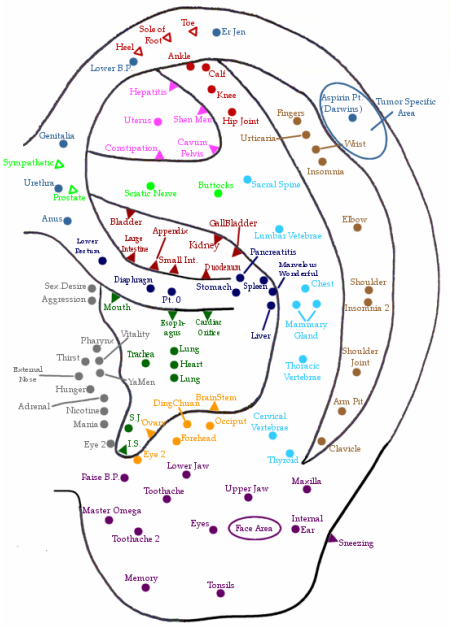
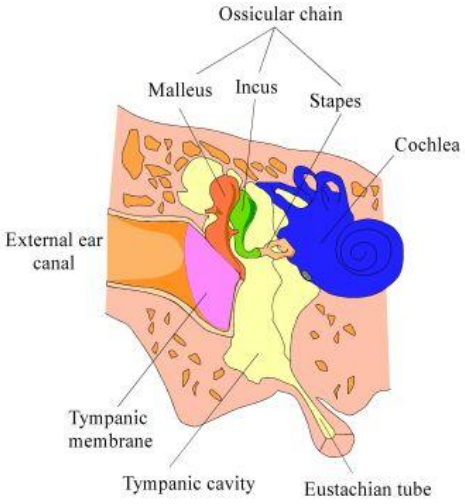
Auditory and vestibular system



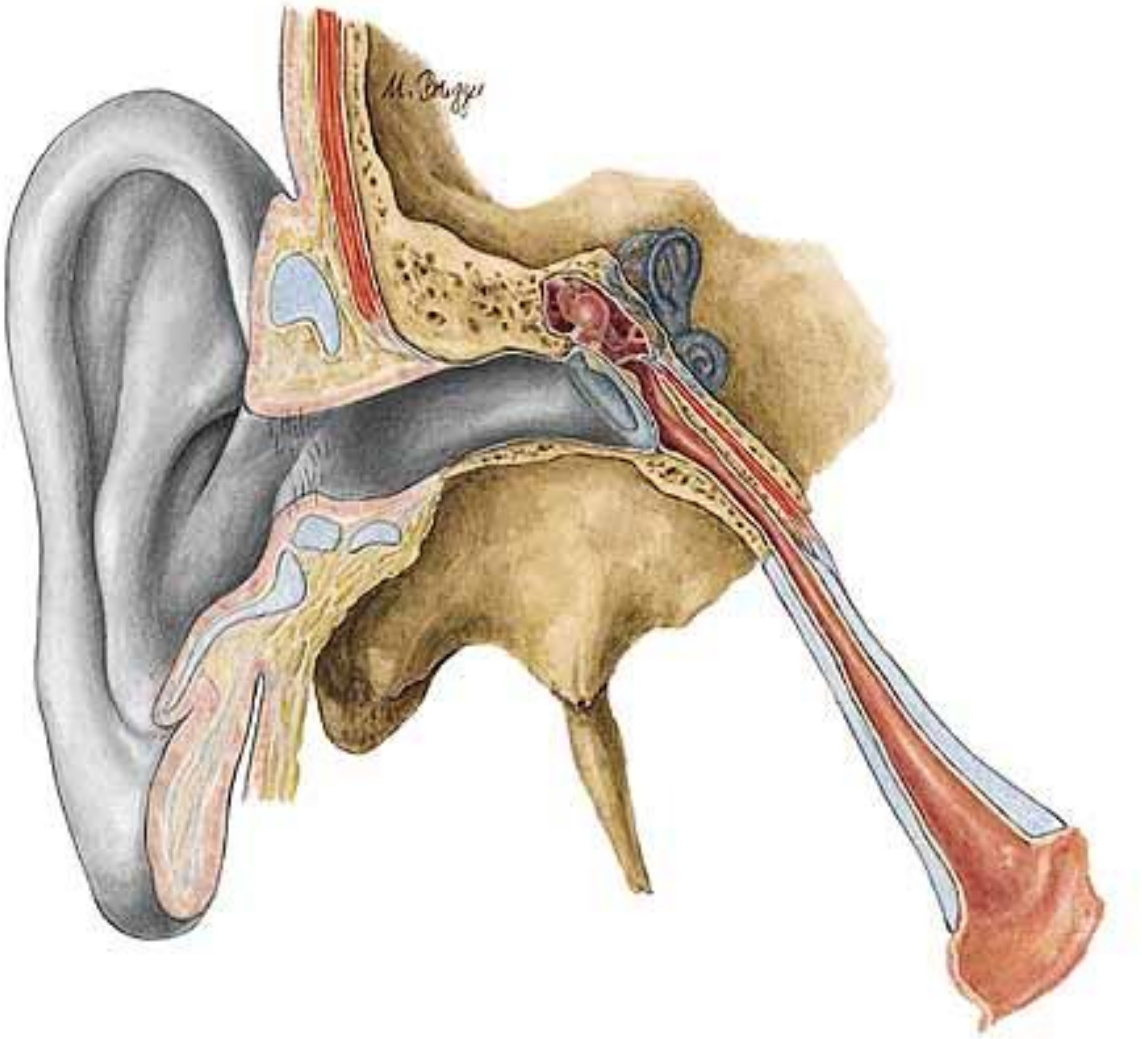
Auris, is = **Us**, oton



Auditory and vestibular system

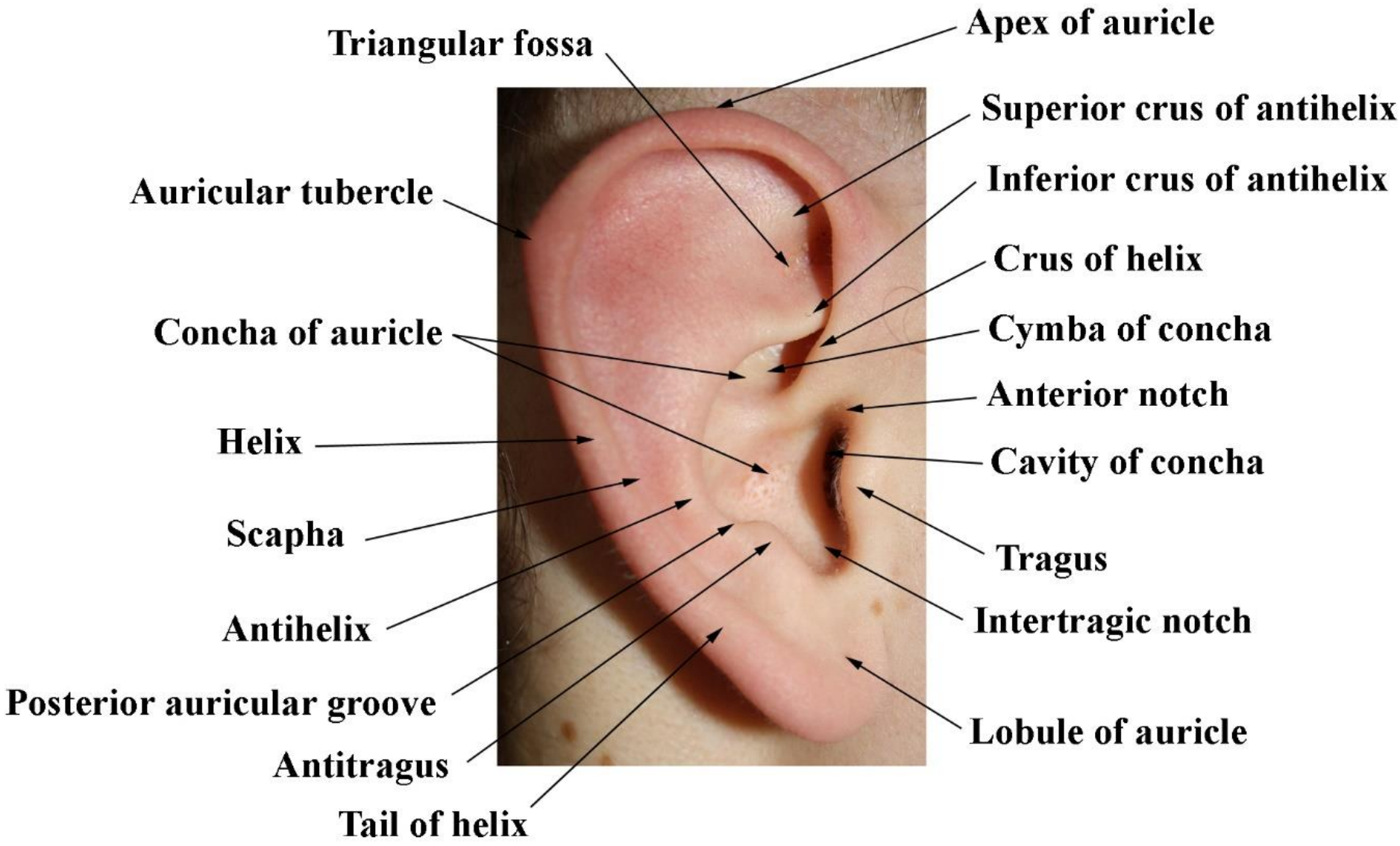
- external ear (*auris externa*)
- middle ear (*auris media*)
- internal ear (*auris interna*)

= organum vestibulo-cochleare

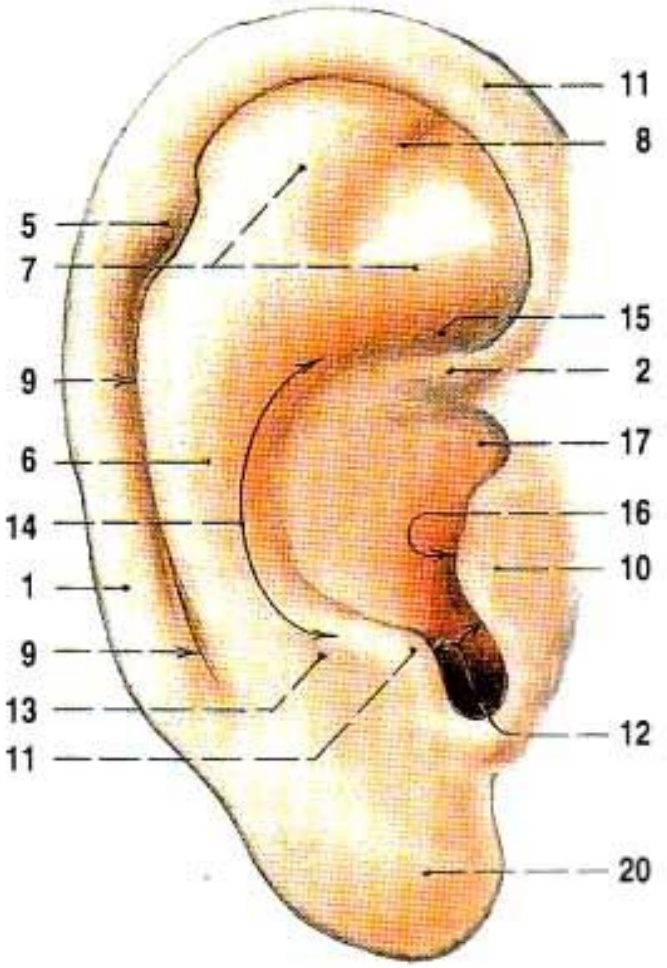


External ear (*Auris externa*)

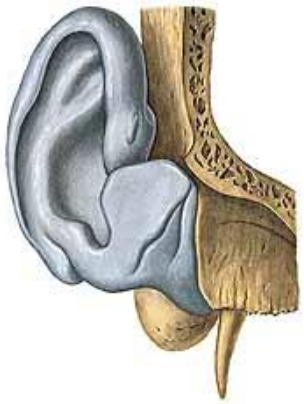
- **auricle** (*auricula*, *pinna*)
  - elastic cartilage
- **external acoustic meatus** (*meatus acusticus externus*)
- **tympanic membrane** (*membrana tympanica, myrinx*)


Triangular fossa
Apex of auricle
Superior crus of antihelix
Auricular tubercle
Inferior crus of antihelix
Crus of helix
Concha of auricle
Cymba of concha
Anterior notch
Helix
Cavity of concha
Scapha
Tragus
Antihelix
Intertragic notch
Posterior auricular groove
Lobule of auricle
Antitragus
Tail of helix

Auricle



- **helix**
  - crus, spina, cauda
  - (tuberculum auriculare *Darwini,* apex auriculae)
- **antihelix**
  - crura, fossa triangularis
- scapha
- **concha auriculae**
  - cymba, cavitas
- **tragus**
- **antitragus**
- incisura intertragica
- **lobulus auriculae**



<u>posterior surface</u> = negative image of the anterior one

ligaments: lig. auriculare ant., sup., post.

muscles – *innervation*: **n. facialis**

- extrinsic muscles = facial muscles
  - mm. auriculares (ant., sup., post.)
  - m. temporoparietalis
- intrinsic muscles: *rudimentary*
  - m. tragicus + antitragicus
  - m. helicis major+minor
  - m. obliquus + transversus auriculae, m. pyramidalis auriculae

cartilage: cartilago auriculae - *elastic*

skin: dorsally more loosen, ventrally firml
fixed to perichondrium - *othematoma*

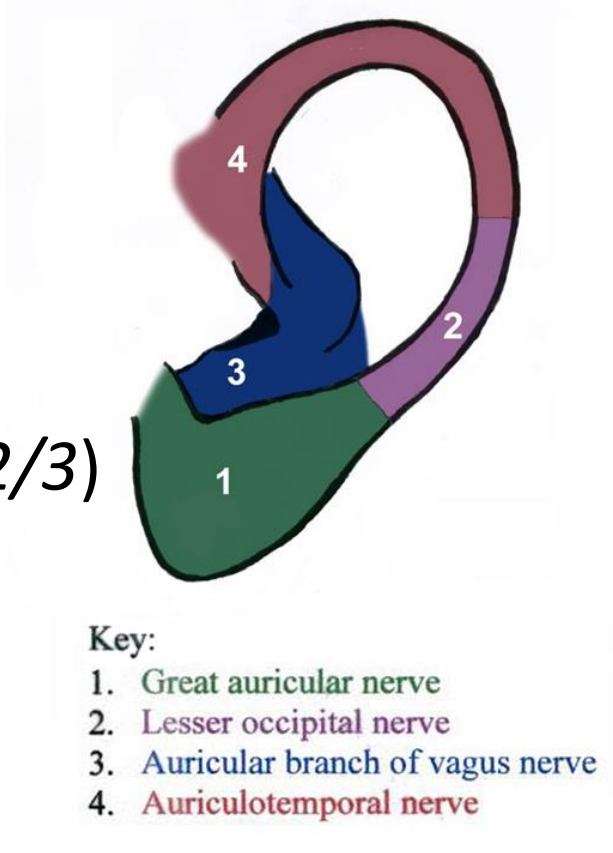
Auricle – *supply*

- arteries: a. temporalis superficialis → rr. auriculares ant.

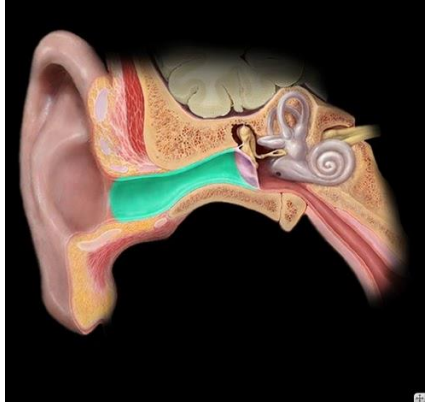
  a. carotis externa → a. auricularis post.

- veins: v. jugularis ext.
- lymph: nn.ll. parotidei, mastoidei
- nerves: sensory
  - nn. auriculares ant. from n. auriculotemporalis (*ventrocranial 2/3*)
  - r. auricularis n. X. (*concha*)
  - n. occipitalis minor (*dosrocranial*)
  - n. auricularis magnus (*cudal*)

  motor: n. VII.



External acoustic meatus (*meatus acusticus externus*)



- porus acusticus externus → oblique ventromedially → medially → again oblique ventromedially (totally converging ventrally 160º and convex descending, length about 22 mm)
- outer 2/3 – elastic cartilage opened ventrally and caudally (incisurae *Santorini*), lamina tragi (ventrally)
- transition – the narrowest point (isthmus) – *foreign bodies !!!*
- inner 1/3 – osseous – incisura tympanica *Rivini*
- glandulae ceruminosae + sebaceae → *cerumen – protection*
- tragi (*after age 30*)
- skin adheres firmly to perichondrium – *even little inflammation is painful !!!*
- anterior wall: realtion to gl. parotidea and art. temporomandibularis

- Giovanni Domenico Santorini
  - 1681 – 1737
  - incisurae cartilagini meatus acustici

- Augustus Quirinus Rivinus
  - 1652 – 1723
  - botanist (*Viola riviniana*)
  - physician
  - incisura tympanica

External acoustic meatus (*meatus acusticus externus*) *supply*

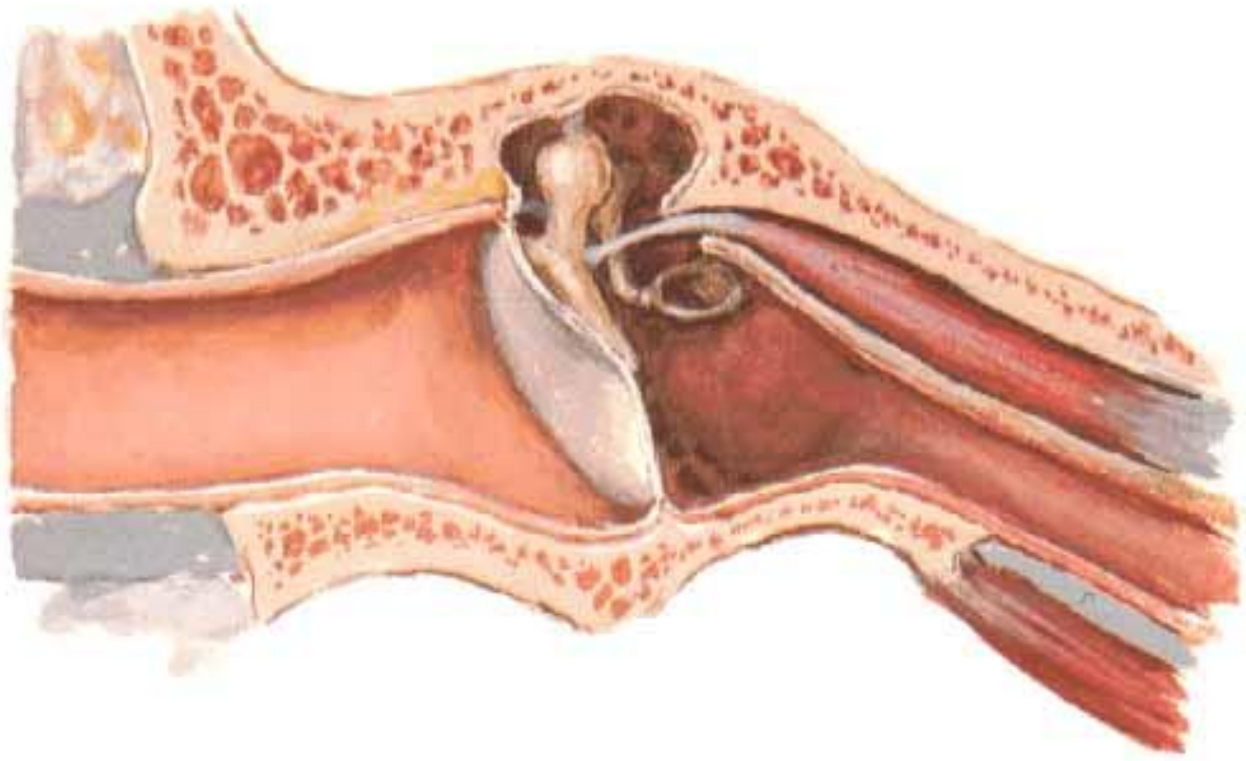
- arteries:
  - a. temporalis superficialis → rr. auriculares ant.
  - a. carotis externa → a. auricularis post.

    → a. maxillaris → a. auricularis prof.
- veins: v. temporalis superficilais, v. auricularis post.
- lymph: nn.ll. parotidei, mastoidei
- nerves: r. auricularis n.X. (dorsocaudal part), n. auriculotemporalis → r. meatus acustici externi

Tympanic membrane (*Membrana tympanica, Myrinx*)

External Ear and Tympanic Cavity

Coronal Oblique Section

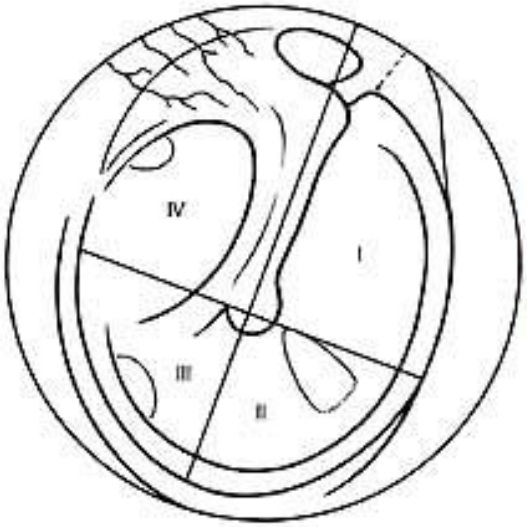


Tympanic membrane – *structure*

- sulcus tympanicus, incisura tympanica *Rivini*
- 9x10 mm, thickness 0,1 mm, surface 55 mm^2
- anulus fribrocartilagineus

- outer surface – thinned epidermis (*ectoderm*)
- layer of dense connective tissue (*mesenchyme*)
- inner surface – simple cuboid epithelium (*endoderm*)

Tympanic membrane *Otoscopy*

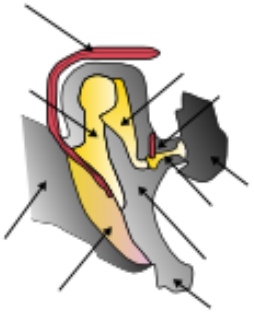


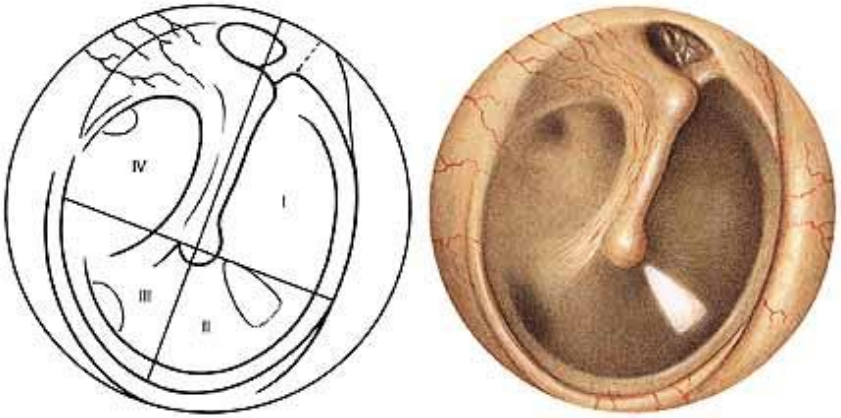
- umbo m.t.
- stria mallearis
- prominetia mallearis
- plica mallearis ant. + post.
- light reflex – trigonum of *Wilde*

(= cone of light, light reflex, Politzer's luminous cone)

Tympanic membrane – *Otoscopy*

- Bezold‘s trias: prominentia + stria + reflex
- pars flaccida *Shrapnelli* (5 mm^2)
- pars tensa
- declination (50° sagittally)
- inclination (45° transversally)
- paracentesis: lower posterior quadrant





- Sir William Robert Wills Wilde
  - 1815 – 1876
  - son – Oscar Wilde
  - trigonum *Wildei* (cone of light)

- Friedrich Bezold
  - 1842 – 1908
  - examination of hearing by tuning fork
  - trias

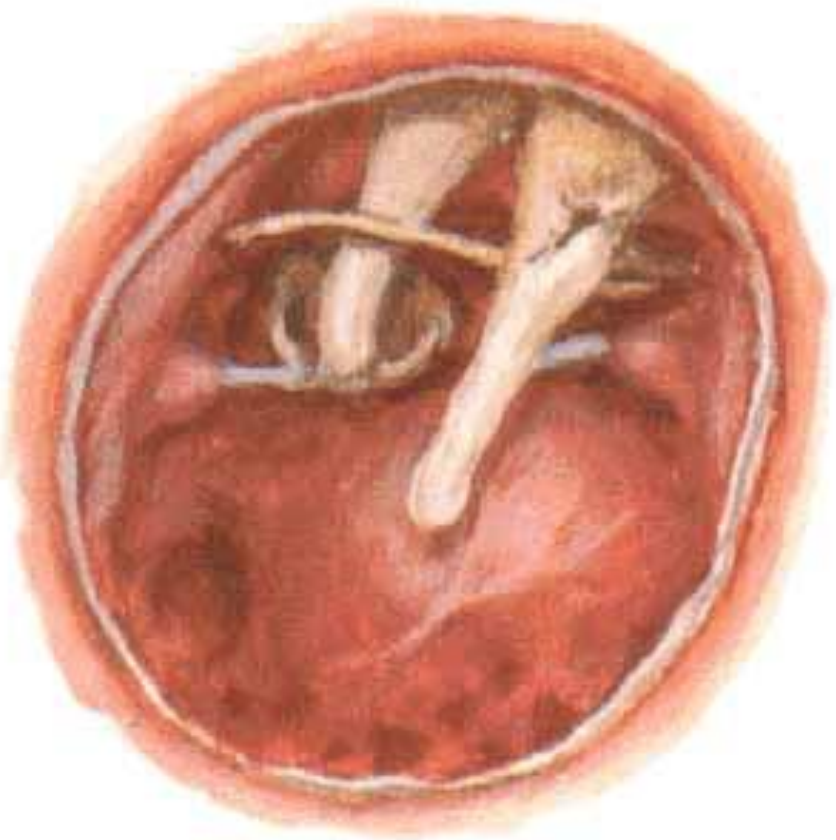
External Ear

Right Tympanic Membrane

Viewed through speculum

Tympanic Cavity

Viewed from External Acoustic Meatus



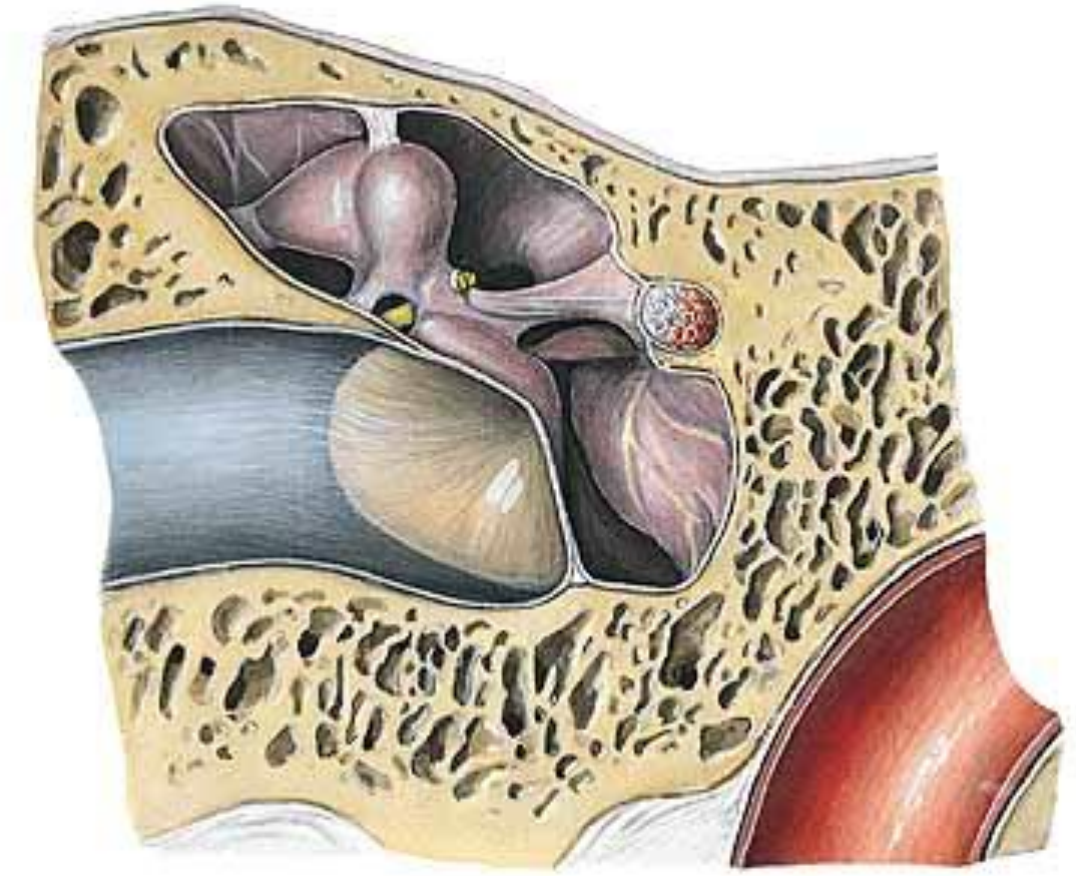
Tympanic Membrane Removed

Tympanic membrane – *supply*

- arteries:
  - a. maxillaris → a. auricularis prof. (*outer surface*)
  - aa. tympanicae (*inner surface*)
- lymph: nnl.l. mastoidei, parotidei
- nerves:
  - a. auricularis n.X.
  - n. auriculotemporalis → r. membranae tympani

Middle ear (*Auris media*)

- Tympanic cavity (*Cavitas tympani*)
- Auditory ossicle (*Ossicula aditus*)
- Articulations of auditor ossicles (*Articulationes ossiculorum auditus*)
- Muscles and ligaments auditory ossicles (*Musculi et ligamenta ossiculorum auditus*)
- Auditory tube (*Tuba auditiva Eustachi*,

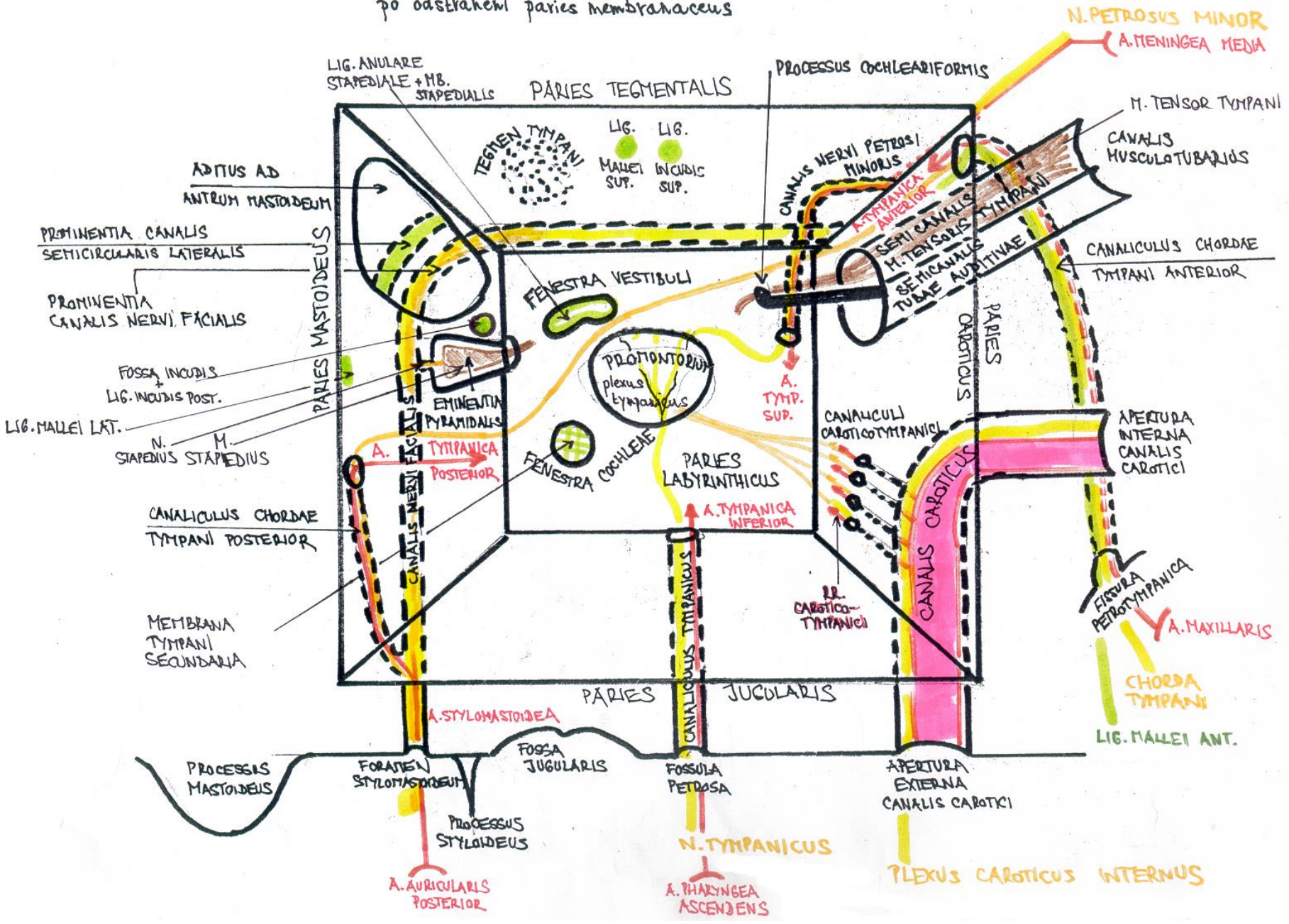


Tympanic cavity (*Cavitas tympani*) *walls*

- paries **tegmentalis**
- paries **jugularis**:
  - prominetia styloidea
  - apertura tympanica canaliculi tympanici
- paries **mastoideus**
- paries **caroticus**
- paries **membranaceus = membrana tympani**
- paries **labyrinthicus**

