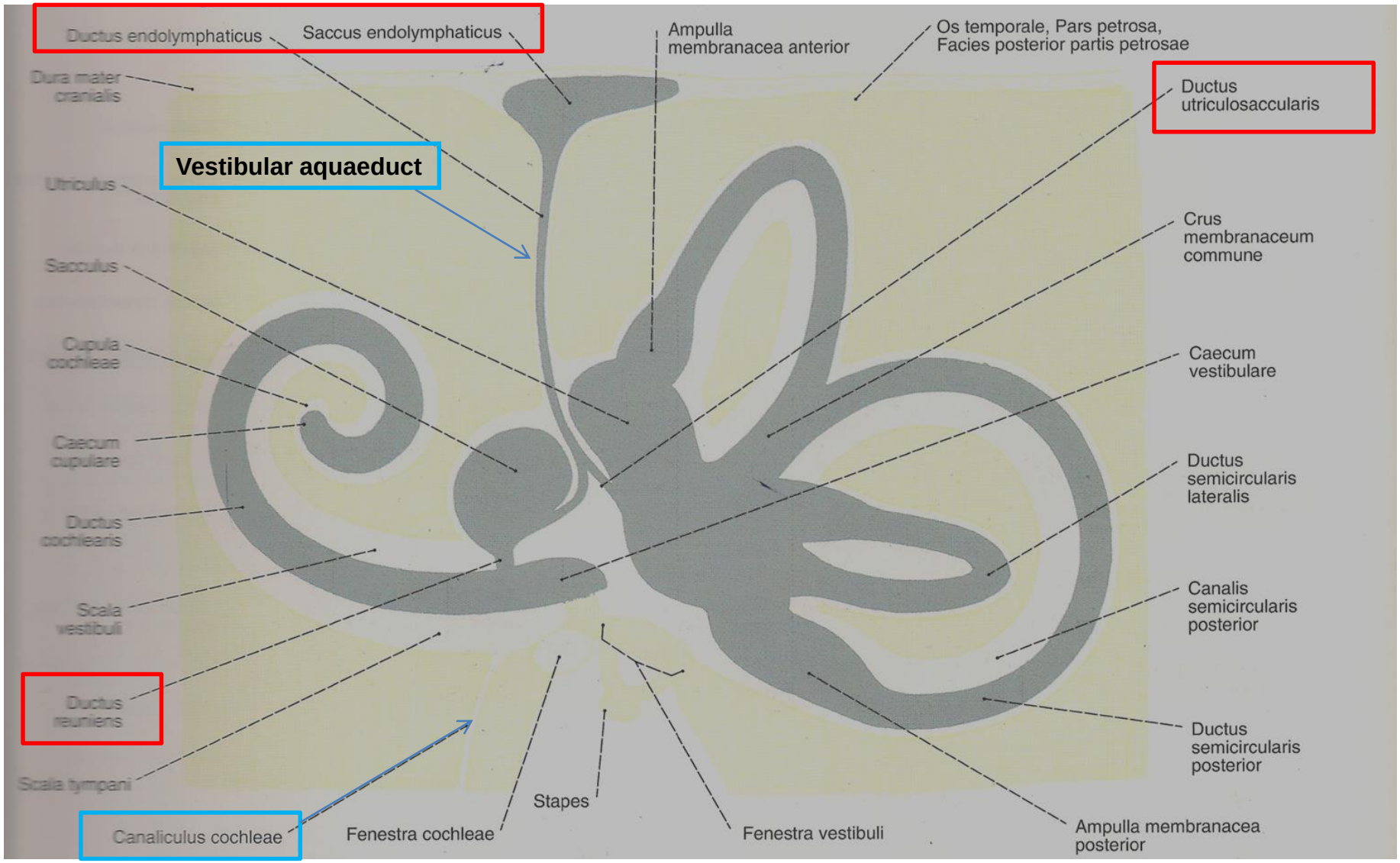
Vestibular crest



658. ábra A dobüreg (cavitas tympanica) medialis fala (paries labyrinthicus) a sziklacsont hossztengelye mentén készített vertikális metszetben, oldalról, elölről (jobb oldal, 170%).



Connections of the perilymphatic and endolymphatic spaces



Features of the perilymph and endolymph

-Endolymph:

- high K^+ conc. Similar to intracellular fluid
- produce by the supporting cells of membranous labyrinth and the stria vascularis of the cochlear duct.
- Absorption by the endolymphatic sac.

-Perilymph:

- Similar to the CSF.
- Production place are not defind.
- This space connects with the subarachnoid space (origin!!! Production?)

-<u>Perilymphatic flood gate</u>:
1) Vestibular aquaeduct – connects the vestibule with the posterior surface of the pyramid (contain the endolymphatic duct)
-2) Cochlear aquaeduct - It's aperture opens between the petrous fossula an jugular fossa, where it allegedly connects with subarachnoid space which follows the CN9.

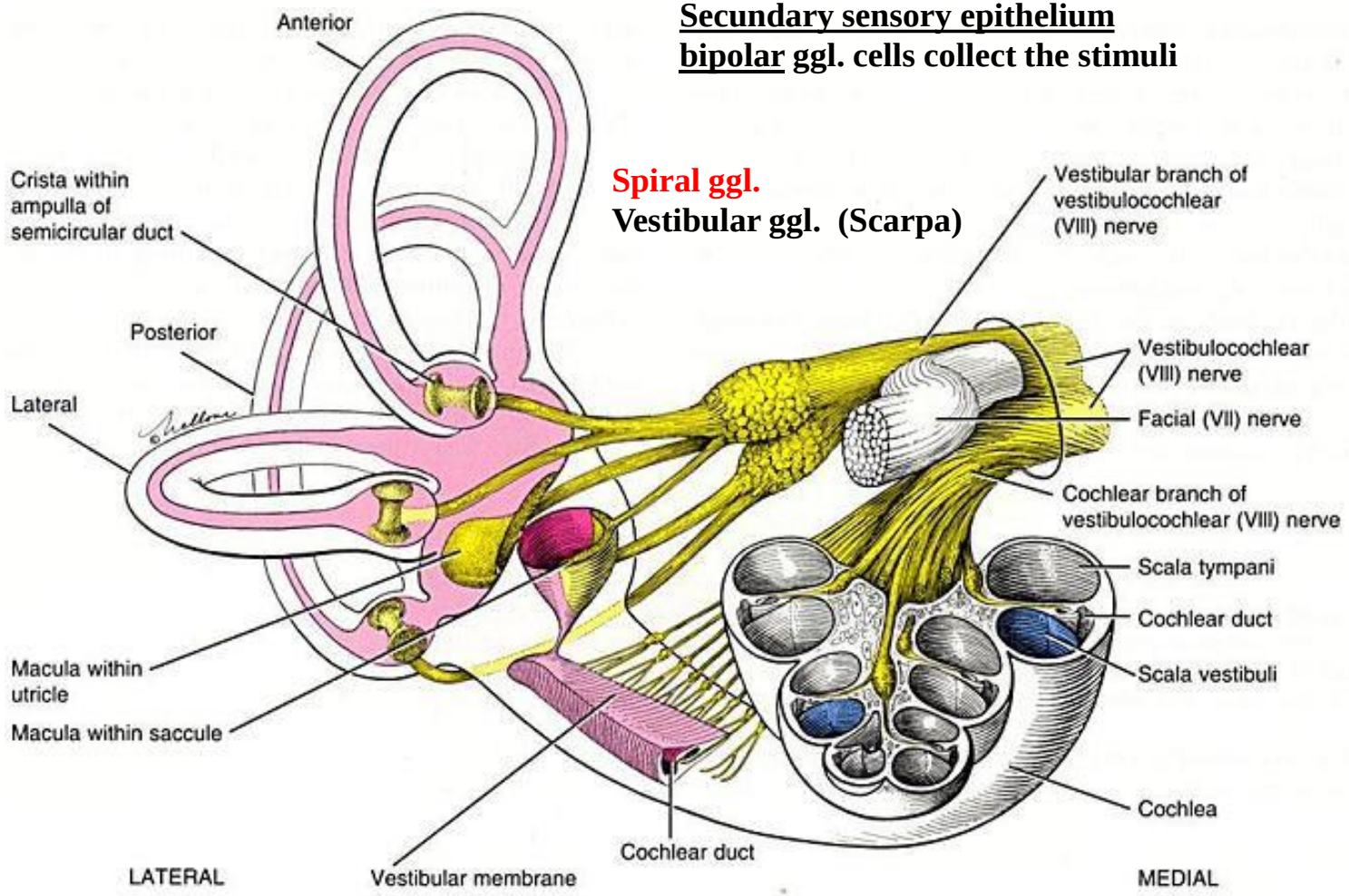
Sensor areas in the labyrinth

Hearing: Organ of Corti

Vestibular organ:
2 macula (one in saccule and one in utricle)
3 ampullary crest (within the ampullae)

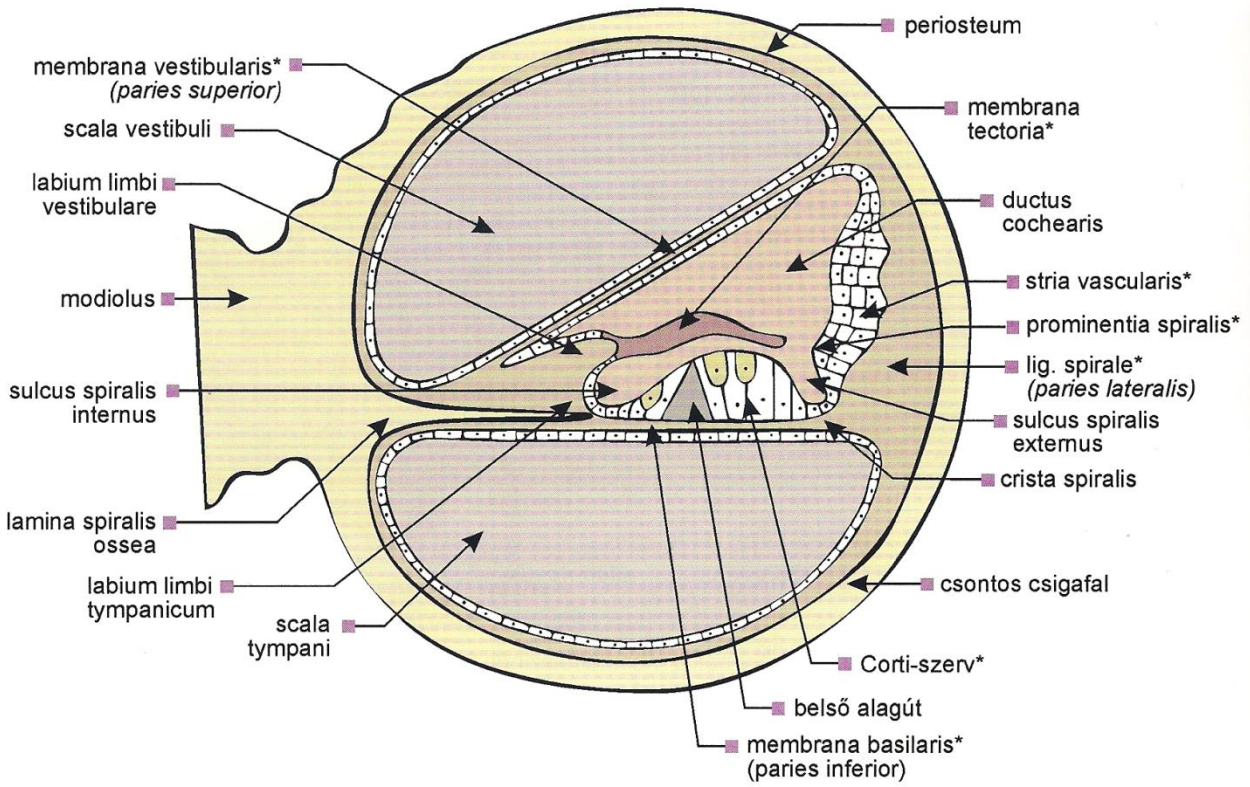
Common points:
Secundary sensory epithelium
bipolar ggl. cells collect the stimuli

Spiral ggl.
Vestibular ggl. (Scarpa)



(b) Parts of the vestibulocochlear (VIII) nerve of the right ear

Organ of Corti



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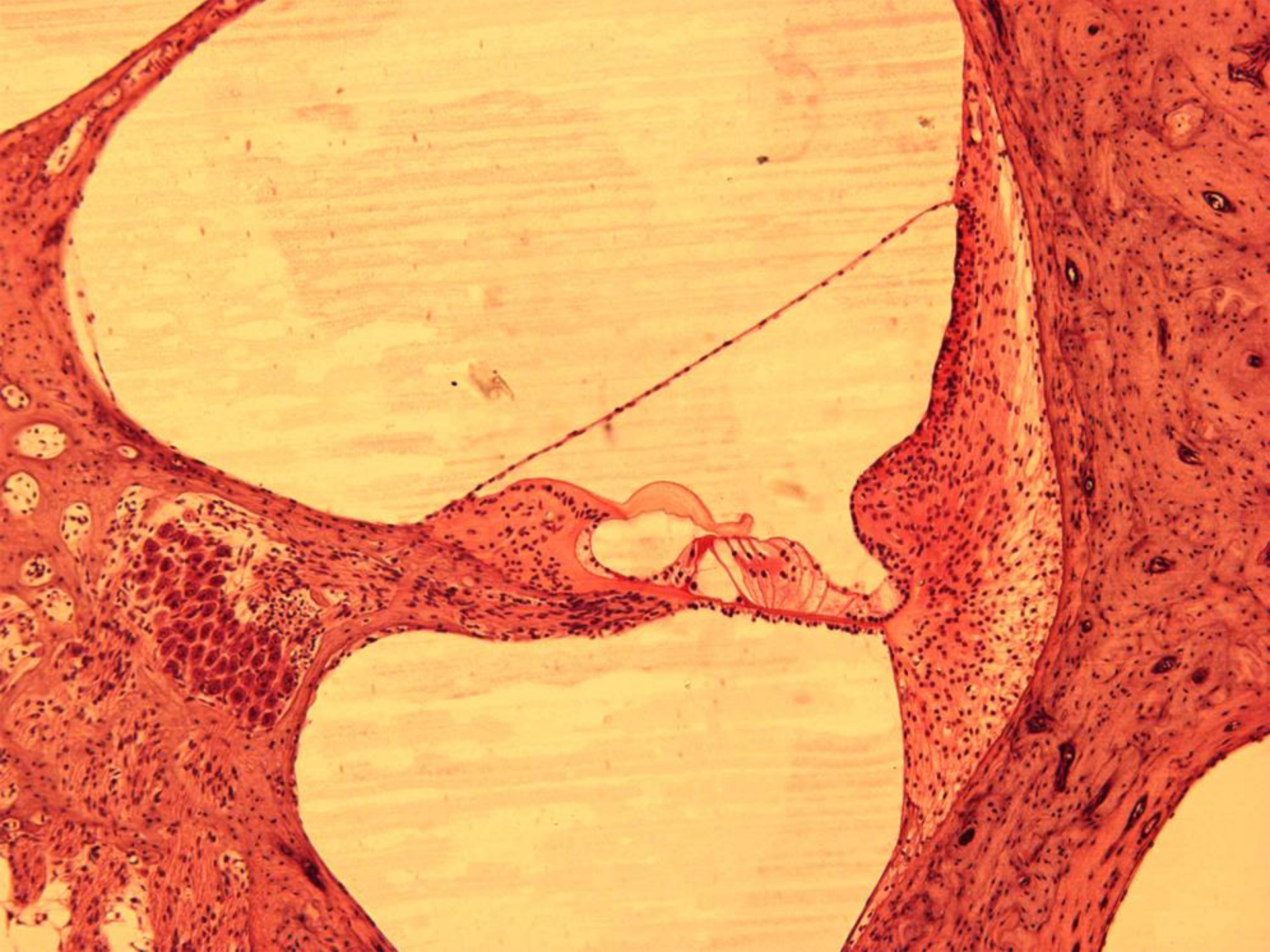
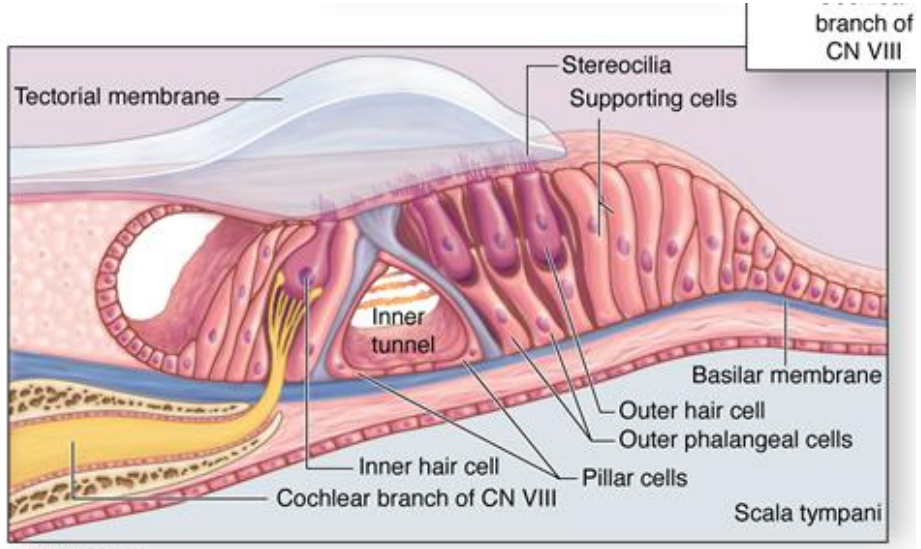
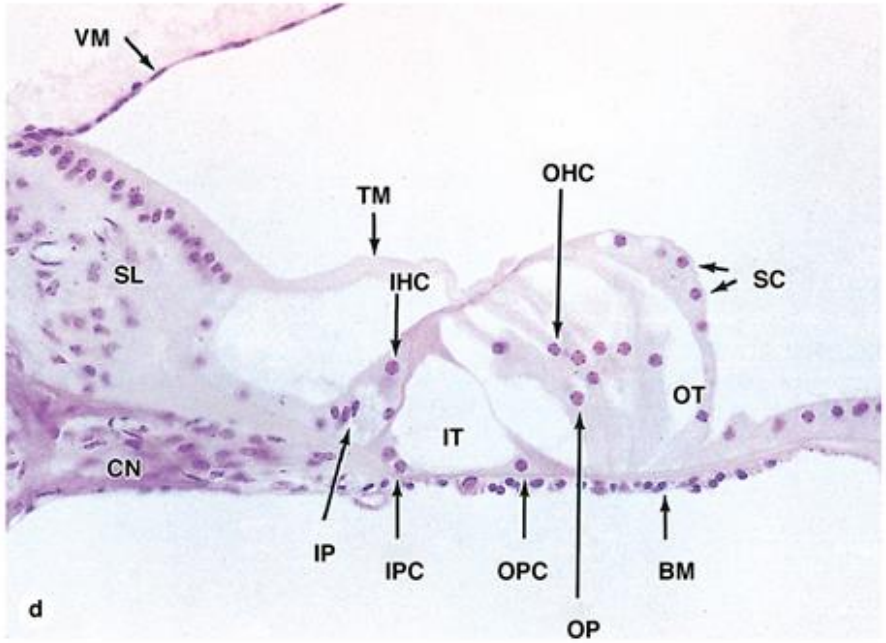
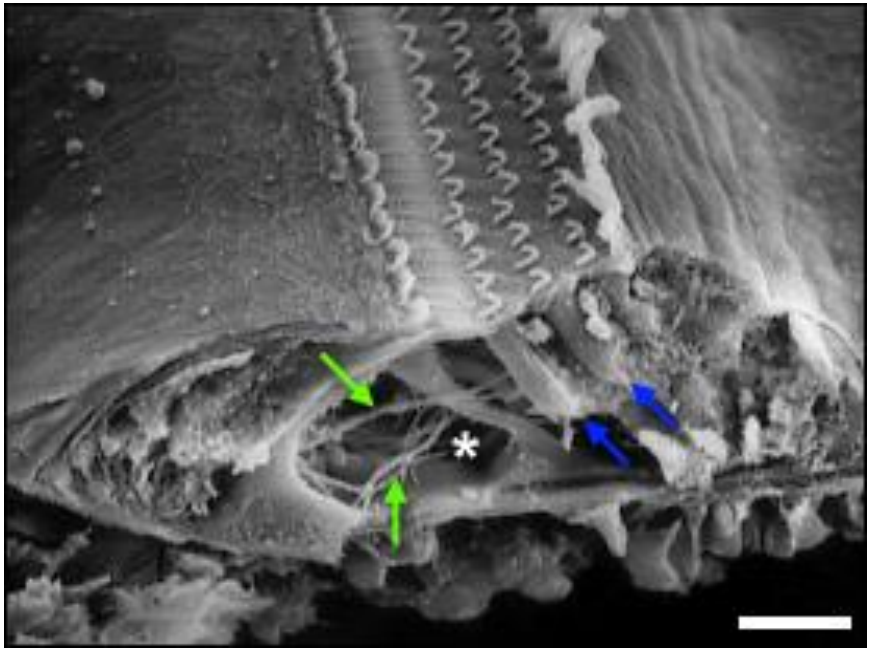


