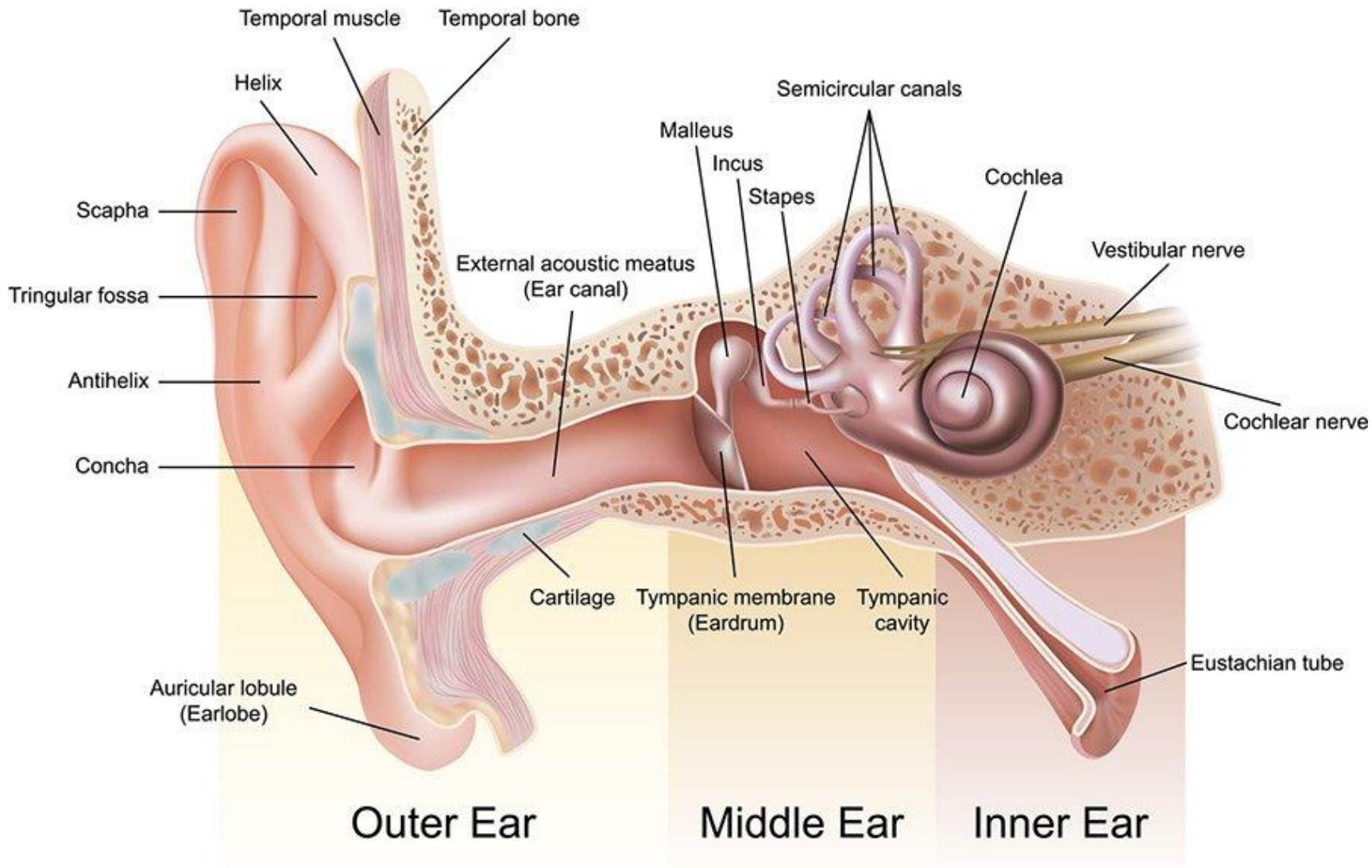
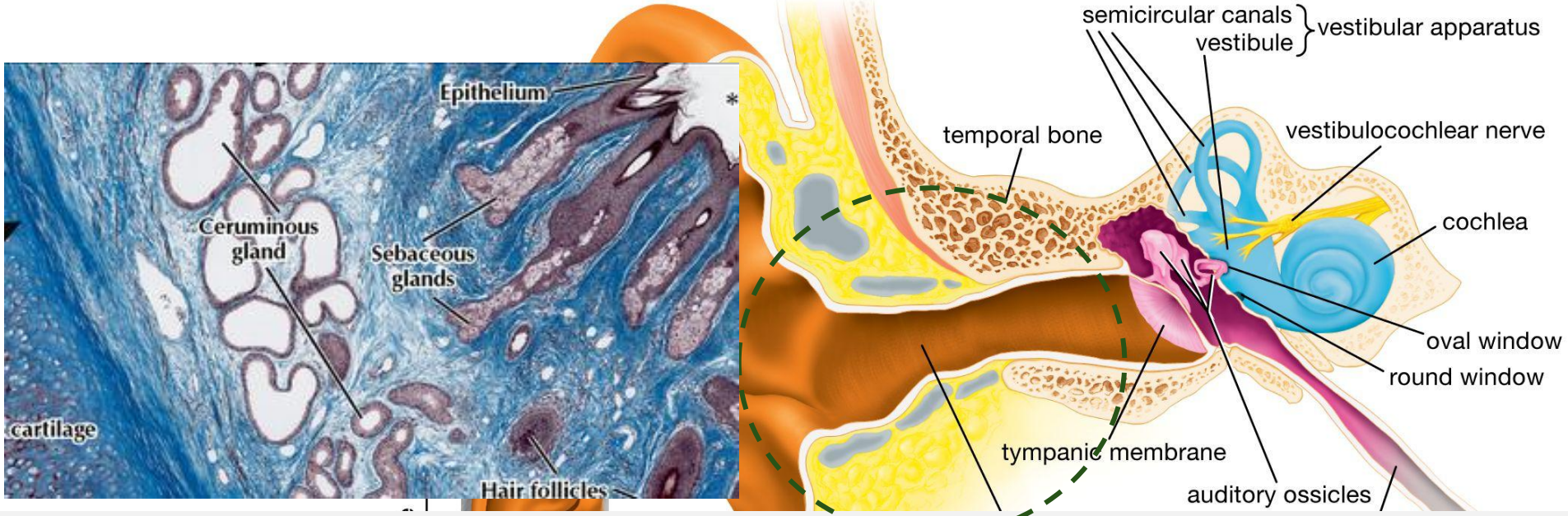
Hearing and balance
Ear structure

Anatomy of the Ear