CAVITAS TYMPANI

l.dx.
po odstranění paries membranaceus



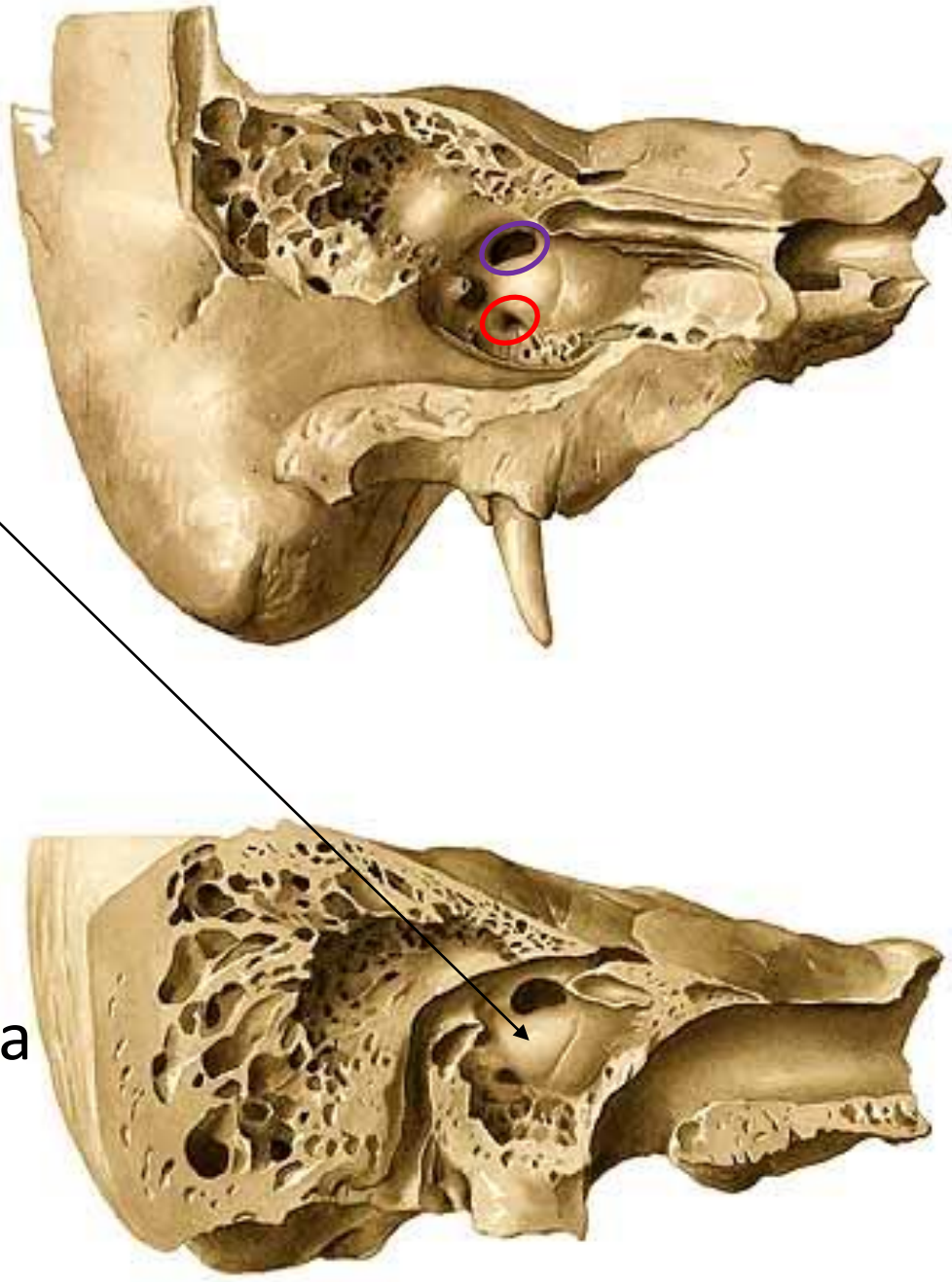
Cavitas tympani
paries labyrinthicus

- **promontorium**

= first trun of cochlea

  - sulcus promontorii (plexus tympanicus)

- fenestra vestibuli (f. ovalis = oval window)
  - basis stapedis + membrana stapedia
- **fenestra cochlae** (f. rotunda = round window)
  - membrana tympani secundaria

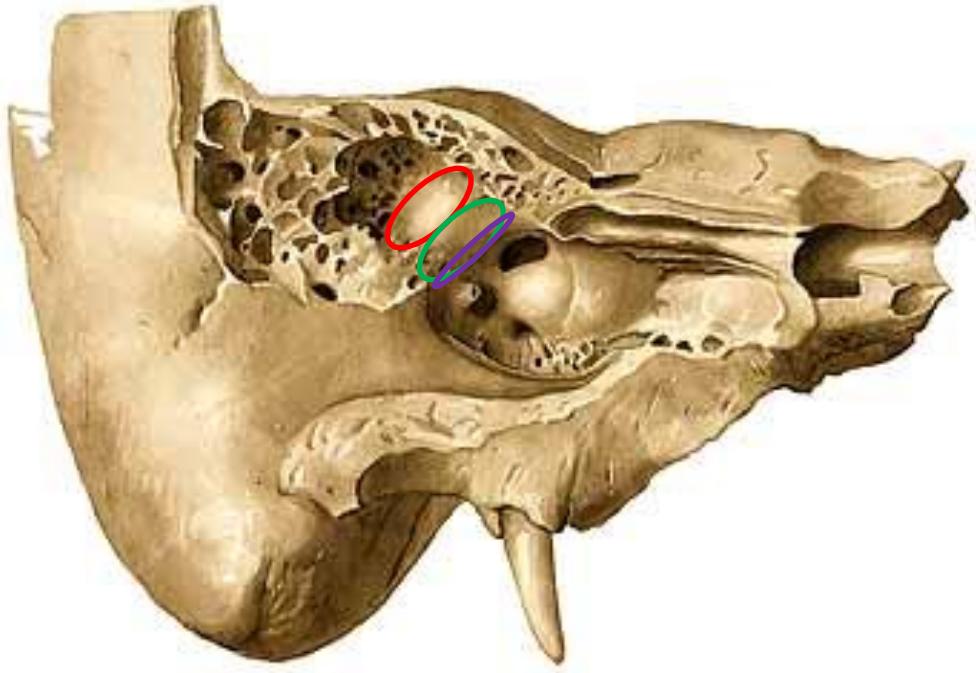


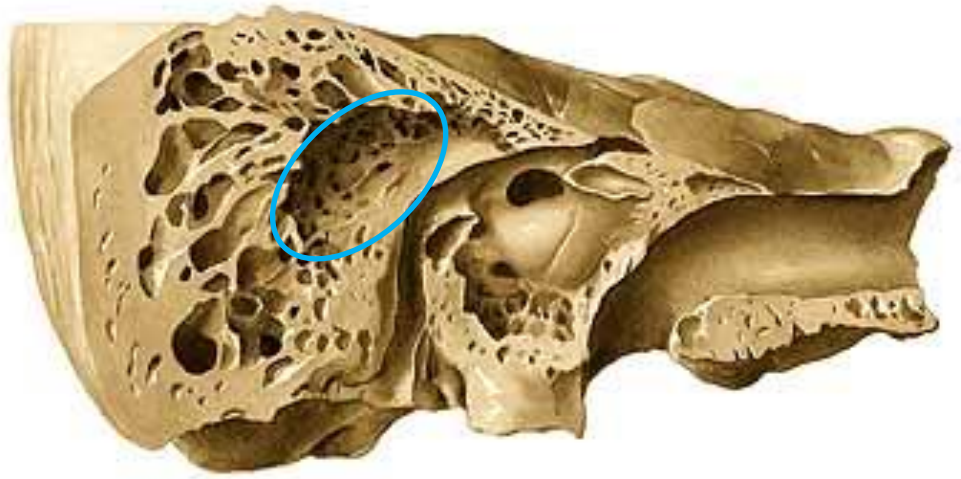
Cavitas tympani
paries mastoideus

- **aditus antri mastoidei**

= entrance to antrum mastoideum + cellulae mastoideae

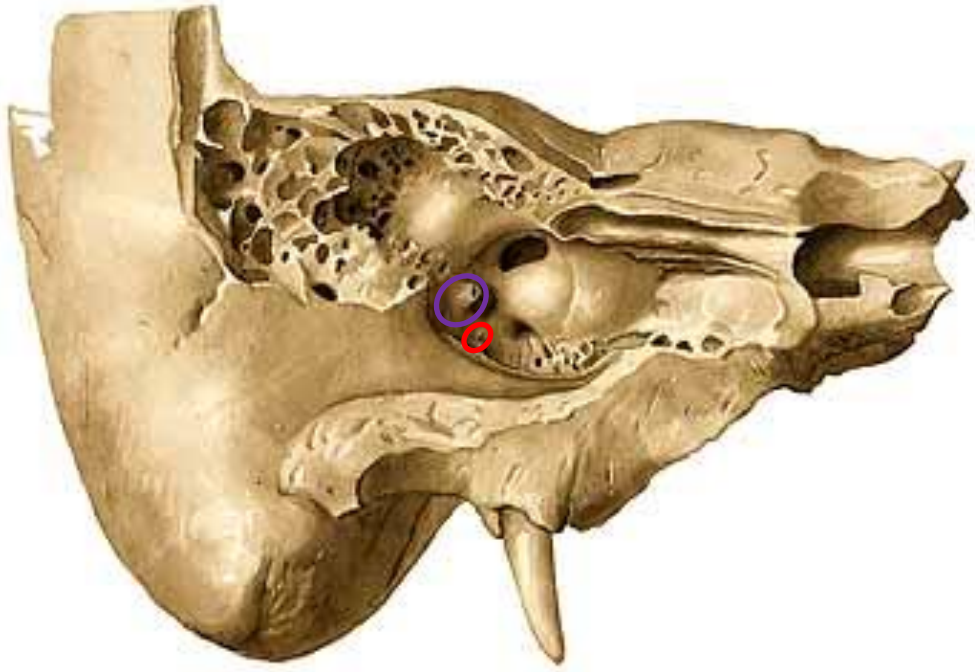
- prominentia canalis semicircularis lateralis
- prominentia canalis nervi facialis

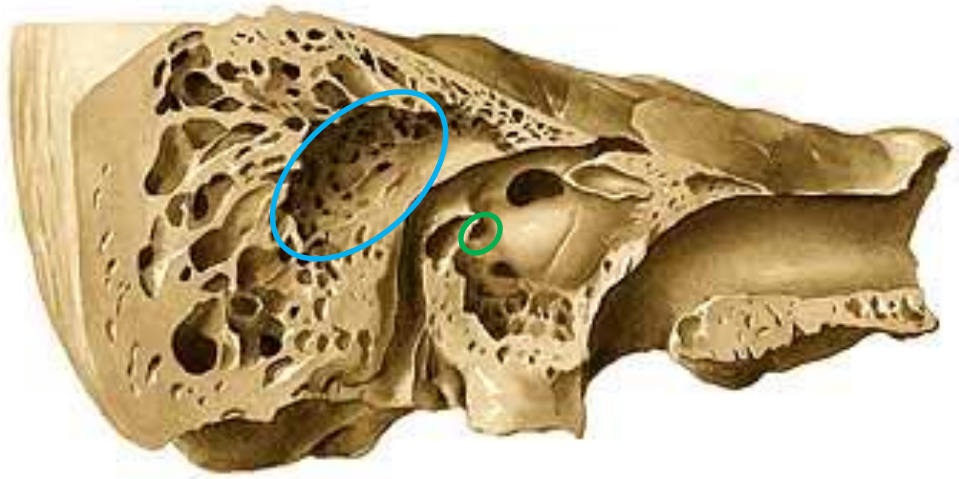




Cavitas tympani
paries mastoideus

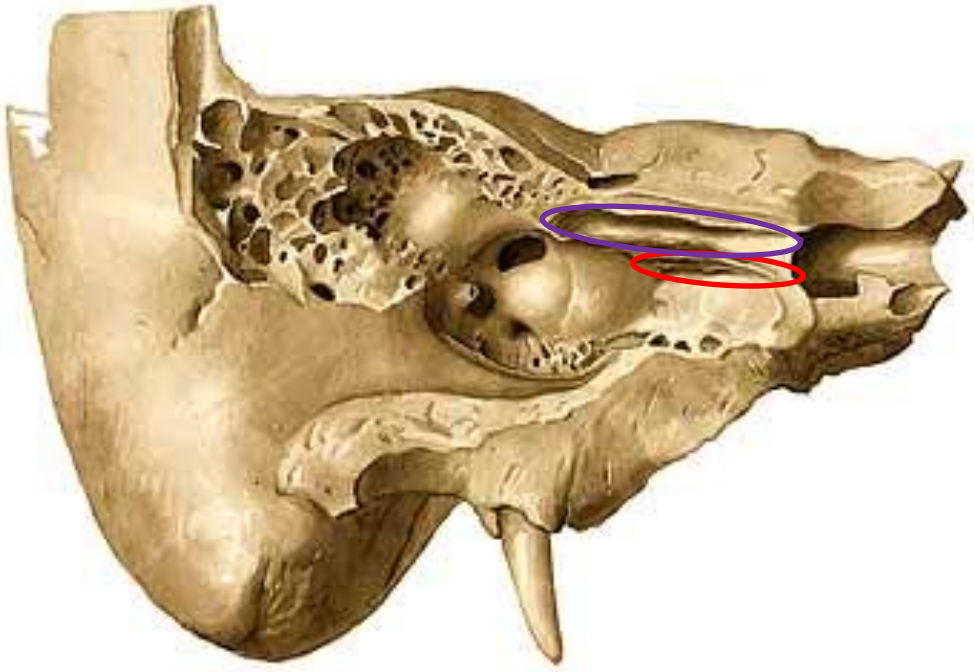
- eminetia pyramidalis
- eminentia chordae tympani
  - apertura tympanica canaliculi chordae tympani posterioris
- sinus tympani
- fossa incudis





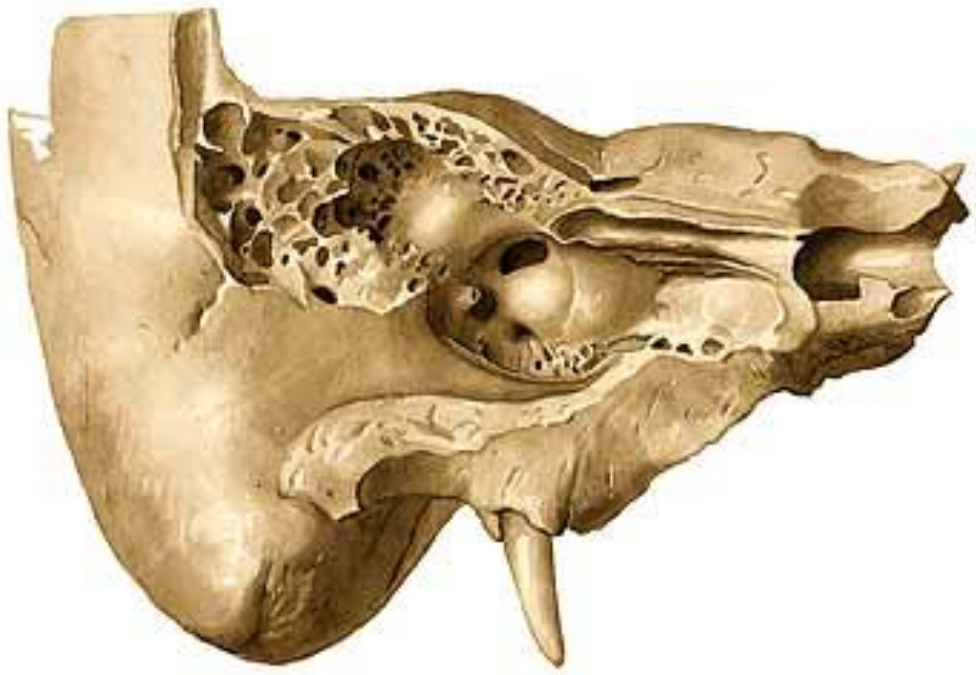
Cavitas tympani
paries caroticus

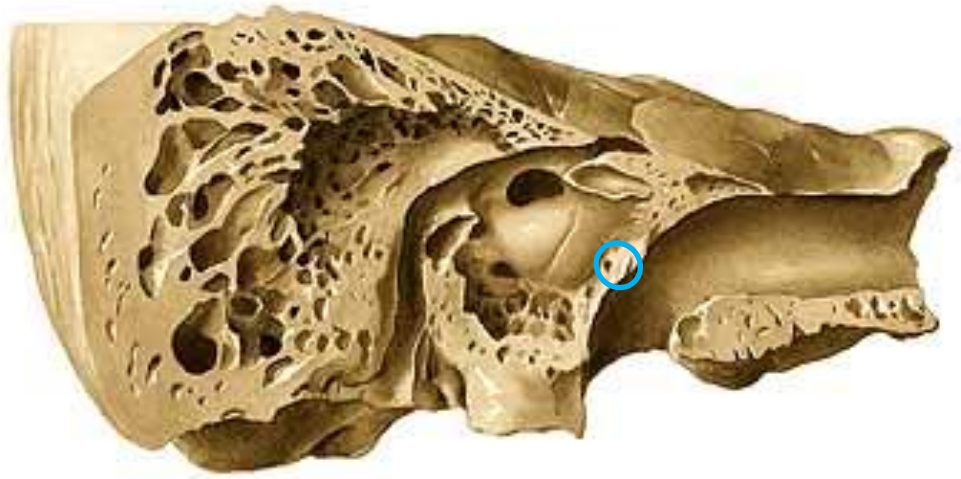
- apertura tympanica canalis nervi petrosi minoris
- **canalis musculotubarius**
  - semicanalis m. tensoris tympani
  - processus cochleariformis
  - semicanalis tubae auditivae



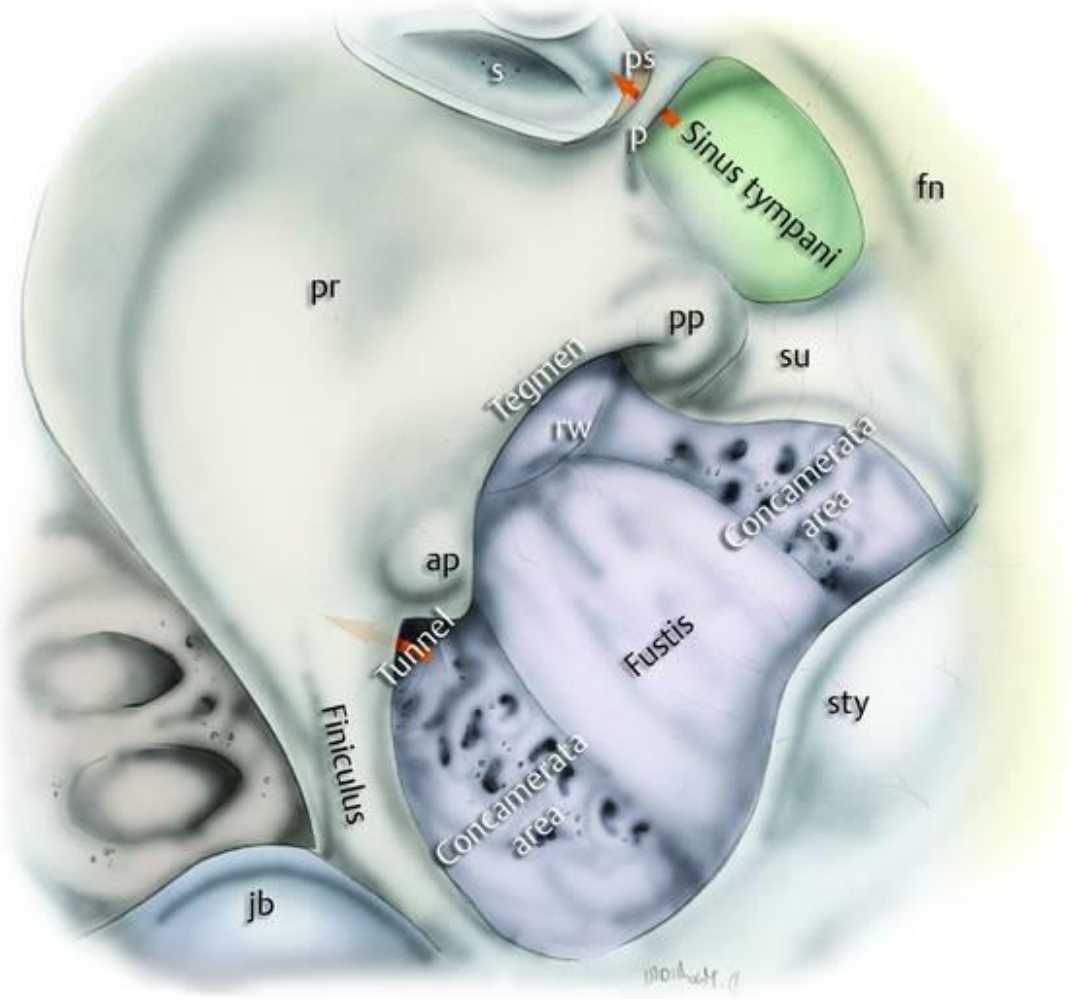
Cavitas tympani
paries caroticus

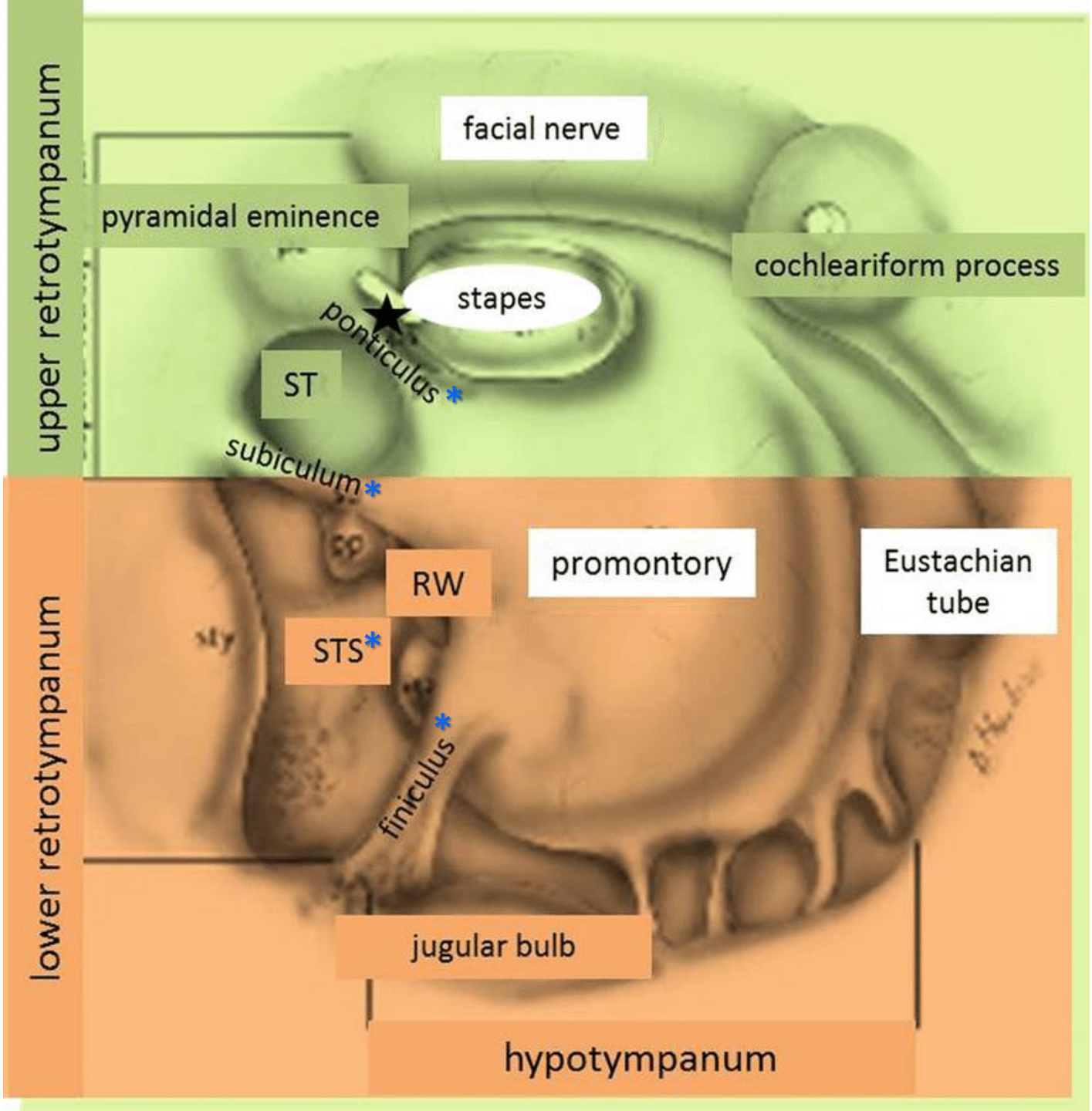
- apertura tympanica canaliculi chordae tympani anterioris (*Huguieri*)
- fissura petrotympanica (*Glaseri*)
- canaliculi caroticotympanici





Cavitas tympani
paries labyrithicus – further details*




upper retrotympanum
facial nerve
pyramidal eminence
cochleariform process
stapes
ponticulus *
ST
subiculum *
lower retrotympanum
promontory
Eustachian tube
RW
STS *
finiculus *
jugular bulb
hypotympanum

Tympanic cavity – *supply*

- arteries: **4 aa. tympanicae**, rr. caroticotympanici
- veins: vv. tympanicae to plexus pterygoideus + sinus petrosus sup.
- lymph: nn.ll. parotidei, mastoidei, cervicales profundi, retropharyngei
- nerves:
  - n. tympanicus (n.IX) – somatosensory + parasympathetic (ganglion tympanicum)
  - r. pharyngeus (n.V2) for cartilaginous part of auditory tube
  - nn. caroticotympanici (sympathetic)

Auditory ossicles (*Ossicula aditus*)

Malleus *(Hammer)*

- caput
- collum
- manubrium
  - processus spatuliformis
- processus lateralis
- processus anterior

Auditory ossicles (*Ossicula aditus*)

Incus (*Anvil*)

- corpus
- crus longum
  - processus lenticularis
- crus breve

Stapes (*Stirrup*)

- caput
- (collum)
- crus anterius + posterius
- basis

Joints of auditory ossicles
(*Articulationes ossiculorum auditus*)

- syndesmosi tympanomallearis
- art. incudomallearis (saddle-shape)
- art. incudostapedia (ball-and-socket)
- syndesmosis tympanostapedialis

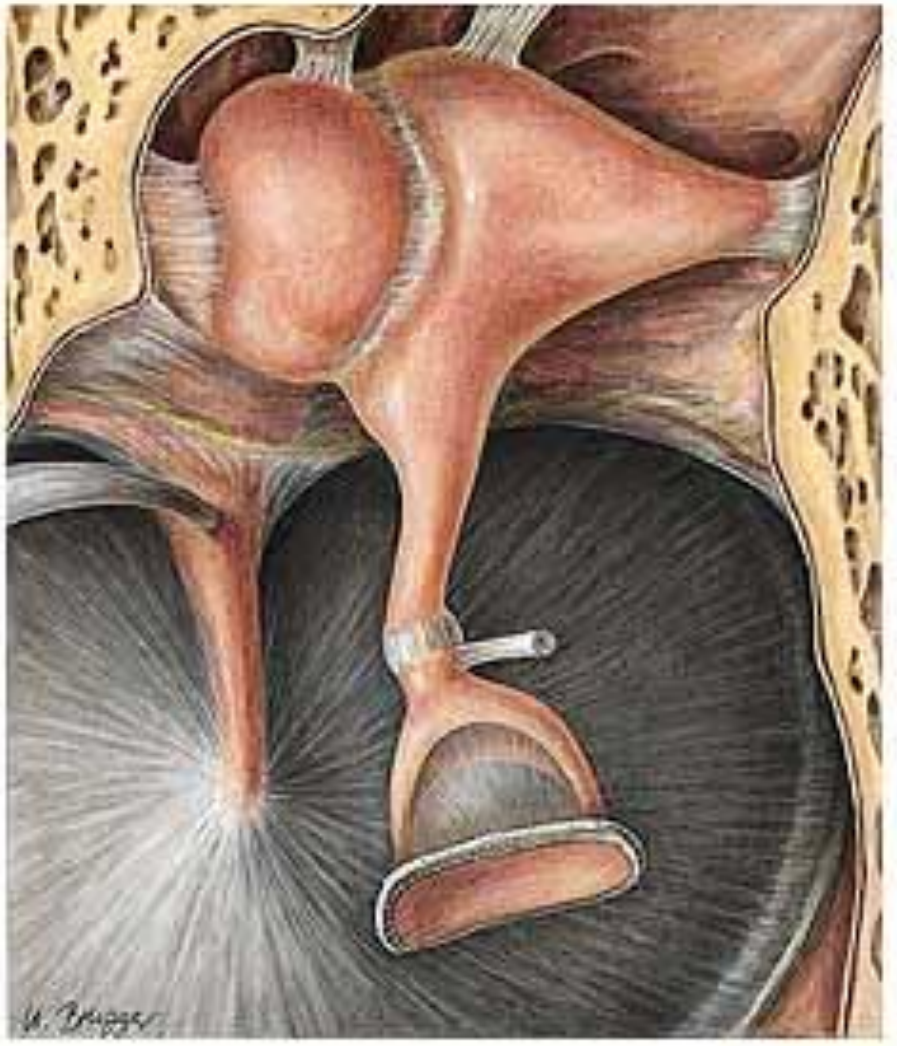
otosclerosis – *ossification*

sometimes both articulations areare replaced with syndesmosis

Ligaments (*Ligg. ossiculorum auditus*)

- **lig. mallei ant**. (spina o.s.)+ **sup**.+ **lat**.
- **lig. incudis sup**. (fossa i.) + **post**.
- **membrana stapedialis** (between crura stapedis)
- **lig. anulare stapediale** (fenestra vestibuli)
- **membrana tympani secundaria**