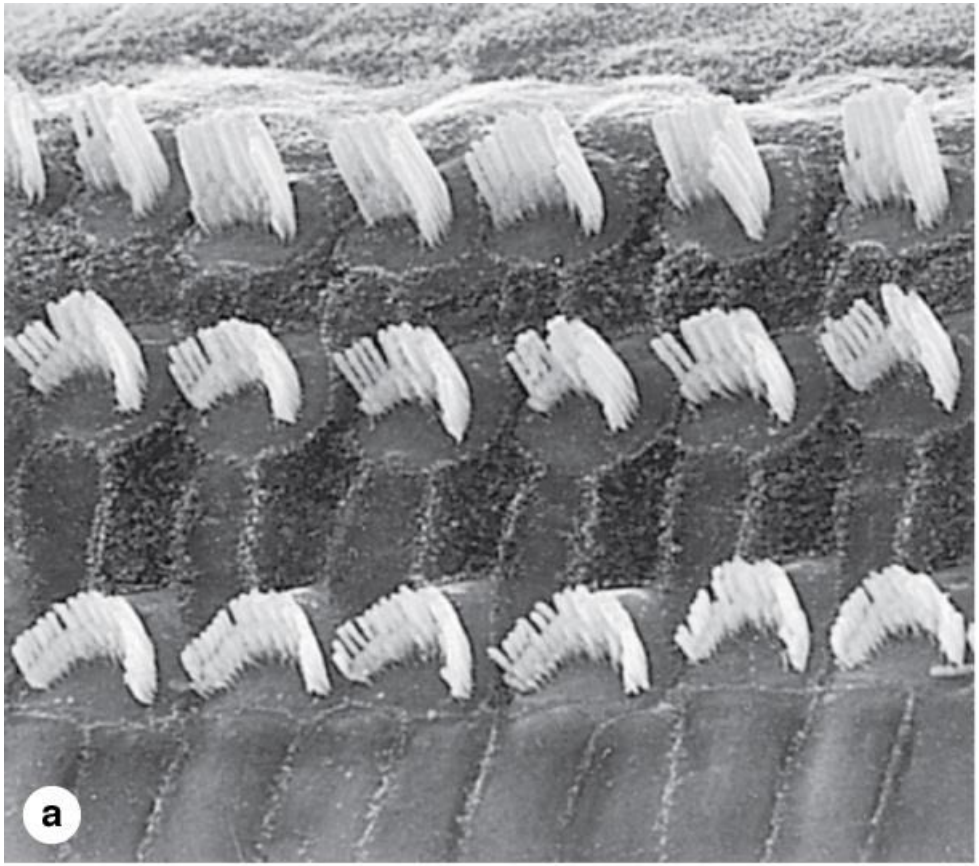
Organ of Corti

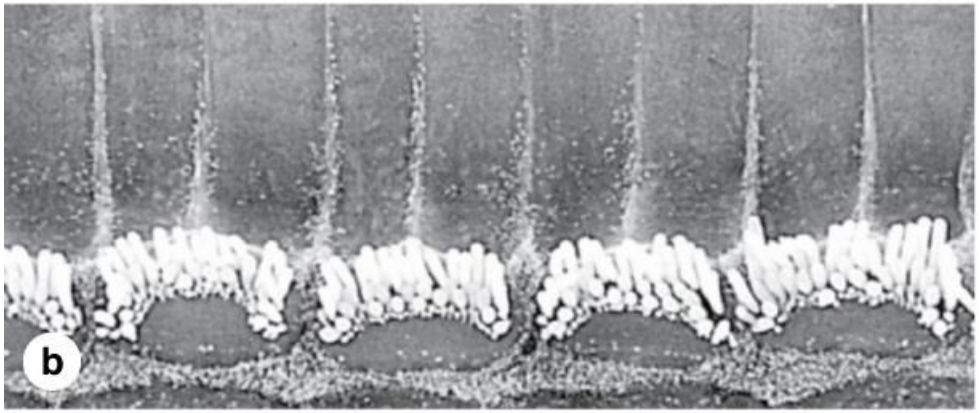


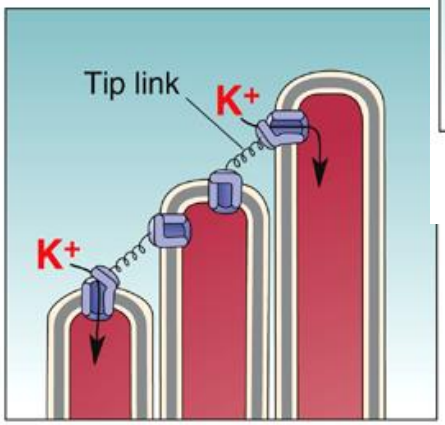
c Spiral organ

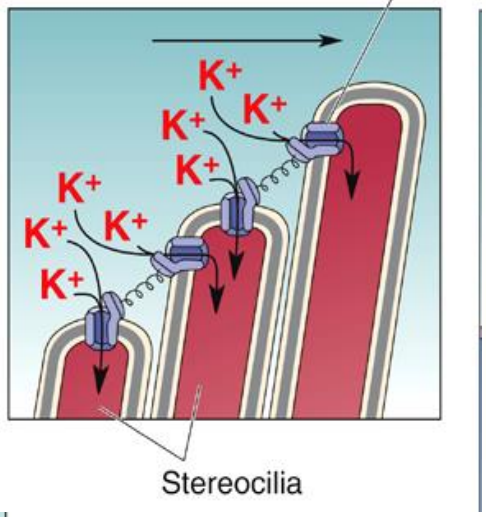


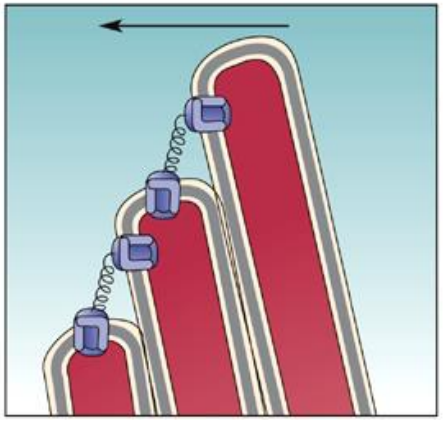


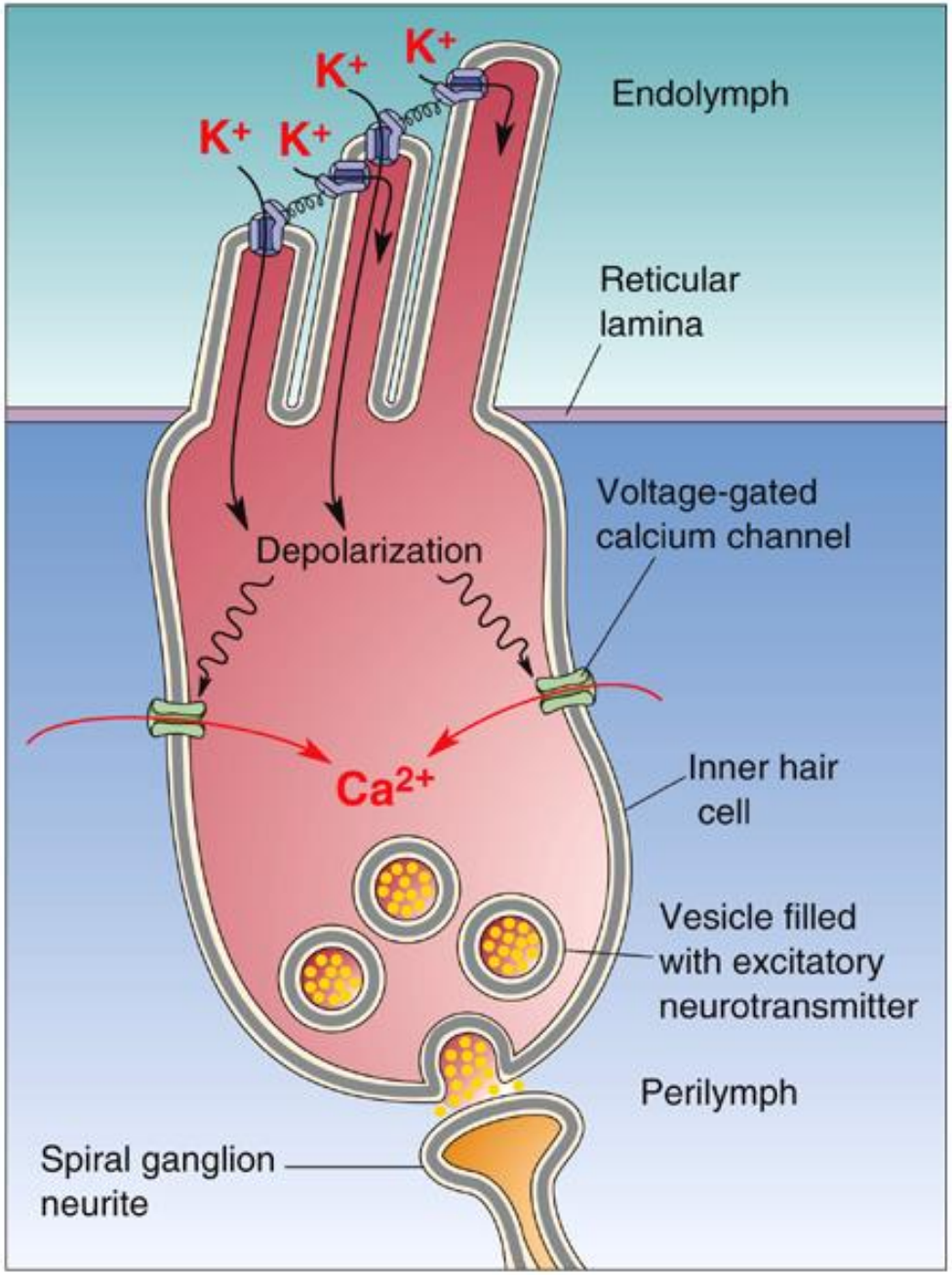

a

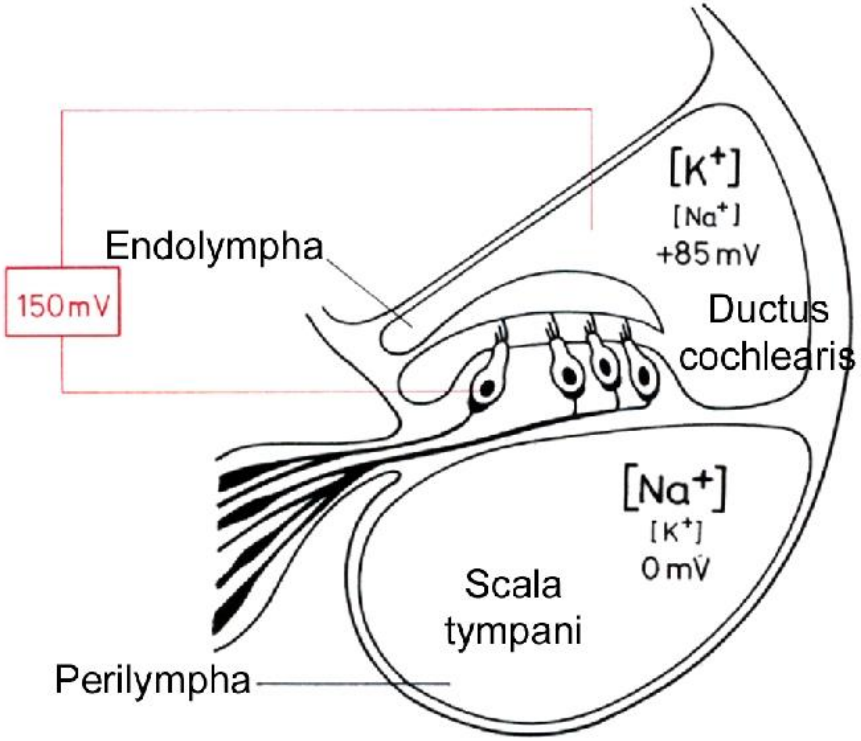

b

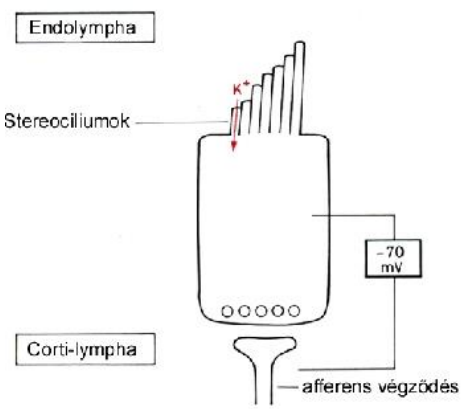

Tip link
K+
K+

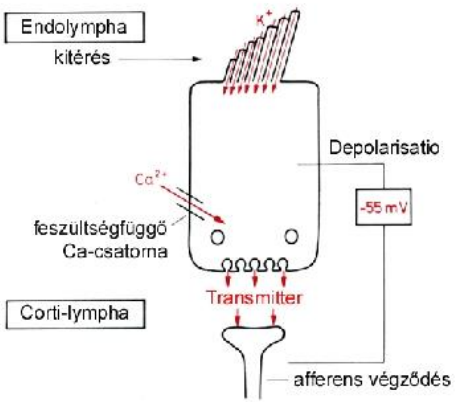

Mechanically g
TRPA1 channe
K+
K+
K+
K+
K+
K+
K+
Stereocilia

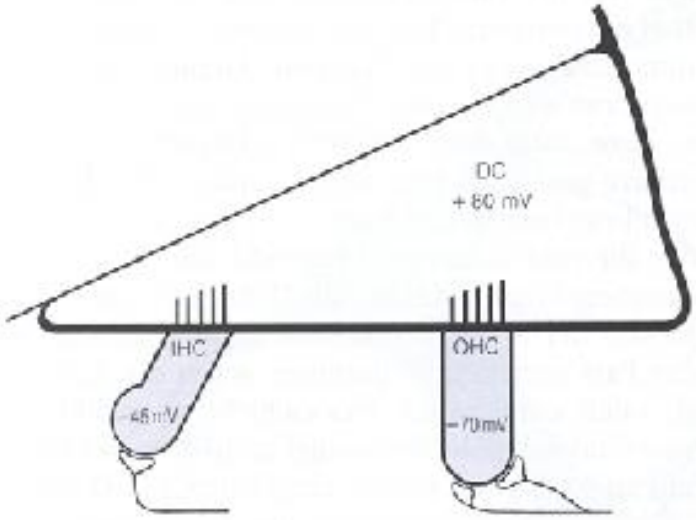


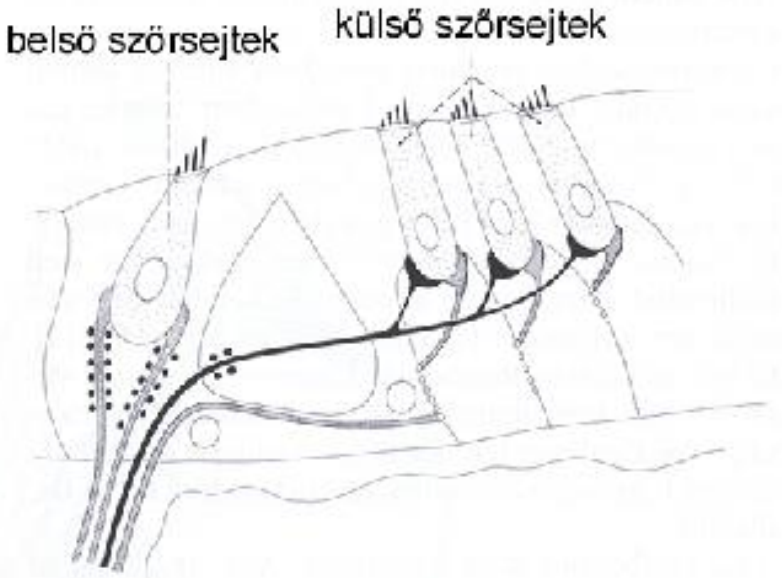

K+
K+
K+
K+
K+
Endolymph
Reticular
lamina
Voltage-gated
calcium channel
Depolarization
Ca2+
Inner hair
cell
Vesicle filled
with excitatory
neurotransmitter
Perilymph
Spiral ganglion
neurite