Outer ear

Auricle - a skeleton made of elastic cartilage (except for the lobe), hairy skin with sebaceous glands (holocrine)

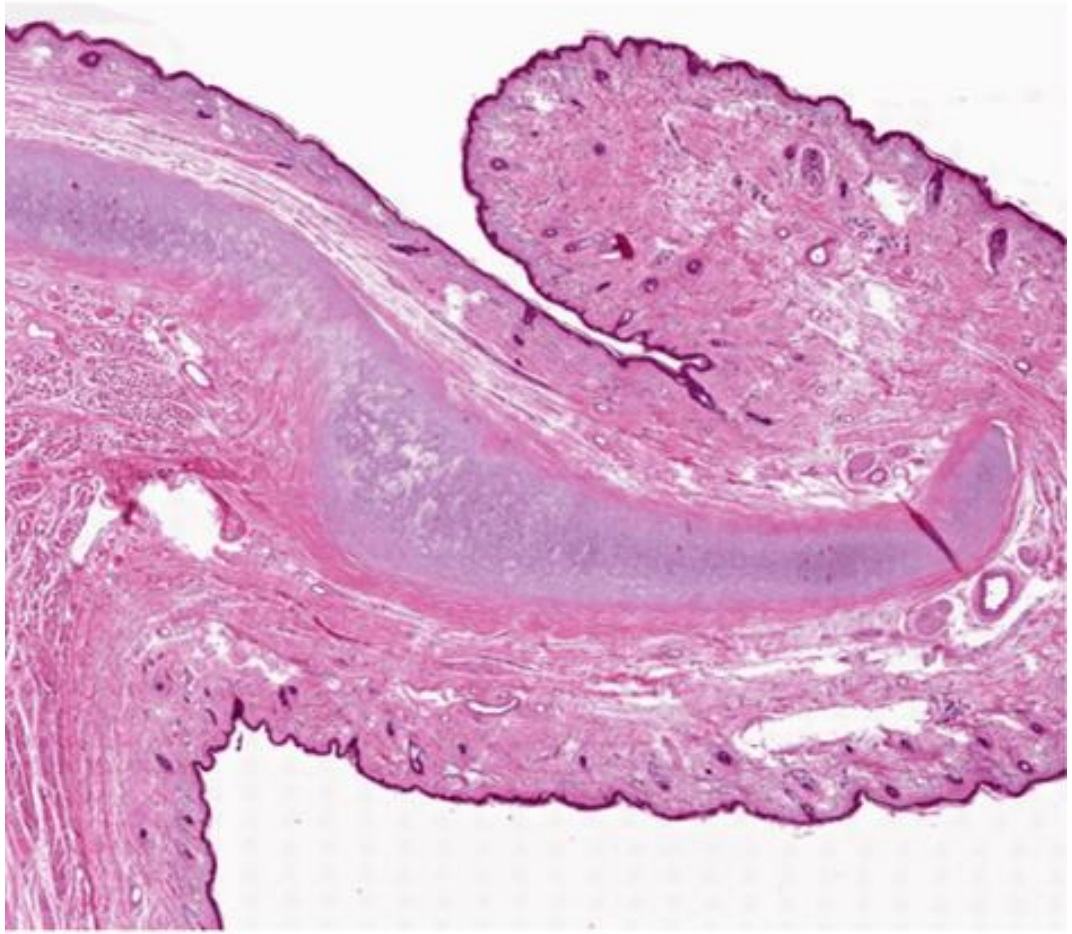
External ear canal :

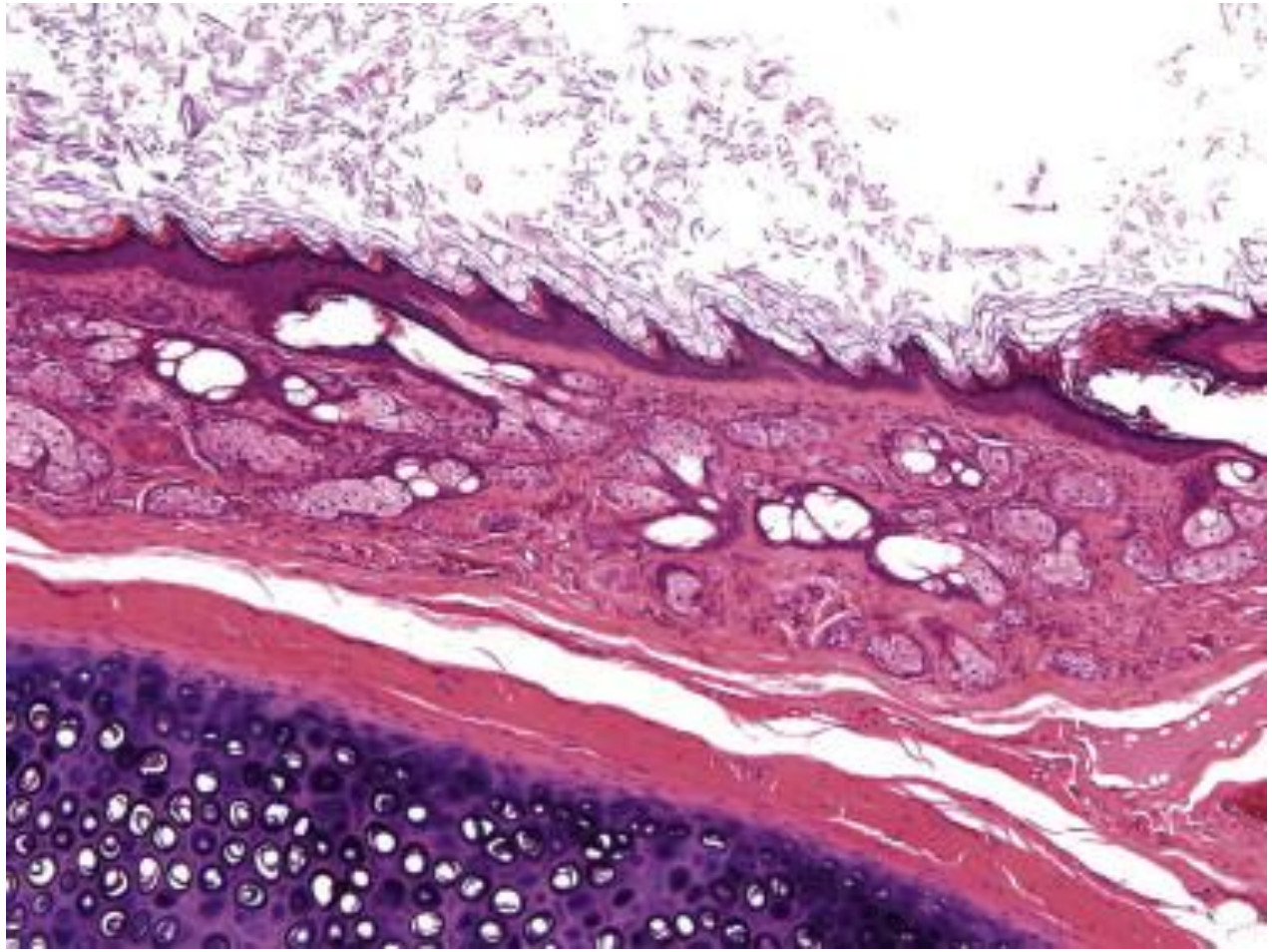
Outer part - skeleton made of elastic cartilage, cartilaginous