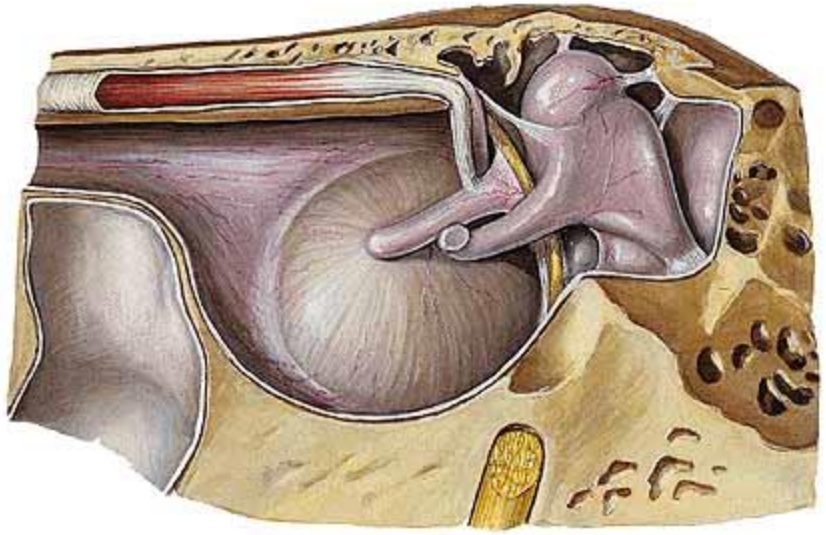
  (fenestra cochleae)



Muscles of auditory ossicles

- **m. tensor tympani**
  - semicanalis m.t.t.
  - processus cochleariformis
  - manubrium mallei

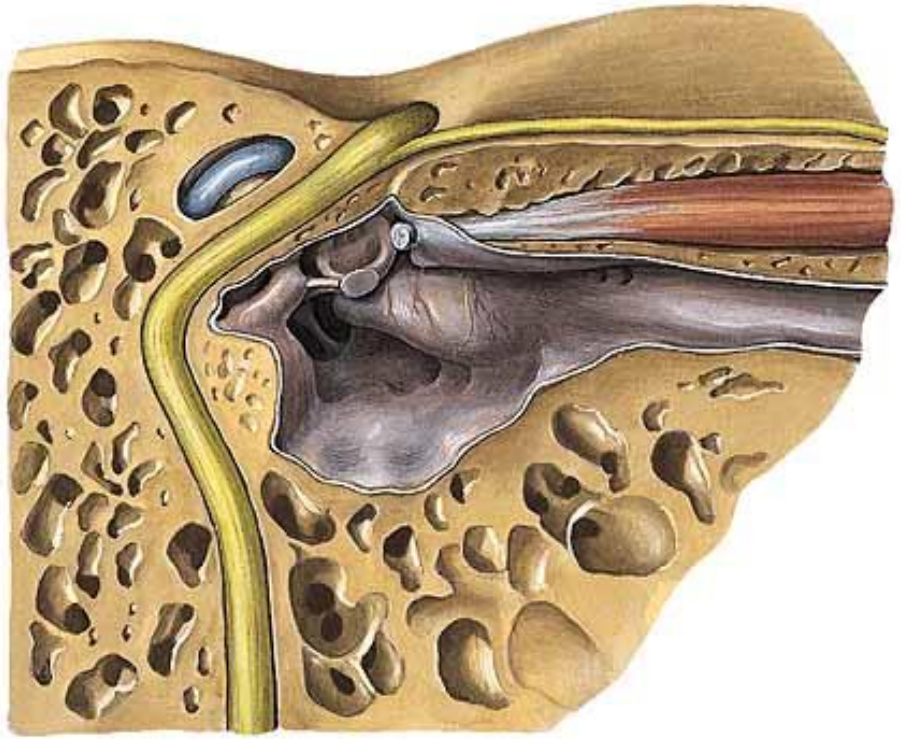
inervation: n.V3



- **m. stapedius**
  - eminetia pyramidalis
  - collum stapedis

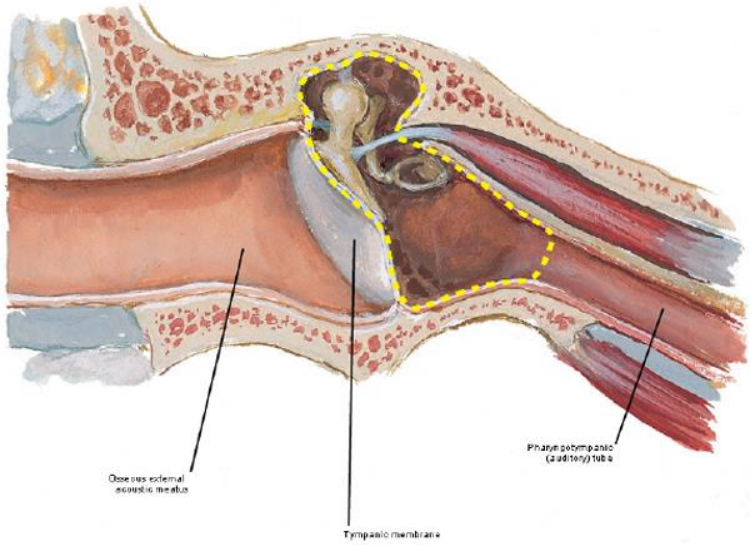
innervation: n.VII

n. stapedius from pars mastoidea canalis nervi facialis

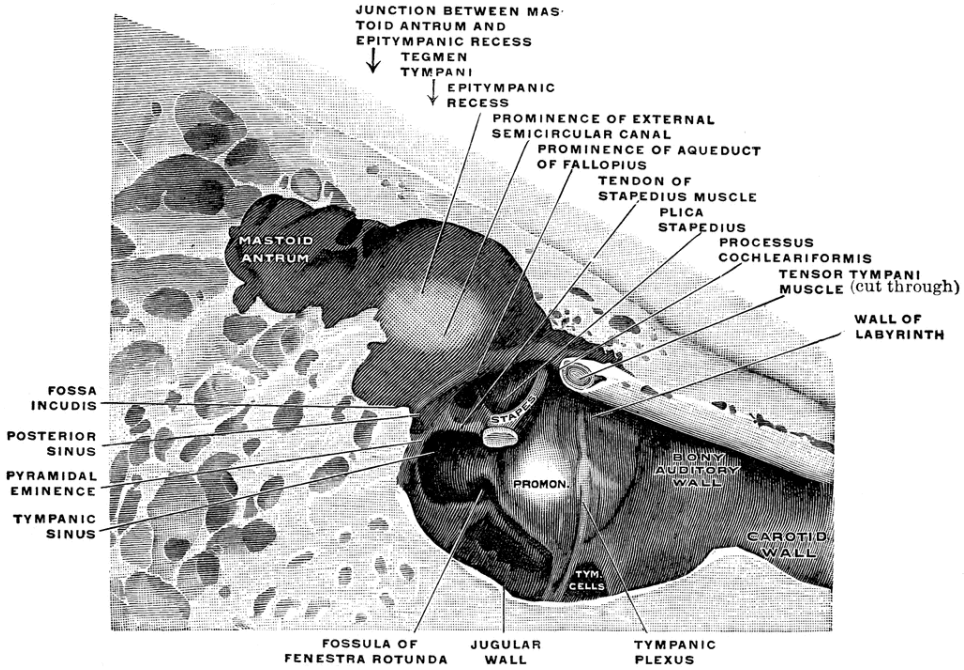


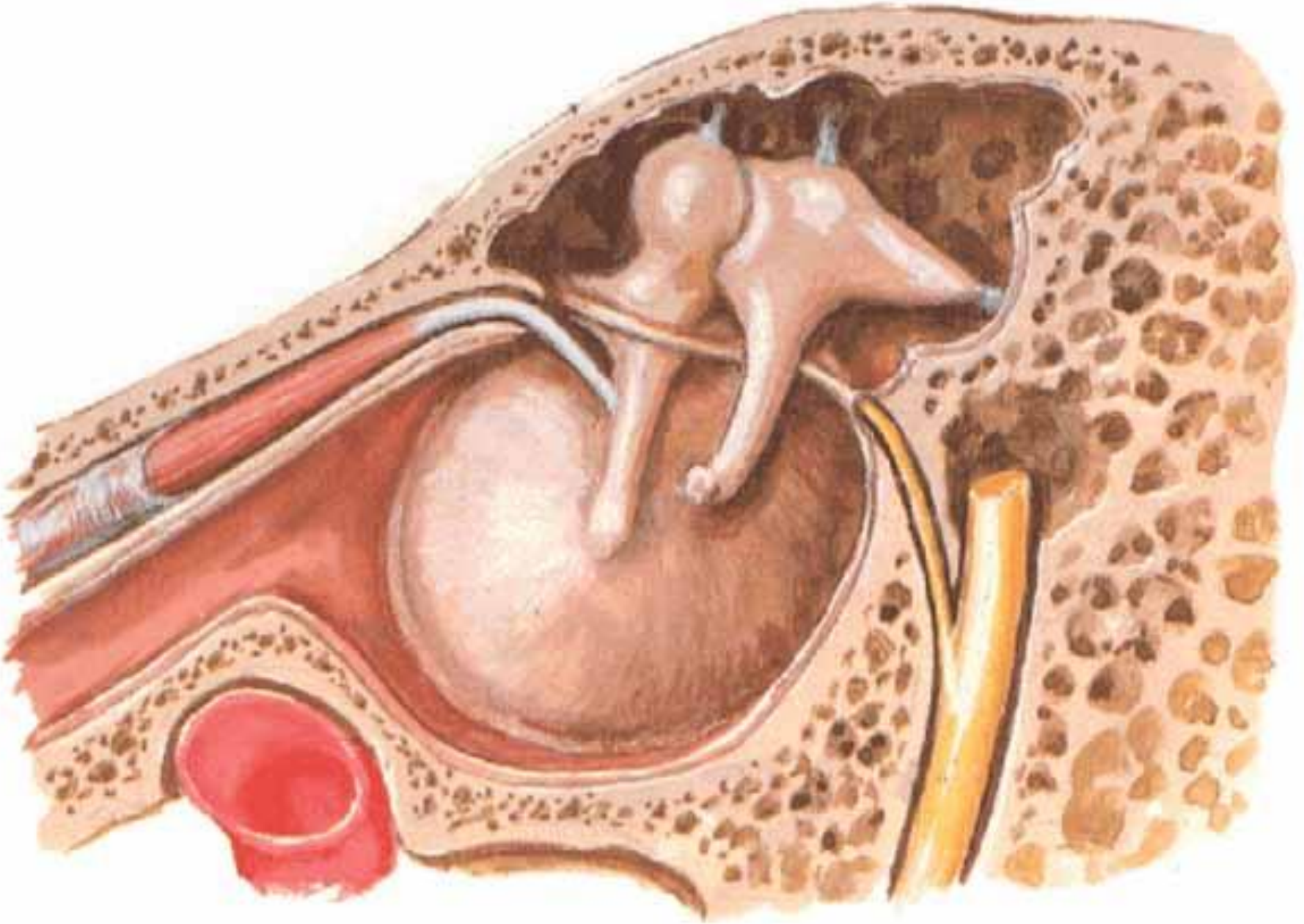
Middle ear cavity

- cavitas tympani propria
  - recessus epitympanicus
  - recessus hypotympanicus



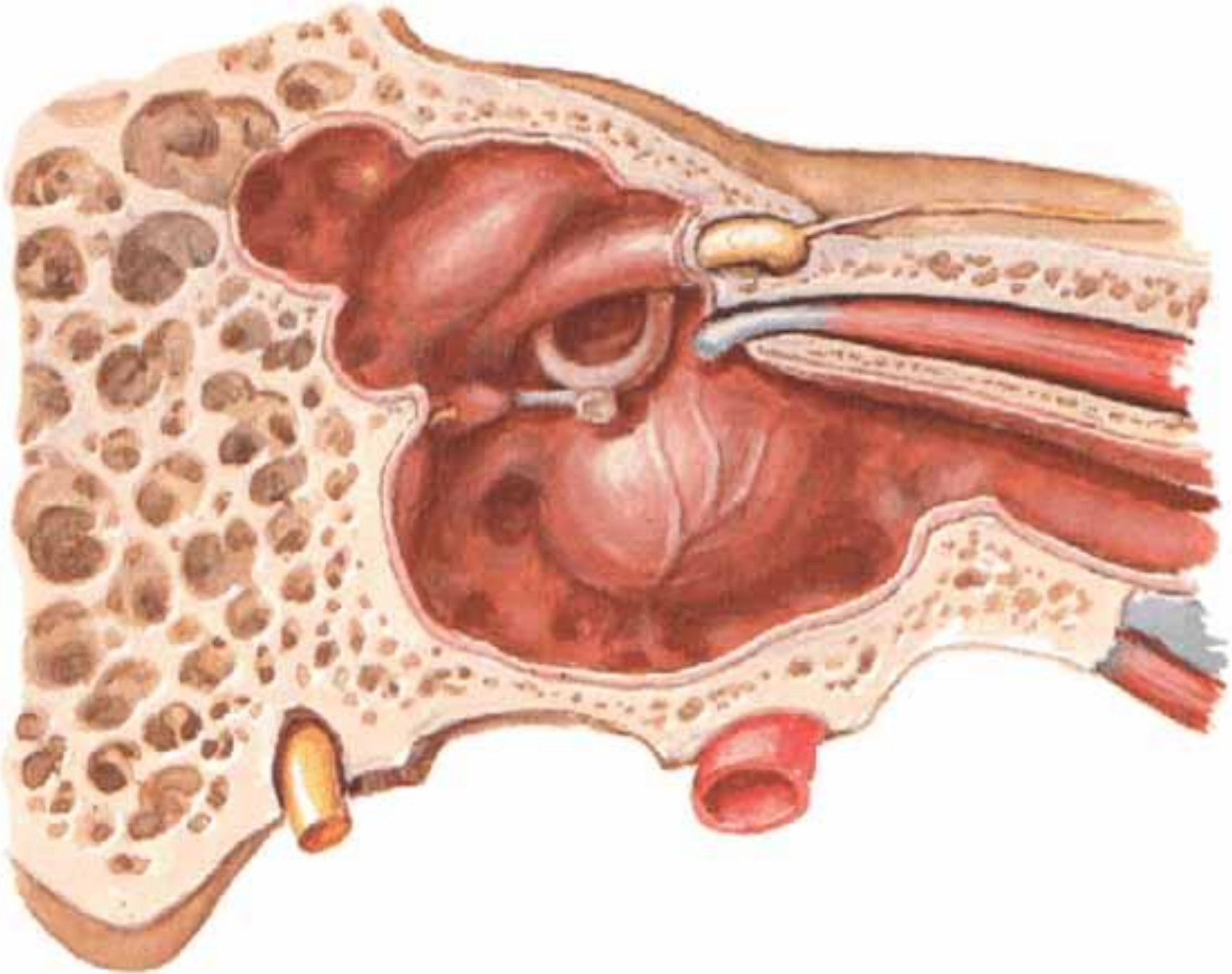
- extensions:
  - antrum mastoideum
  - cellulae mastoideae
  - celullae tympanicae
  - cellulae accessoriae
  - protypanum (*tuba auditiva Eustachii*)





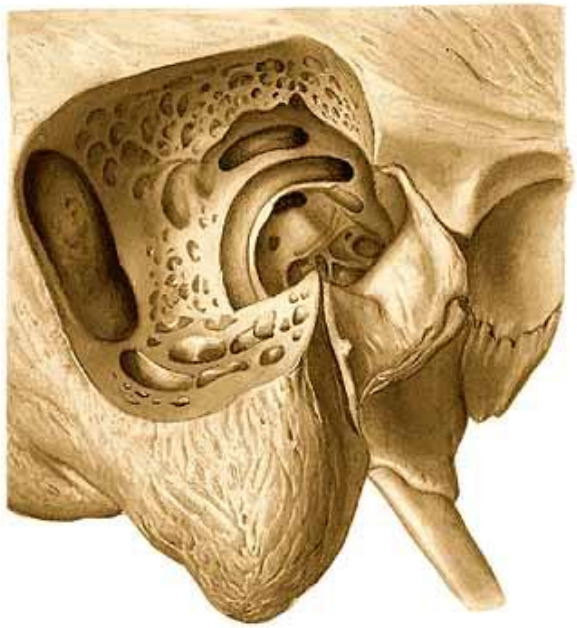
Tympanic cavity

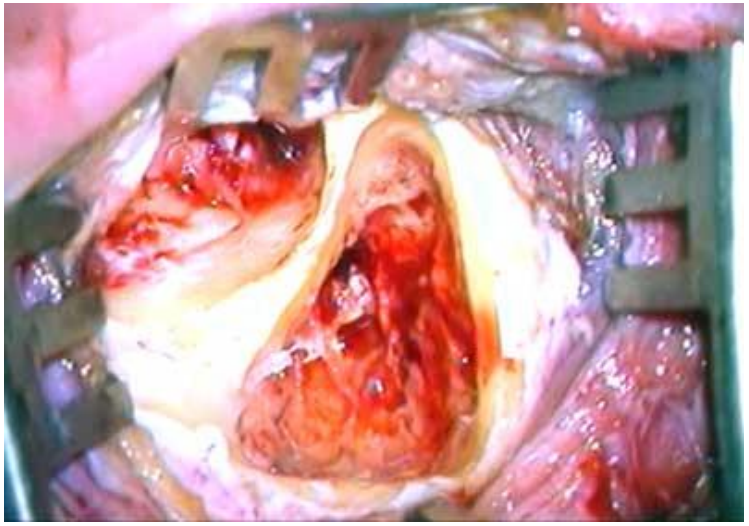
- shape of hourglass– 2 mm at level of tympanic membrane (= mesotympanon)
- recessus epitympanicus (= **atticus**, epitympanon, epitympanum) – 6 mm
- recessus hypotympanicus (hypotympanon) – 4 mm
- plicae malleares ant.+ post. ⟶ recessus ant.+ sup. (*Tröltsch's space*) + post. (*Prussak's space*)
- plica chordae tympani, incudialis, stapedialis
- mucosa – simple cuboid epithelium (various height)
- *neither goblet cells nor glands*
  - *only close to ostium pharyngeum tubae auditivae*



Mastoid antrum (*Antrum mastoideum*)

- aditus antri mastoideim
- **cellulae mastoideae**
  (*developing postnatally – 6th year of age*)
  - pneumatic type
  - diploic type
  - sclerotic type
- cellulae tympanicae
- simple flat epithelium
- closely related to sinus sigmoideus
- *mastoidectomy*



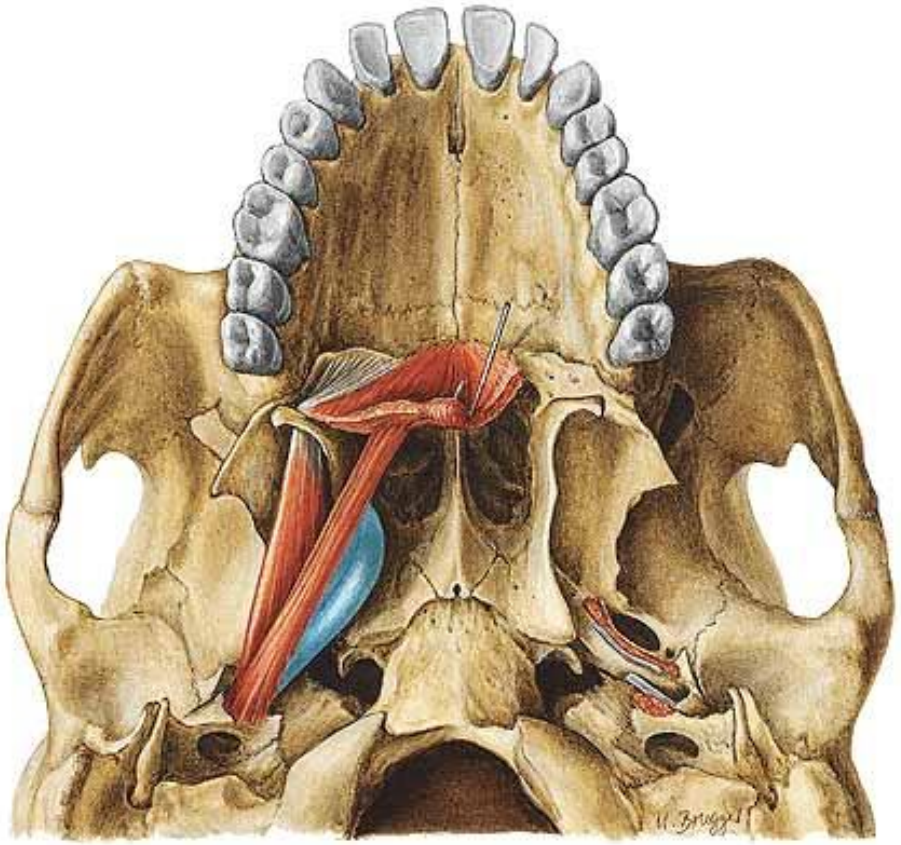


Auditory tube (*Tuba auditiva*)

Tuba auditoria, tuba pharyngotympanica (pharyngotympanic tube), *salpinx, tuba Eustachii*

- ostium tympanicum
- pars ossea (= semicanalis t.a.) – cellulae pneumaticae
- pars cartilaginea – cartilago (lamina med.+ lat., lamina membranacea) – tonsilla tubaria *Gerlachi* located under the mucosa
  - *in hypertorphy of tonsilla pharyngea → ventilation disturbance (mainly in children) → mesotitis*
- ostium pharyngeum (at level of meatus nasi inf.)

Auditory tube (*Tuba auditiva*)



Auditory tube (*Tuba auditiva*)

Tuba auditoria, tuba pharyngotympanica (pharyngotympanic tube), *salpinx, tuba Eustachii*

- equalizes pressure in pharynx and in tympanic cavity
- width 2 mm, length 40 mm
- transition of pseudostratified columnar epithelium into simple columnar
- glandulae tubariae, goblet cells – *in cartilaginous part*
- in children: more, horizontal, shorter and wider
- *cathetrization via nasal cavity*

Auditory tube (*Tuba auditiva*)

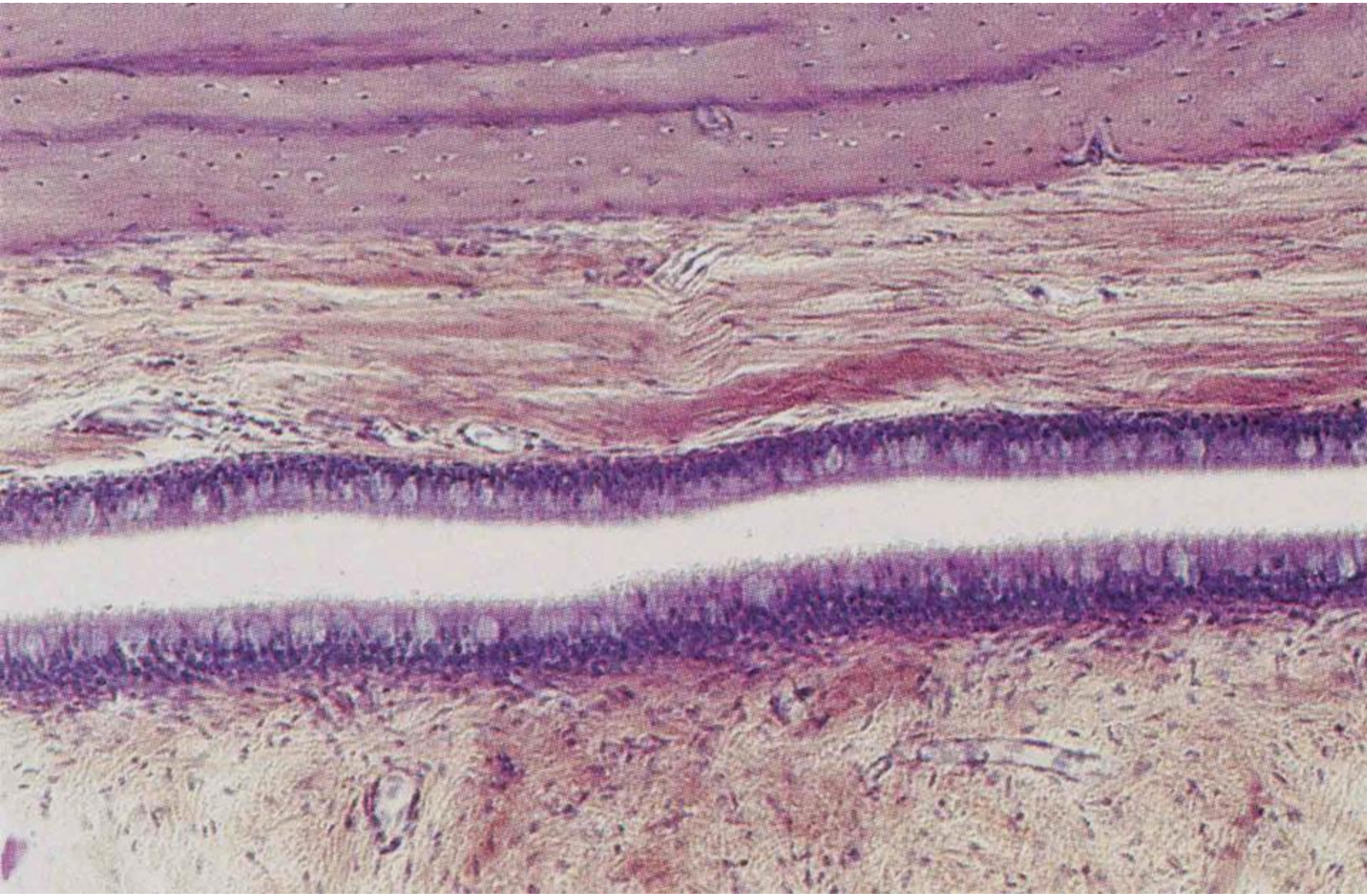
Tuba auditoria, tuba pharyngotympanica (pharyngotympanic tube), *salpinx, tuba Eustachii*

opened by:

- m. tensor tympani
- m. salpingopharyngeus

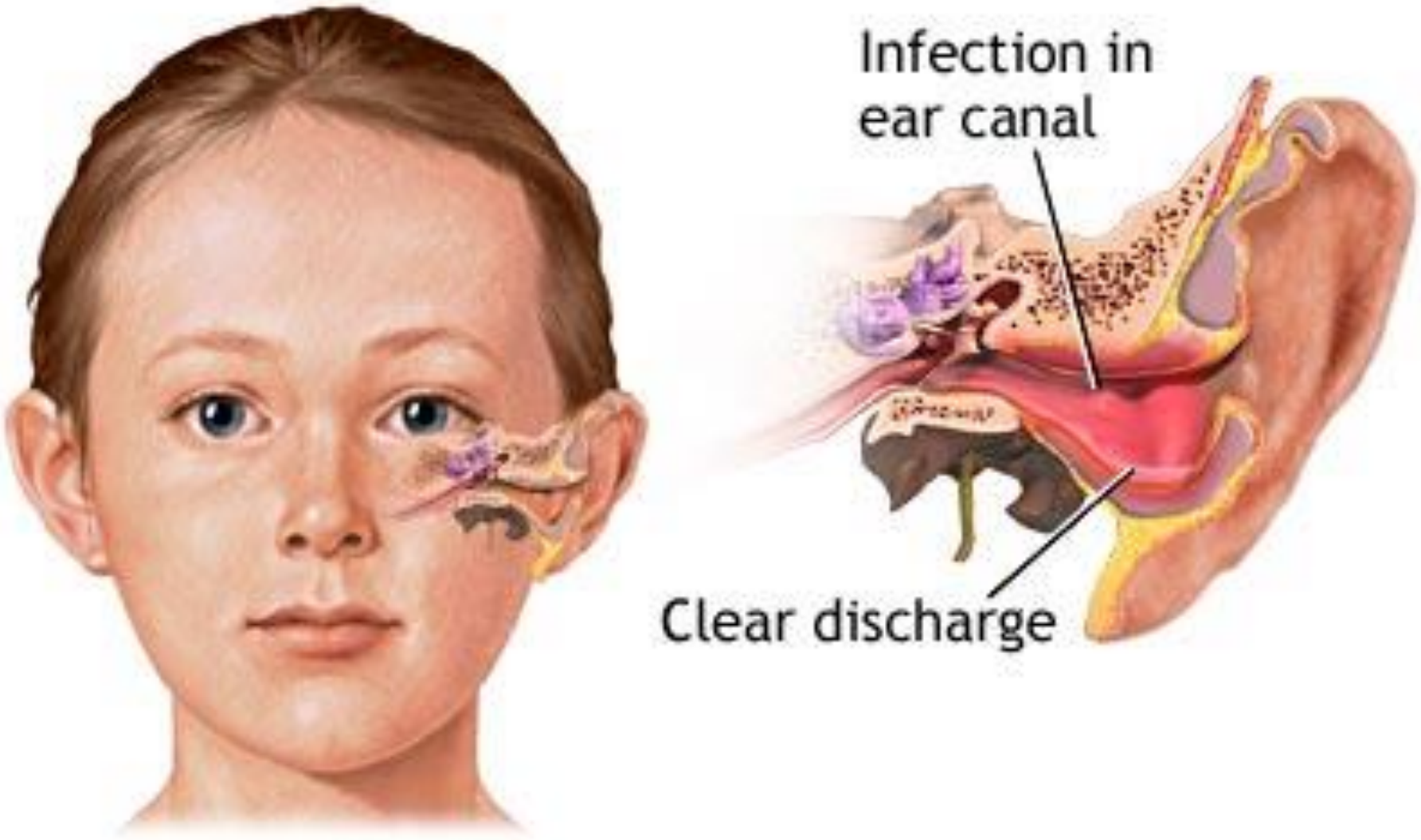
? role of m. levator veli palatini unclear

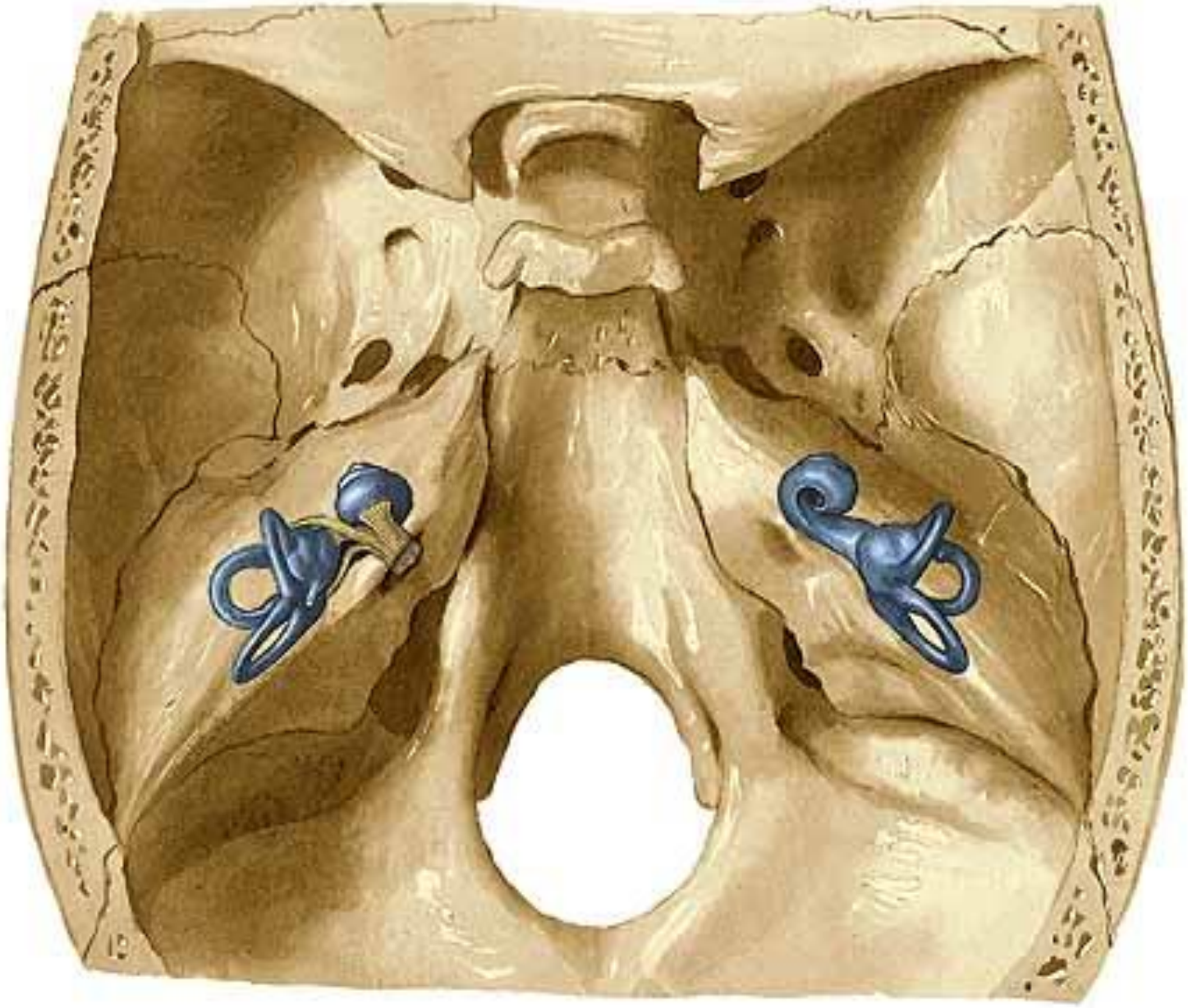
- corpus adiposum tubae auditivae (Ostmann‘s fat pad)