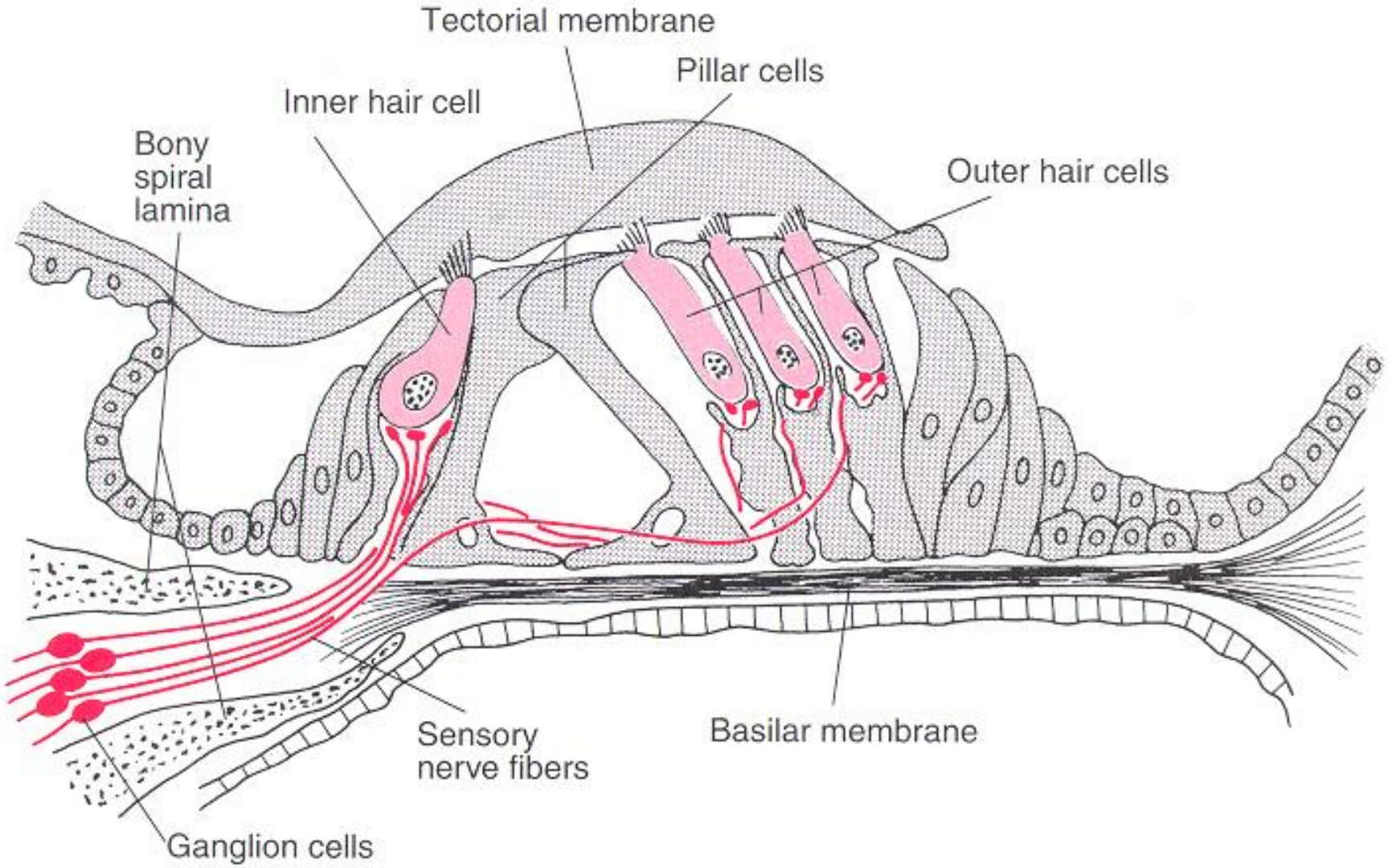

Endolympha
150 mV
[K+]
[Na+]
+85 mV
Ductus cochlearis
[Na+]
[K+]
0 mV
Scala tympani
Perilympha

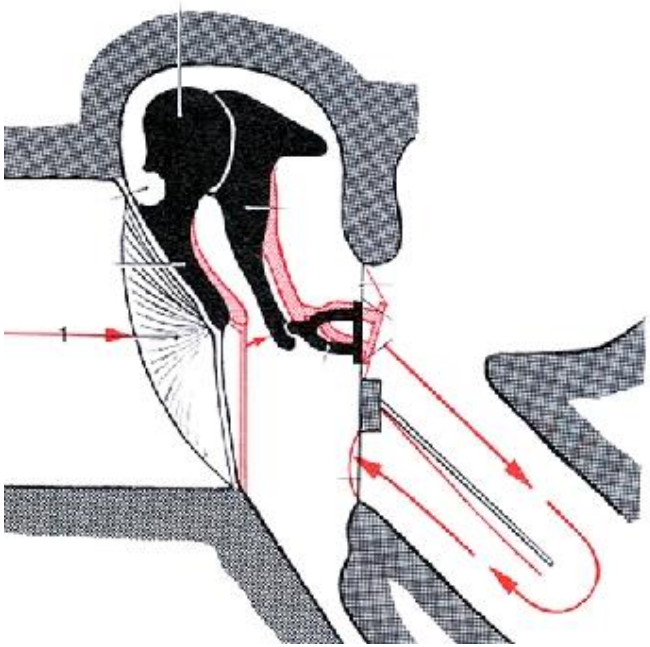

Endolympha
Stereociliumok
K+
-70 mV
Corti-lympha
afferens végződés

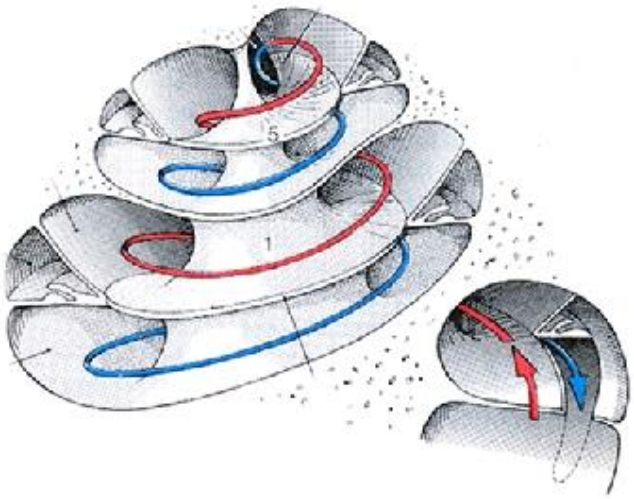

Endolympha
kitérés
K+
Depolarisatio
Ca2+
feszültségfüggő
Ca-csatorna
-55 mV
Transmitter
Corti-lympha
afferens végződés

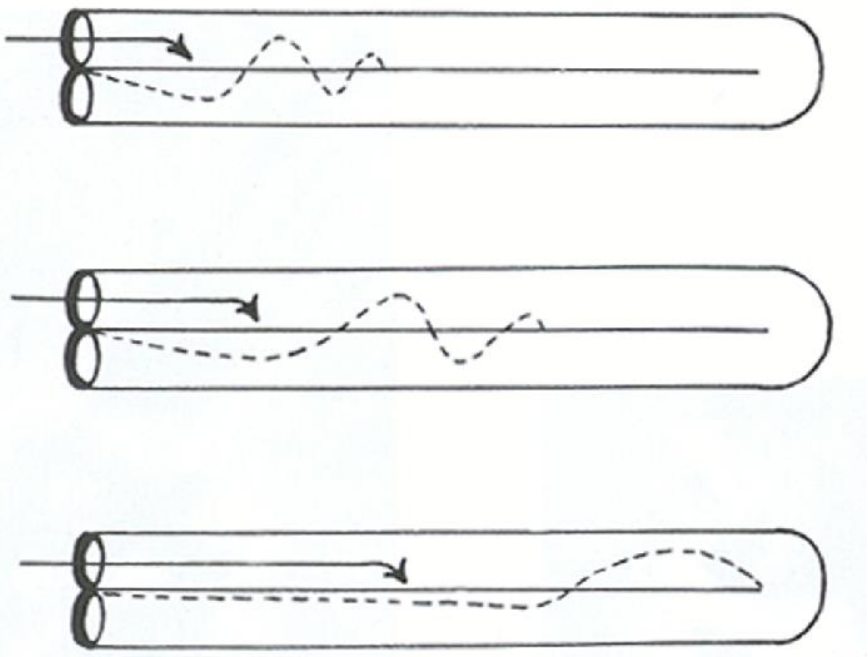

DC
+ 80 mV
IHC
OHC
-45 mV
-70 mV

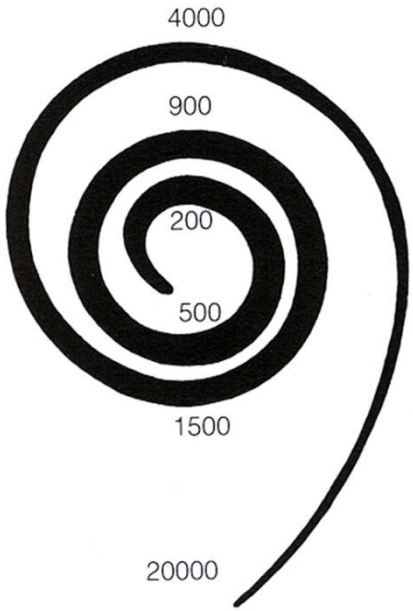

belső szörsejtek
külső szőrsejtek


Tectorial membrane
Pillar cells
Inner hair cell
Bony spiral lamina
Outer hair cells
Sensory nerve fibers
Basilar membrane
Ganglion cells