Internal ear (*Auris interna*)

- organum vestibulocochleare
- osseous labyrinth (*labyrinhtus osseus*)
  - vestibule (*vestibulum*)
  - semicircular canals (*canales semicirculares*)
  - *cochlea*
  - internal acoustic meatus (*meatus acusticus internus*)
  - spatium perilymphaticum
- membranous labyrinth (*labyrinthus membranaceus*)
  - labyrinthus vestibularis
  - labyrinthus cochlearis
  - spatium endolymphaticum

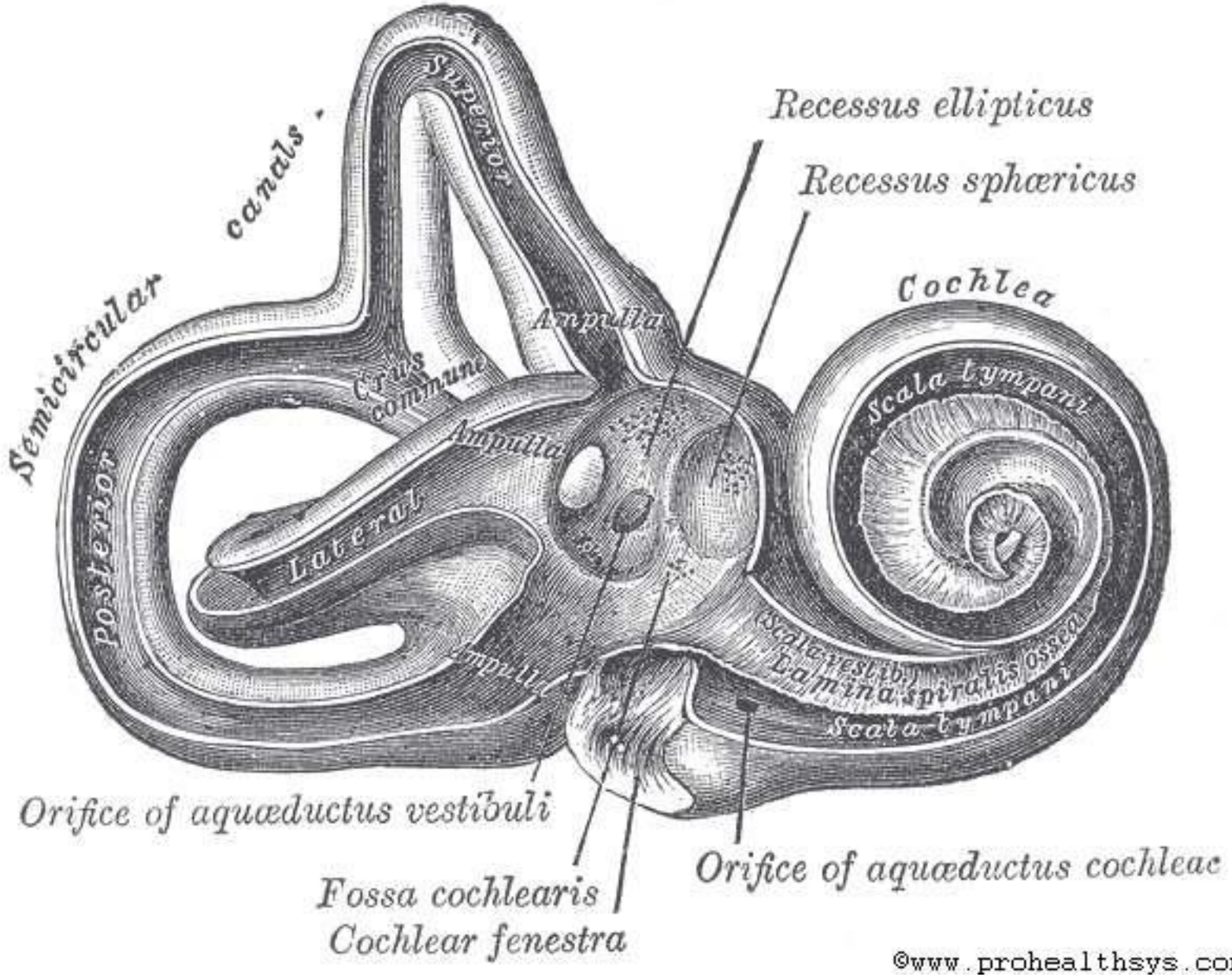




Osseous labyrinth (*labyrinthus osseus*)
vestibule (*vestibulum*)

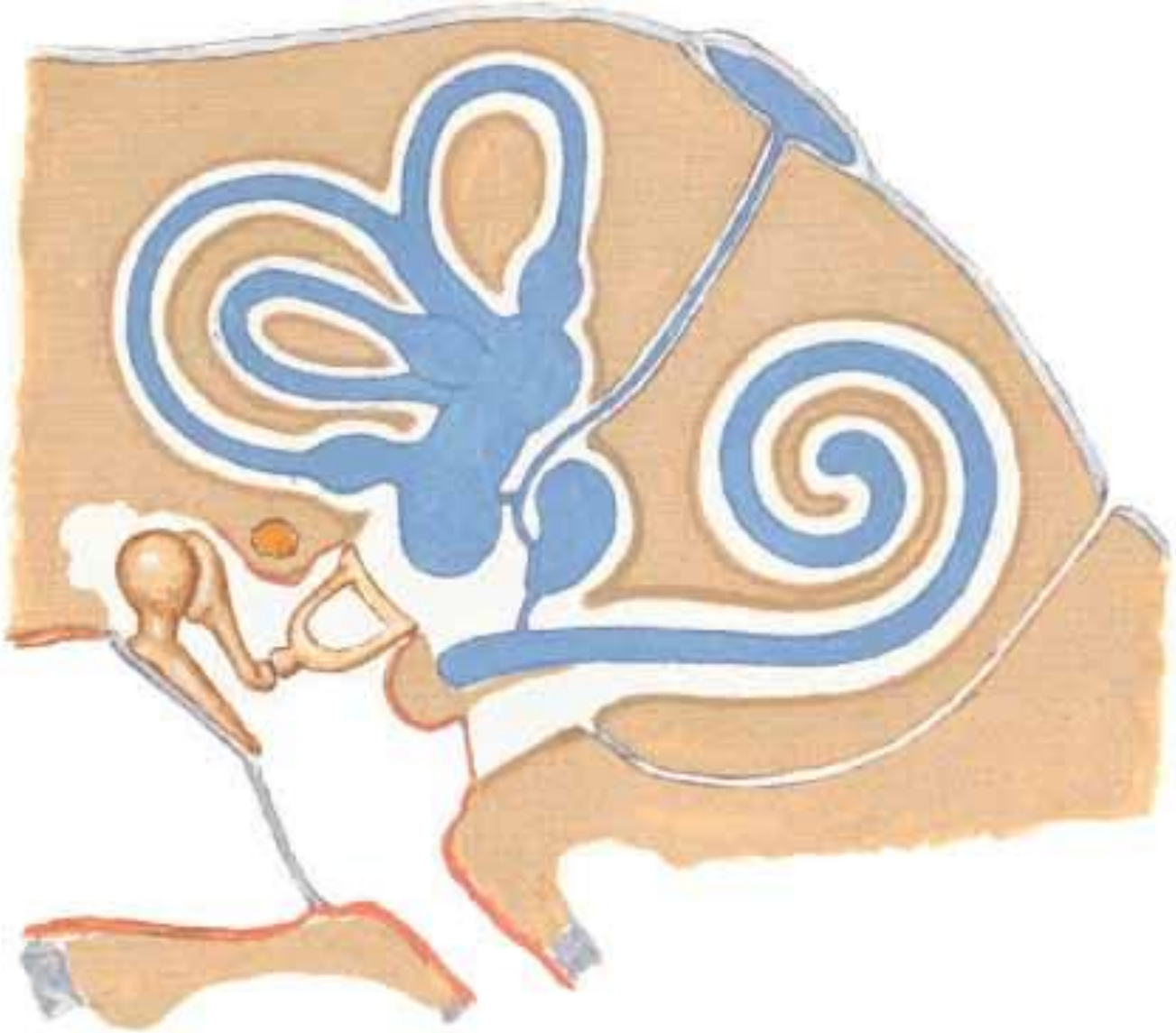
- **recessus ellipticus** (utricularis)
  - apertura interna canaliculi vestibuli
  - macula cribrosa superior
- crista vestibuli (pyramis vestibuli)
- **recessus sphericus** (saccularis)
- **recessus cochlearis**
  - macula cribrosa media
- macula cribrosa inferior (in ampulla canalis semicircularis posterioris)

Osseous labyrinth (*labyrinthus osseus*)

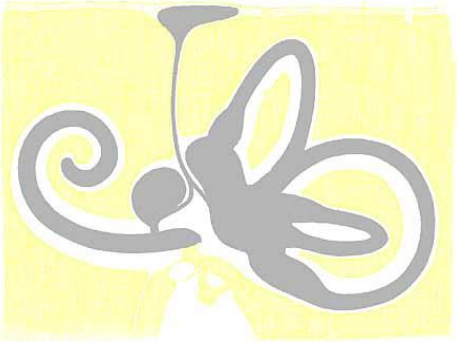


Bony and Membranous Labyrinths

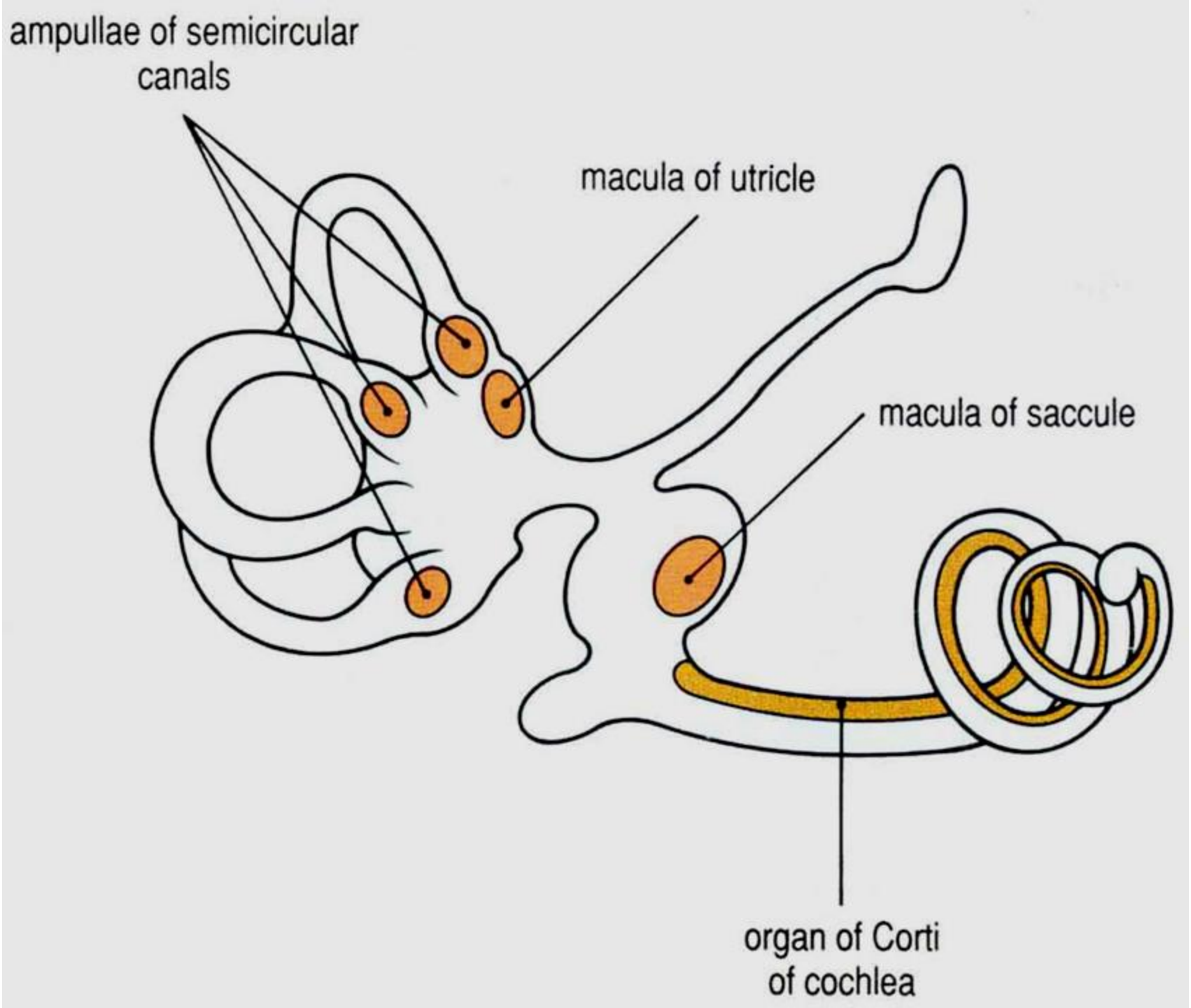
Schema



Membranous labyrinth (*Labyrinthus membranaceus*)
Vestribular labyrinth (*Labyrinhtus vestibularis)*

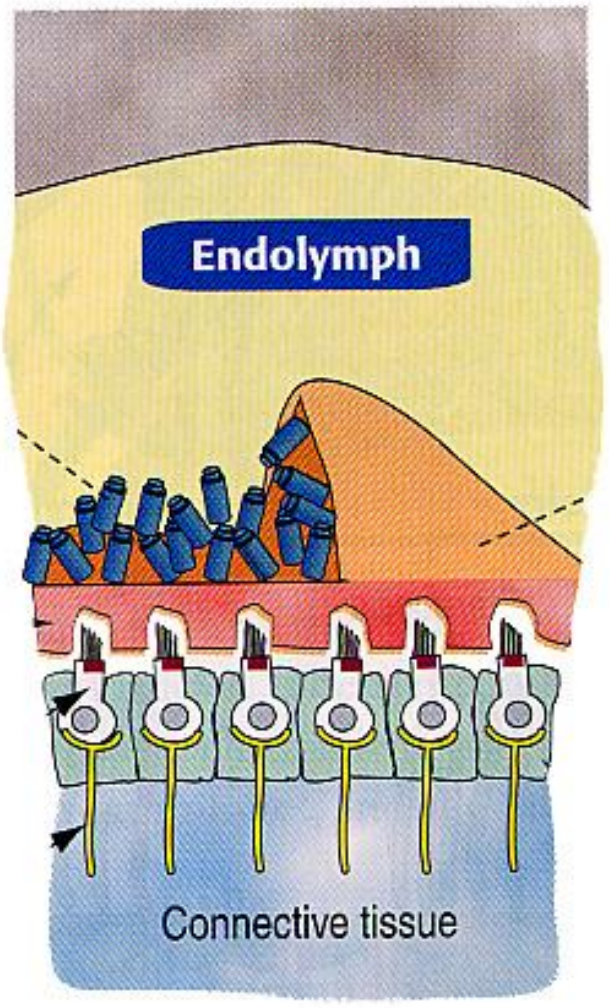


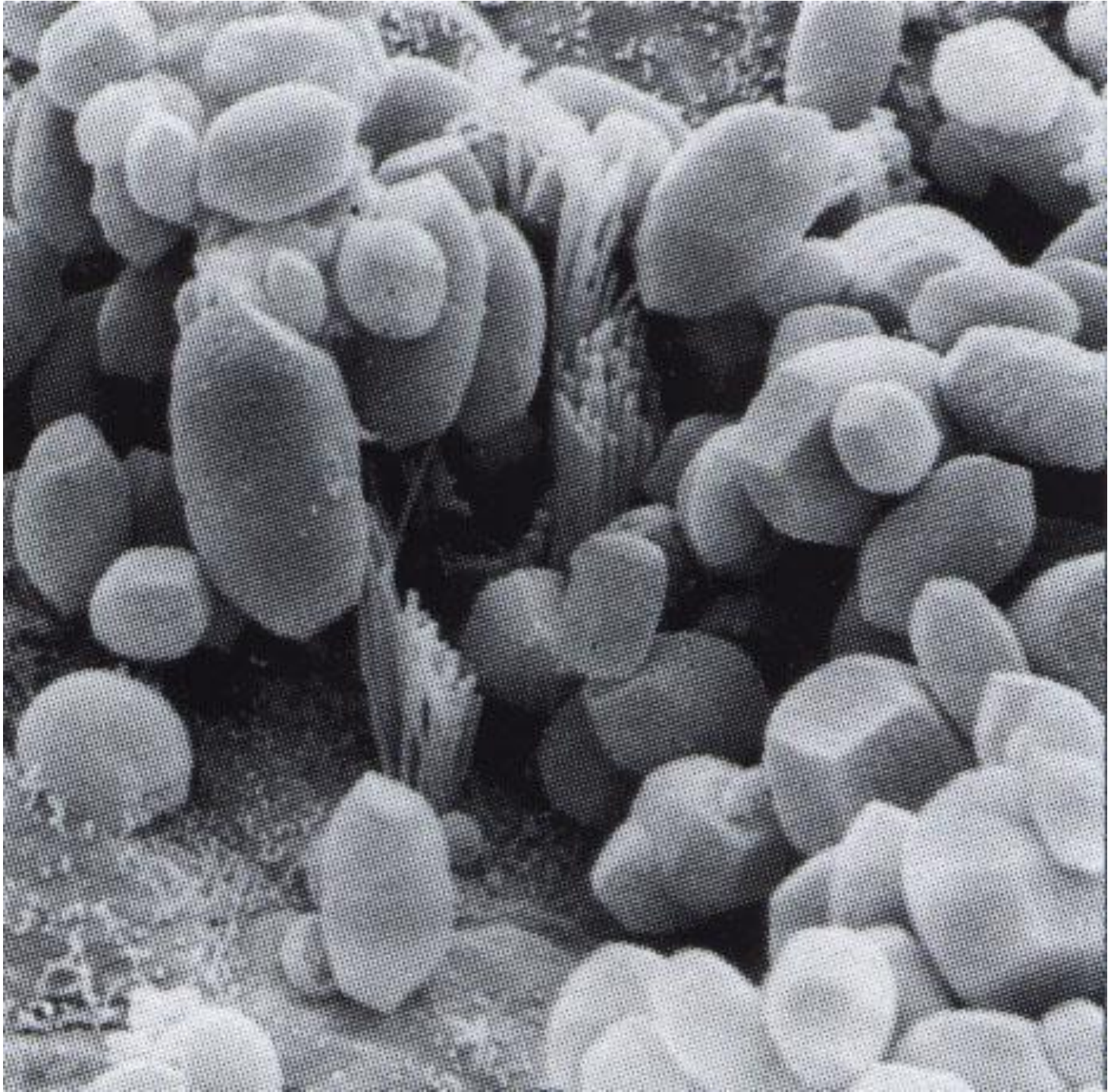
- utricle (*utricuus*)
- saccule (*sacculus*)
- semicircular ducts (*ductus semicirculares*)
  - ampullae, crura
- ductus utriculosaccularis, reuniens
- macula utriculi, sacculi
  - membrana statoconiorum (statoconium, striola)
- crista ampullaris (sulcus, cupula)


ampullae of semicircular canals
macula of utricle
macula of saccule
organ of Corti of cochlea

Otolithic organs
saculus et utriculus

- macula
- hair cells
- supporting cells
- gelatinous layer
- **otoconia** – crystals of $CaCO_3$
  - *otoliths = term for crystal in reptiles*





Osseous labyrith (*Labyrinhtus osseus*)
Semicircular canals (*Canales semicirculares*)

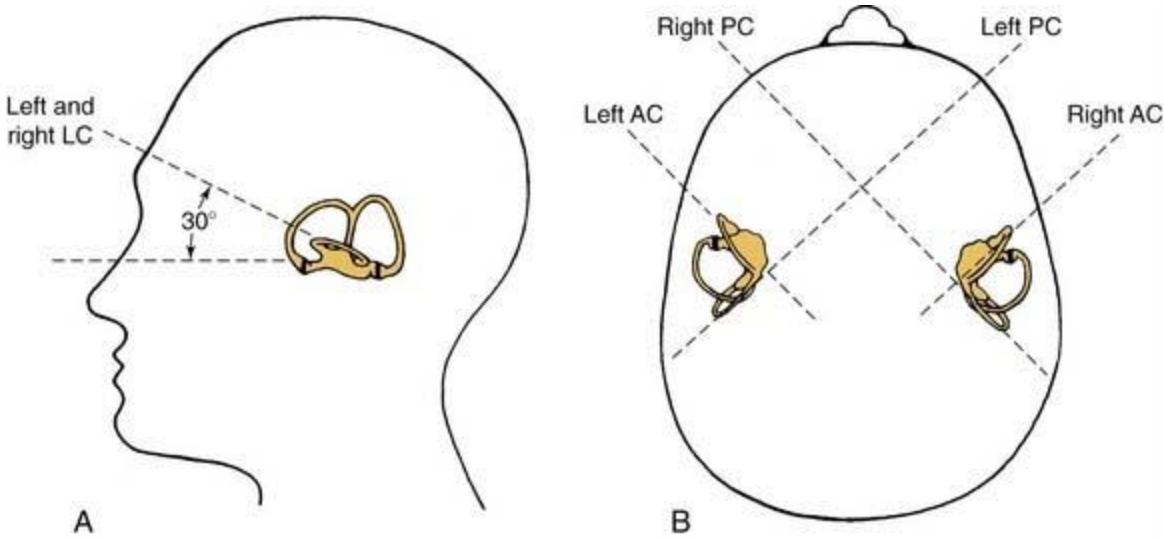
- Canalis semicircularis **anterior** (parallel with axis of petrosal bone) – eminentia arcuata
- Canalis semicircularis **posterior** (perpendicular)
- Canalis semicircularis **lateralis** (horizontal) – prominentia c.s.l.

ampulla ossea (3)

crus commune

(ant. + post.),

crus simplex (lat.)

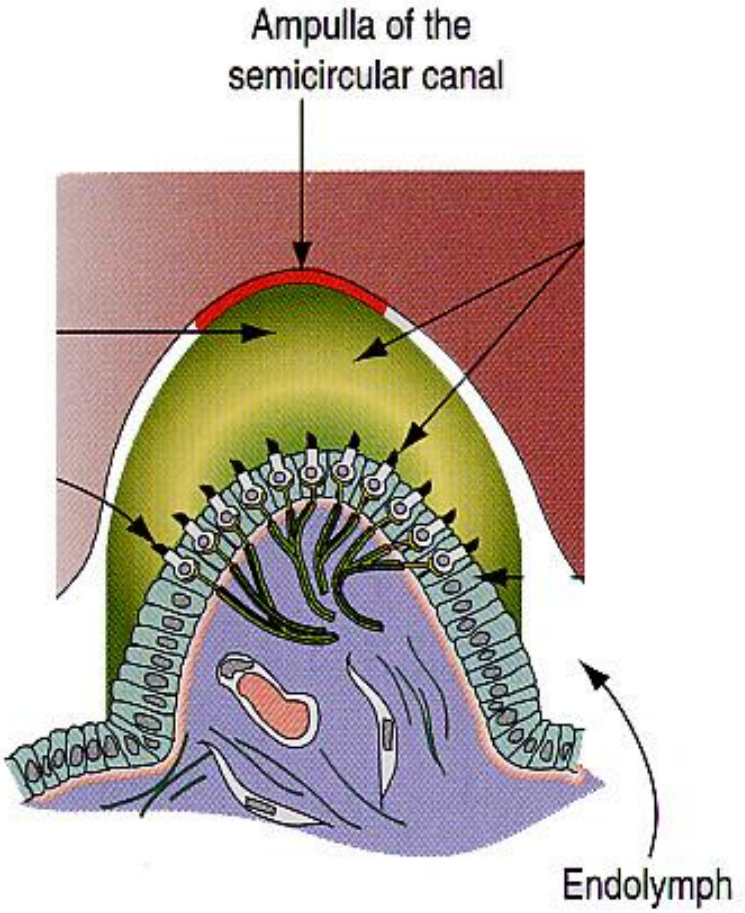


a

b

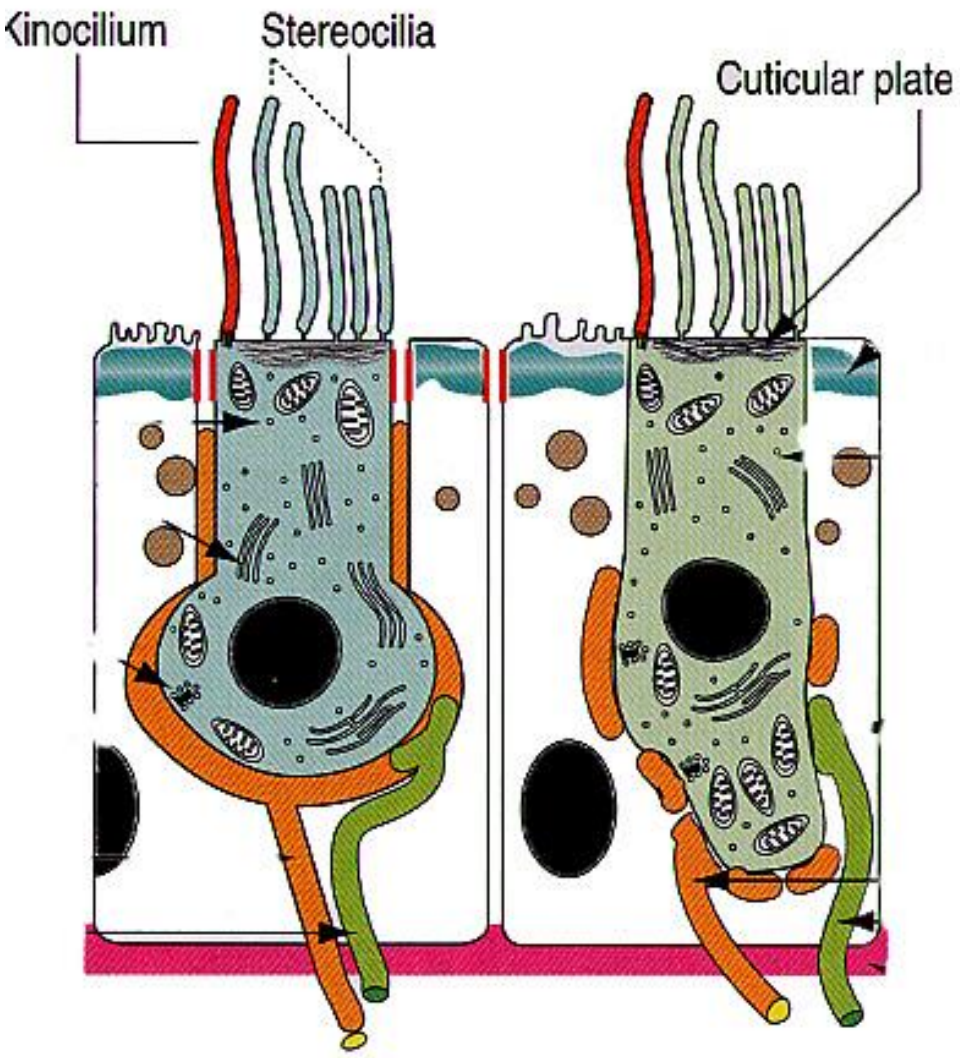
Semicircular canals and ducts

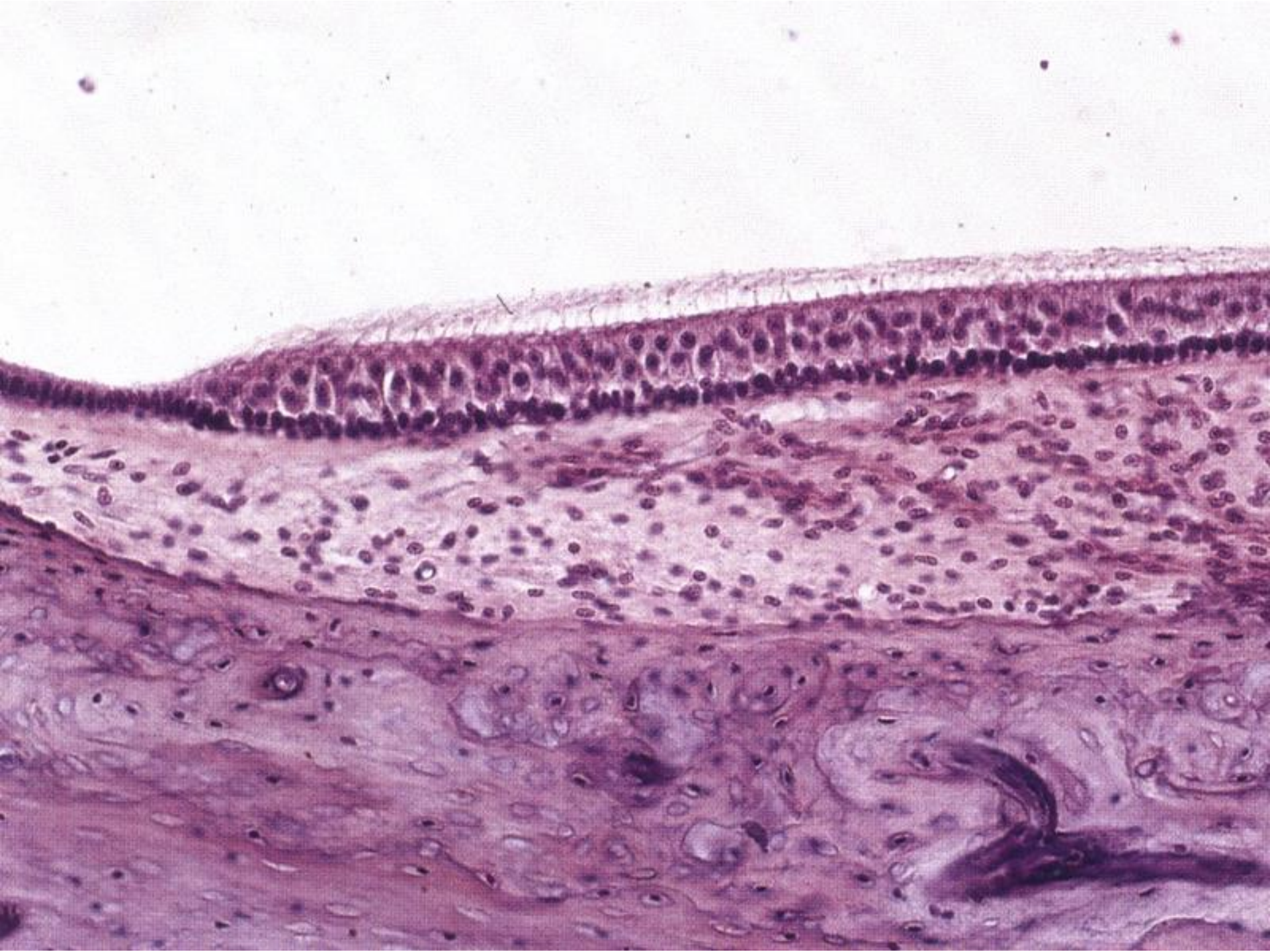
- membranous **ducts** inside bony **canals**
- receptors in ampullae
- cristae ampullares
  - perpendicular to axis of canal
  - gelatinous mass
  - hair cells
  - supporting cells