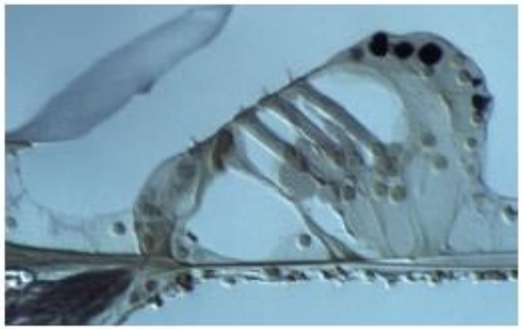

4000
900
200
500
1500
20000

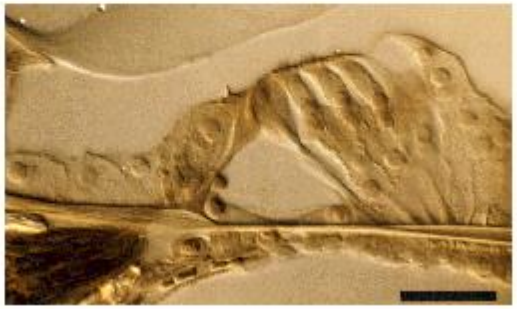
György Békésy 1961. Nobel Prize

The tonotopic organisation of the cochlea

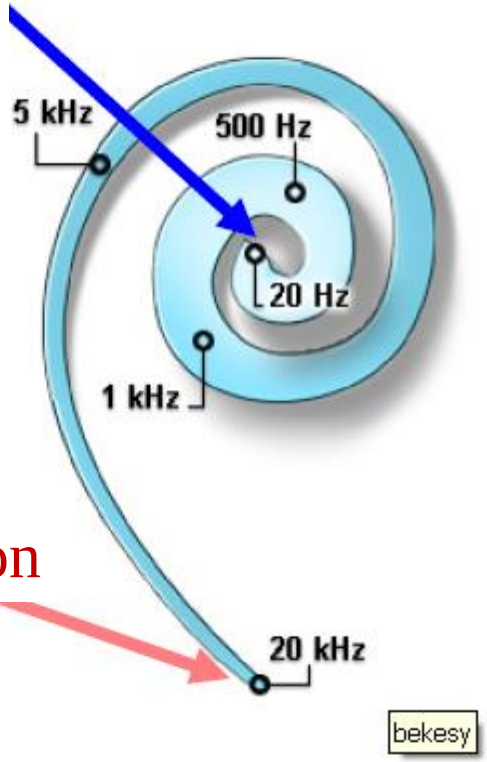
Frequency encoding

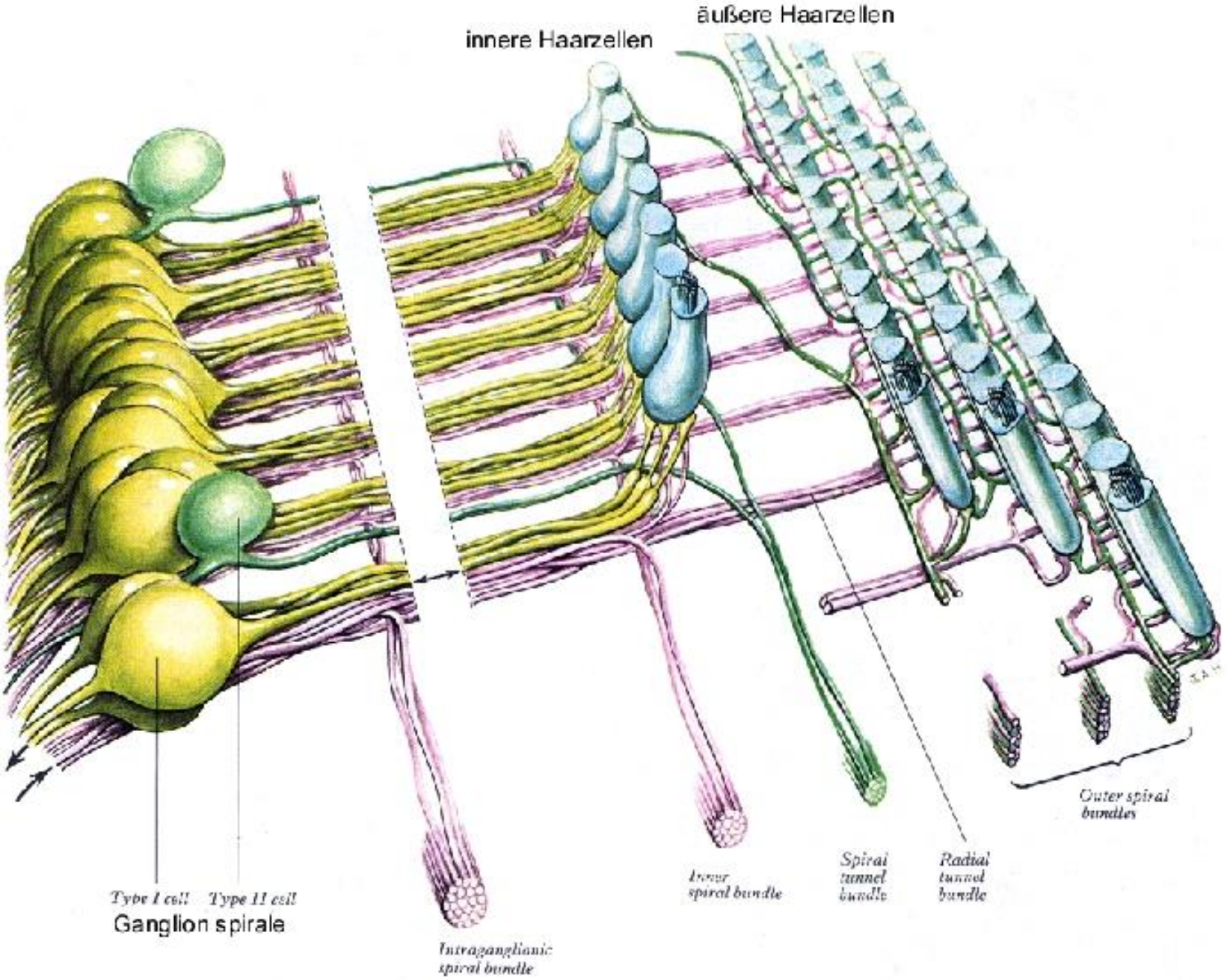
Apical region





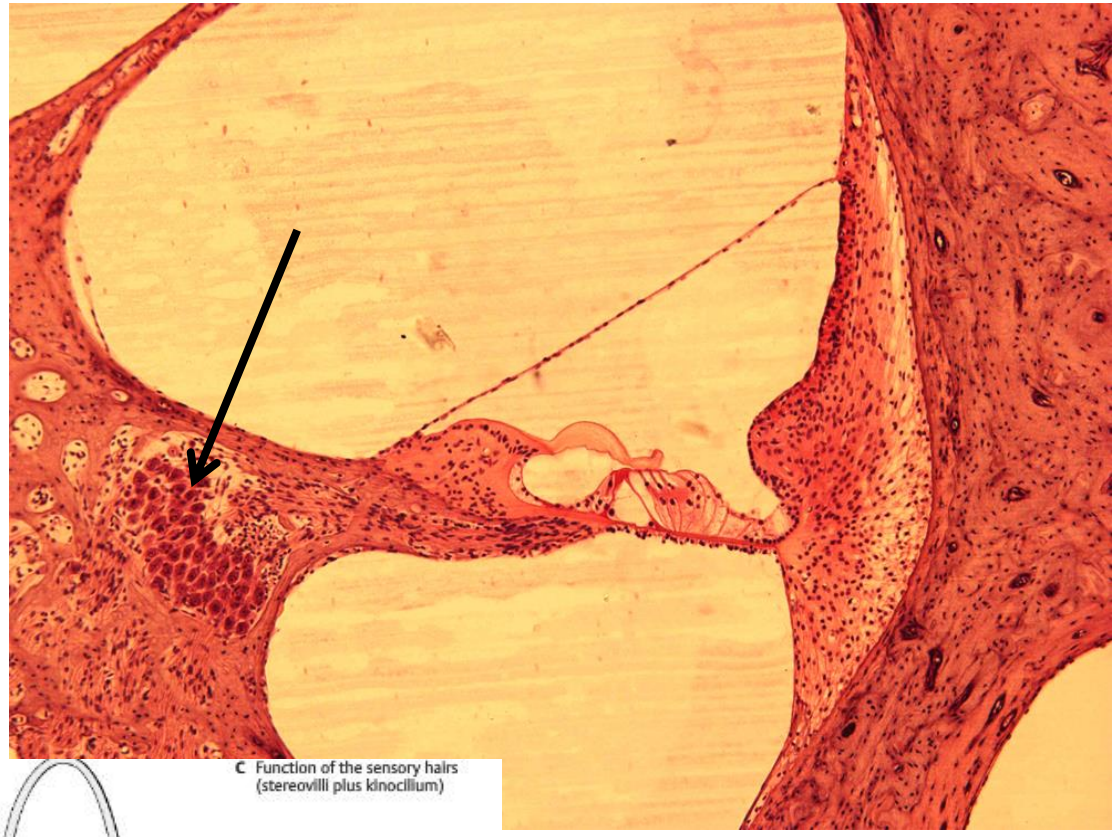
Basal region



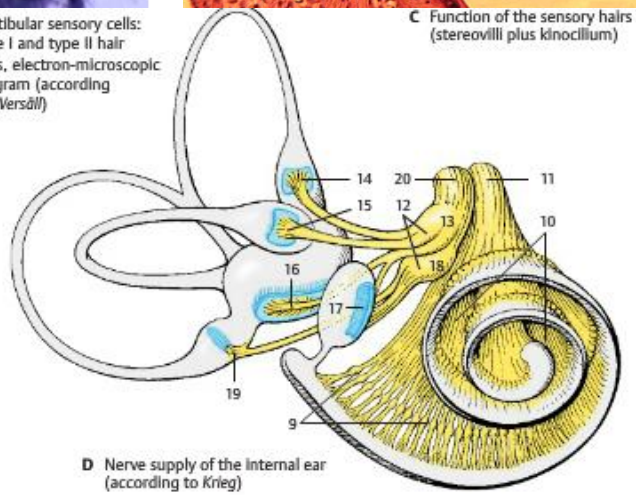

äußere Haarzellen
innere Haarzellen
Type I cell
Type II cell
Ganglion spirale
Intraganglionic spiral bundle
Inner spiral bundle
Spiral tunnel bundle
Radial tunnel bundle
Outer spiral bundles

Spiral ganglion

Vestibular sensory cells: type I and type II hair cells, electron-microscopic diagram (according to *Wersäll*)

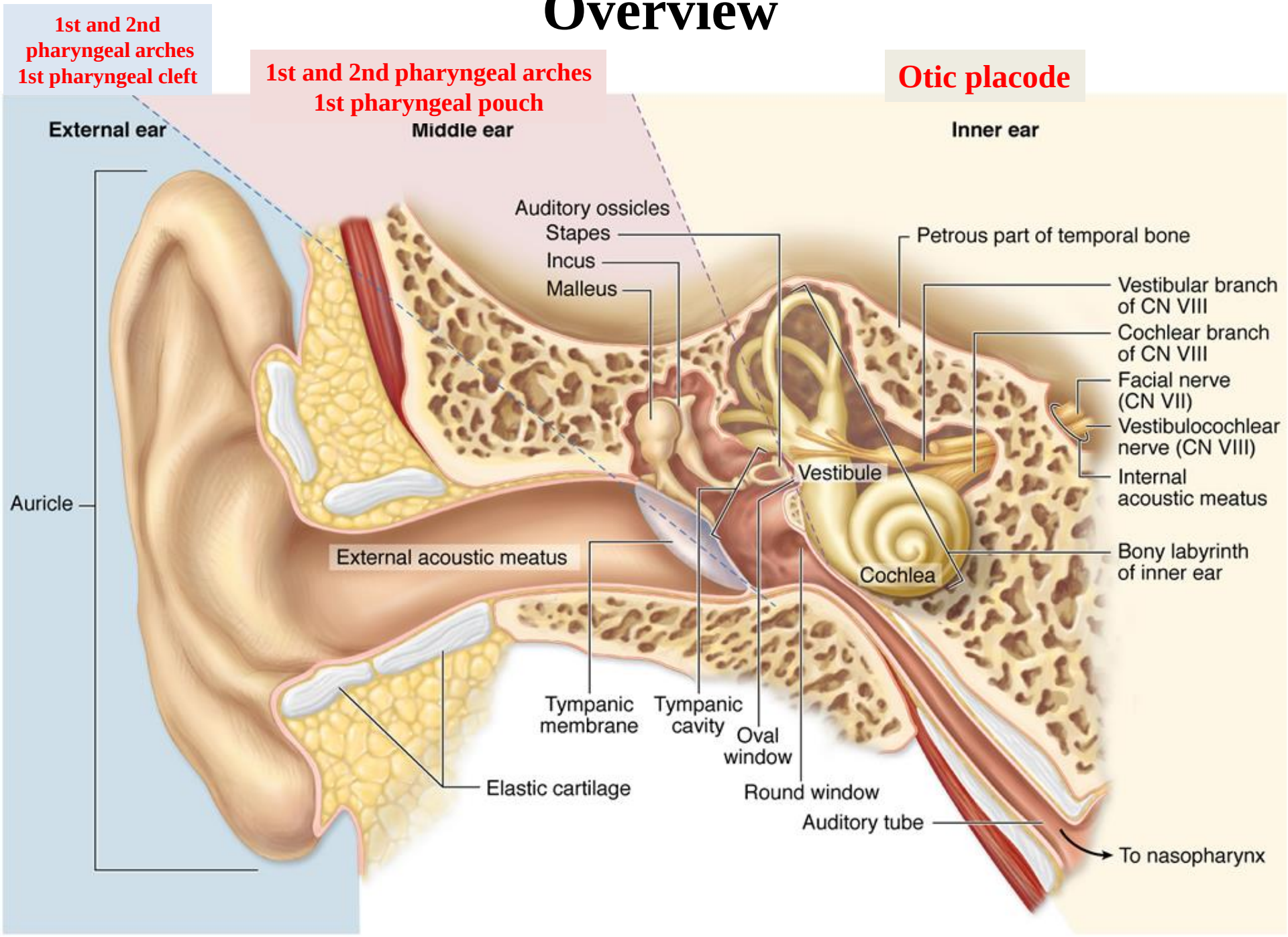


C Function of the sensory hairs (stereovilli plus kinocilium)



D Nerve supply of the internal ear (according to *Krieg*)

Overview


1st and 2nd pharyngeal arches
1st pharyngeal cleft
1st and 2nd pharyngeal arches
1st pharyngeal pouch
Otic placode
External ear
Middle ear
Inner ear
Auditory ossicles
Stapes
Incus
Malleus
Petrous part of temporal bone
Vestibular branch of CN VIII
Cochlear branch of CN VIII
Facial nerve (CN VII)
Vestibulocochlear nerve (CN VIII)
Internal acoustic meatus
Vestibule
Auricle
External acoustic meatus
Cochlea
Bony labyrinth of inner ear
Tympanic membrane
Tympanic cavity
Oval window
Round window
Elastic cartilage
Auditory tube
To nasopharynx

Ectodermal placodes

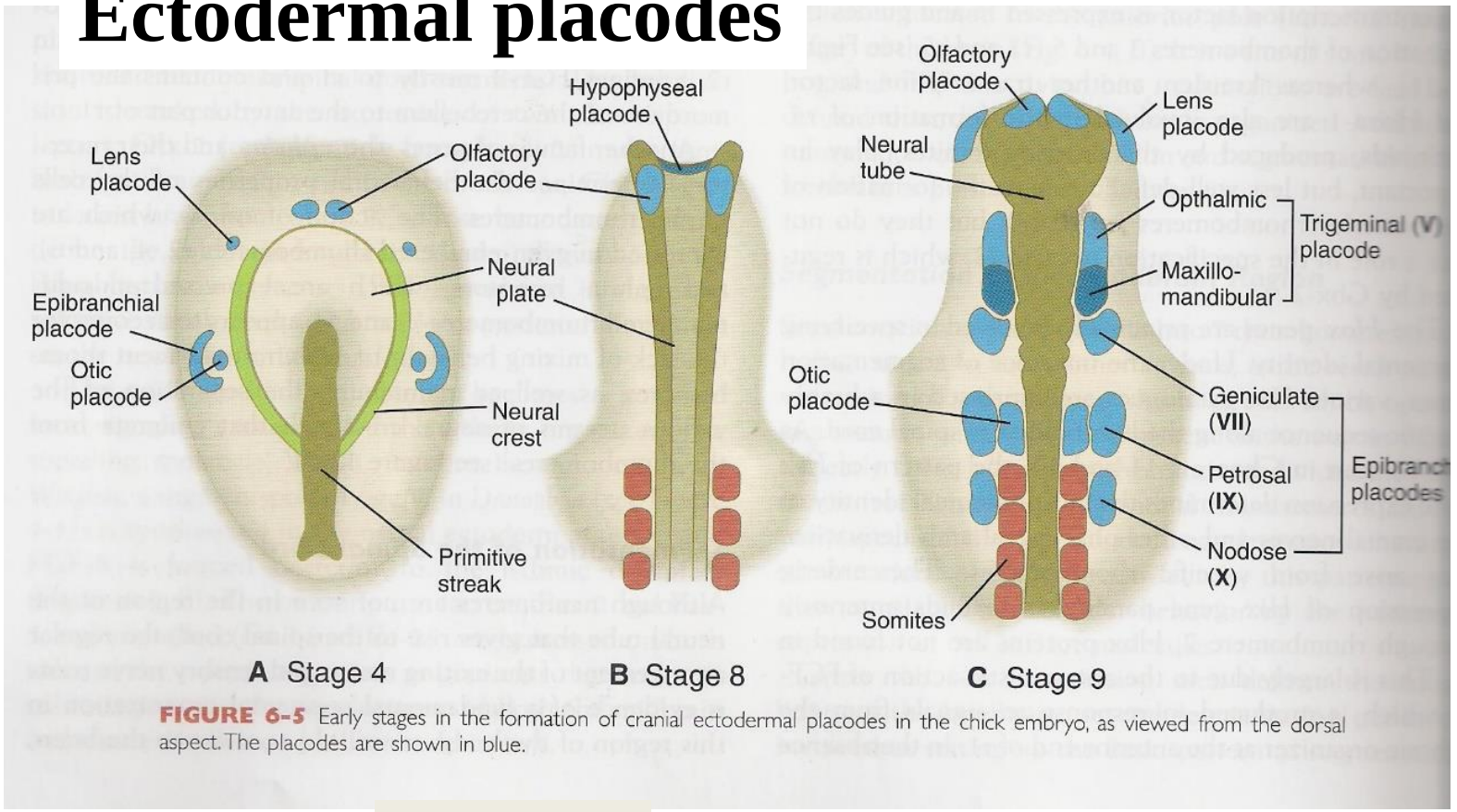
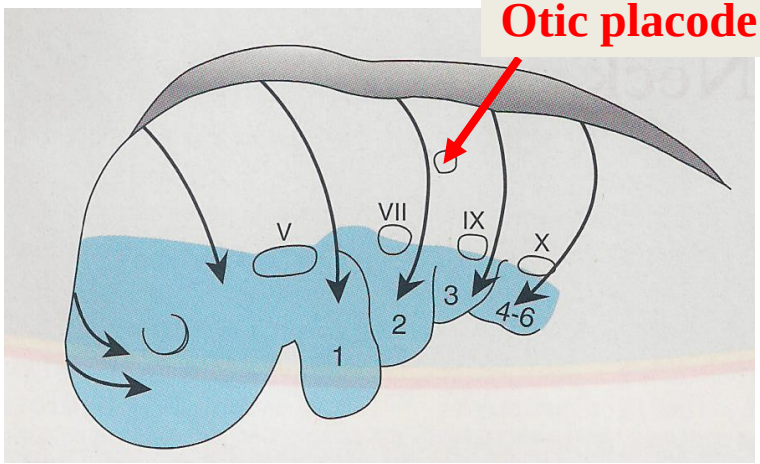


FIGURE 6-5 Early stages in the formation of cranial ectodermal placodes in the chick embryo, as viewed from the dorsal aspect. The placodes are shown in blue.



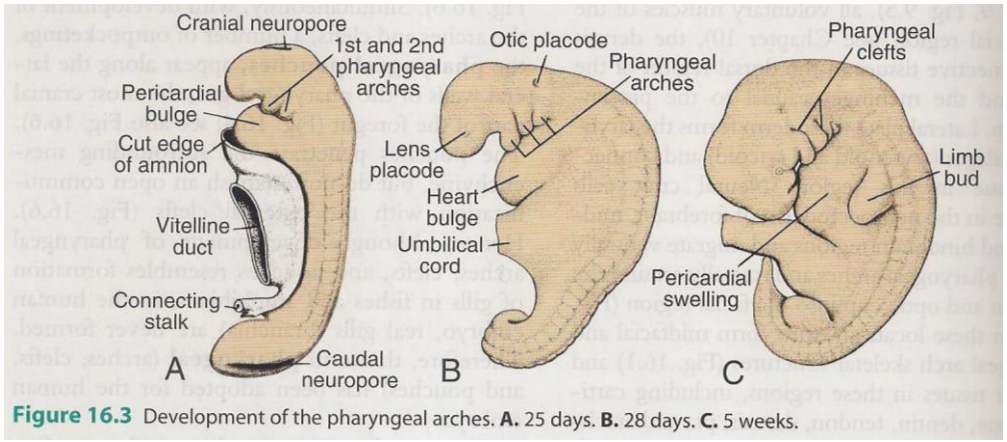


Figure 16.3 Development of the pharyngeal arches. **A.** 25 days. **B.** 28 days. **C.** 5 weeks.

Development of the inner ear

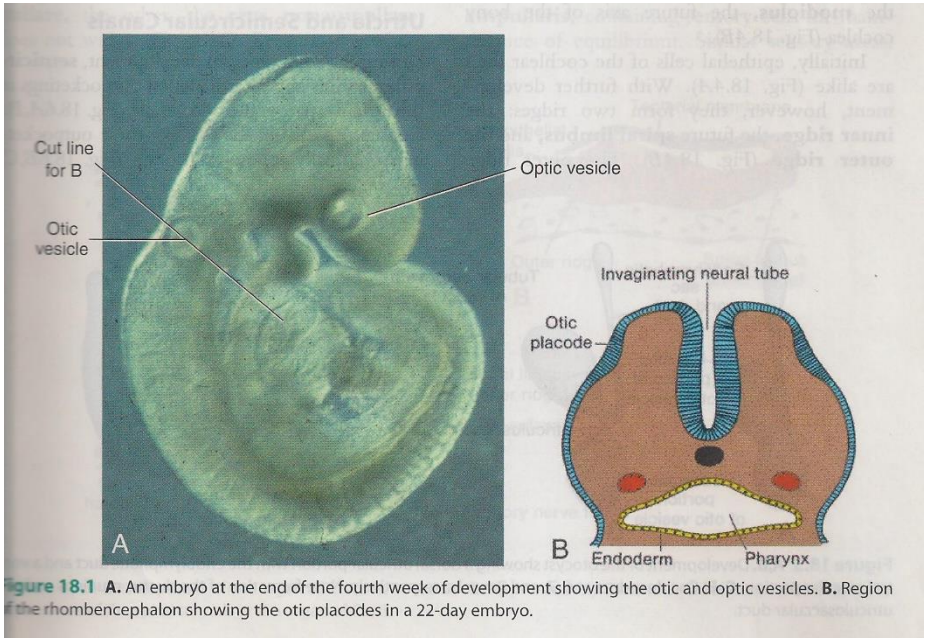


Figure 18.1 **A.** An embryo at the end of the fourth week of development showing the otic and optic vesicles. **B.** Region of the rhombencephalon showing the otic placodes in a 22-day embryo.