Hair cells

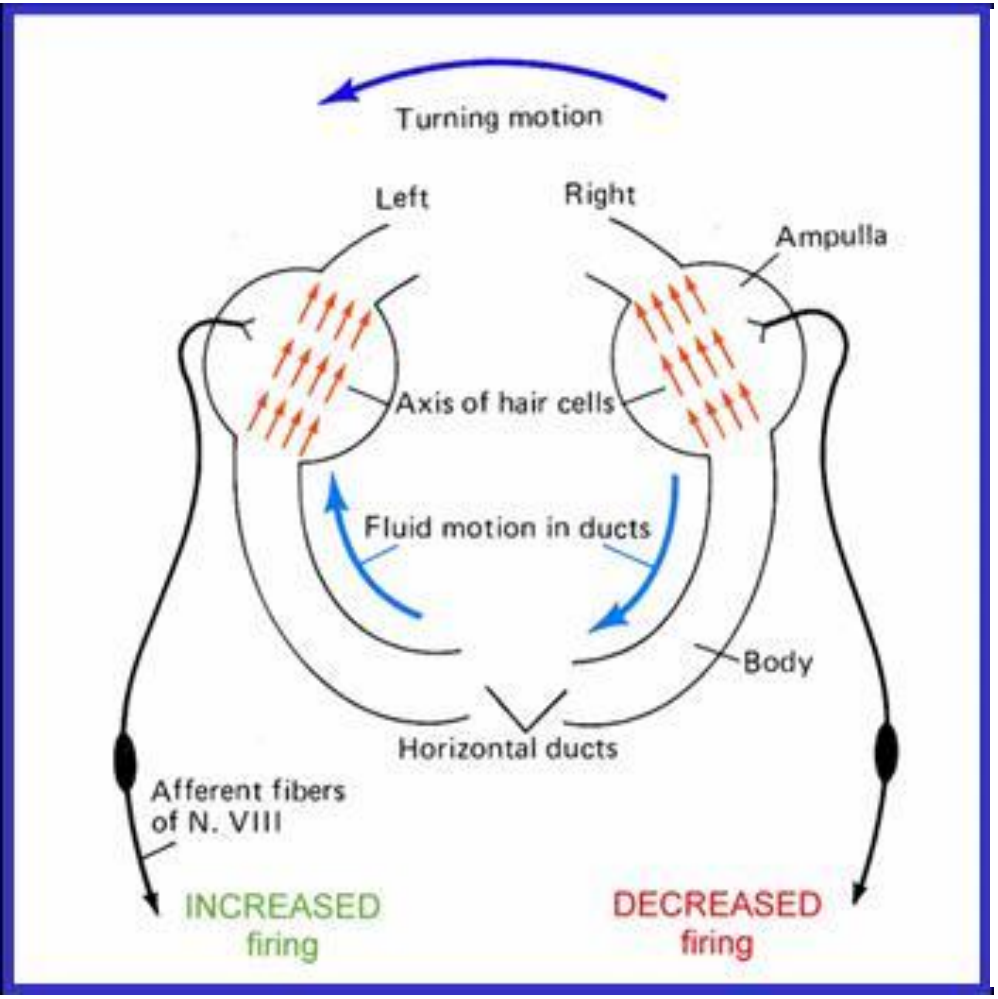
- two types
- apical surface:
  - 1 kinocilia
  - more stereocilia
- basally – synapsis with nerve fibers

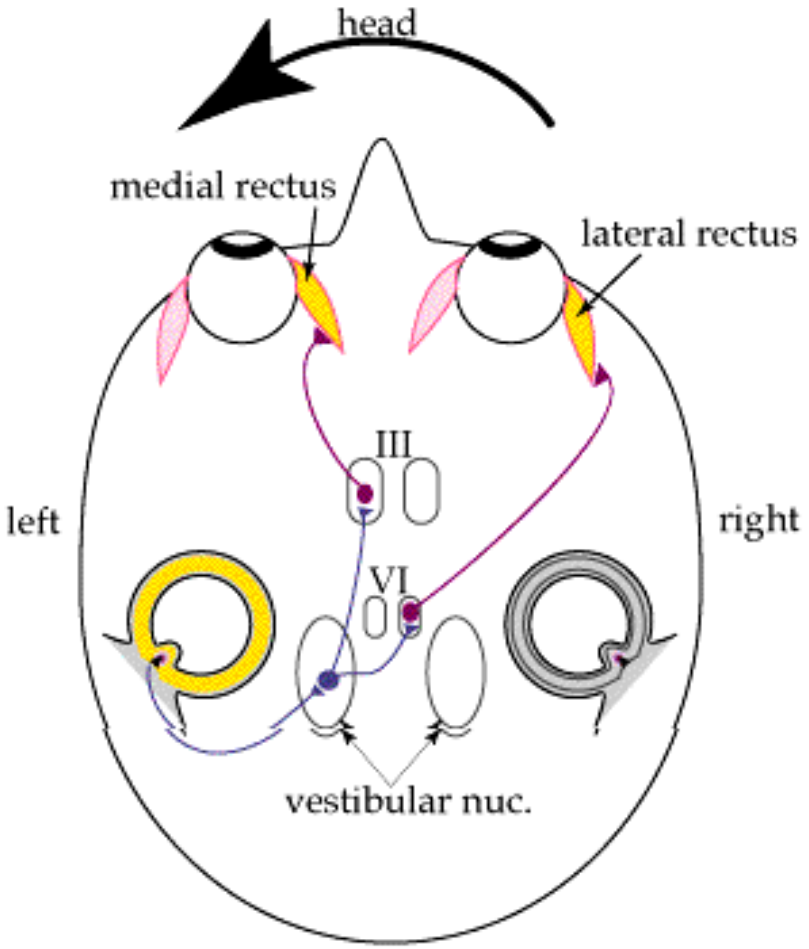


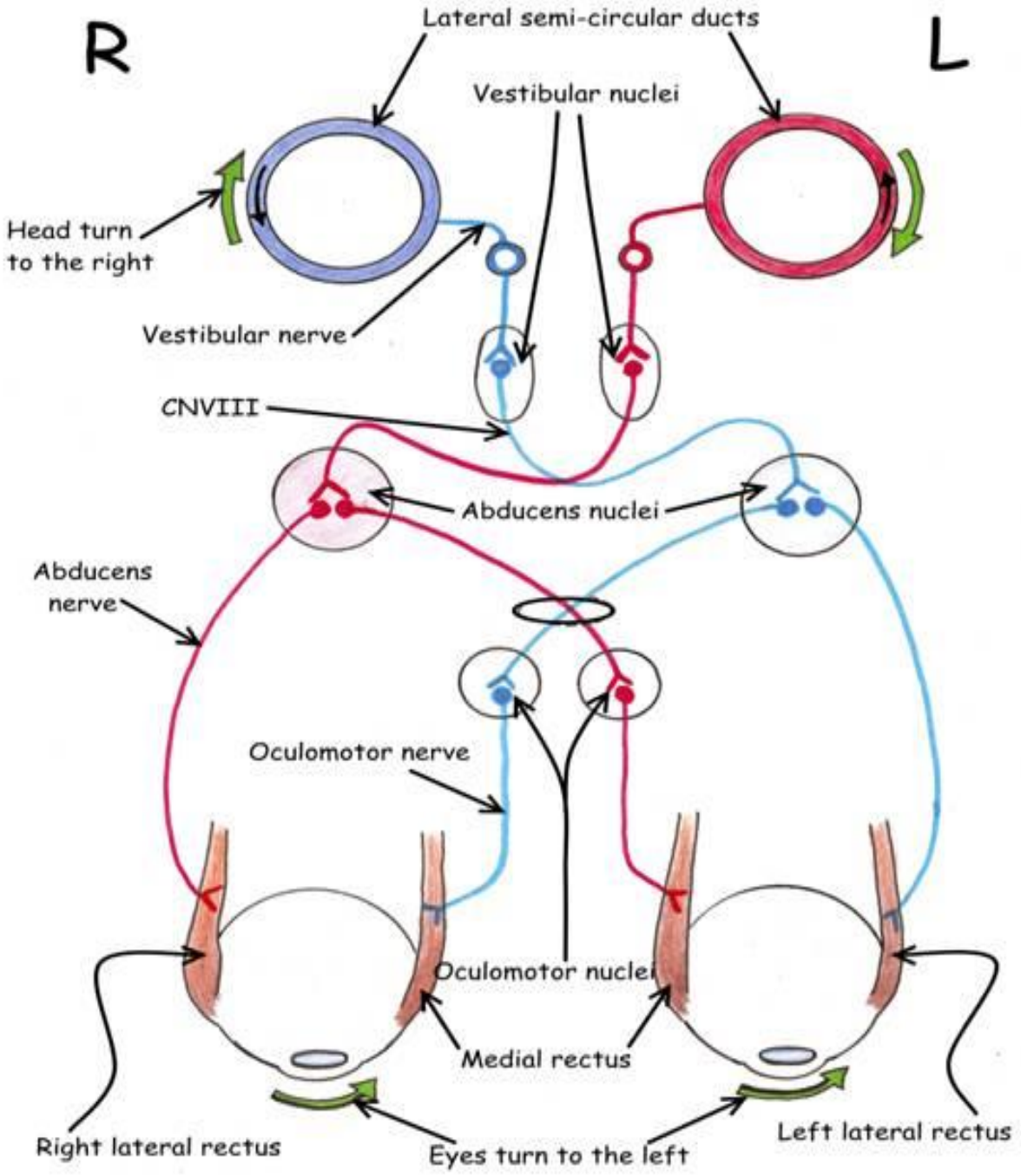


Movements of the head and eyes

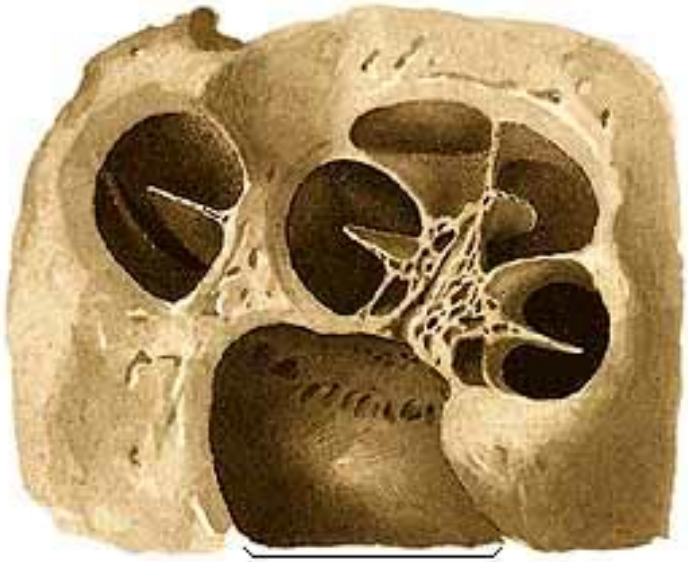
Vestibulo-ocular reflex






R
L
Lateral semi-circular ducts
Vestibular nuclei
Head turn
to the right
Vestibular nerve
CNVIII
Abducens nuclei
Abducens
nerve
Oculomotor nerve
Oculomotor nuclei
Medial rectus
Right lateral rectus
Eyes turn to the left
Left lateral rectus

Osseous labyrinth (*Labyrinhtus osseus*)
Cochlea



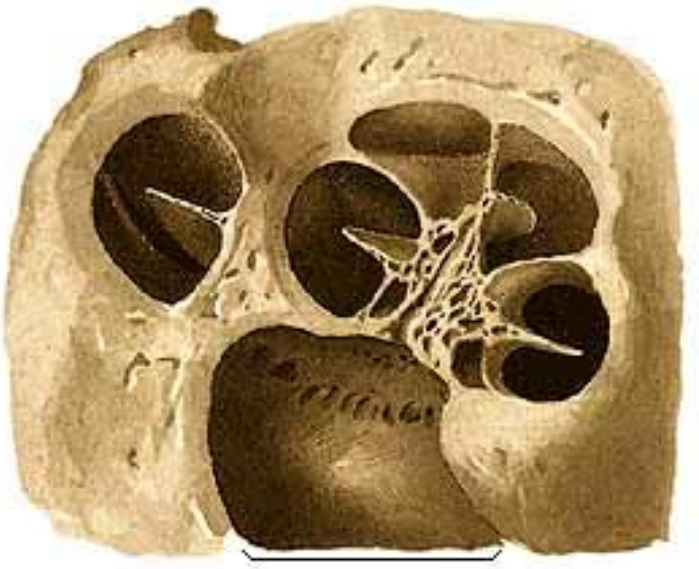
length 34 mm

- cupula, basis (2 and ¾ turn)
- scala vestibuli → helicotrema → scala tympani
- canalis spiralis cochleae
- lamina spiralis ossea
  - lamella vestibularis + spiralis
  - hamulus l.s. (*ends in helicotrema)*
- lamina spiralis secundaria (*in first turn only)*
- apertura interna canaliculi cochleae

Osseous labyrinth (*Labyrinhtus osseus*)
Cochlea

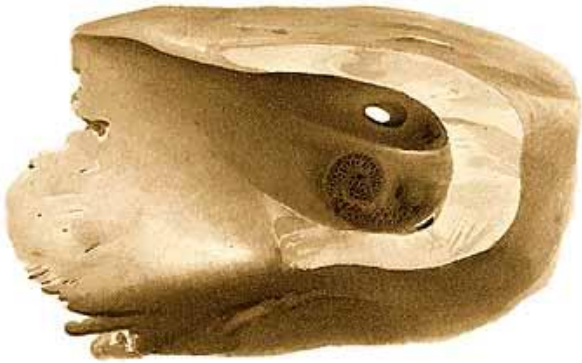
Modiolus

- basis
- lamina
- canalis spiralis – *ganglion cochleare*
- canales longitudinales – *n. cochlearis*



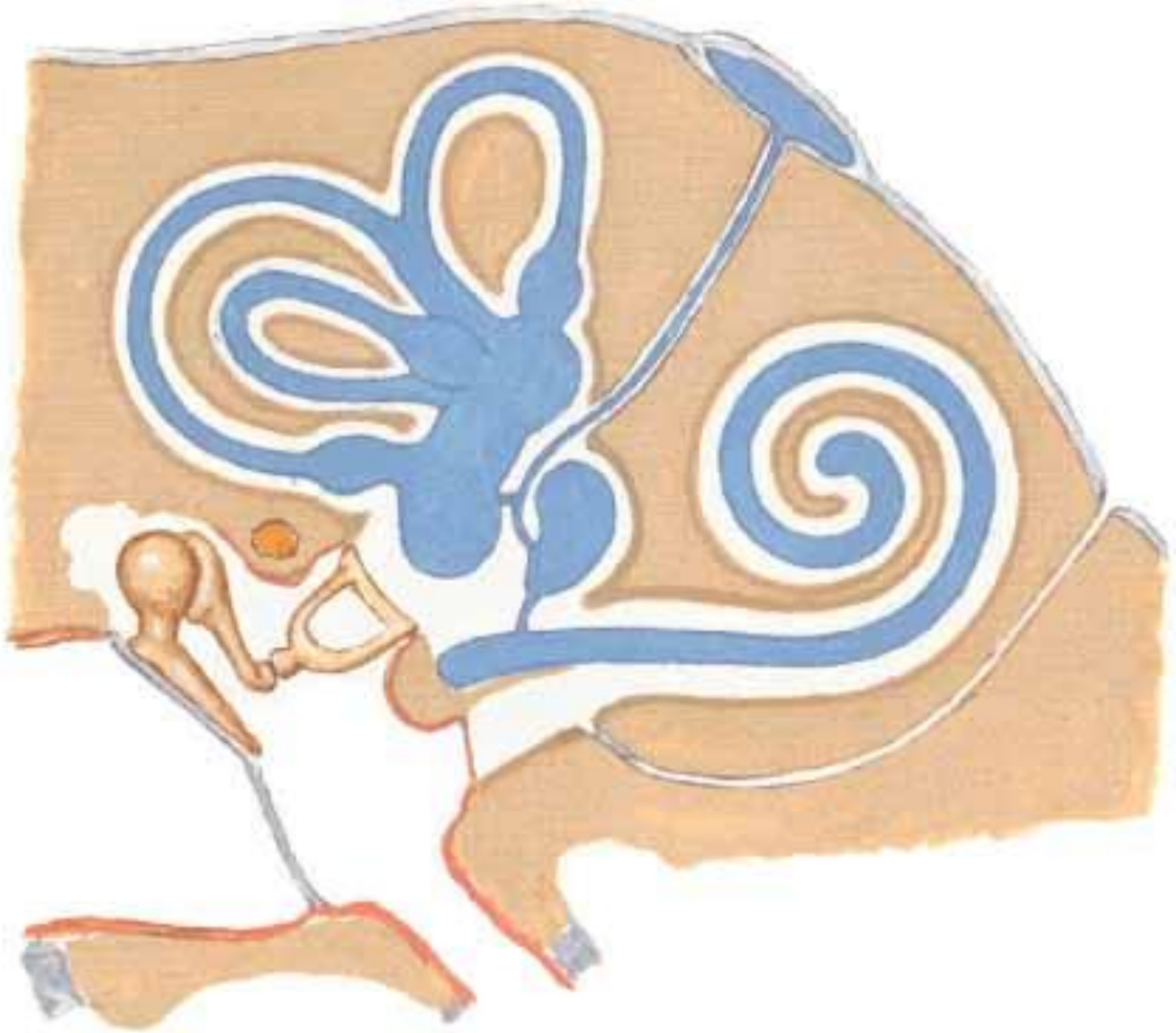
Osseous labyrinth (*Labyrinhtus osseus*)
Internal acoustic meatus (*Meatus acusticus internus*)

- porus acusticus internus
- fundus m.a.i.
- crista transversa + verticalis
- area n. VII.
- area cochlearis – tractus spiralis foraminosus
- area vestibularis sup. + inf.
- foramen singulare



Bony and Membranous Labyrinths

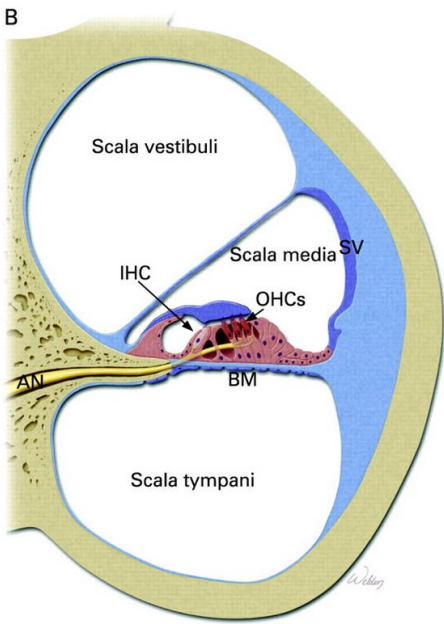
Schema



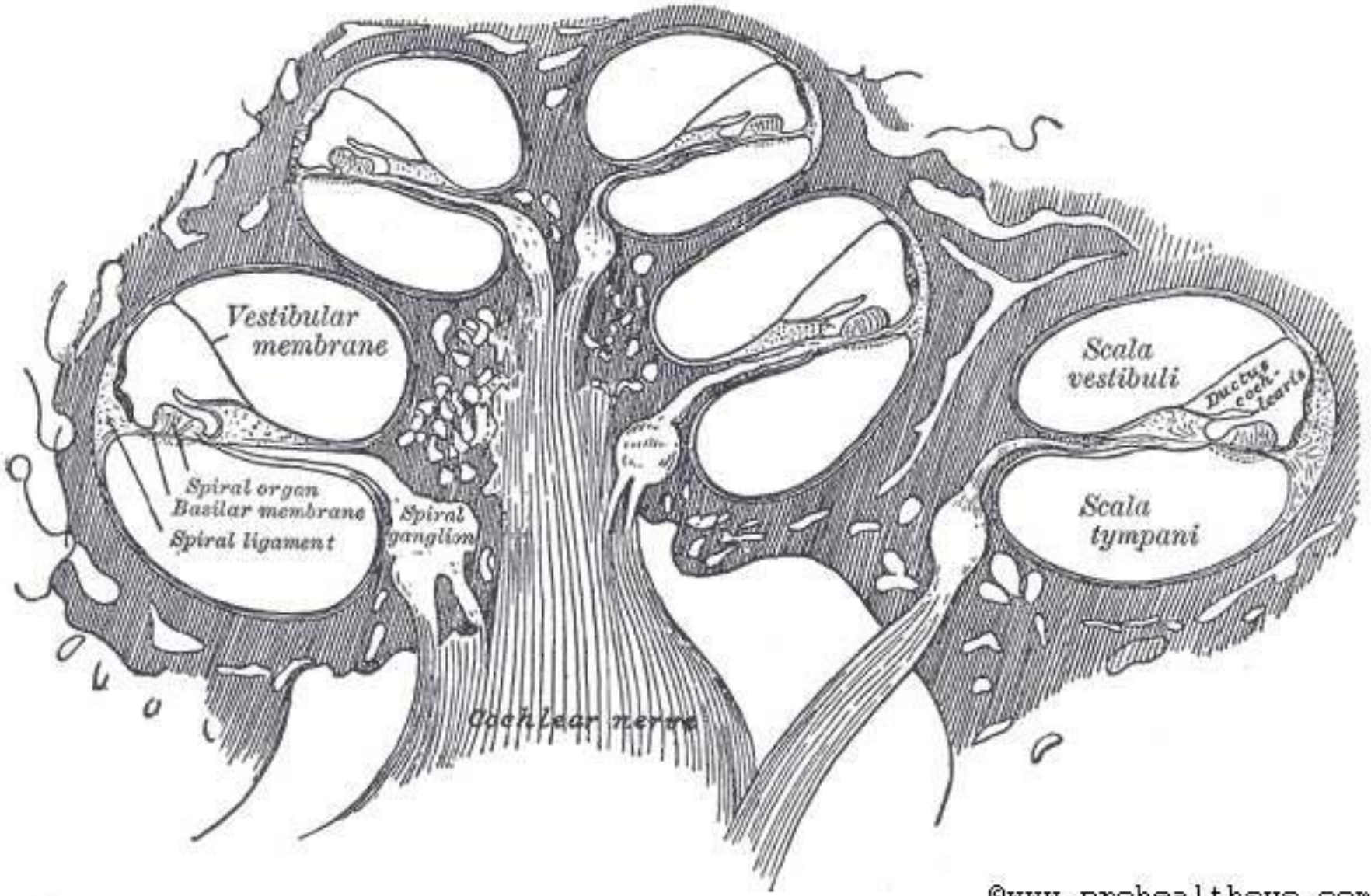
Membranous labyrinth (*labyrinthus membranaceus*)
Cochlear labyrinth (*Labyrinthus cochlearis*)

scala media = ductus cochlearis

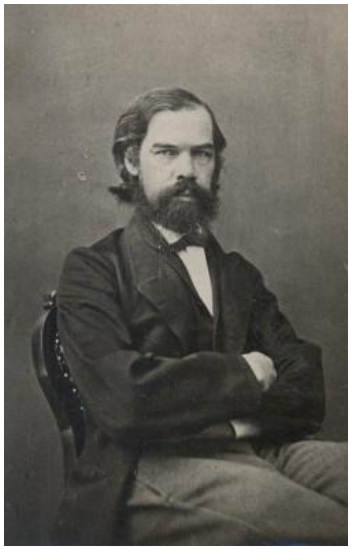
- paries vestibularis: **membrana vestibularis *Reissneri***
- paries externus: **stria vascularis**, prominentia spiralis, vas prominens, lig. spirale
- paries tympanicus (= membrana spiralis): crista basilaris, **lamina basilaris**, vas spirale
- limbus spiralis: labium limbi tympanici, labium limbi vestibularis, (dentes acustici)
- **membrana tectoria**
- **organum spirale *Corti***
  - membrana reticularis, sulcus spiralis int.+ ext.



Membranous labyrinth (*labyrinthus membranaceus*)
Cochlear labyrinth (*Labyrinthus cochlearis*)

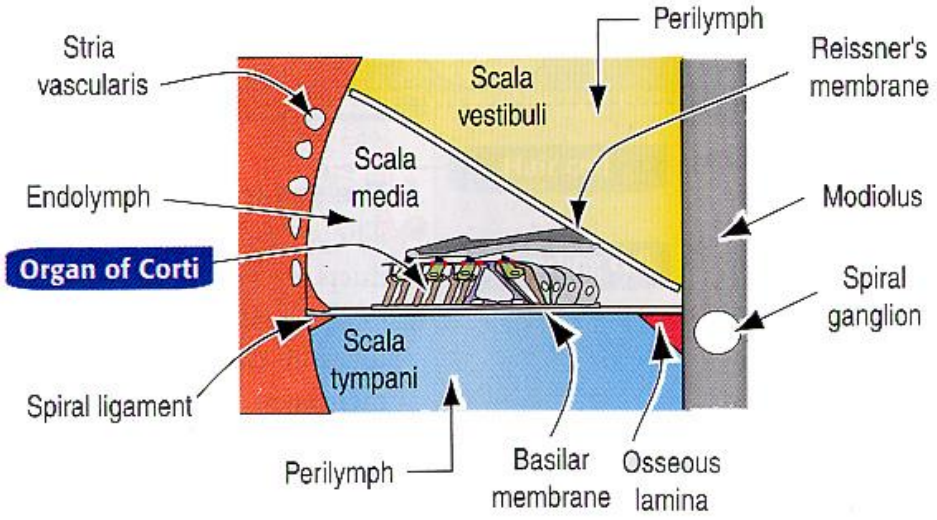


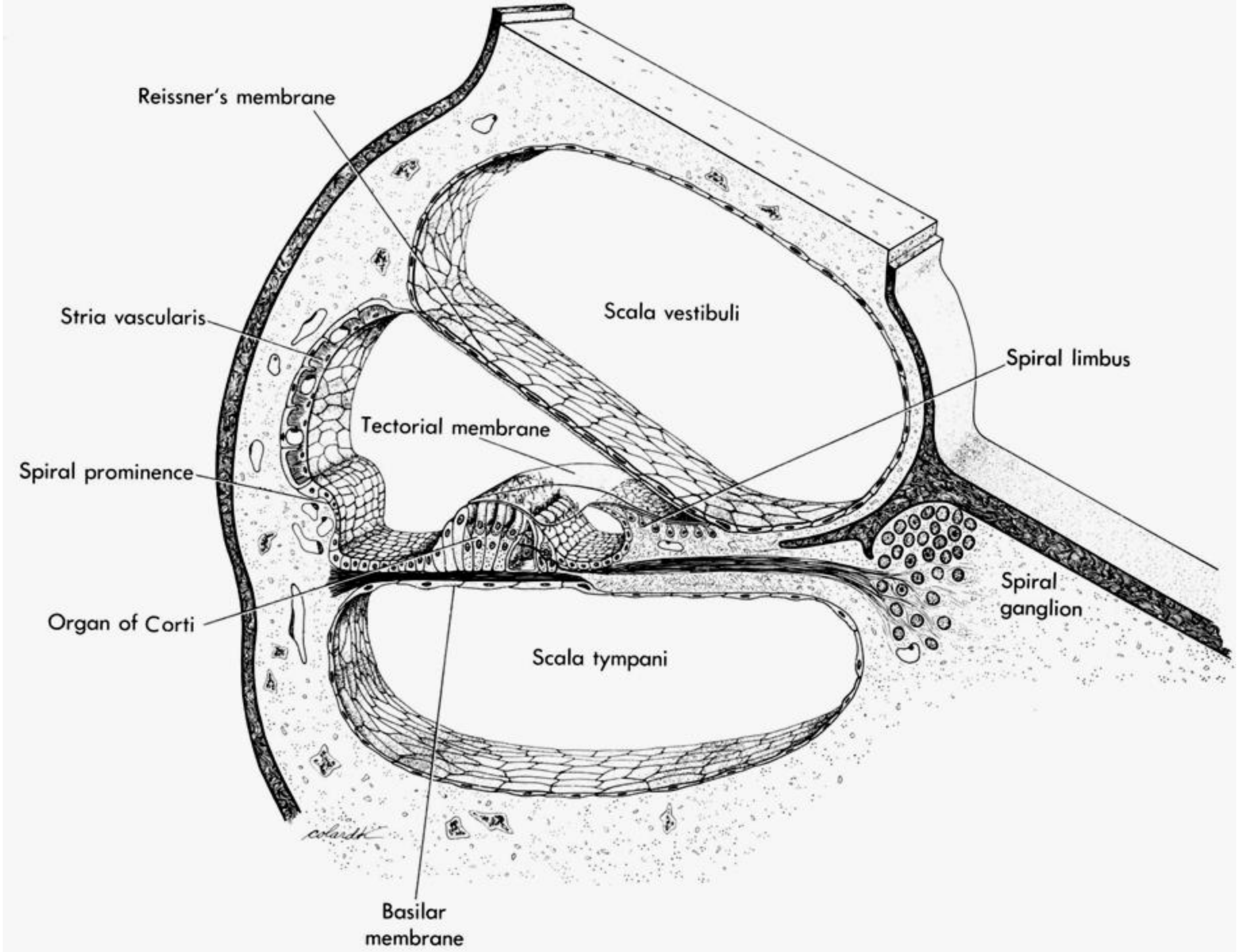
- Alfonso Giacomo Gaspare Corti
  - 1822 – 1876
  - Marquis (Marchese de San Stefano Belbo)
  - organum spirale
  - ganglion cochleare
- Ernst Reissner
  - 1824 – 1878
  - membrana vestibularis
- Antonio Scarpa
  - 1752 – 1832
  - ganglion vestibulare
  - His head is exhibited in university history museum in Pavia (Italy)



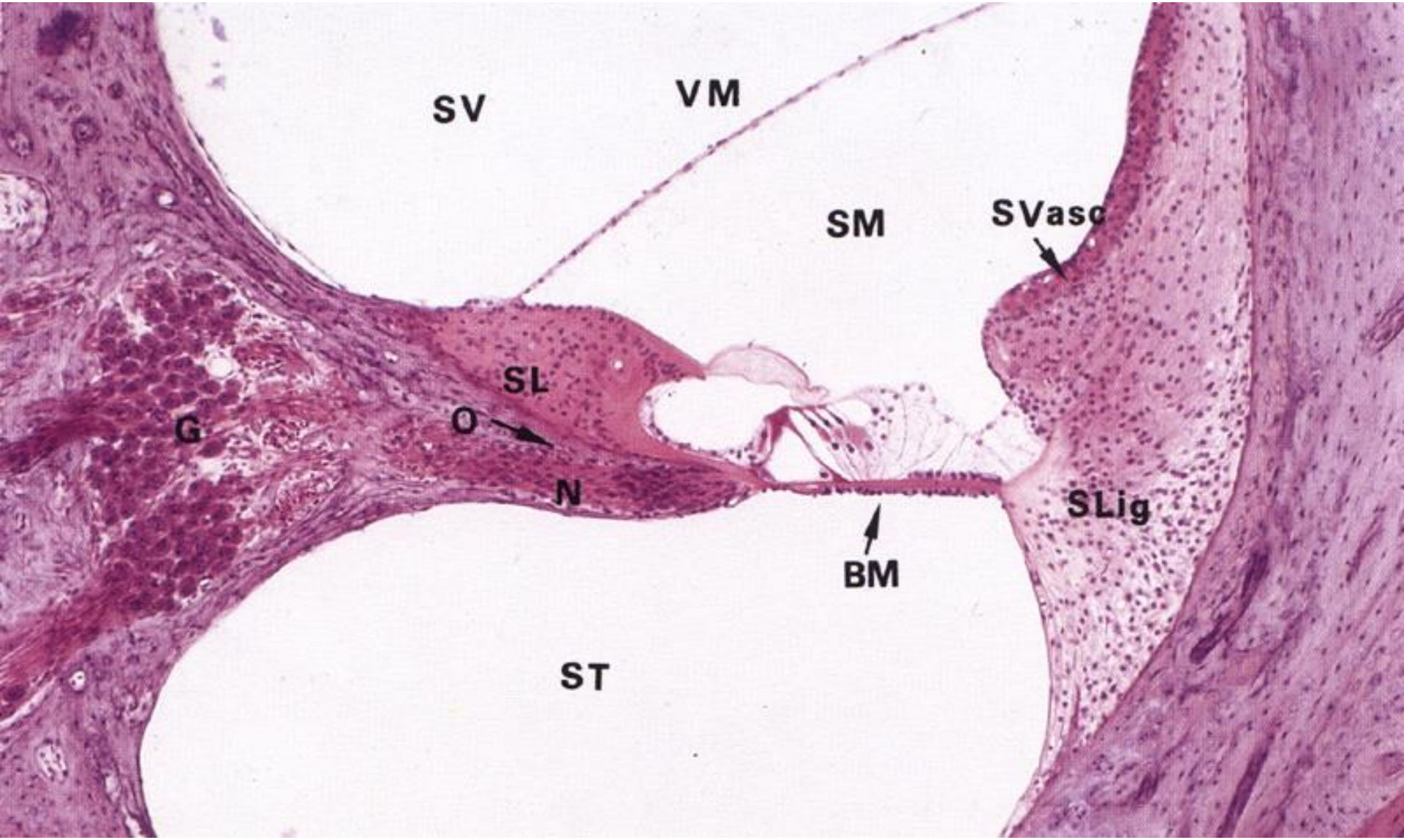
Cochlear labyrinth (*Labyrinthus cochlearis*)
Scala media = Cochlear duct (*ductus cochlearis*)

- contains endolymph
- lamina basilaris with Corti‘s spiral organ
- Gelatinous membrana tectoria covers Corti‘s spiral organ
- osseous lamina spiralis
- ligamentum spirale




Reissner's membrane
Stria vascularis
Scala vestibuli
Spiral limbus
Tectorial membrane
Spiral prominence
Spiral ganglion
Organ of Corti
Scala tympani
Basilar membrane

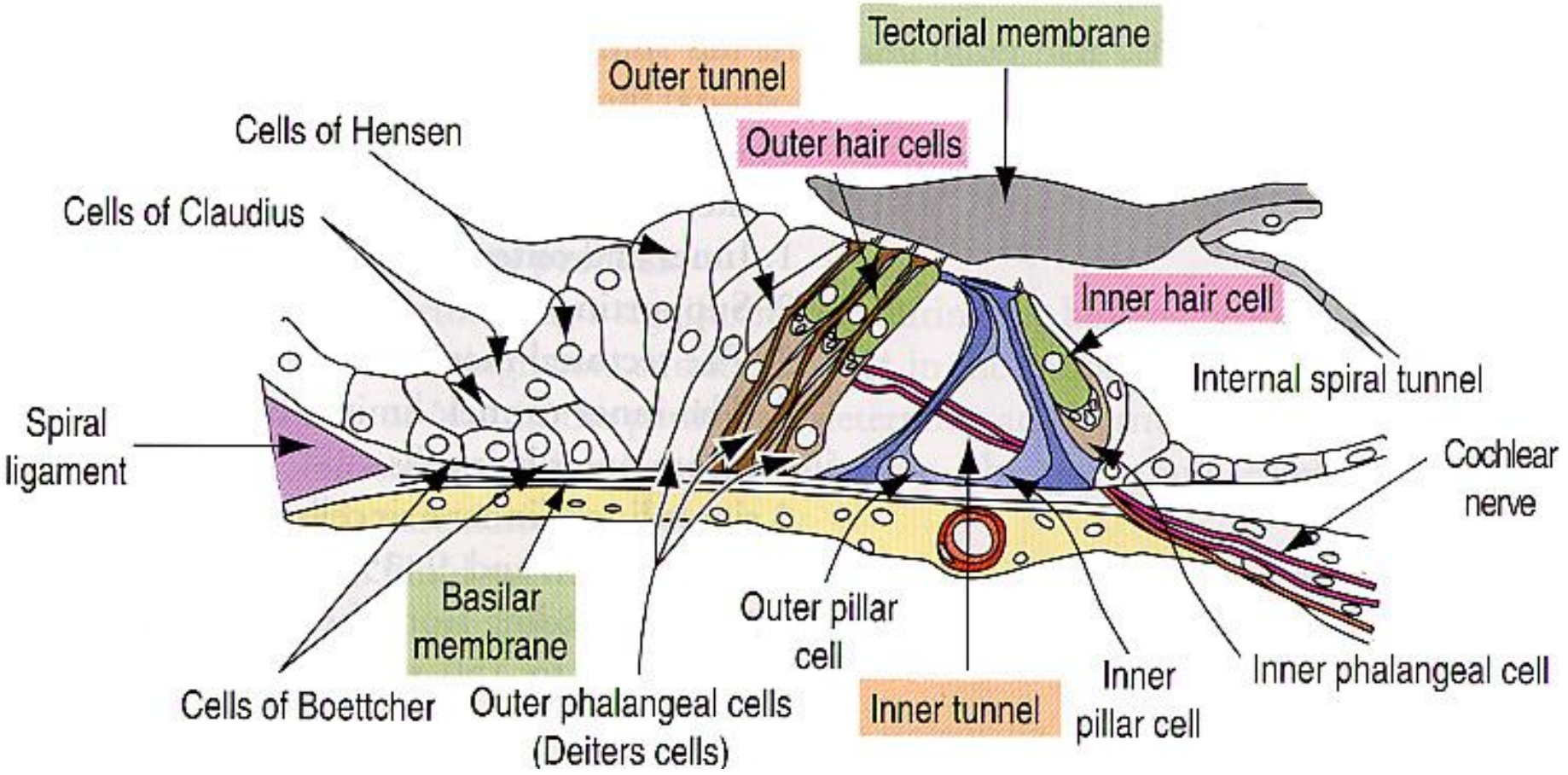
Cochlear labyrinth (*Labyrinthus cochlearis*)
Scala media = Cochlear duct (*ductus cochlearis*)



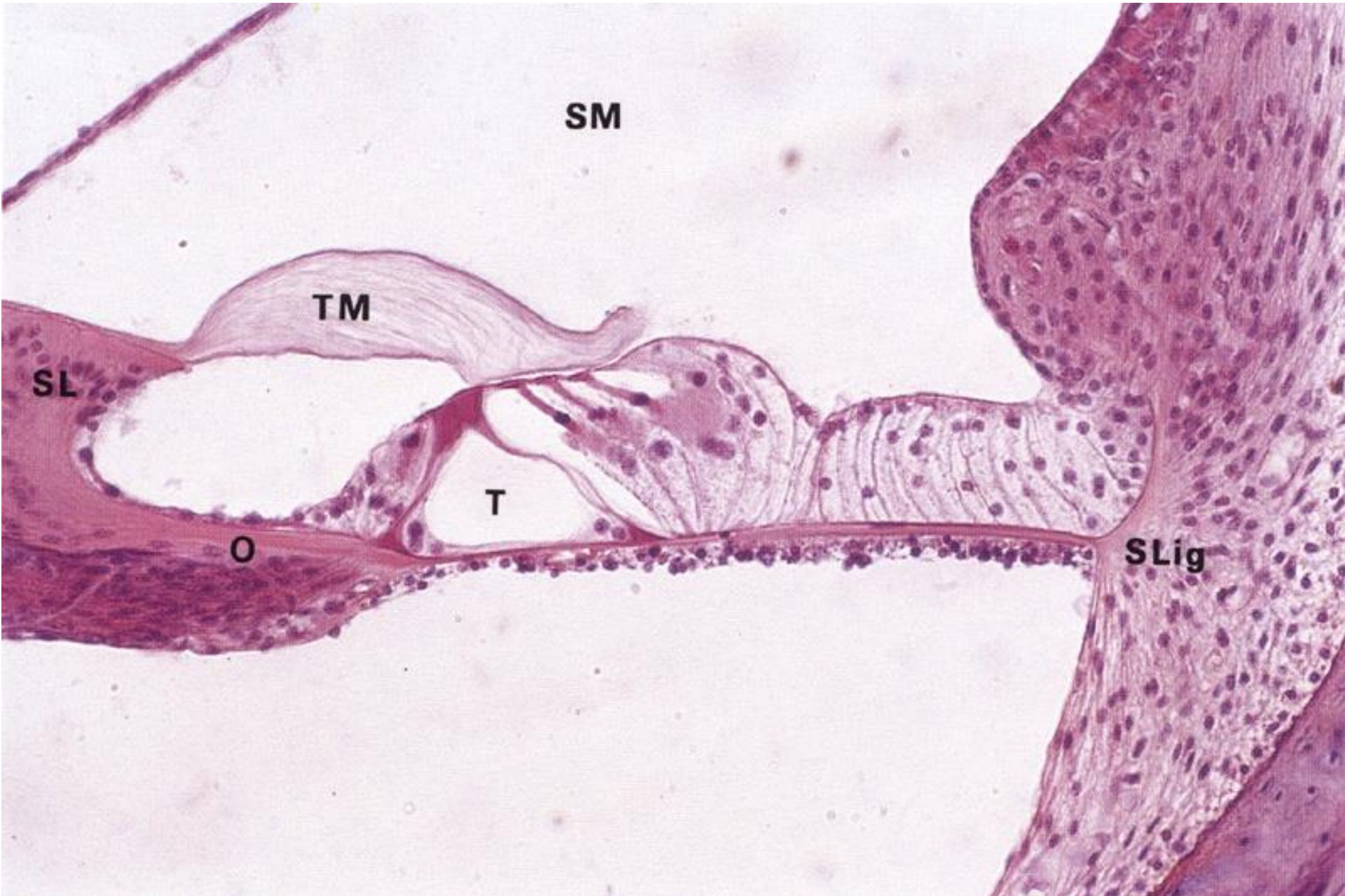
Corti‘s spiral organ (*Organum spirale*)

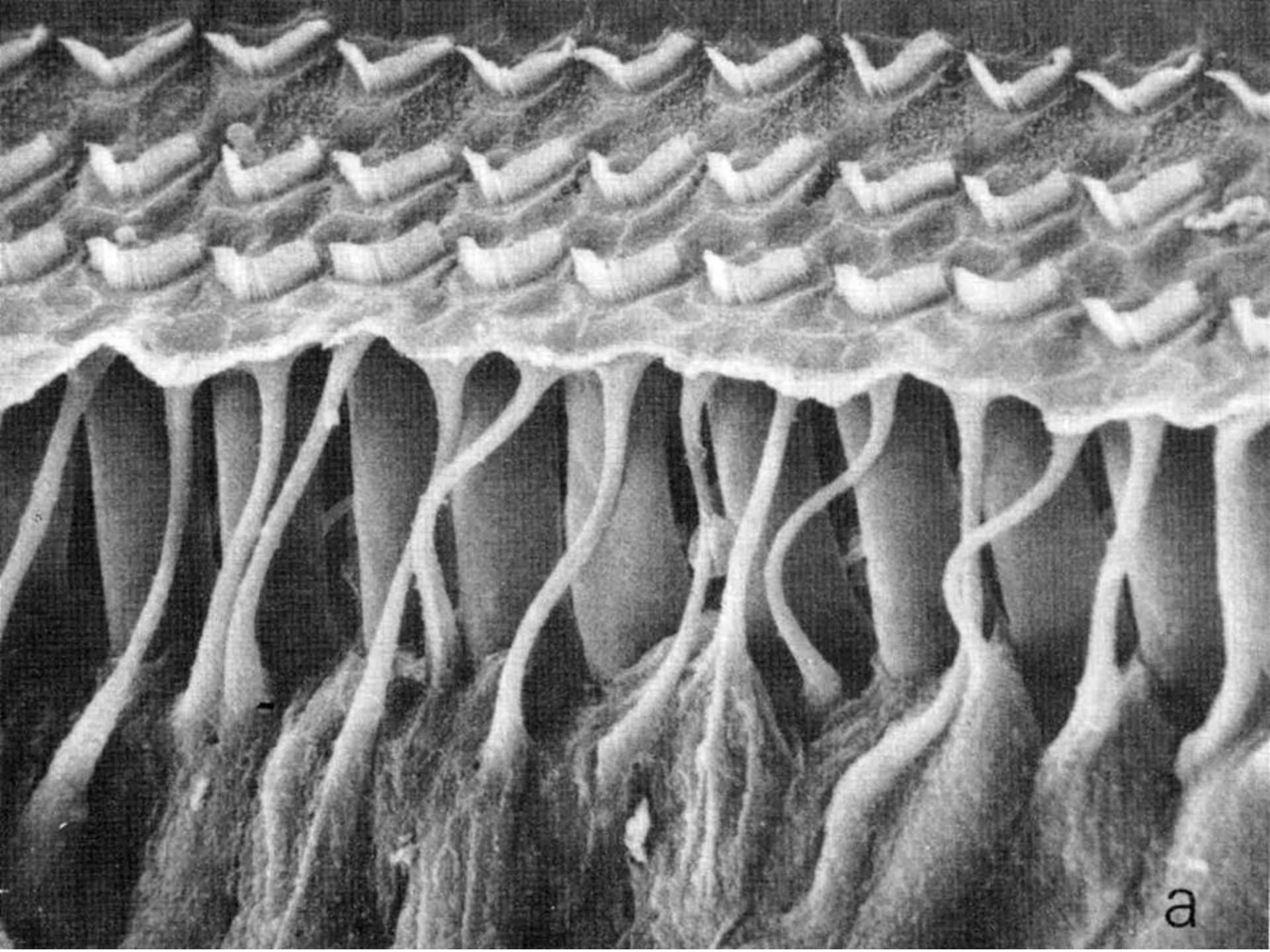
- hair cells
  - external (3-4 rows) and internal (1 row)
  - stereocilia on surface
    - apical ends inserted in membrana tectoria
  - cuniculus intermedius (*Nuel‘s* space) in between
- supporting cells
  - pillar cells (*Corti*) – lay the internal tunnel
  - phalangeal (*Deiters*) – cover hair cells
  - outer supporting – columnar (*Hensen*) and cuboid (Claudius)

Corti‘s spiral organ (*Organum spirale*)



Corti‘s spiral organ (*Organum spirale*)



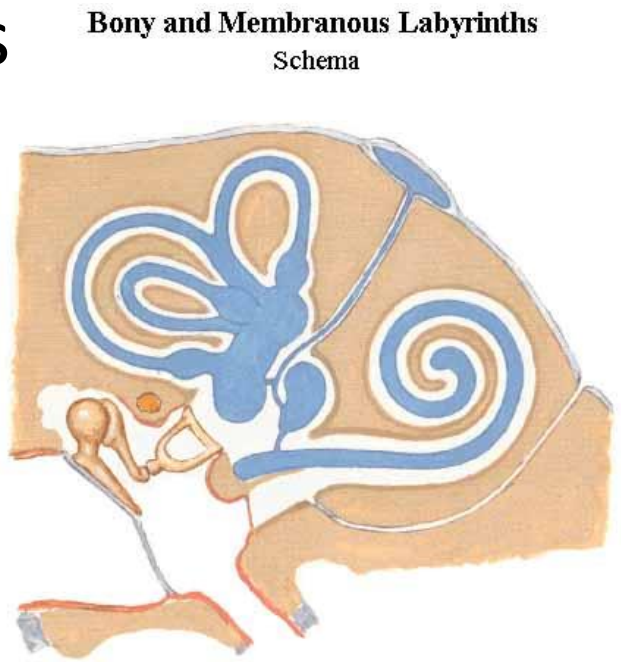

a

Endolymph and perilymph

- endolymph: similar to intracellular fluid

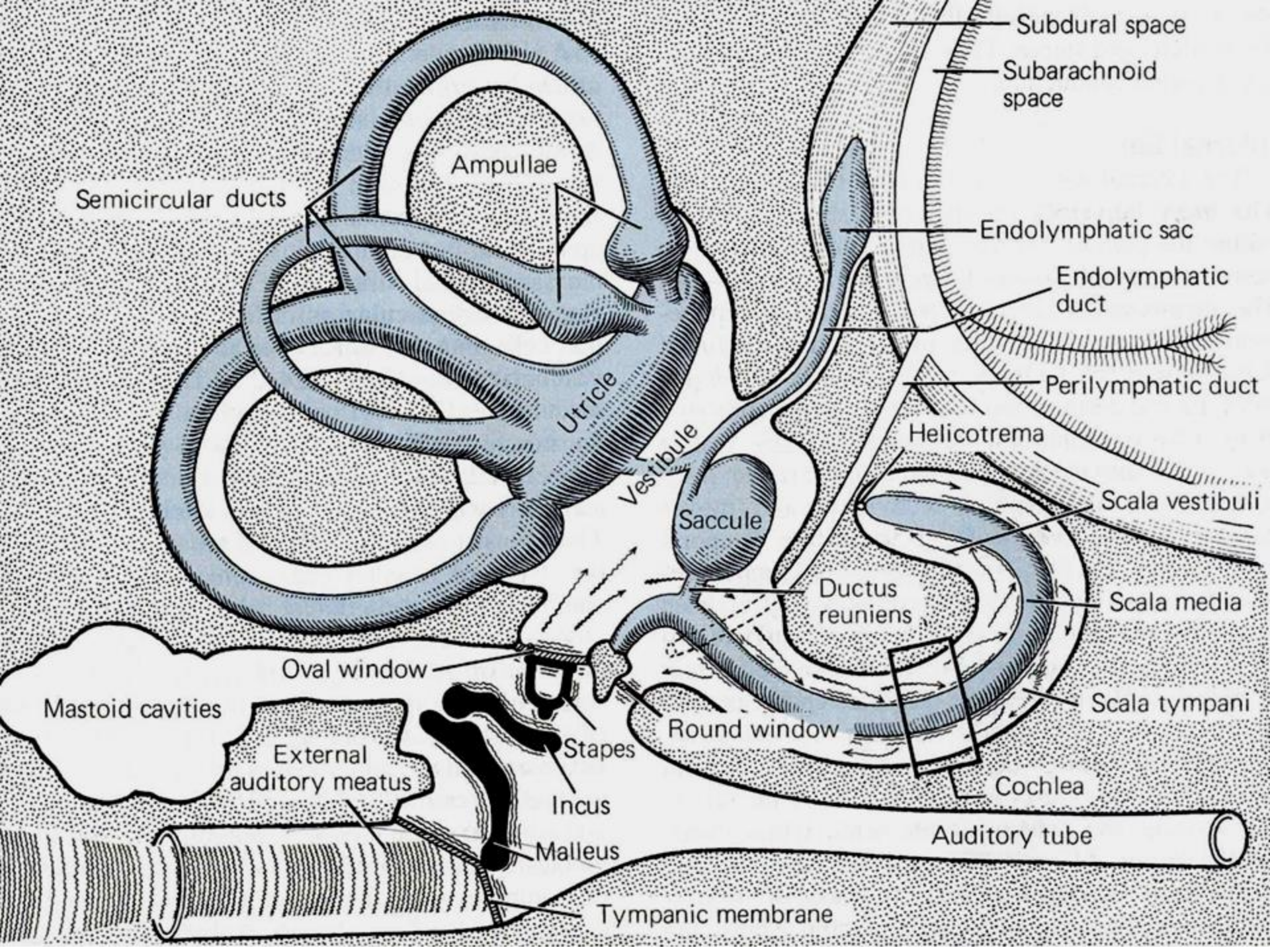
stria vascularis → scala media → ductus reuiens → sacculus → ductus utriculosaccularis → ductus endolymphaticus → saccus endolymphaticus (blind) → veins

also produced in maculae



- perilymph: similar to CSF

canalicus cochleae is connected with subarachnoid space


Subdural space
Subarachnoid space
Ampullae
Semicircular ducts
Endolymphatic sac
Endolymphatic duct
Perilymphatic duct
Utricle
Vestibule
Helicotrema
Saccule
Scala vestibuli
Ductus reuniens
Scala media
Oval window
Mastoid cavities
Scala tympani
Round window
Stapes
External auditory meatus
Cochlea
Incus
Auditory tube
Malleus
Tympanic membrane

Internal ear – *vascular supply*

arteries:

a. basilaris → a. cerebelli inf. ant. → **a. labyrinthi**

veins:

- vv. labyrinthi → sinus petrosus inf.
- v. aqueductus vestibuli
- v. aqueductus cochleae

lymph: replaced with endolymph and perilymph

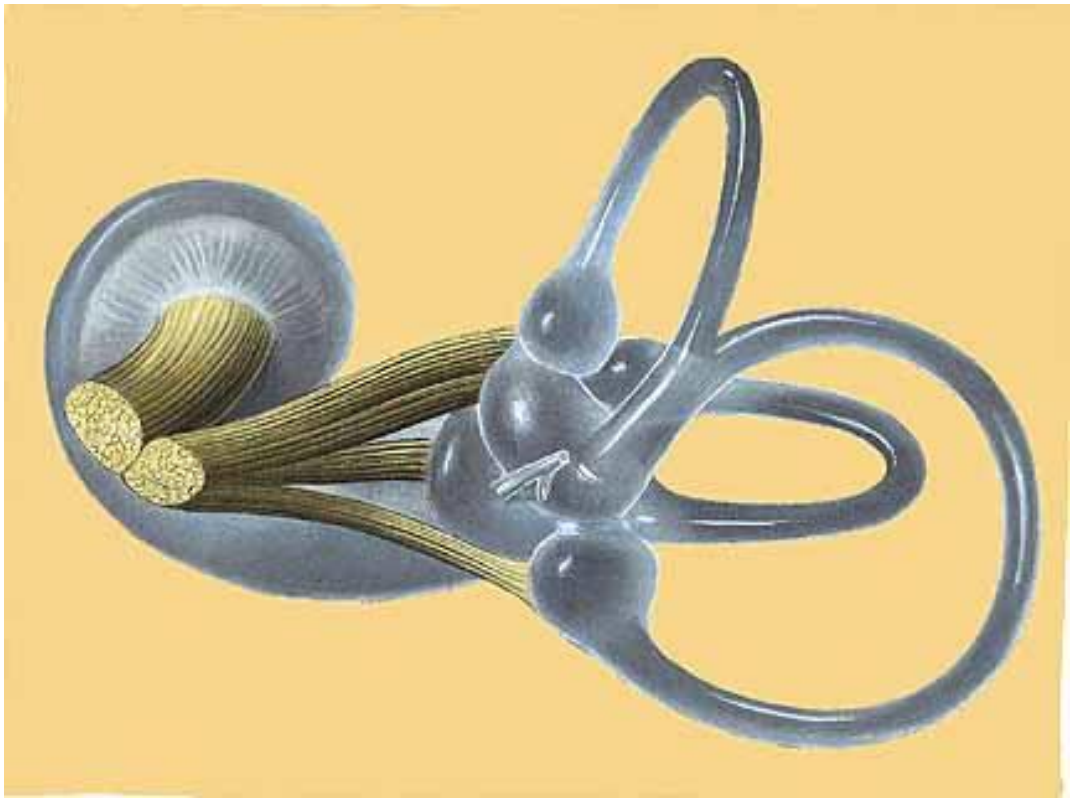
Internal ear – *nerves*

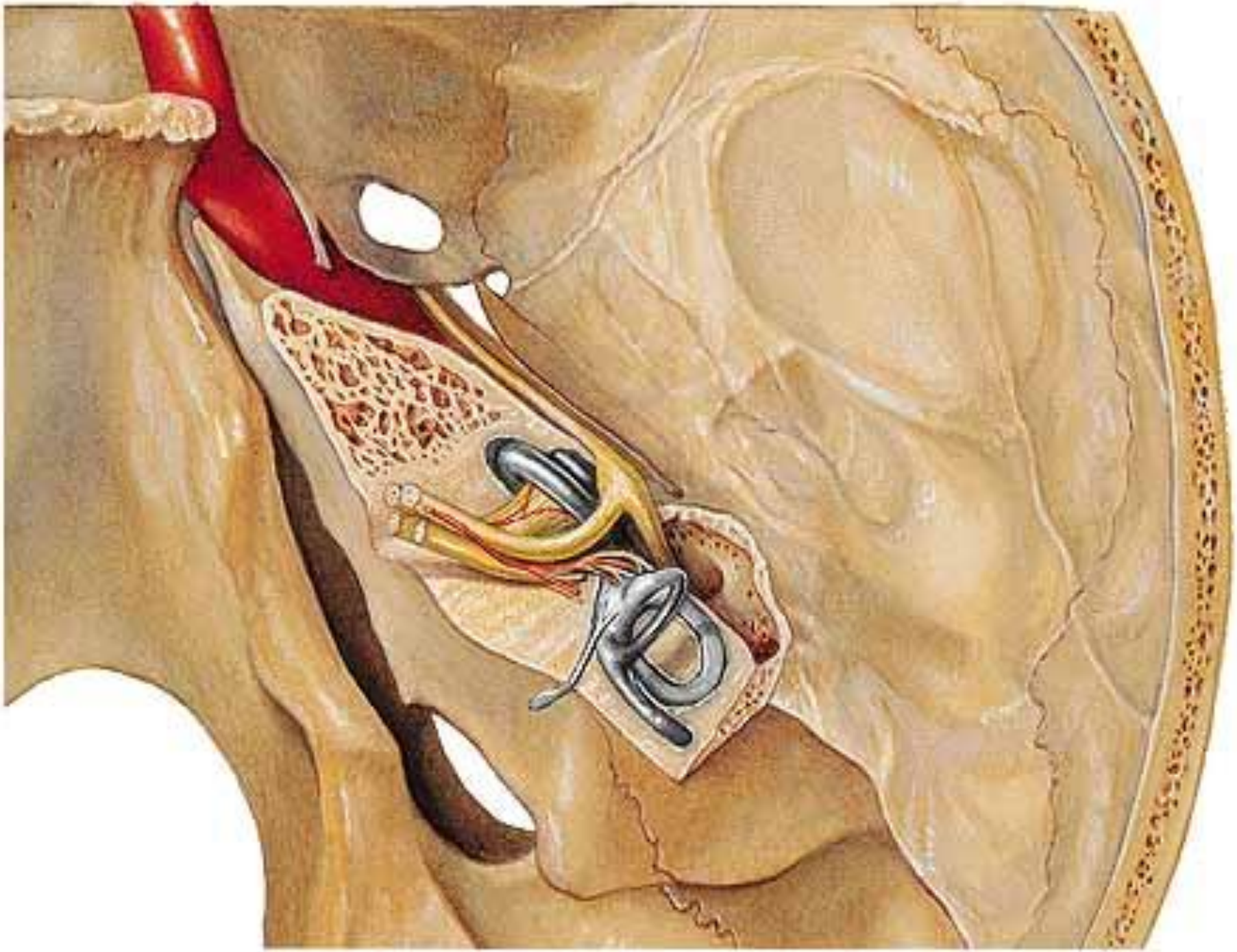
nervus vestibularis – ggl. vestibulare *Scarpae*

- pars superior
  - n. utriculoampullaris
- pars inferior
  - n. saccularis
  - n. ampullaris posterior

nervus cochlearis – ggl. cochleare *Corti*

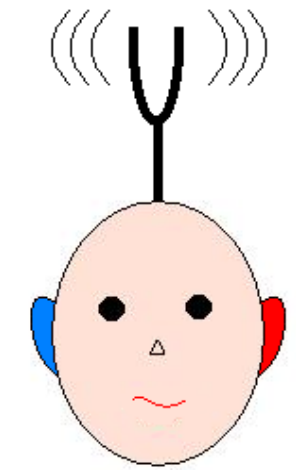
bipolar neurons





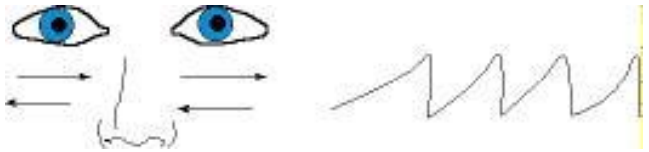
VIII. – Nervus vestibulocochlearis *examination*

- tuning-fork examination (Rinné, Weber, Schwabach)
- examination of nystagmus (9 direction after Hering)
- Romberg – stand with closed eyes
- Hautant – sit, strecht arms forwards and close eyes
- Unterberger – close eyes and march on site for 30 s



VIII. – Nervus vestibulocochlearis
irritation / palsy

- affection of hearing (= **hypacusis** → anacusis)
  - deafness (= **surditas**)



- **tinnitus** – humming, screeching, ringing…
- dizziness (= **vertigo**)
- involuntary eye movement (= **nystagmus**)

= alternating smooth pursuit in one direction and saccadic movements in the other direction.

  - slow-phase – stronger side suppresses the weaker one
  - fast-phase – compensatory movements back – serve for description of nystagmus

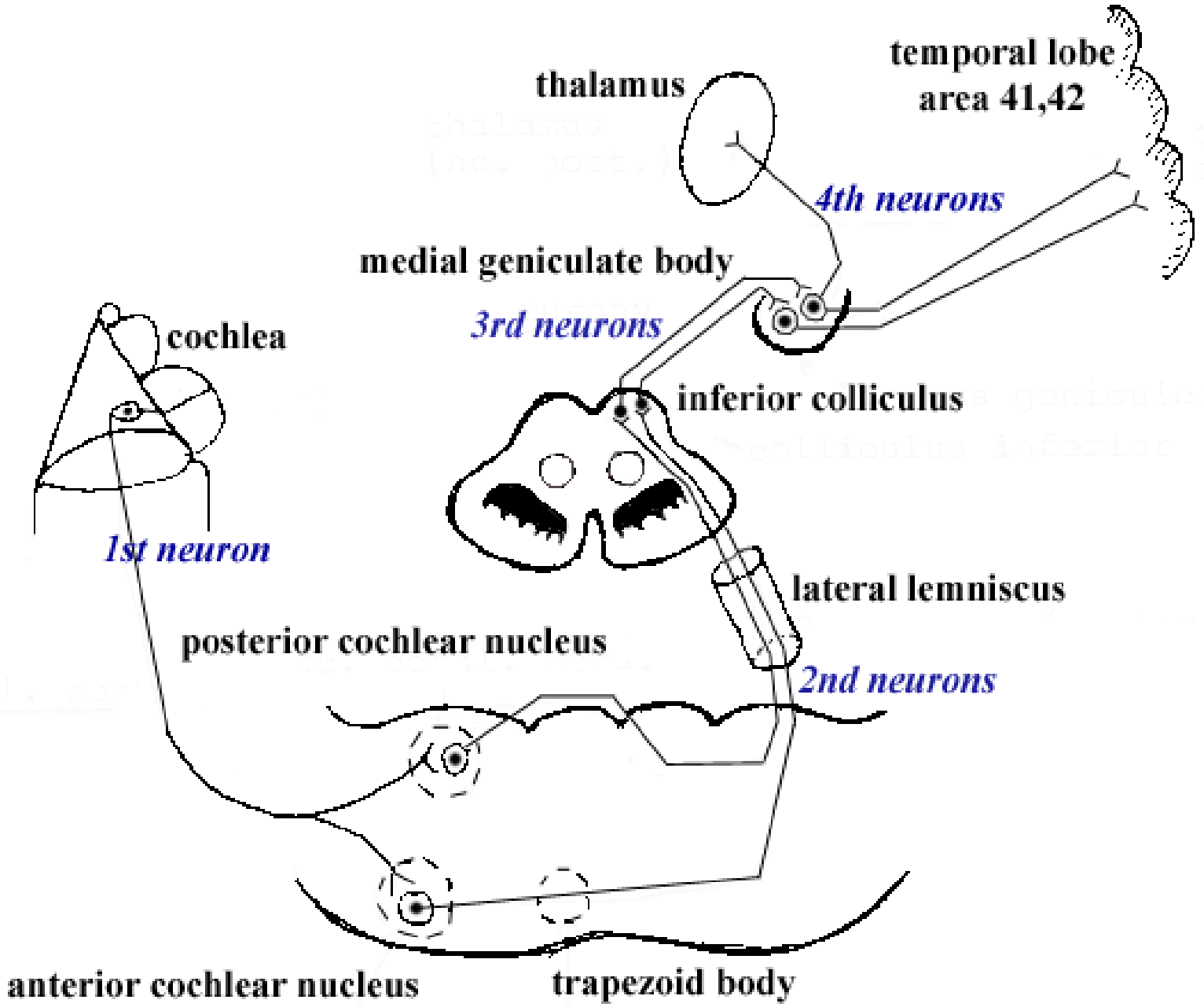
- disorders of stand and gait (= **ataxia**)

Auditory pathway I.

- projection → ascending → sensory
- 4-neuronal pathway
- decussated and partially non-decussated

<u>1st-order neuron</u>:

bipolar cell in ganglion cochleare *Corti* in shape of a spiral → n. cochlearis → n. VIII → splits into two fasciculi → nucleus cochlearis ant. + post.


temporal lobe
area 41,42
thalamus
4th neurons
medial geniculate body
3rd neurons
cochlea
inferior colliculus
1st neuron
lateral lemniscus
posterior cochlear nucleus
2nd neurons
anterior cochlear nucleus
trapezoid body

Auditory pathway II.