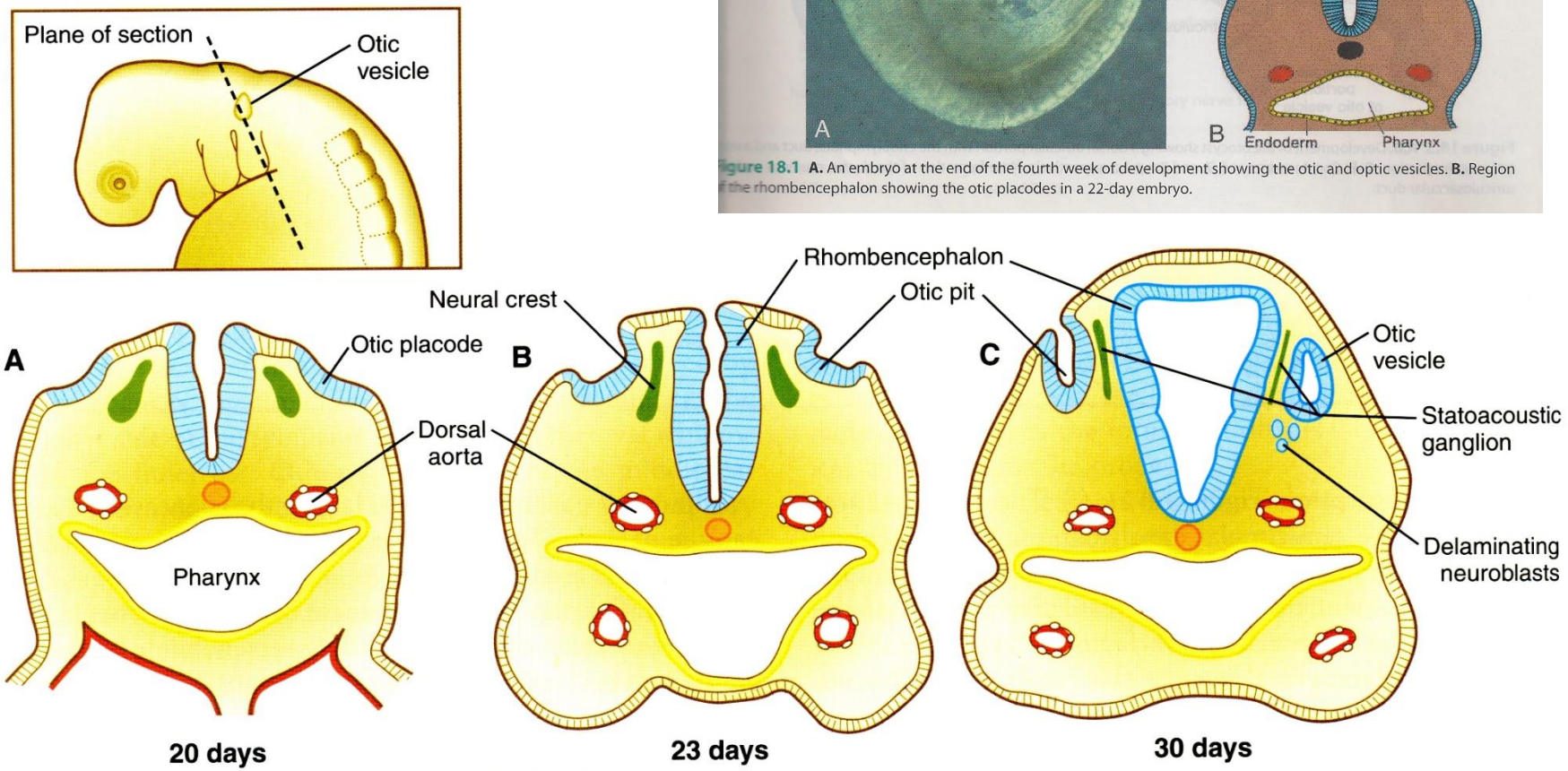
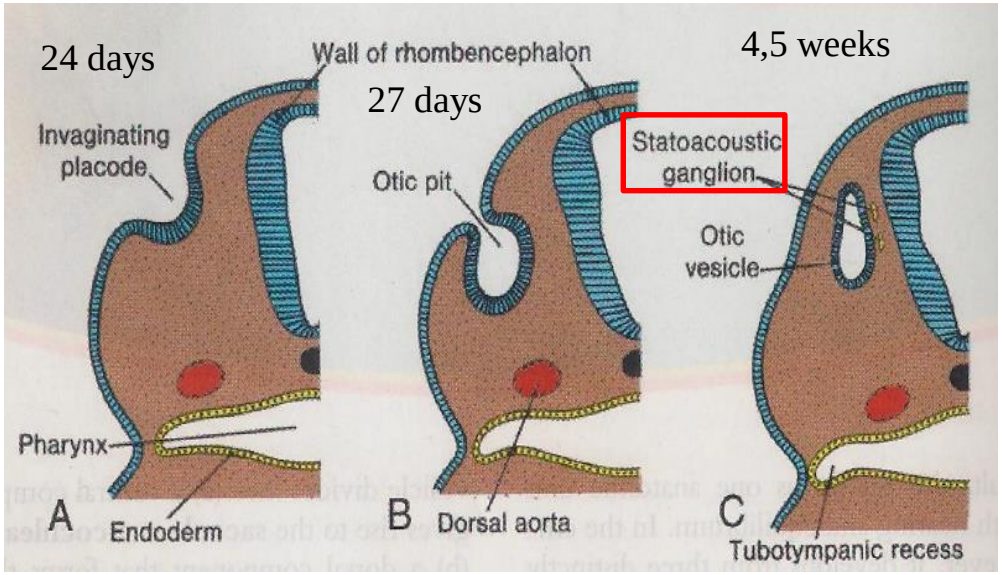
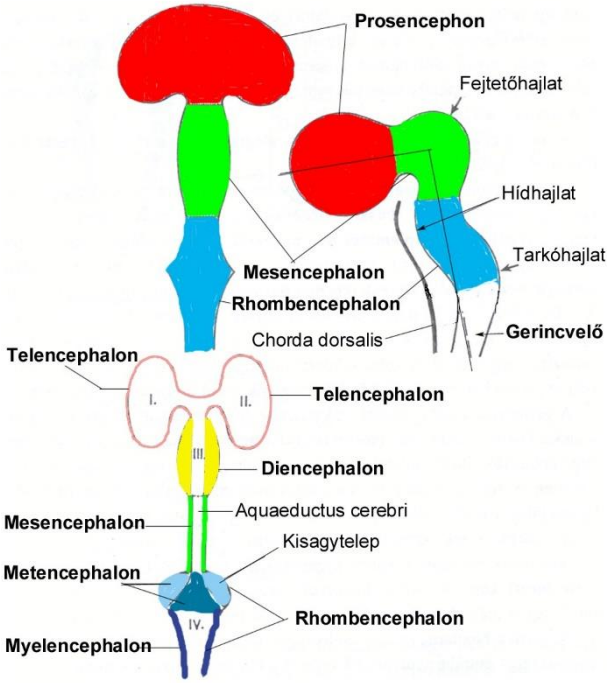
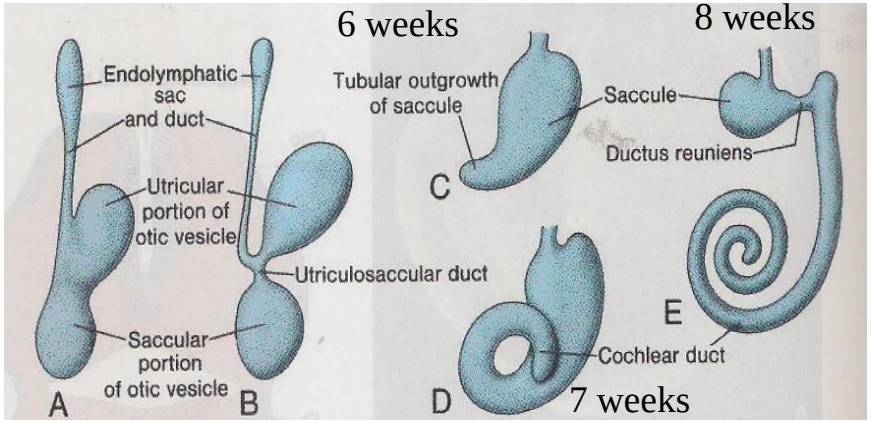


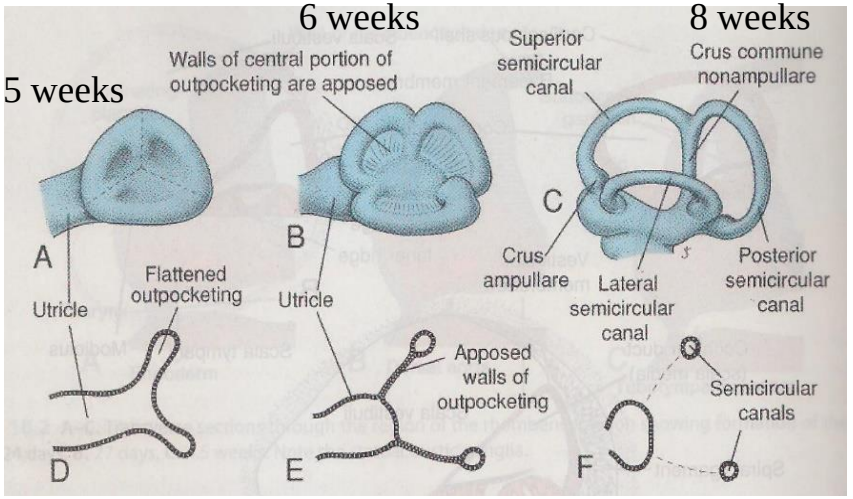
FIGURE 13-20 Formation of the otic vesicles from thickened otic placodes.

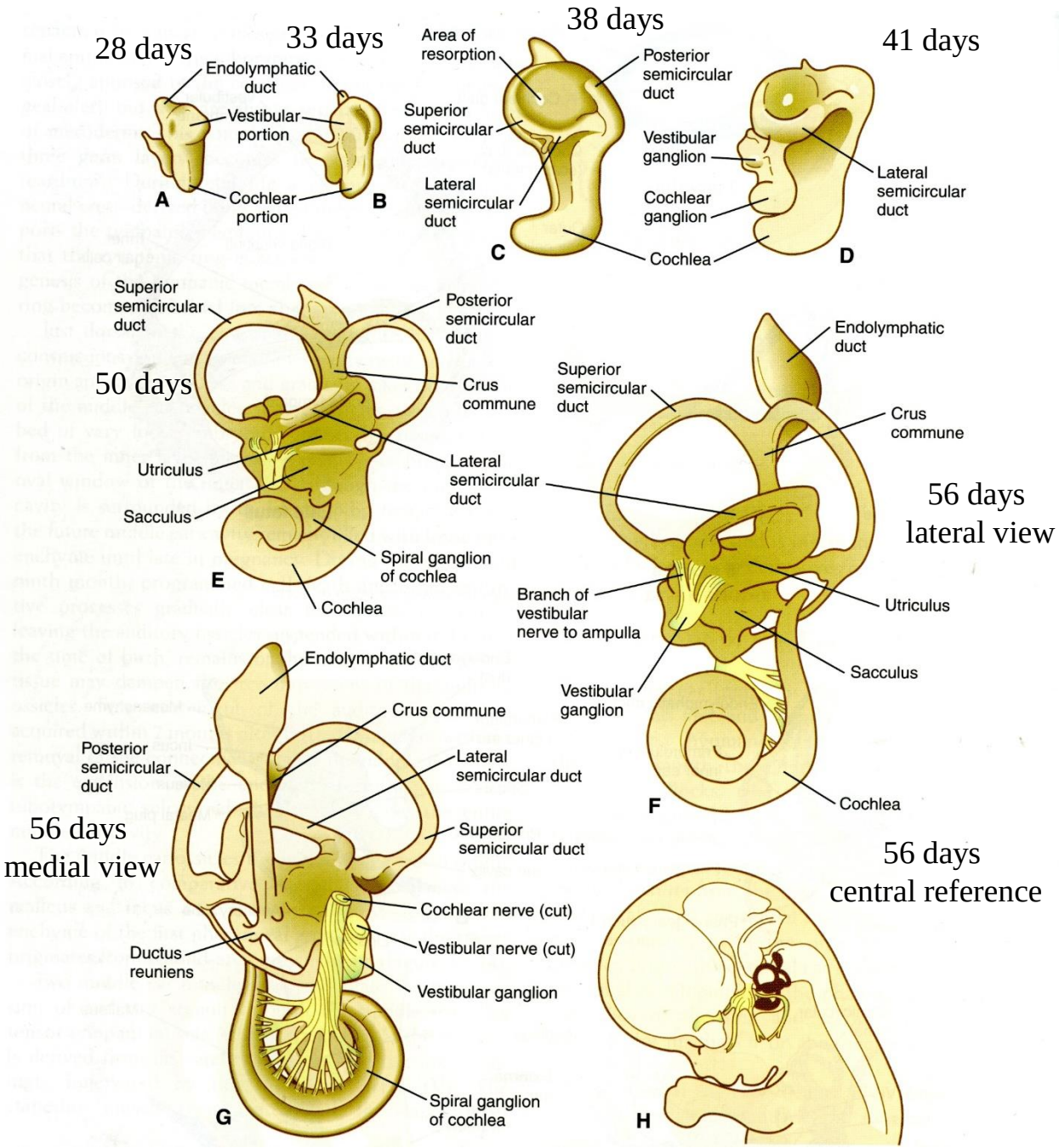
Development of the inner ear










28 days
33 days
38 days
41 days
Endolymphatic duct
Vestibular portion
Cochlear portion
A
B
Area of resorption
Superior semicircular duct
Lateral semicircular duct
Posterior semicircular duct
Vestibular ganglion
Cochlear ganglion
Cochlea
C
D
Lateral semicircular duct
50 days
Superior semicircular duct
Posterior semicircular duct
Crus commune
Utriculus
Sacculus
Lateral semicircular duct
Spiral ganglion of cochlea
Cochlea
E
56 days lateral view
Endolymphatic duct
Superior semicircular duct
Crus commune
Branch of vestibular nerve to ampulla
Utriculus
Sacculus
Vestibular ganglion
Cochlea
F
56 days medial view
Endolymphatic duct
Crus commune
Posterior semicircular duct
Lateral semicircular duct
Superior semicircular duct
Cochlear nerve (cut)
Vestibular nerve (cut)
Ductus reuniens
Vestibular ganglion
Spiral ganglion of cochlea
G
56 days central reference
H

Development of the organ of Corti

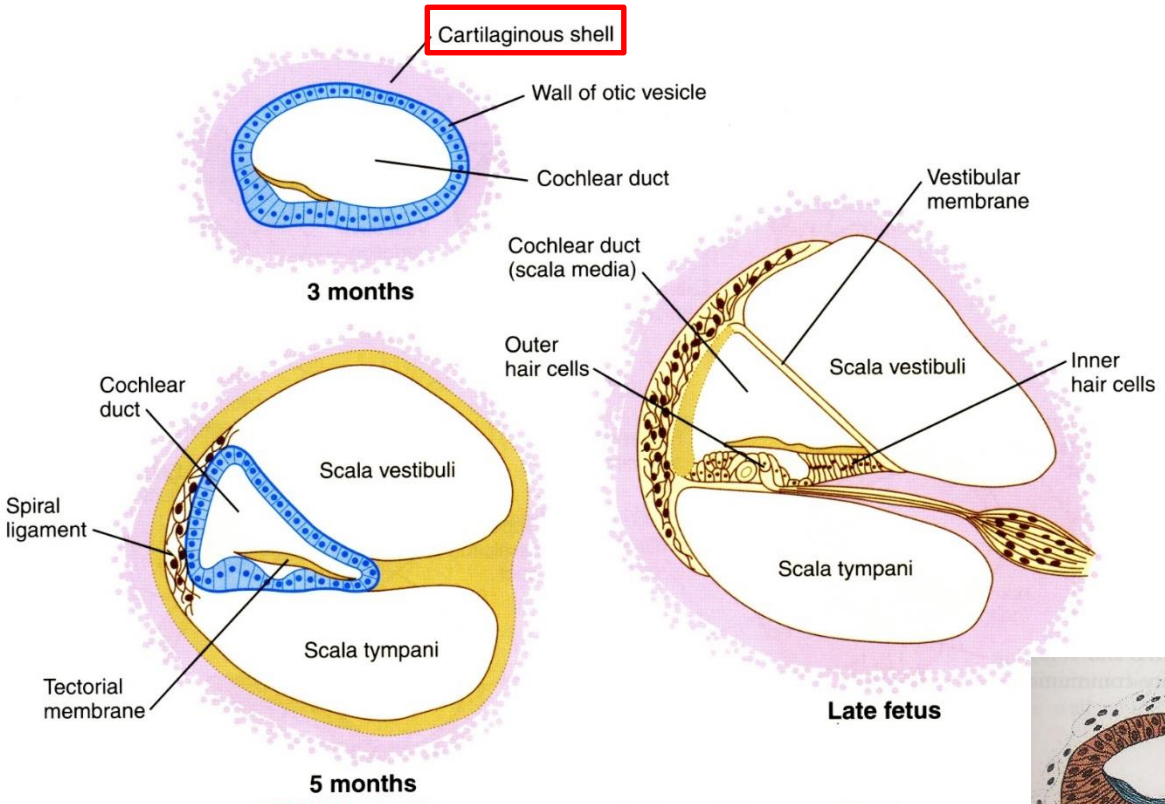
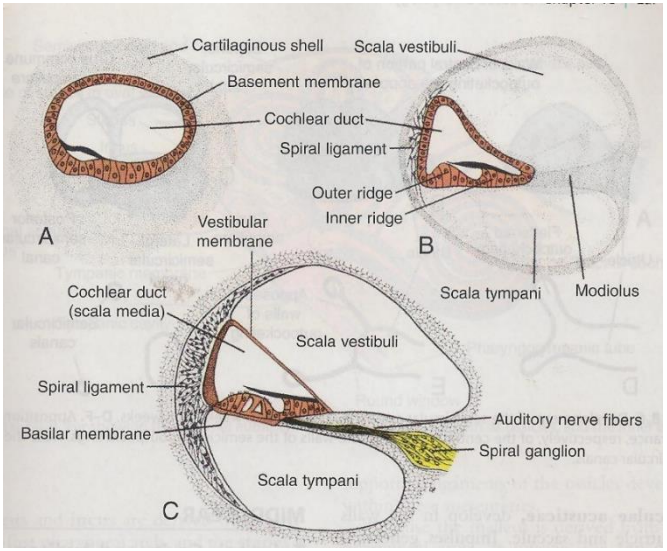
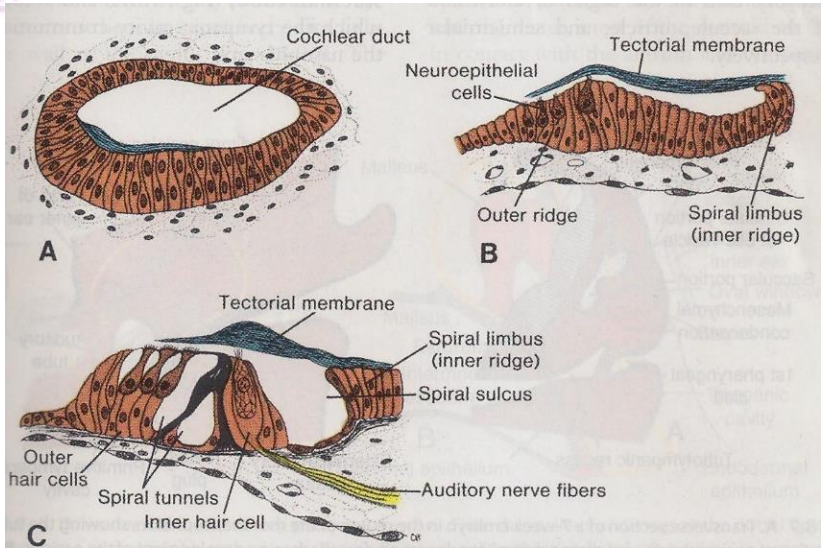
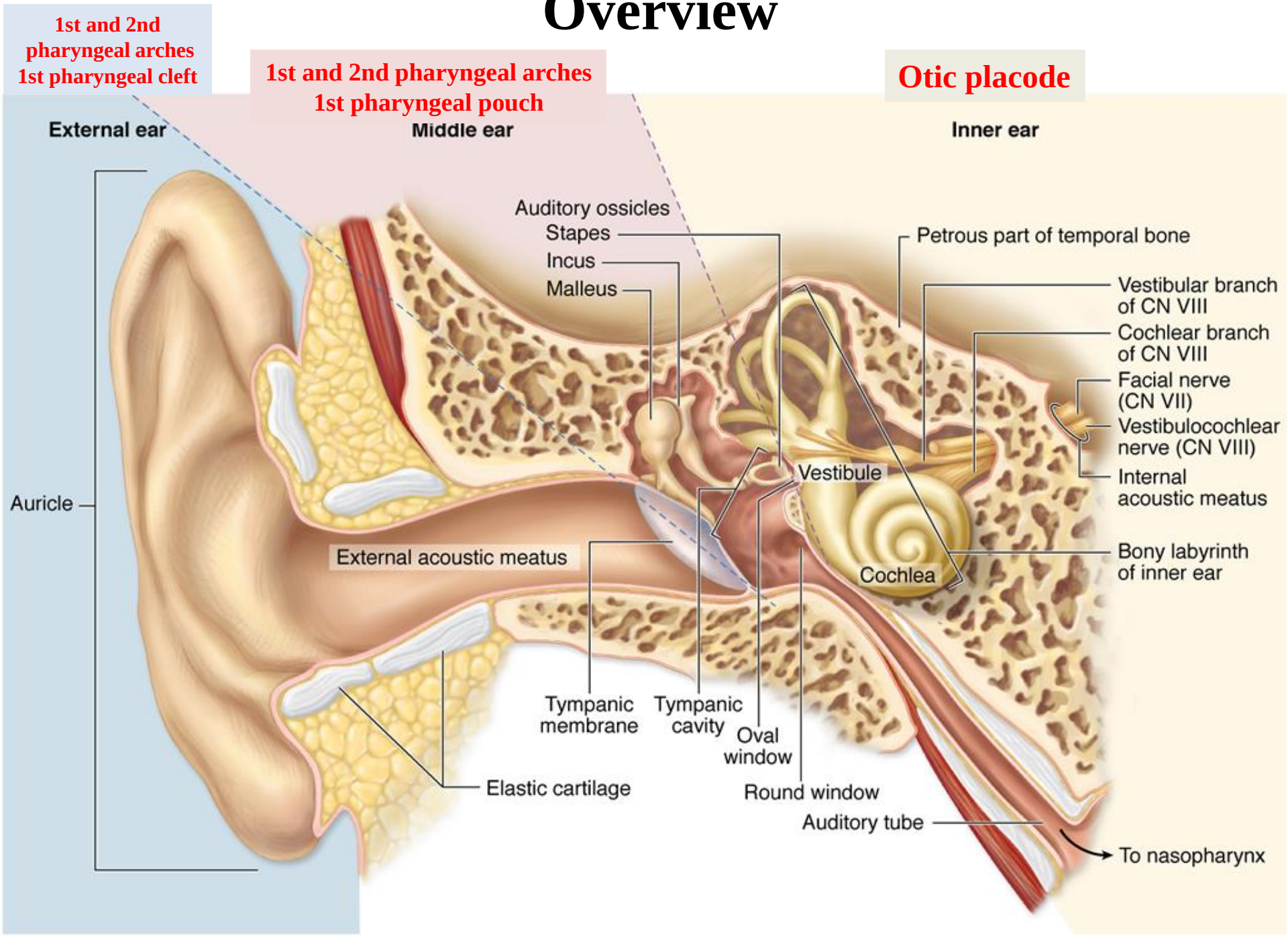


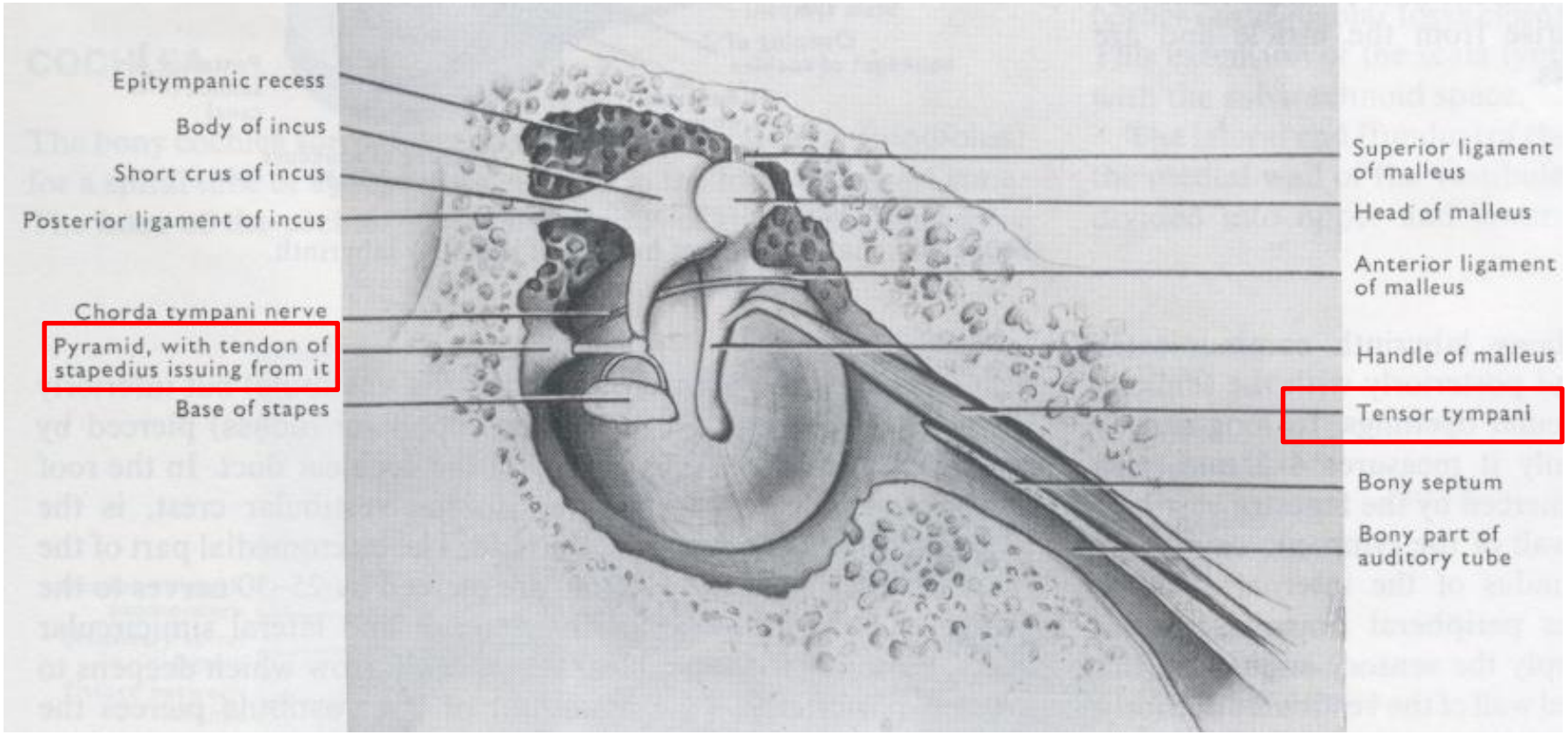
FIGURE 13-22 Cross sections through the developing organ of Corti.





Overview


1st and 2nd pharyngeal arches
1st pharyngeal cleft
1st and 2nd pharyngeal arches
1st pharyngeal pouch
Otic placode
External ear
Middle ear
Inner ear
Auditory ossicles
Stapes
Incus
Malleus
Petrous part of temporal bone
Vestibular branch of CN VIII
Cochlear branch of CN VIII
Facial nerve (CN VII)
Vestibulocochlear nerve (CN VIII)
Internal acoustic meatus
Vestibule
Auricle
External acoustic meatus
Cochlea
Bony labyrinth of inner ear
Tympanic membrane
Tympanic cavity
Oval window
Round window
Elastic cartilage
Auditory tube
To nasopharynx

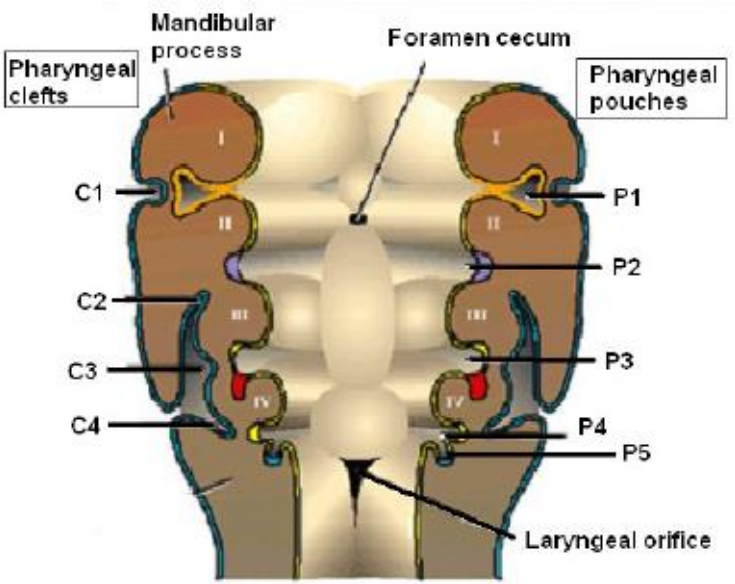

Epitympanic recess
Body of incus
Short crus of incus
Posterior ligament of incus
Chorda tympani nerve
Pyramid, with tendon of stapedius issuing from it
Base of stapes
Superior ligament of malleus
Head of malleus
Anterior ligament of malleus
Handle of malleus
Tensor tympani
Bony septum
Bony part of auditory tube

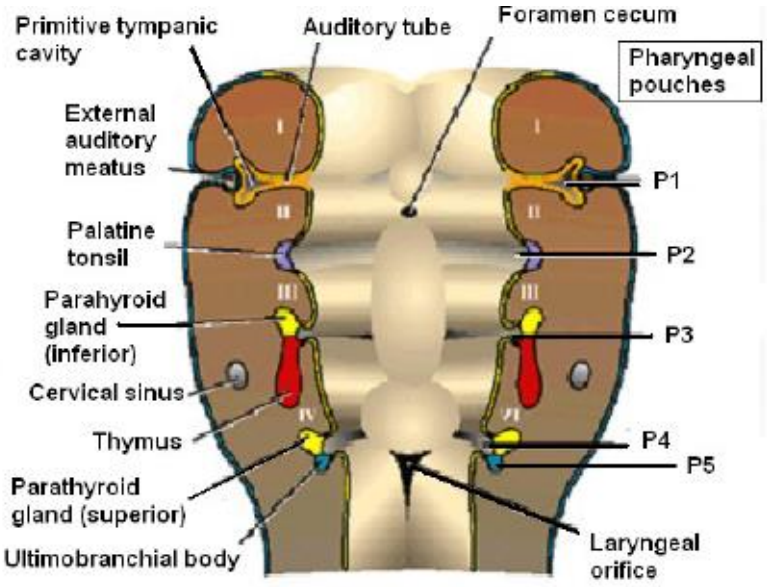
Branchial Apparatus

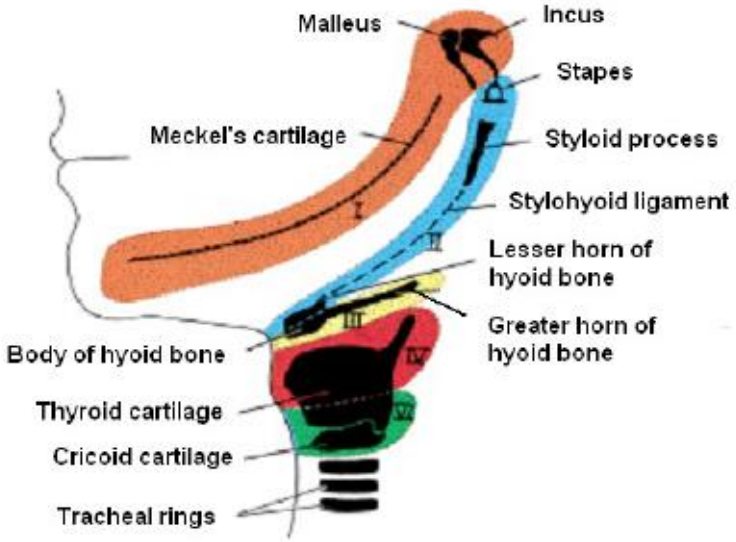
Made by: dr. Károly Altdorfer and dr. János Hanics - Semmelweis University Medical School - Department of Anatomy, Histology and Embryology, Budapest, 2009.