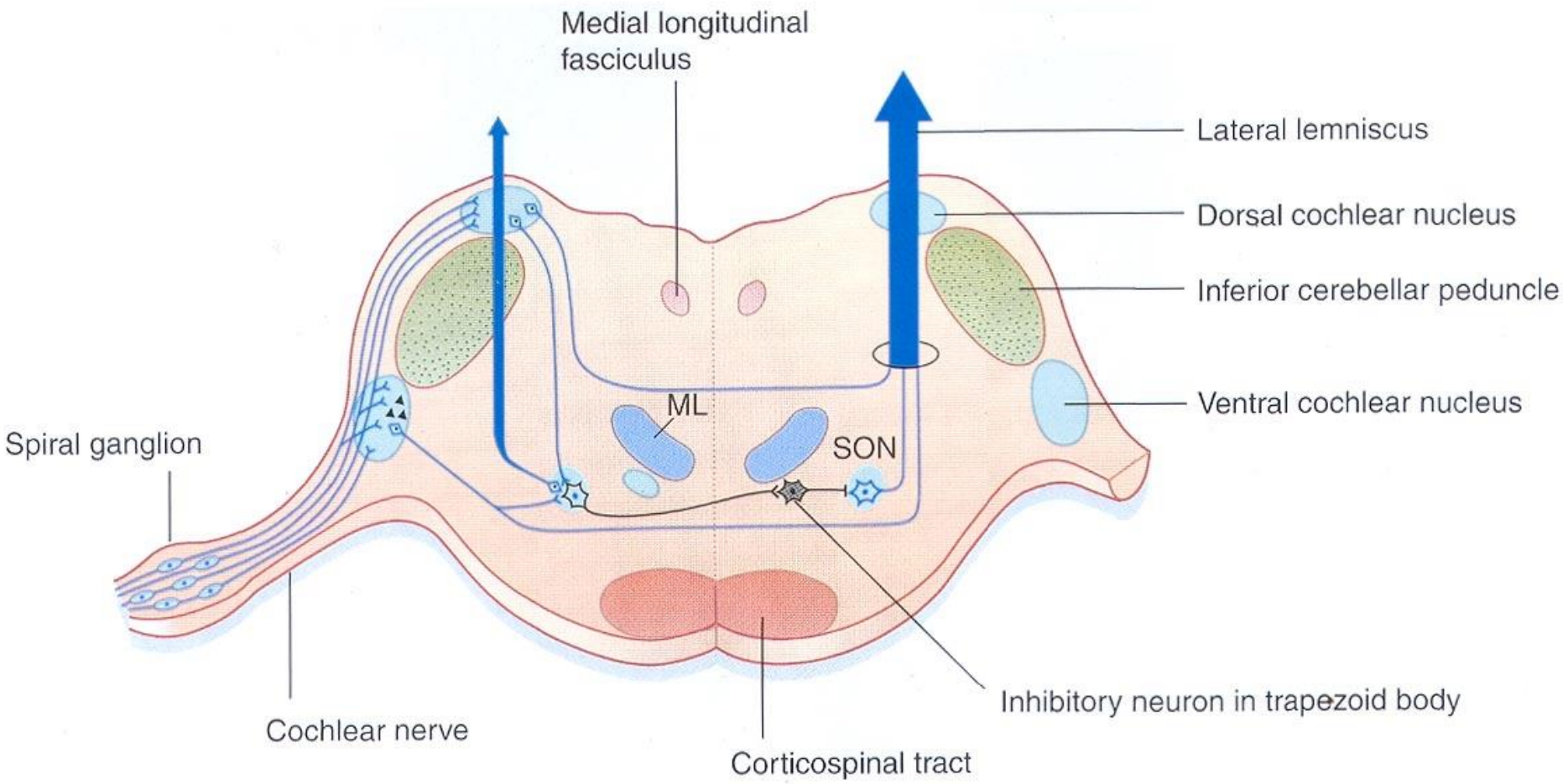
2nd-order-neuron: ***pons***

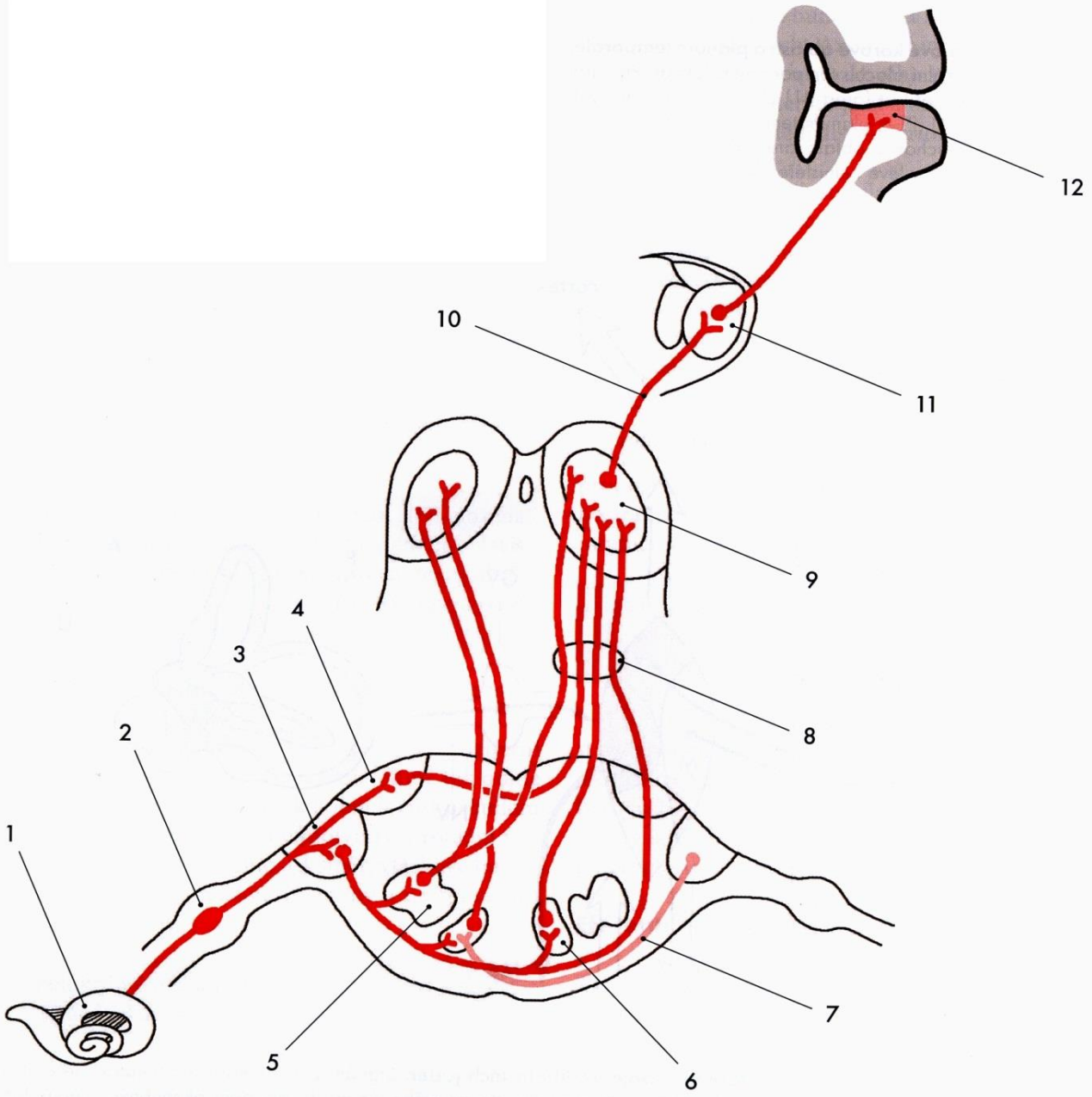
cells in nucleus cochlearis posterior (depth of tones) et anterior (intensity of tones) – separated with pedunculus cerebellaris inferior → decussatio → lemniscus lateralis → colliculus inferior

collateral to:

nucleus olivaris superior (← contralateral inhibited from ncl. corporis trapezoidei) → *learning of auditory space orientation*

Auditory pathway





Obr. 181. Obecné schéma sluchové dráhy savců. 1 – cochlea, 2 – ganglion cochleare, 3 – nc. cochlearis ventralis, 3 – nc. cochlearis dorsalis, 5 – nc. olivaris superior lateralis, 6 – nc. olivaris superior medialis, 7 – corpus trapezoideum, 8 – lemniscus lateralis, 9 – colliculus inferior (centrální jádro), 10 – brachium colliculi inferioris, 11 – corpus geniculatum mediale (nc. ventralis), 12 – primární sluchová korová oblast (A I, area 41)

Auditory pathway III.

3rd-order-neuron: **mesencephalon**

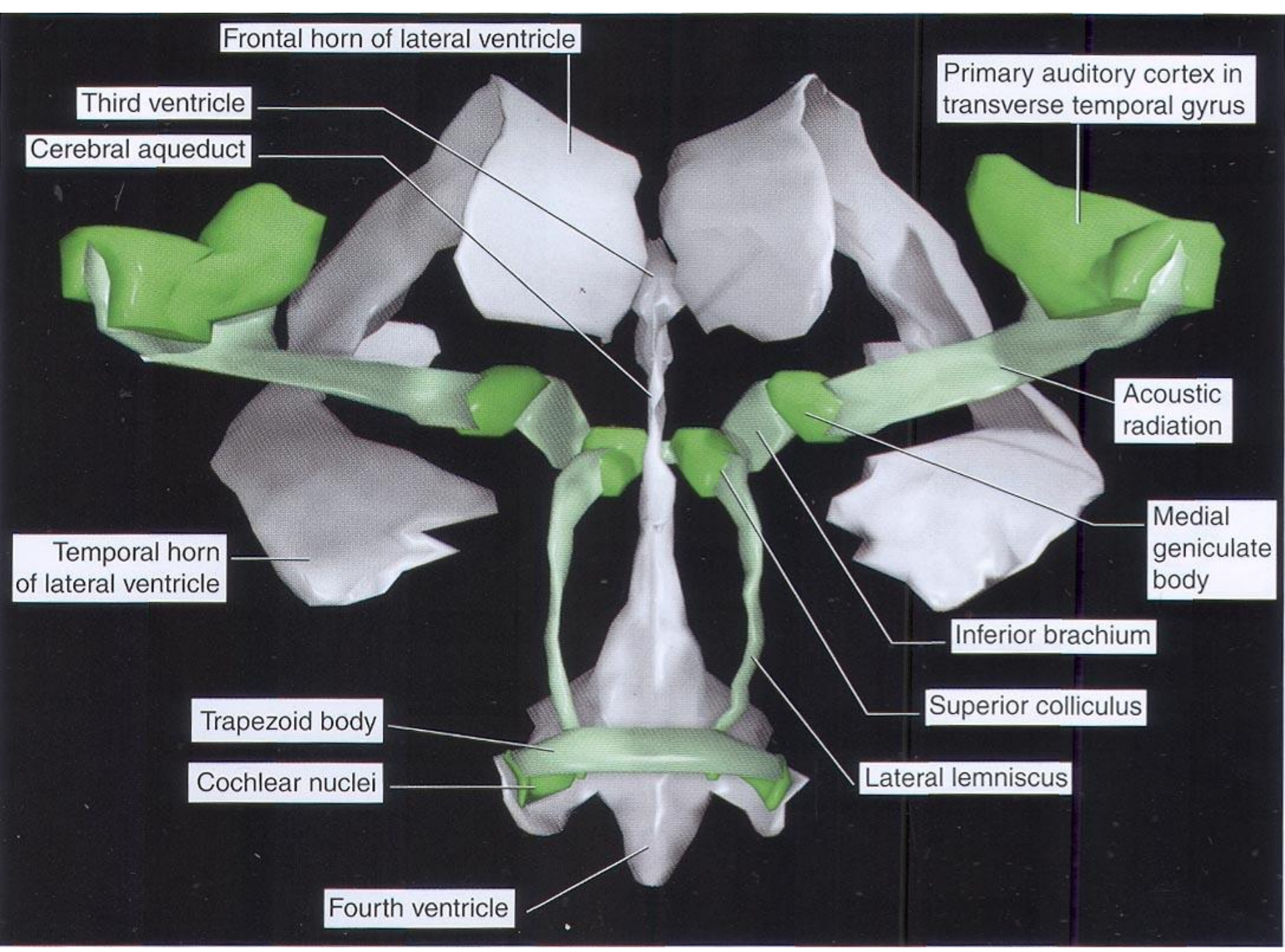
cells in colliculus inferior → brachium colliculi inferioris

tonotopic arrangement

commissura colliculi inferioris

4. neuron: **diencephalon – metathalamus**

cells in corpus geniculatum mediale → lobus temporalis – gyrus temporalis transversus Heschli, area 41


Frontal horn of lateral ventricle
Third ventricle
Cerebral aqueduct
Primary auditory cortex in transverse temporal gyrus
Acoustic radiation
Medial geniculate body
Temporal horn of lateral ventricle
Inferior brachium
Superior colliculus
Trapezoid body
Cochlear nuclei
Lateral lemniscus
Fourth ventricle

Vestibular pathway I.

- projection → ascending → sensory
- 3-neuron-tract, decussated and non-decussated

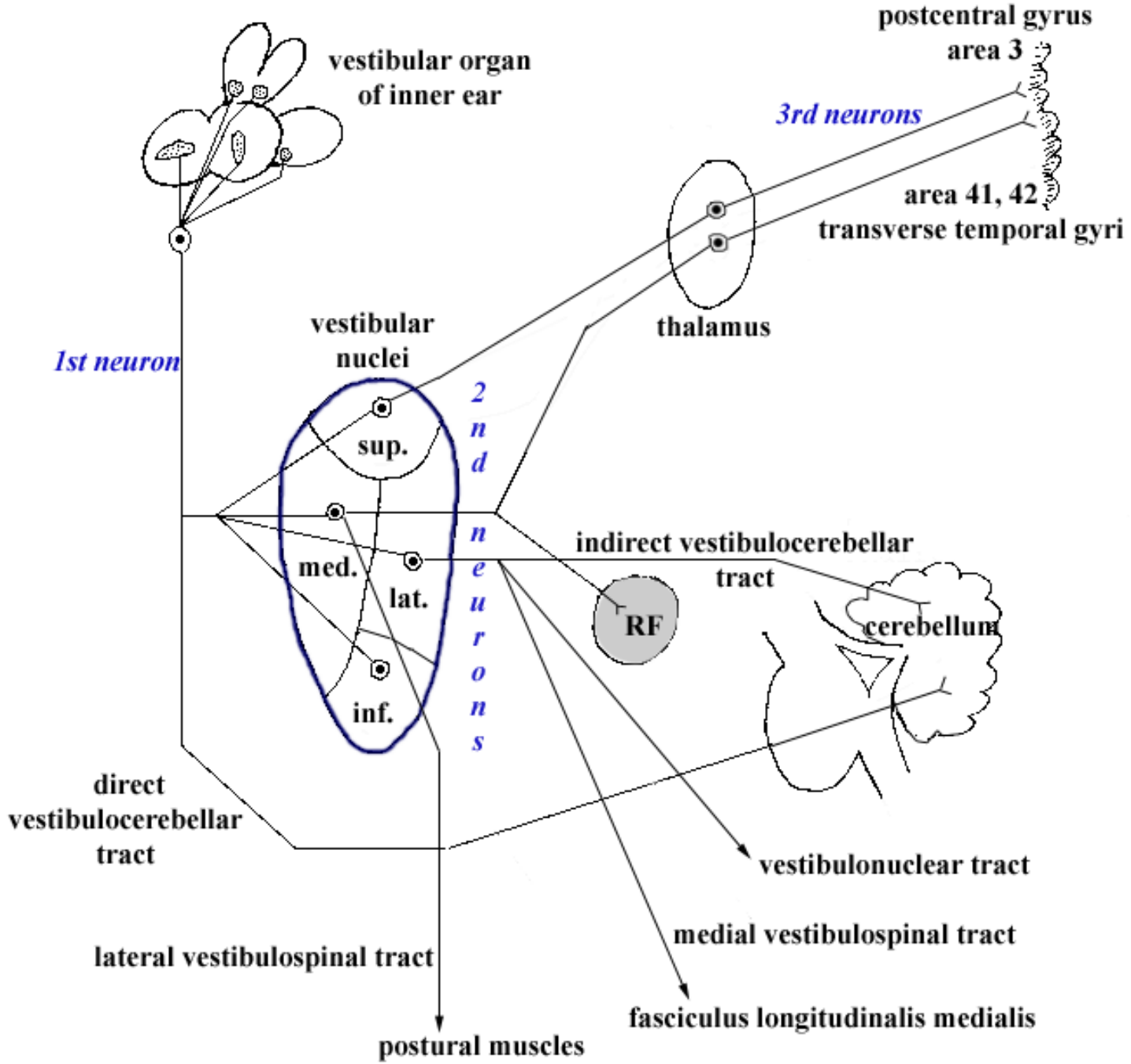
1st-order-neuron: bipolar cell in **ganglion vestibulare** *Scarpae* → n. vestibularis → n. VIII

- some fibers run as tractus vestibulocerebellaris directus to cerebellum without interpolation

2nd-order-neuron: cells in **nuclei vestibulares pontis** → axons into various structures of CNS

Vestibular pathway II. – *general target*

- cerebral cortex
- cerebellum
- RF → fascilitating descending system
- spinal cord
- nuclei of oculomotor nerves
  - via paramedian pontine RF
  - *reflex head-eye*


postcentral gyrus
area 3
vestibular organ
of inner ear
3rd neurons
area 41, 42
transverse temporal gyri
thalamus
vestibular
nuclei
1st neuron
2nd neurons
sup.
med.
lat.
inf.
indirect vestibulocerebellar
tract
RF
cerebellum
direct
vestibulocerebellar
tract
vestibulonuclear tract
medial vestibulospinal tract
lateral vestibulospinal tract
fasciculus longitudinalis medialis
postural muscles

Vestibular pathway III. – *to cortex*

3rd-order-neuron: cells in **nuclei ventrales thalami** → cerebral cortex

- lobus parietalis – gyrus postcentralis (area 2) – *primary cortex*
- parieto-insular cortex (gyrus insularis longus) + lobus temporalis – gyrus temporalis transversus *Heschli* (area 41,42)

Vestibular tract III. – *to cerebellum*

- tractus vestibulocerebellaris directus

vestibulum → corpus juxtarestiforme (via PCI) → nodulus + uvula *(ipsilat.)*

- tractus vestibulocerebellaris indirectus

vestibulum → ncl. vestibulares → corpus juxtarestiforme (via PCI) → lobulus flocculonodularis + vermis *(bilat.)*

Vestibular tract III. – *to spinal cord*

- ncl. fastigii cerebelli → ncl. vestibularis lat. *Deitersi* (*bilat.*) → tr. vestibulospinalis lateralis → alfa + gama-motoneurons for extensors

- ncl. vestibularis medialis + inferior → fasciculus longitudinalis medialis → interneurons (+ a -) in cervical spinal cord

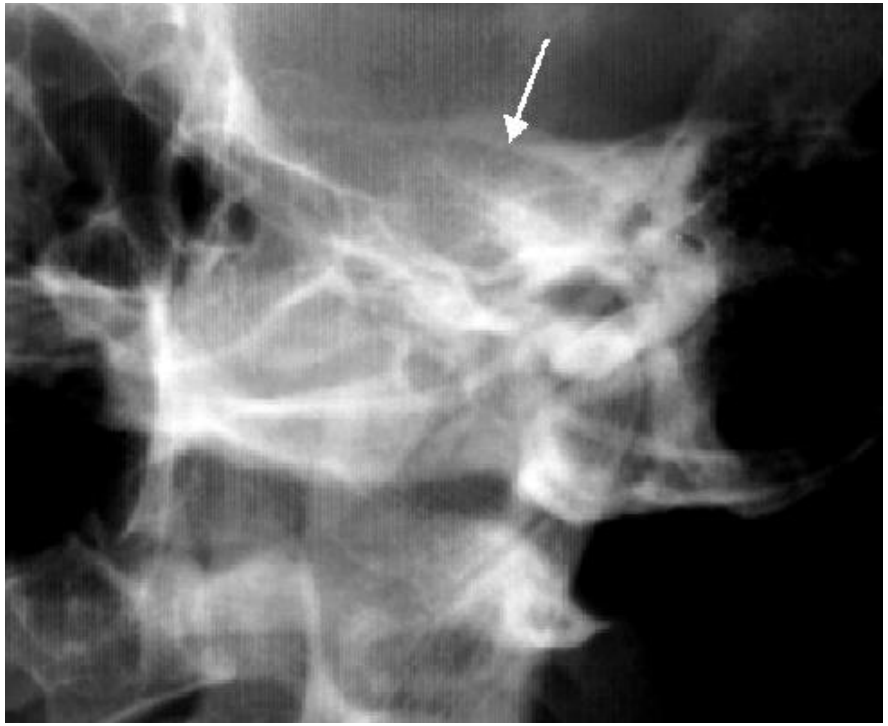
reflex head-eye

Examination

- otoscopy, otomicroscopy – tympanic membrane
  - paracentesis, grometes
- tuning fork examinations
- vestibuloocular reflex – nystagmus
- vestibulospinal reflexes (*Romberg‘s, Unterberger‘s test)*
- X-ray (*Stenvers‘ projection – meatus acusticus internus, Schüller‘s – proc. mastoideus)*, CT, angiography
- audiometry
- BER/BERA (ERA, AEP, ABR)
- oto-acustic emission (*from outer hair cells*)
- nystagmus – ENG (PENG), caloric test

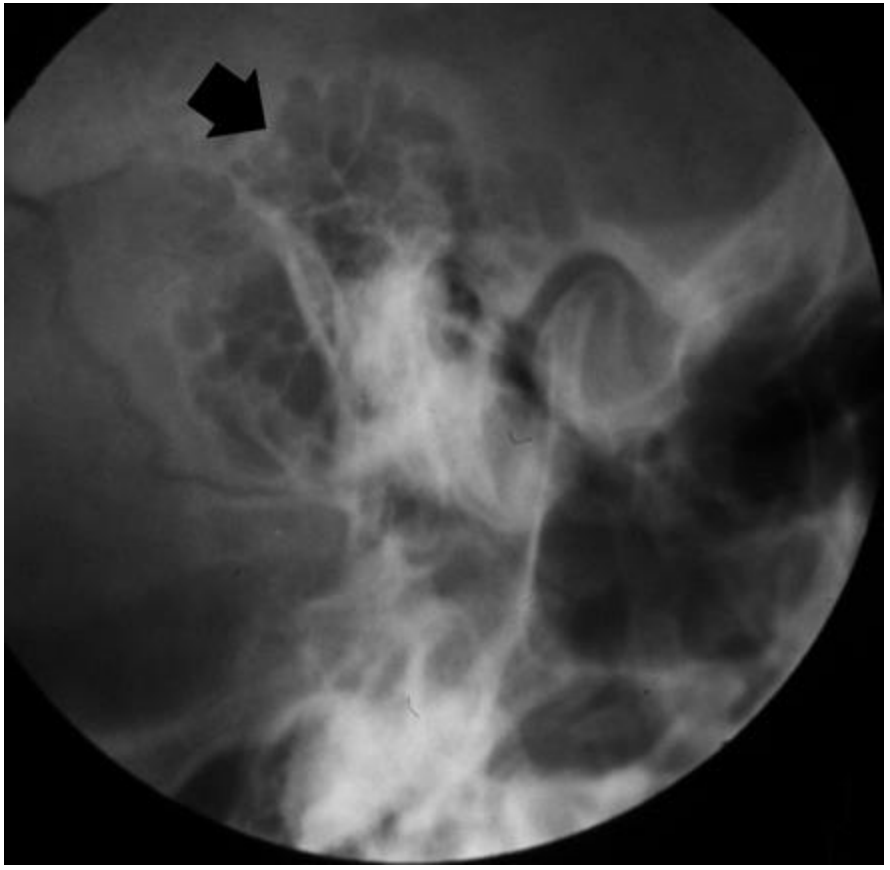
Stenvers‘ projection

meatus acusticus internus



Schüller‘s projection

proc. mastoideus



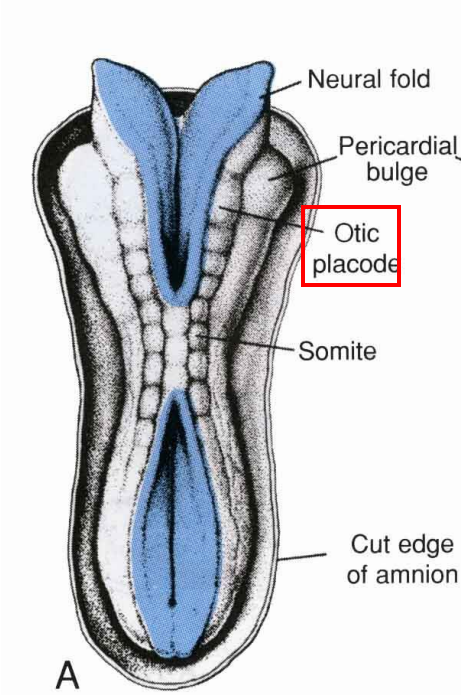
Symptoms and diseases

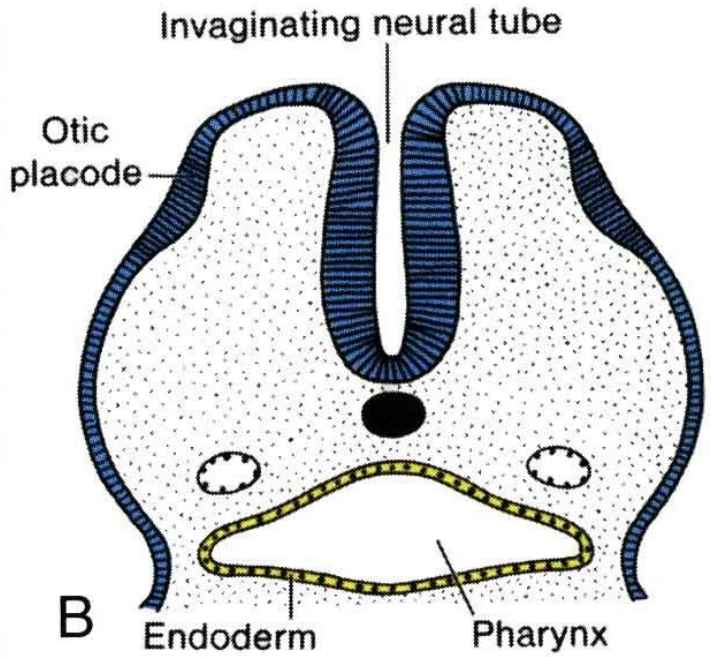
- ear pain = otalgia
- dizziness = vertigo
- spontaneous ringing and buzzing in ears = tinnitus
- nystagmus = rhythmic, oscillating motions of eyes
- hypacusis
- deafness = surditas
- morbus Menière – ions dysbalance
- atherosclerosis of a. labyrinthi
- meningitis – *most frequent cause of acquired deafness*
- *treatment: vasodilating drugs*

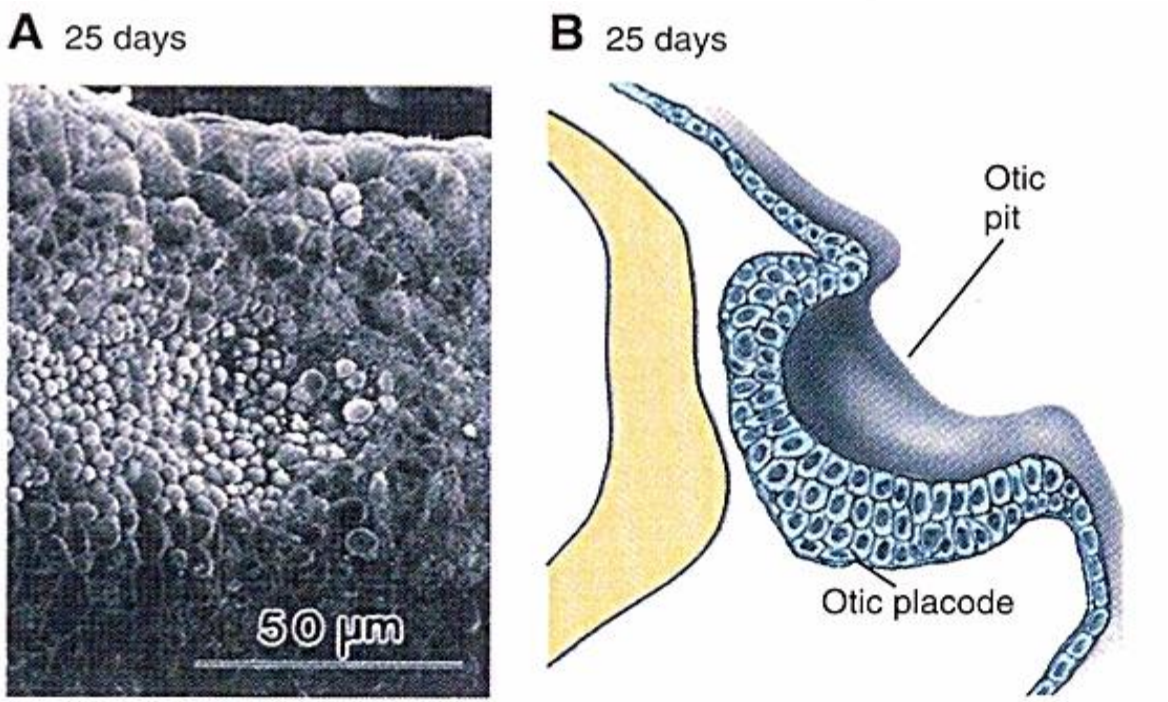
Development of vestibulo-cochlear system

3 sources+ nerve fibers

- 1st pharyngeal pouch, cleft and membrane
- ectomesenchyme of 1st and 2nd pharyngeal arch
- surface ectoderrm of head
- fibers from mesencephalon




Invaginating neural tube
Otic placode
B
Endoderm
Pharynx

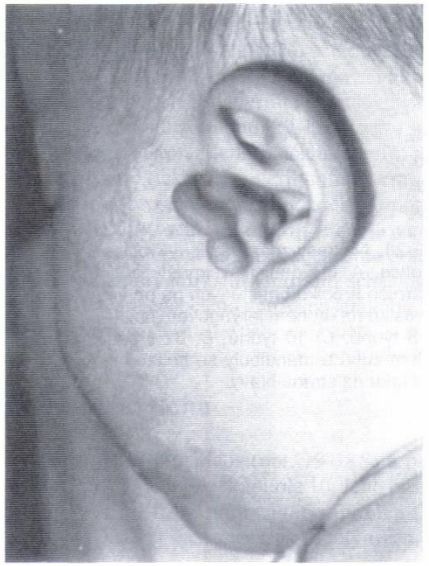

A 25 days
50 µm
B 25 days
Otic pit
Otic placode

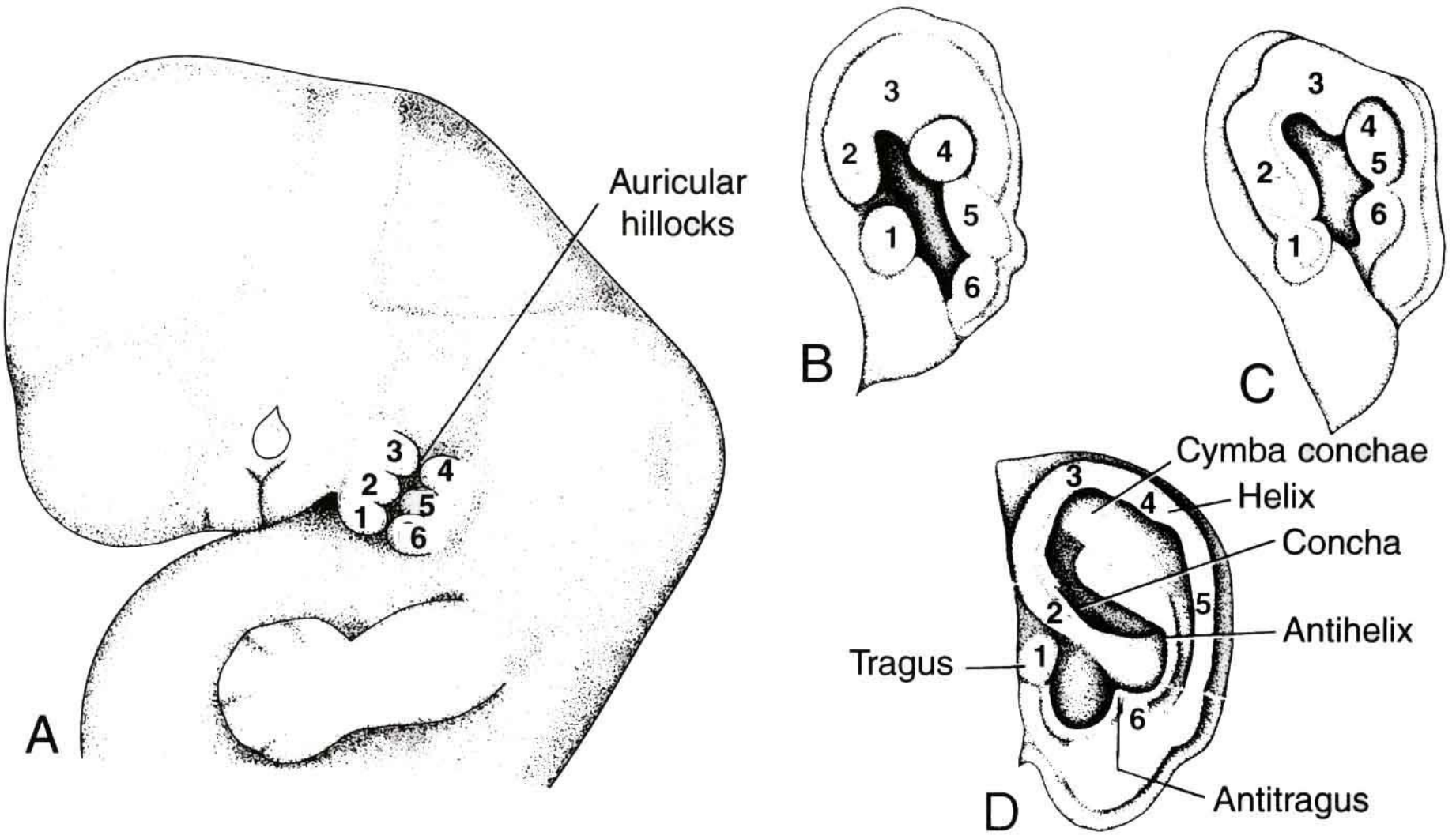
3:10

- https://www.youtube.com/watch?v=WiE7LJu3AL4

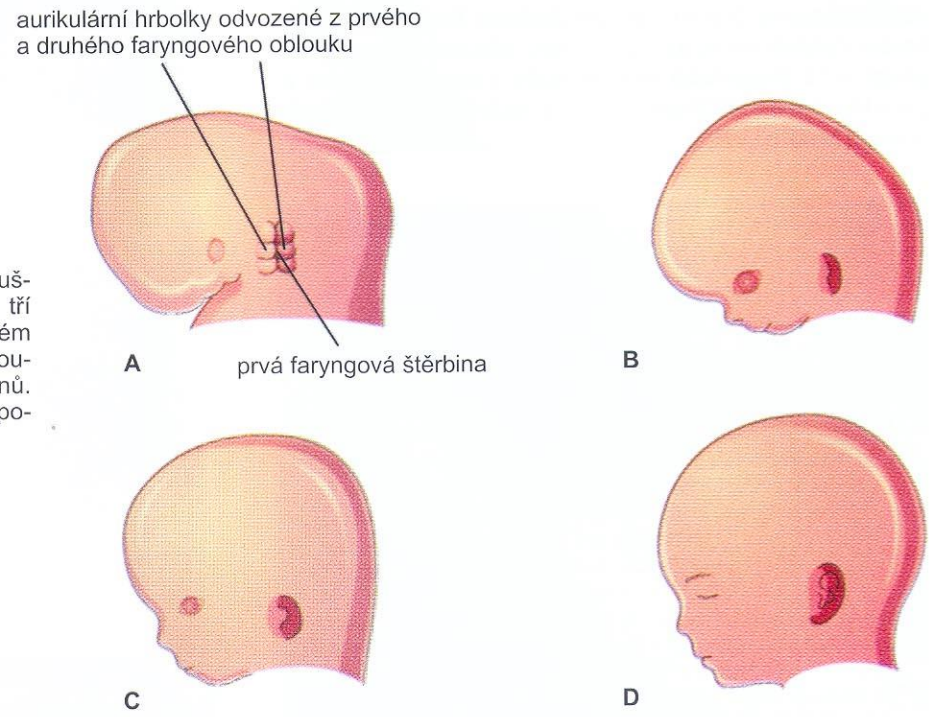
Development of external ear

- meatus acusticus externus
  - 1st pharyngeal cleft
  - short in birth (beware of injury!)
- pinna
  - 6 auriculr tubercles (mesenchyme)
  - mainly from 2nd pharyngela arch
    - with contribution of 1st one as well
  - *appendices preauriculares*




Auricular hillocks
A
B
C
D
1
2
3
4
5
6
Cymba conchae
Helix
Concha
Antihelix
Tragus
Antitragus

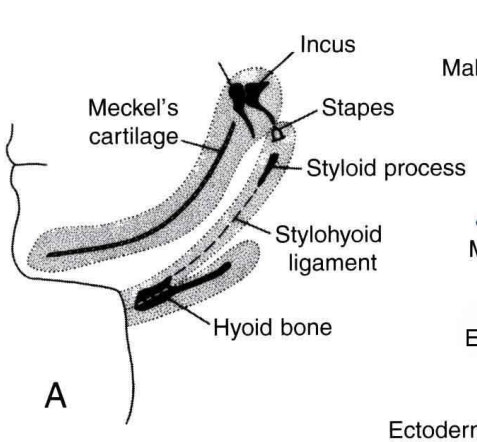
Development of external ear

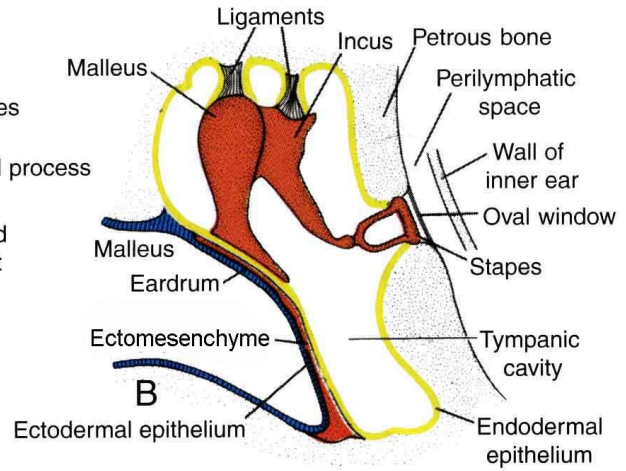


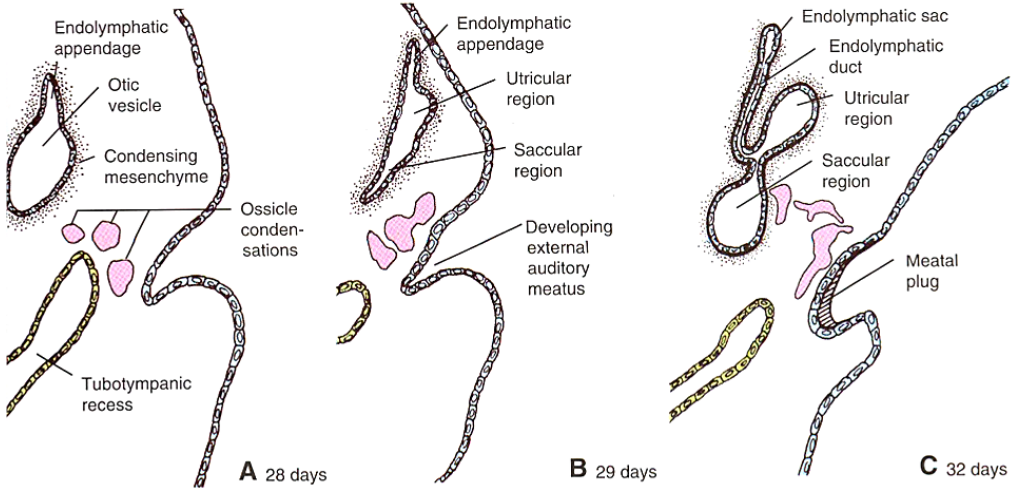
Obr. 19-20. Nákresy znázorňující vývoj ušního boltce. *A*, 6 týdnů. Povšimněte si tří aurikulárních hrbolků umístěných na prvém a tří výrůstků na druhém faryngovém oblouku. *B*, 8 týdnů. *C*, 10 týdnů. *D*, 32 týdnů. S vývojem zubů a mandibuly se boltec posouvá z krku na stranu hlavy.

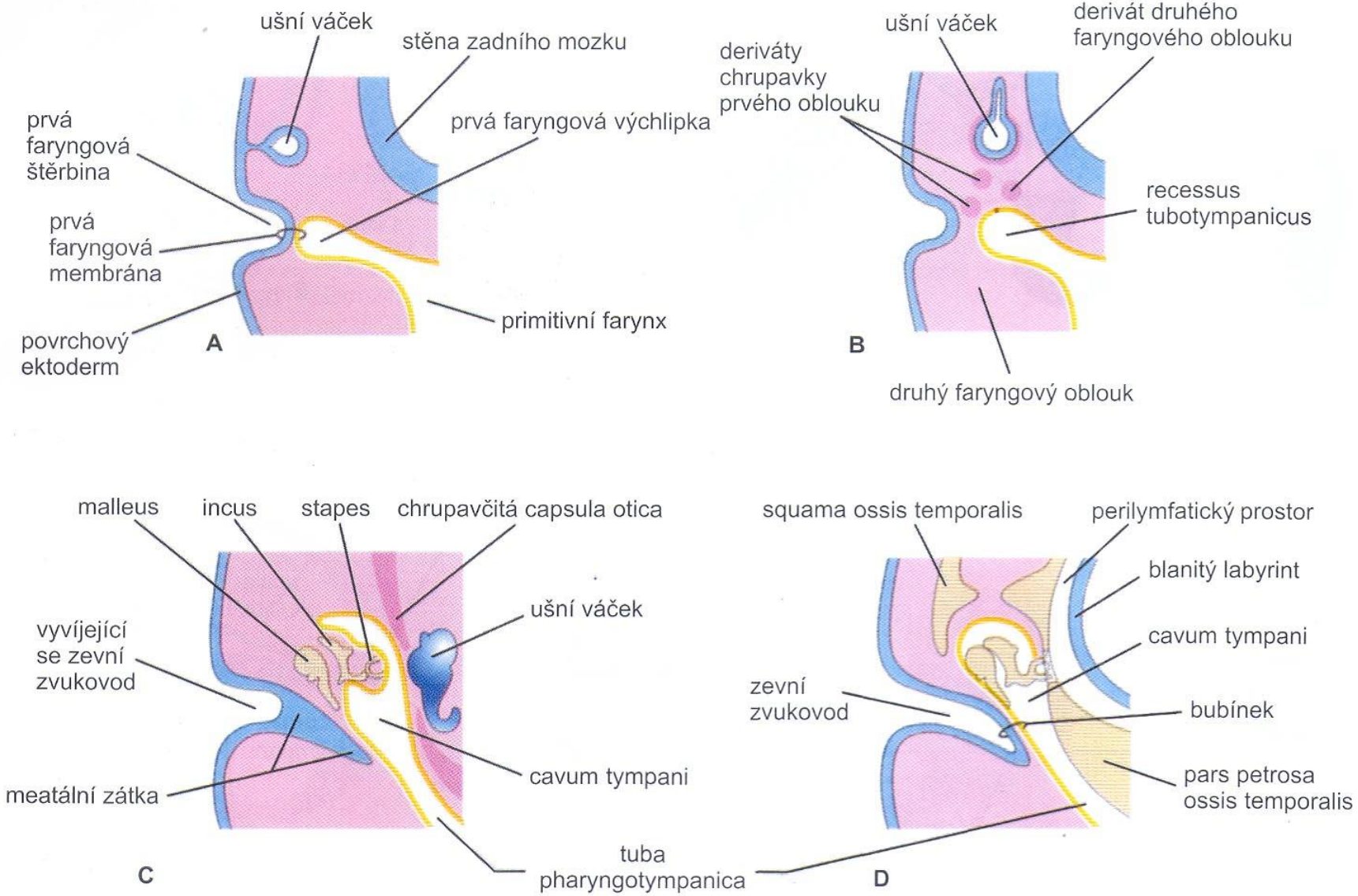
Development of middle ear

- 1st pharyngeal pouch
  - tuba auditiva et cavum tympani
- 1st pharyngeal arch
  - malleus, incus
  - lig. mallei anterius
  - m. tensor tympani
- 2ndst pharyngeal arch
  - stapes
  - m. stapedius









Obr. 19-19. Schematické nákresy znázorňující vývoj zevního a středního ucha. Povšimněte si vztahů těchto částí sluchového ústrojí k ušnímu váčku, základu vnitřního ucha. *A*, 4 týdny, vztah ušního váčku k faryngovému aparátu. *B*, 5 týdnů, recessus tubotympanicus a chrupavky faryngových oblouků. *C*, Pozdější stadium, recessus tubotympanicus (pozdější cavum tympani a antrum mastoideum) počíná obalovat ušní kůstky. *D*, Nákres konečného stadia vývoje ucha znázorňující vztahy středního ucha k perilymfatickému prostoru a zevnímu zvukovodu. Povšimněte si, že bubínek vzniká ze tří zárodečných listů: povrchového ektodermu, mezodermu a endodermu tubotympanické výchlipky.

Development of middle ear

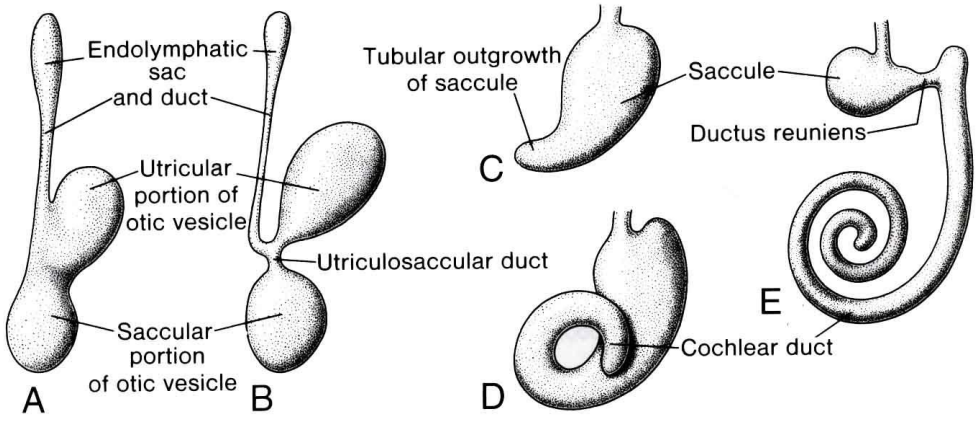
- antrum mastoideum
  - cellulae mastoideae are not developed at birth
  - appear in 2nd year of age
  - pneumatization finished in 6th year of age

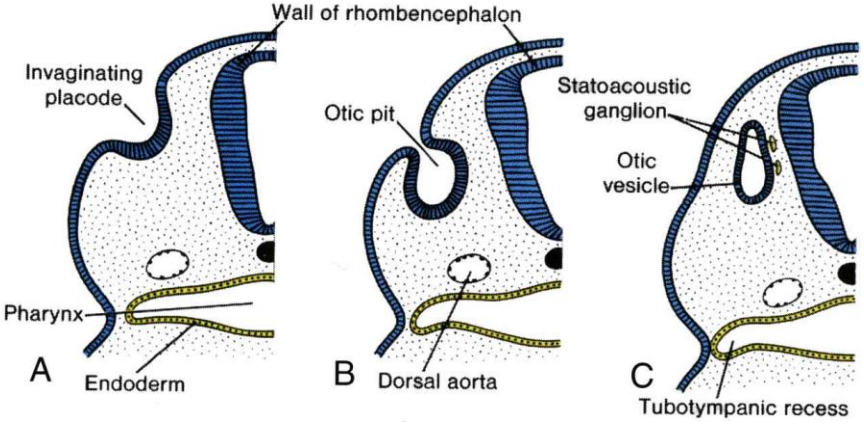
Development of membrana tympani

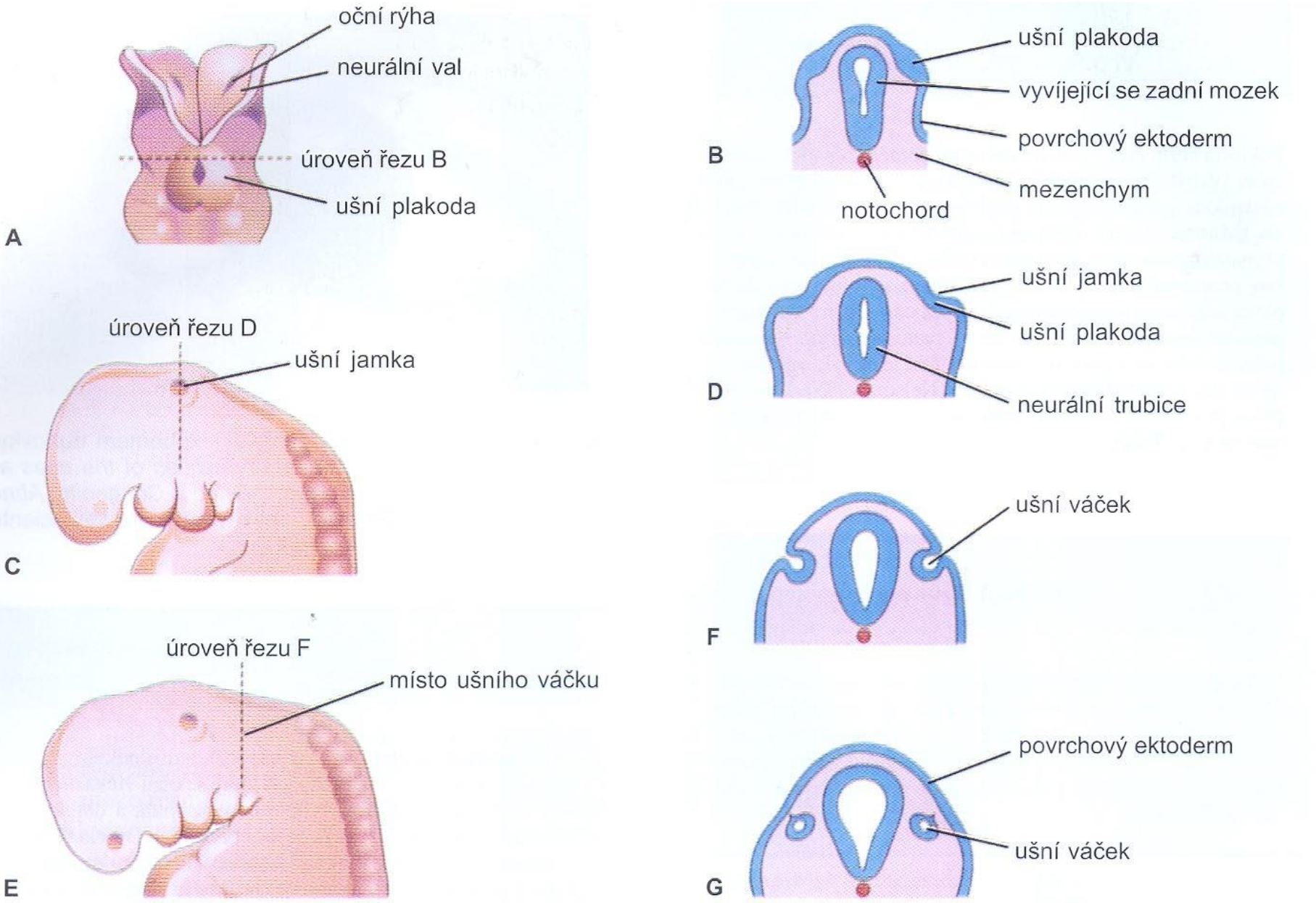
- outer epithelium from 1st pharyngeal cleft
- inner epithelium from 1st pharyngeal pouch
- ectomesenchyme from 1st and 2nd pharyngeal arch

Development of internal ear

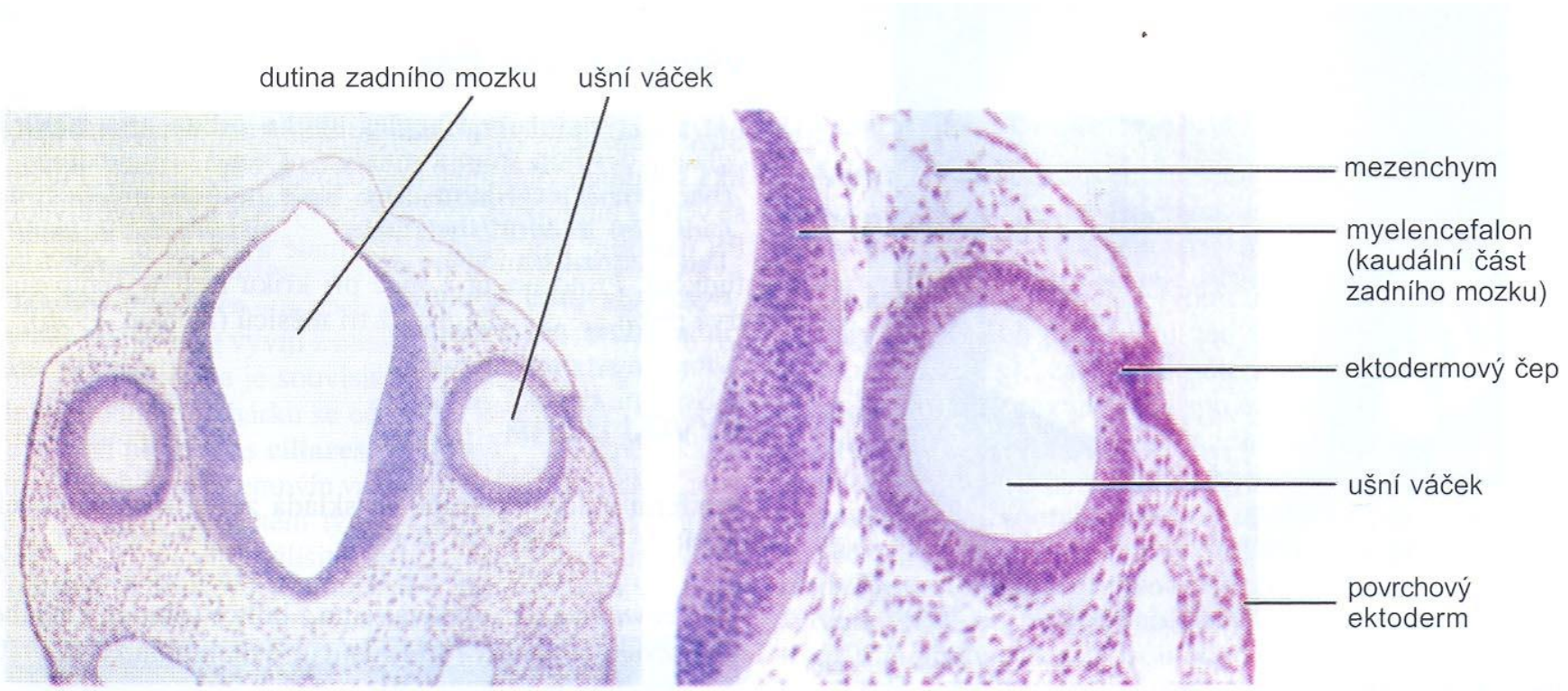
- beginning of 4th week – **otic placod** *(ectoderm)*
- auditory pit
- auditory vesicle (otocyst)
  - process for ductus + saccus endolymphaticus
  - dorsal part - utricular







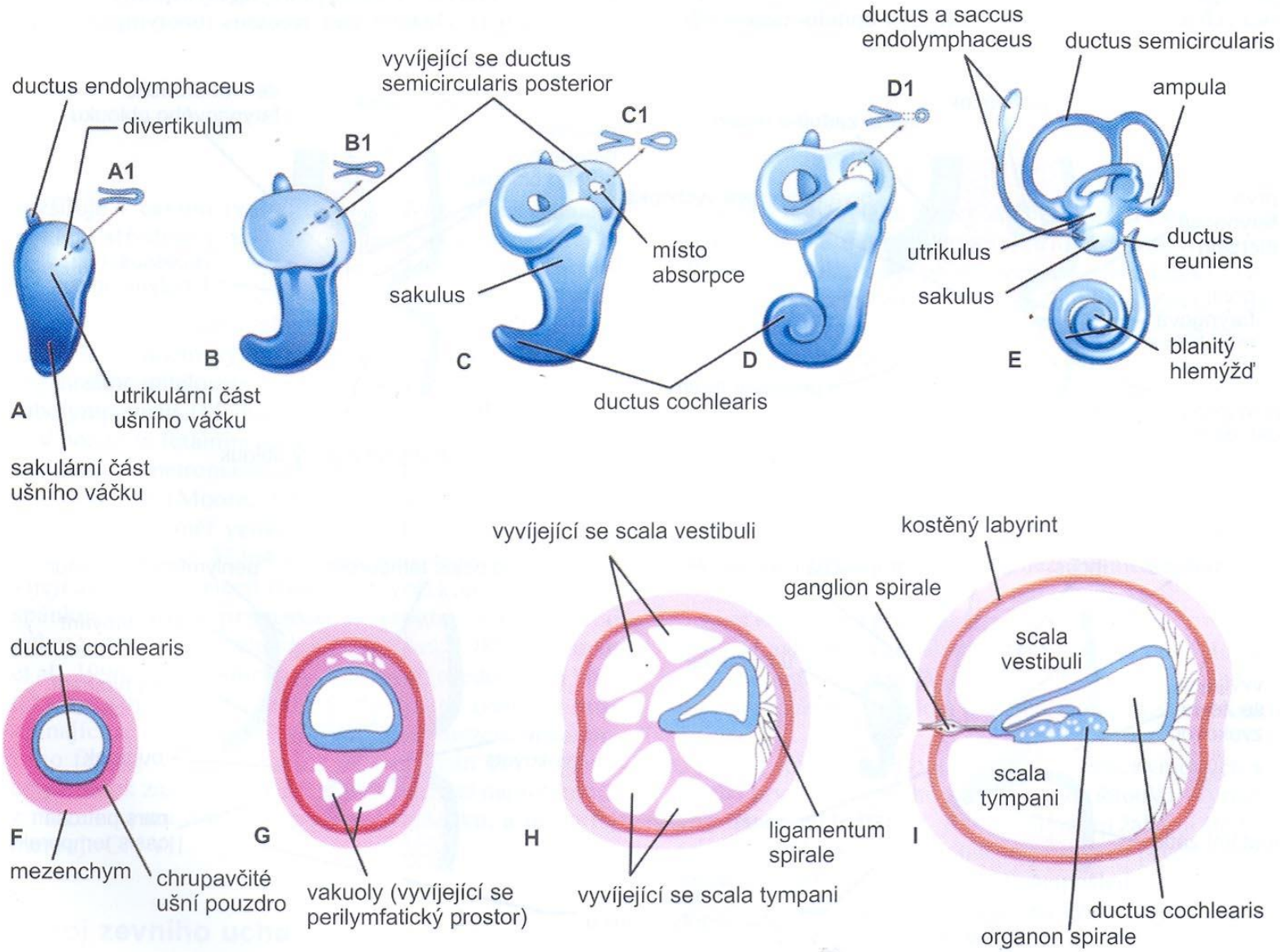
Obr. 19-16. Nákresy zobrazující časný vývoj vnitřního ucha. *A*, Pohled na dorzální stranu čtyřtýdenního zárodku (kolem 22. dne), znázorňující ušní plakody. *B*, *D*, *F* a *G*, Schémata koronálních řezů ilustrující vývojová stadia ušních váčků. *C* a *E*, Boční pohledy na hlavovou krajinu embryí kolem 24. a 28. dne.



Obr. 19-17. *Vlevo*, Mikrofotografie příčného řezu zárodkem (× 55) v Carnegie stadiu 12, kolem 26 dnů. Věnujte pozornost ušním (otickým) váčkům, základům blanitého labyrintu, jež dávají vznik vnitřnímu uchu. *Vpravo*, Pravý otický váček ve vyšším zvětšení (× 120). Povšimněte si ektodermového čepu, který je dosud spojen se zbytkem ušní plakody. Otický váček brzy ztratí spojení s povrchovým ektodermem (základem epidermis). (Z Nishimura H [ed.]: *Atlas of Human Prenatal Histology*. Tokyo, Igaku-Shoin, 1983.)

Development of internal ear

- utricular part → :
  - discoid processes → ductus semicirculares
  - widening into the ampulla, formation of crostae ampullares
- saccular part →:
  - diverticulum ductus cochlearis (getting spiral)
  - ductus reuniens appears
  - Corti‘s organ (from wall of ductus cochlearis)
  - ganglion cochleare appears



Obr. 19-18. Nákresy ušního váčku zobrazující vývoj blanitého a kostěného labyrintu vnitřního ucha. *A* až *E*, Boční pohledy znázorňující přeměnu ušního váčku v blanitý labyrint mezi pátým a osmým týdnem. A_1 až D_1, Schematické náčrtky vystihující vývoj polokruhovitých duktů. *F* až *I*, Řezy kochleárním duktem znázorňující postupný vývoj organon spirale (Corti) a perilymfatických prostorů mezi osmým a dvacátým týdnem.

Development of internal ear

- surrounding mesenchyme changes into cartilagineous capsula otica
- cavities appears inside the capsula → perilymphatic spaces
- Week 20-22: ossification of cartilagineous walls

Case-report 1

- male, 28 let
- returned back fron holiday in Egypt
- otalgia for 3 days
- palpation painful

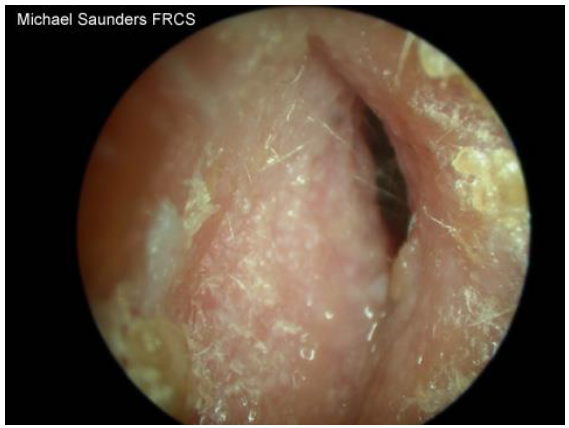
- objective examination: tragus sensitive in palpation
- otoscopic examination: swollen reddish external acoustic meatus with white matter of dead cells

Case report 1 - diagnosis

- otitis externa
- disease of summer months and bathin

- *complications:* mainly in diabetes mellitus

  → perichondritis or even destruction of temporal bones

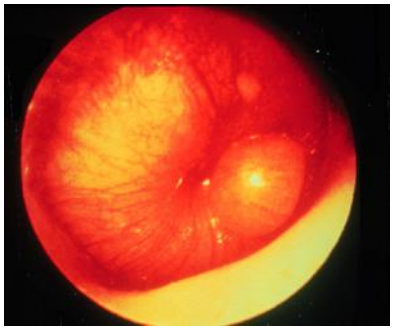


Case report 2

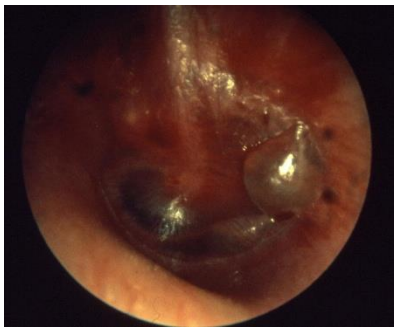
- female, 3 years
- during night sleep severe pain of right ear, weeping, cannot be calmed, blowing her nose for 2 days
- vomitting during examination
- temperature 38,3°C

- otoscopic examinatio: tympanic membrane dark red, without contours, convex

Case report 2 - diagnosis



- mesotitis (otitis media) acuta l. dx.



treatment: paracentesis

complications:

- perforation of tympanic membrane
- mastoiditis → thrombosis of sinus sigmoideus
- labyrinthitis
- (chronic mesotitis)

grometa

Case report 3

- female, 34 years
- feeling of pressure in left ear, sudden hypoacusis, buzzing tinnitus, rotation vertigo, vomitus
- vertigo disapeared, other symptoms persist
- objective examination: harmonic vestibular phenomens (signaling prevailing one labyrinth)
- audiometry: perceptive hypacusis with apicocochlear predominance

Case report 3 - diagnosis

- Menièr‘s disease
  - hydrops of labyrinth

- pacient will return in one month with same symptoms

- *dif.dg*.: circulation disorders, atherosclerosis, sclerosis multiplex, acoustic neurinoma

Further study

- https://www.youtube.com/watch?v=PeTriGTENoc
- https://www.youtube.com/watch?v=1JE8WduJKV4
- https://www.youtube.com/watch?v=K13lOqcb5ng