	Mesenchyme					Ectoderm		Endoderm
	Artery	**Cartilage[1]**	**Bone[1]**	**Ligament[1]**	**Muscle[2]**	**Nerve**		
Pharyn-geal arch							**Clefts**	**Pouches**
I. (mandi-bular)	(Maxillary artery)	Meckel's *(as model for mandible)*	Mandible *(intramembranous ossification);* Malleus; Incus; **(*)**	Sphenomandi-bular lig.; Ant. lig. of malleus	**Mm. of mastification;** Tensor tympani; Tensor veli palatini; Mylohyoid; Digastric ant. belly;	Mandibular nerve (V/3.)		
							C1: External ac. meatus; ext. epithelium of tympanic membrane	**P1:** Auditory tube; Tympanic cavity; Int. epithelium of tympanic membrane
II. (hyoid)	(Stapedial artery; Hyoid artery)	Reichert's	Stapes; Styloid process; Hyoid (lesser horn and upper part of body)	Stylohyoid lig.	**Muscles of facial expression**; Stylohyoid; Digastric post. belly; Stapedius; Platysma (from Opercular proc.)	Facial nerve (VII.)		
							C2: (Cervical sinus)	**P2:** Epithelium of tonsillar fossa
III.	Internal carotid (prox. part)		Hyoid (greater horn and lower part of body)		Pharynx (upper part); Stylopharyngeus	Glossopharyngeal nerve (IX.)		
							C3: (Cervical sinus; Cervical vesicula)	**P3:** (Thymus) Inferior parathyroid glands
IV.	*Left:* Arch of aorta; *Right:* Right subclavian artery (prox. part)	Thyroid cartilage			Pharynx (lower part); Larynx: cricothyroid	Vagus nerve (X.) (Superior laryngeal nerve)		
							C4: (Cervical sinus)	**P4:** Thymus; Superior parathyroid glands
V. (**)		Thyroid cartilage			Phaynx and larynx muscles (n. XI.: arytenoid)	Vagus nerve (X.) + Accessory nerve (XI.)		
								P5: Ultimobranchial body, C-cells in thyroid gland
VI.	Right: Right pulmonary artery; Left: Left pulmonary artery and ductus art. Botalli	Cricoid cartilage (?)			Larynx muscles ('intrinsic')	Vagus nerve (X.) (Recurent laryngeal nerve)		

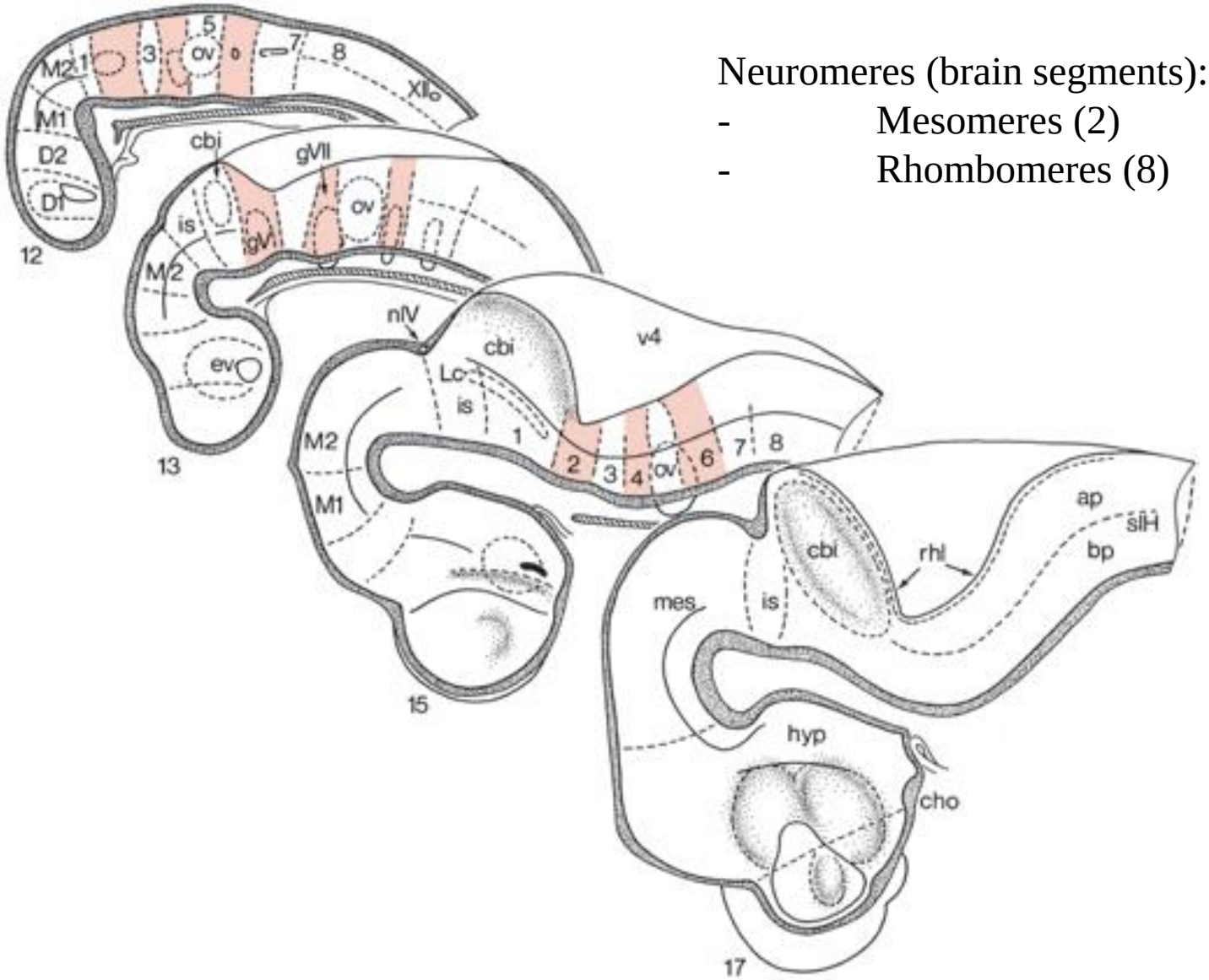
1: derivatives of neural crest (ecto-mesenchyme); **2**: derivatives of paraxial mesoderm or somite (mesoderm); **(*)** partially forms the maxilla (from the maxillary process of the first pharyngeal arch); **(**)** Some authors don't give derivates for fifth pharyngeal arch but mention them at the sixth pharyngeal arch.


Mandibular process
Foramen cecum
Pharyngeal clefts
Pharyngeal pouches
C1
C2
C3
C4
P1
P2
P3
P4
P5
Laryngeal orifice


Primitive tympanic cavity
Auditory tube
Foramen cecum
Pharyngeal pouches
External auditory meatus
Palatine tonsil
Parahyroid gland (inferior)
Cervical sinus
Thymus
Parathyroid gland (superior)
Ultimobranchial body
P1
P2
P3
P4
P5
Laryngeal orifice

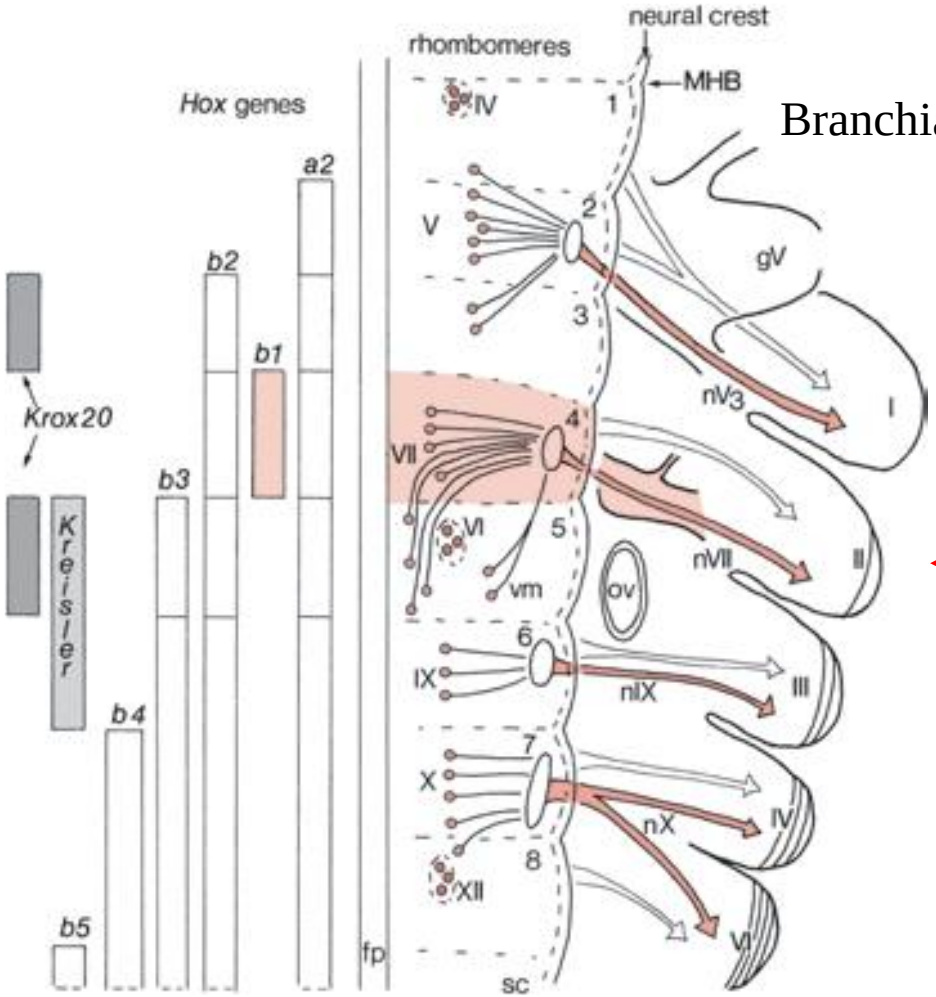

Malleus
Incus
Stapes
Meckel's cartilage
Styloid process
Stylohyoid ligament
Lesser horn of hyoid bone
Greater horn of hyoid bone
Body of hyoid bone
Thyroid cartilage
Cricoid cartilage
Tracheal rings

Development of the brainstem



Neuromeres (brain segments):

- Mesomeres (2)
- Rhombomeres (8)



Branchial apparatus

Tensor tympani m.

Stapedius m.

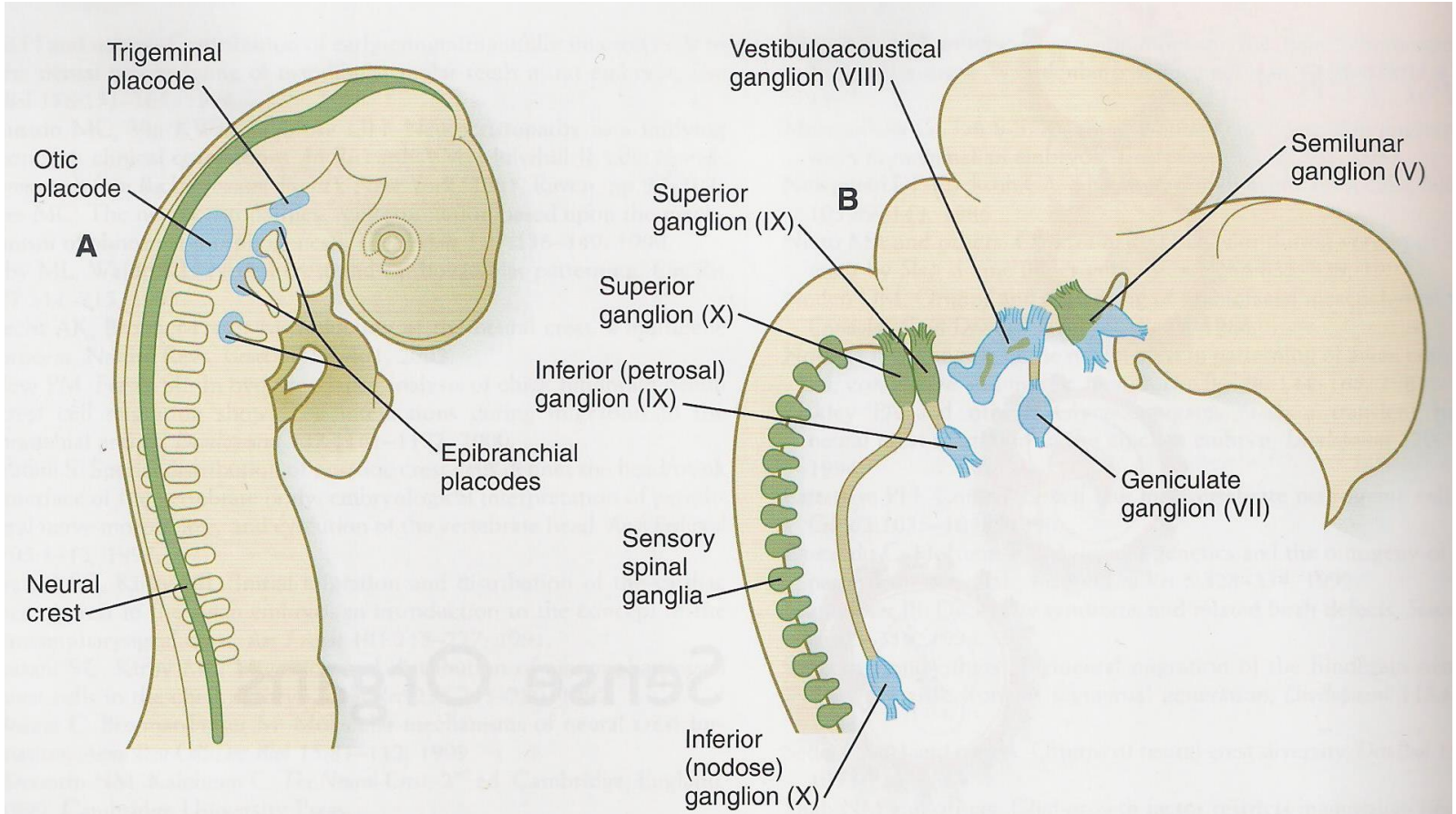


FIGURE 13-1 Ectodermal placodes and neural crest in the formation of sensory ganglia of cranial and spinal nerves in the chick embryo. **A,** At 2 days. **B,** At 8 days. Neural crest is shown in green, placodes in blue. (Modified from LeDouarin N and others: *Trends Neurosci* 9[4]:175–180, 1986.)

Branchial Apparatus

Made by: dr. Károly Altdorfer and dr. János Hanics - Semmelweis University Medical School - Department of Anatomy, Histology and Embryology, Budapest, 2009.

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							C1: External ac. meatus; ext. epithelium of tympanic membrane	**P1:** Auditory tube; Tympanic cavity; Int. epithelium of tympanic membrane
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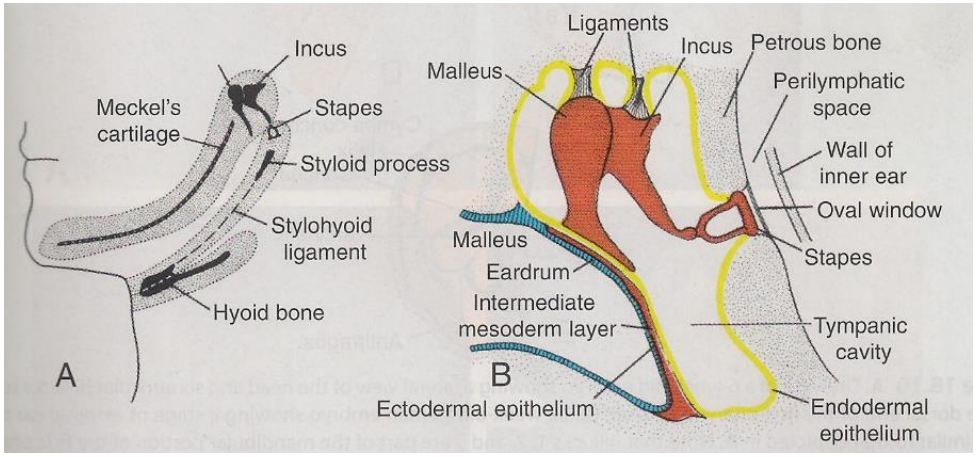
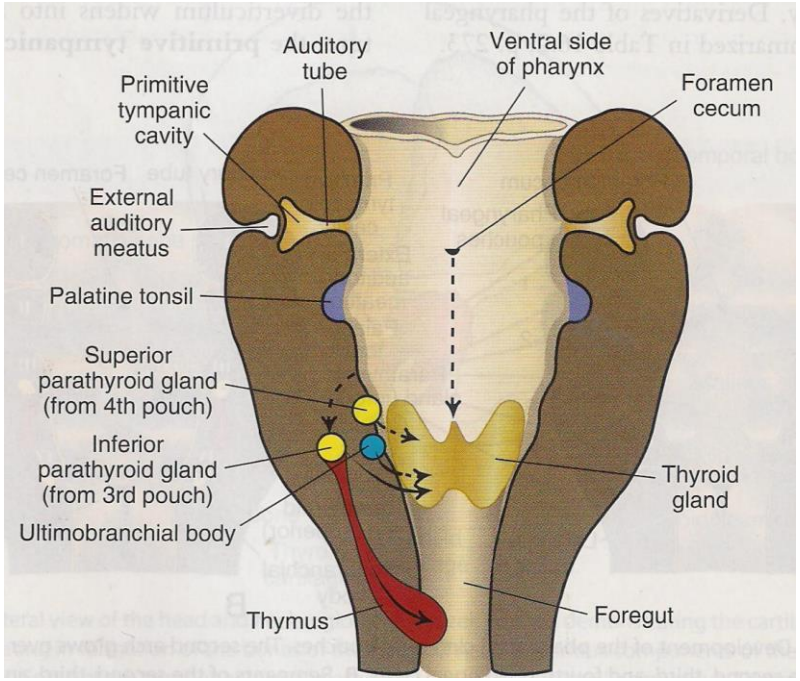
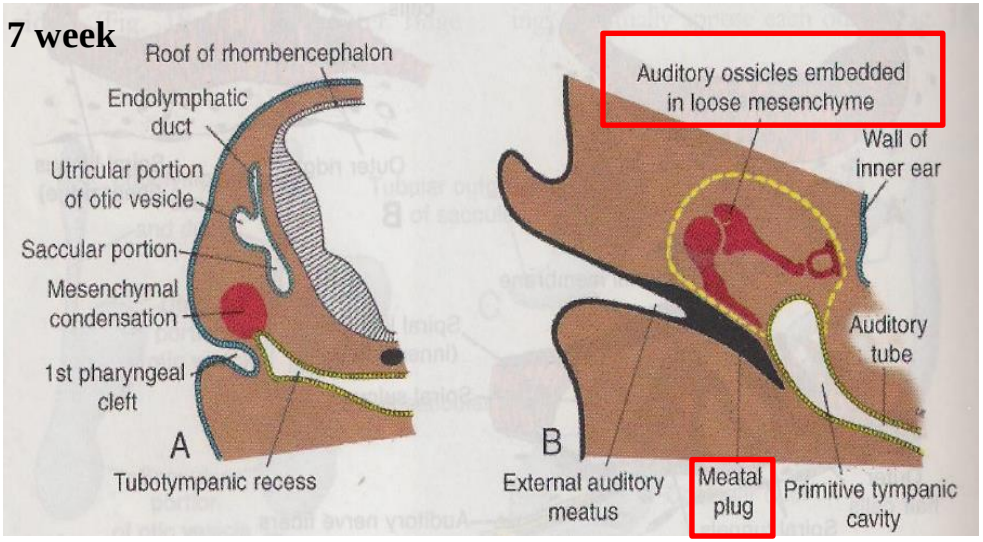
							C2: (Cervical sinus)	**P2:** Epithelium of tonsillar fossa
III.	Internal carotid (prox. part)		Hyoid (greater horn and lower part of body)		Pharynx (upper part); Stylopharyngeus	Glossopharyngeal nerve (IX.)		
							C3: (Cervical sinus; Cervical vesicula)	**P3:** (Thymus) Inferior parathyroid glands
IV.	*Left:* Arch of aorta; *Right:* Right subclavian artery (prox. part)	Thyroid cartilage			Pharynx (lower part); Larynx: cricothyroid	Vagus nerve (X.) (Superior laryngeal nerve)		
							C4: (Cervical sinus)	**P4:** Thymus; Superior parathyroid glands
V. (**)		Thyroid cartilage			Phaynx and larynx muscles (n. XI.: arytenoid)	Vagus nerve (X.) + Accessory nerve (XI.)		
								P5: Ultimobranchial body, C-cells in thyroid gland
VI.	Right: Right pulmonary artery; Left: Left pulmonary artery and ductus art. Botalli	Cricoid cartilage (?)			Larynx muscles ('intrinsic')	Vagus nerve (X.) (Recurent laryngeal nerve)		

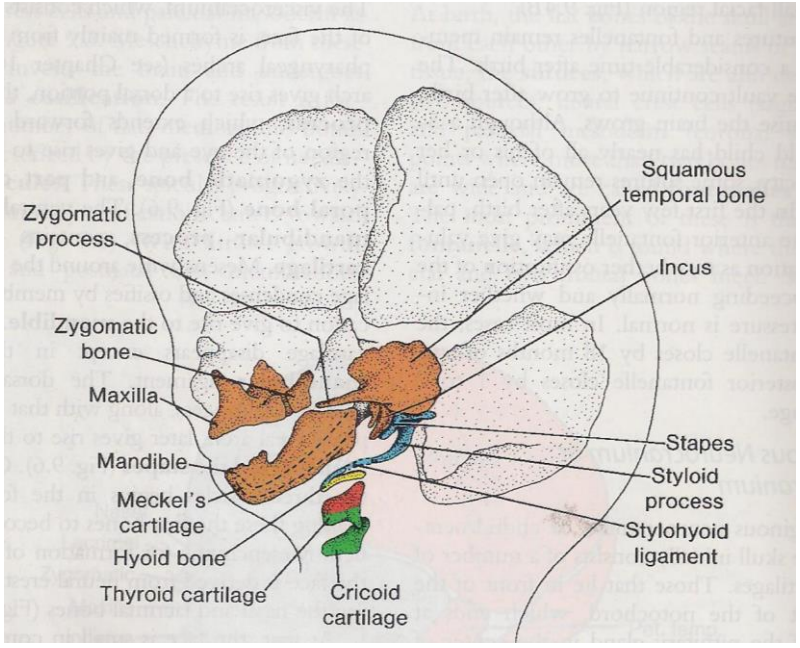
1: derivatives of neural crest (ecto-mesenchyme); **2**: derivatives of paraxial mesoderm or somite (mesoderm); **(*)** partially forms the maxilla (from the maxillary process of the first pharyngeal arch); **(**)** Some authors don't give derivates for fifth pharyngeal arch but mention them at the sixth pharyngeal arch.

Development of the middle and external ear components









Development of the middle ear ossicles and tympanic membrane

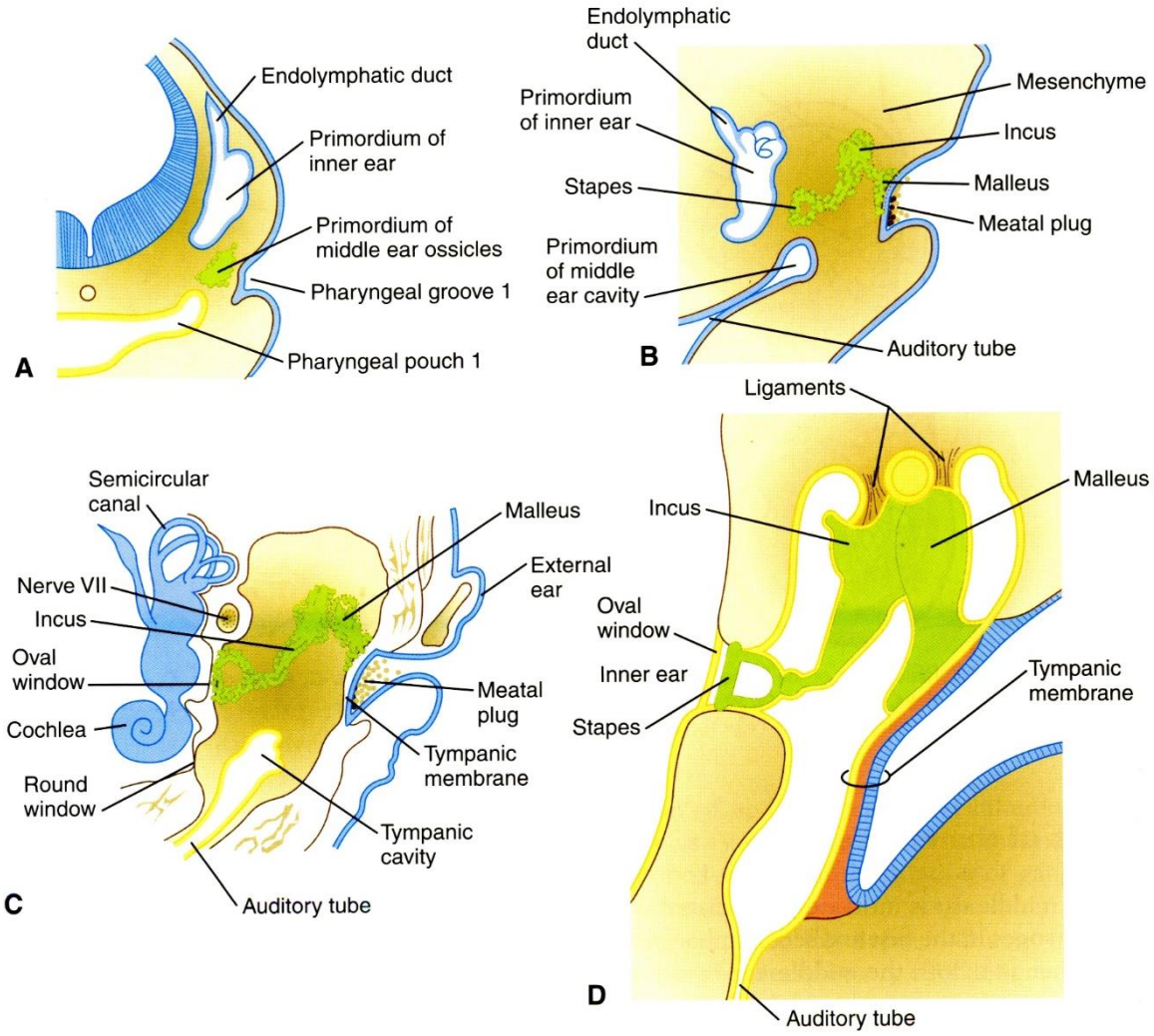


FIGURE 13-23 Stages in development of the middle ear.

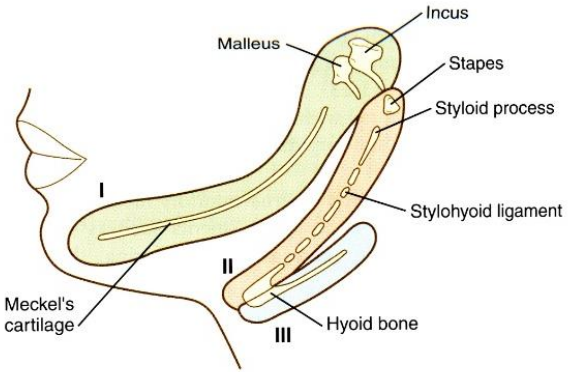


FIGURE 13-24 According to the traditional theory of the formation of the middle ear ossicles, the malleus and incus are derived from arch I and the stapes from arch II.

Development of the auricle

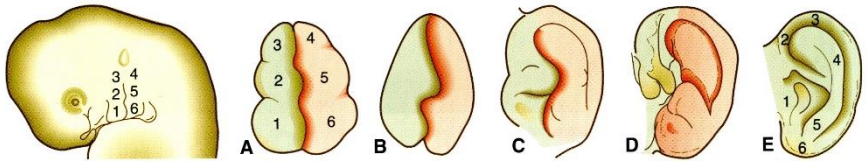
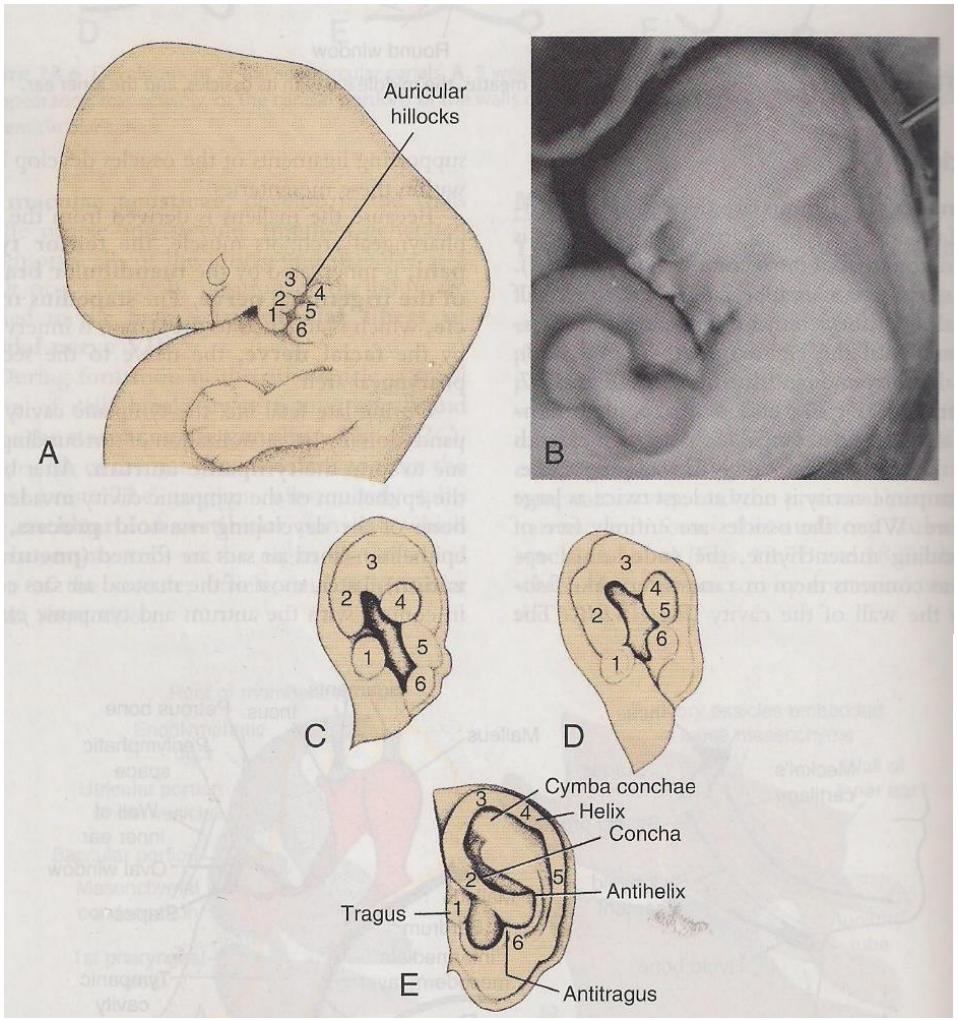


FIGURE 13-25 Stages in development of the external ear. Components derived from the mandibular arch (I) are unshaded; those derived from the hyoid arch (II) are shaded.



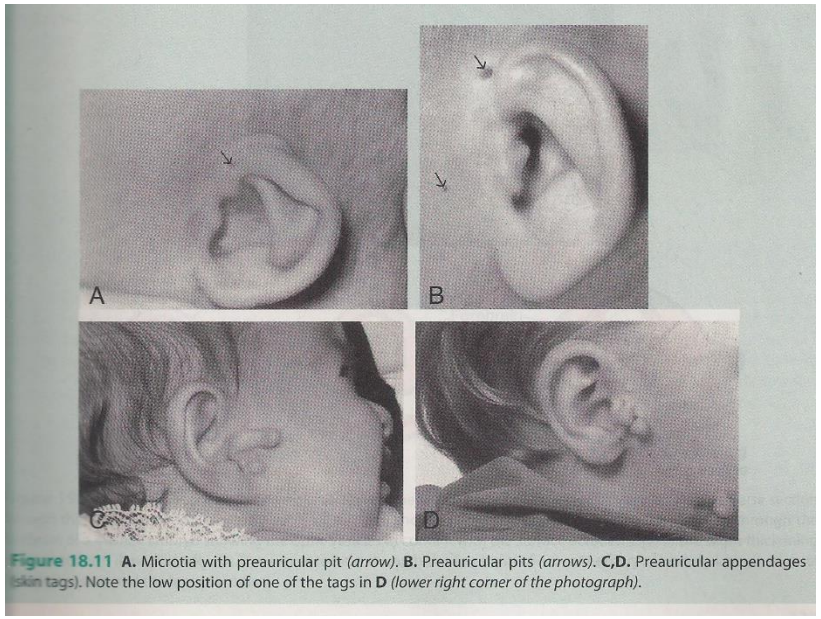


Figure 18.11 **A.** Microtia with preauricular pit *(arrow)*. **B.** Preauricular pits *(arrows)*. **C,D.** Preauricular appendages (skin tags). Note the low position of one of the tags in **D** *(lower right corner of the photograph)*.

FIGURE 13-26 **A,** Auricular anomalies and tags associated with the mandibular arch (I) component of the external ear. **B,** Anotia. The external ear is represented only by a couple of small tags. (Courtesy M Barr, Ann Arbor, Mich.)

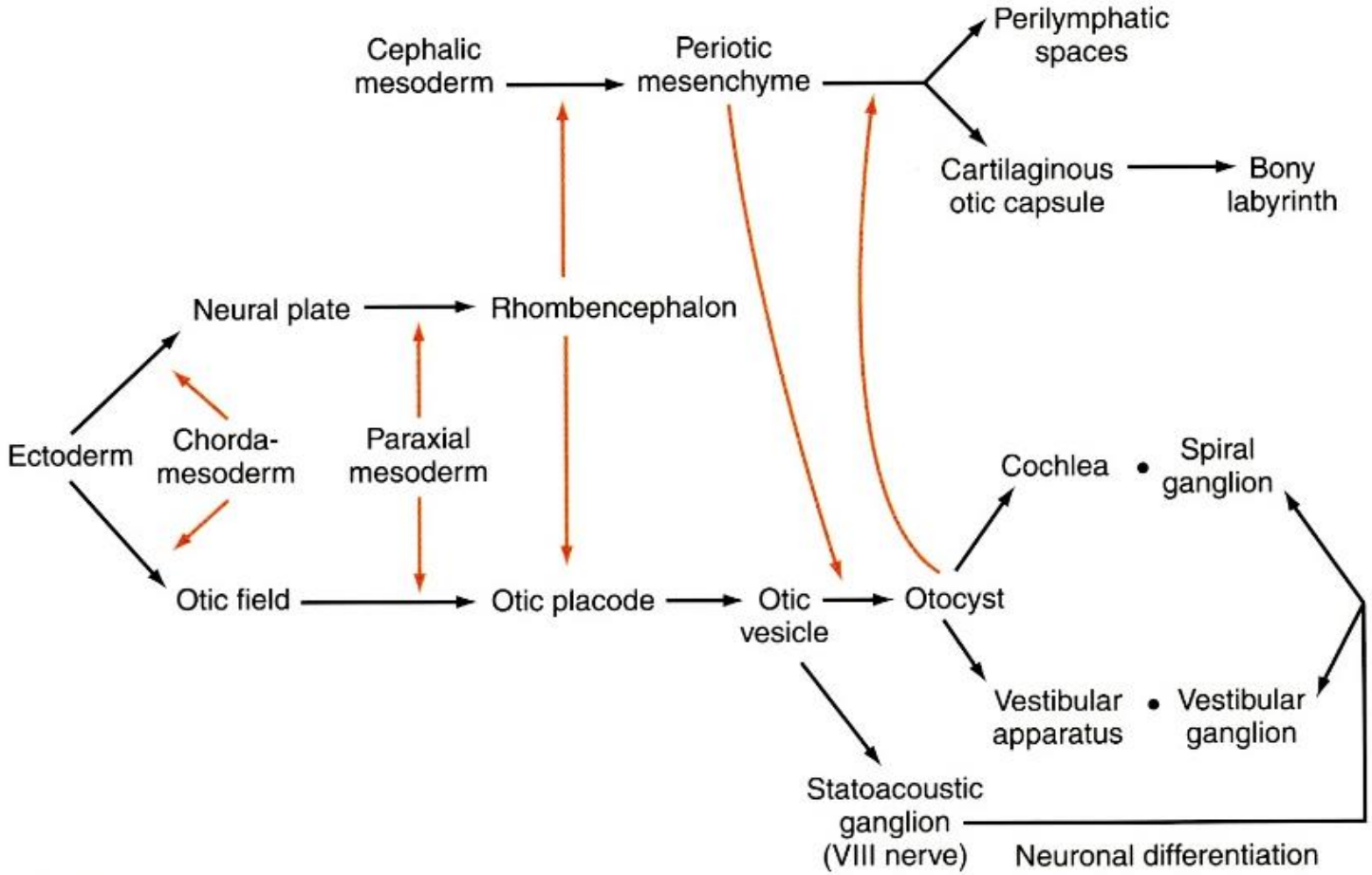


FIGURE 13-19 Flow chart of major inductive events and tissue transformations in the developing ear. Colored arrows refer to inductive events. (Based on McPhee JR, van de Water TR. In Jahn AF, Santos-Sacchi J, eds: *Physiology of the ear*, New York, 1988, Raven, pp 221–242.)

Human development timeline