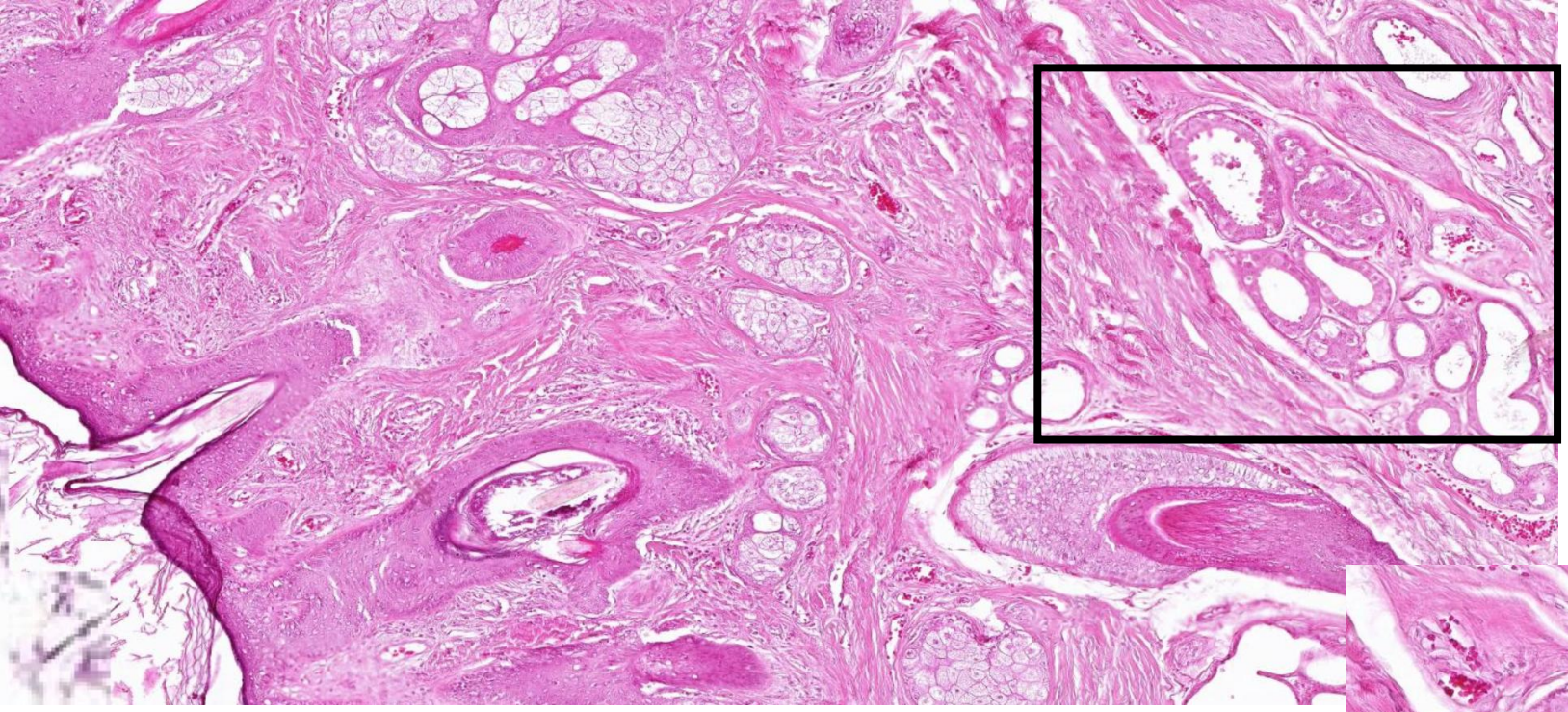
Inner part - skeleton made of temporal bone, periosteum

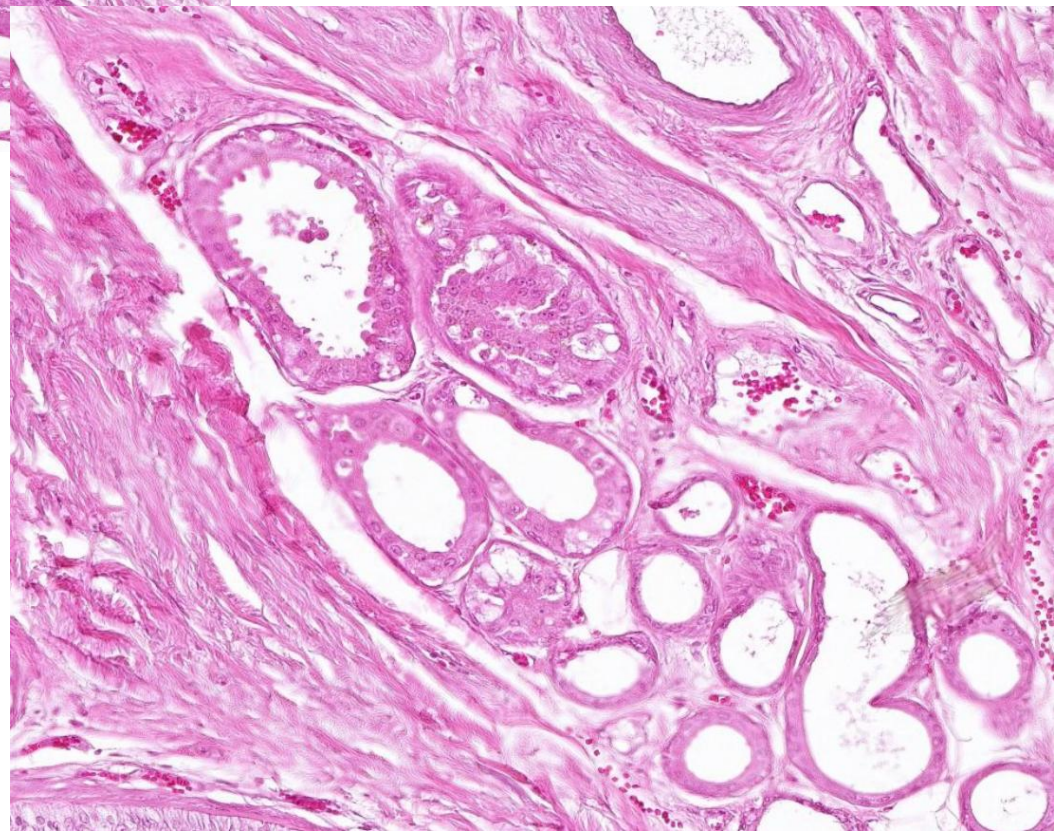
Covered with thin skin with sebaceous and earwax glands (apocrine)

Outer ear – auricle and external auditory canal – cartilaginous part

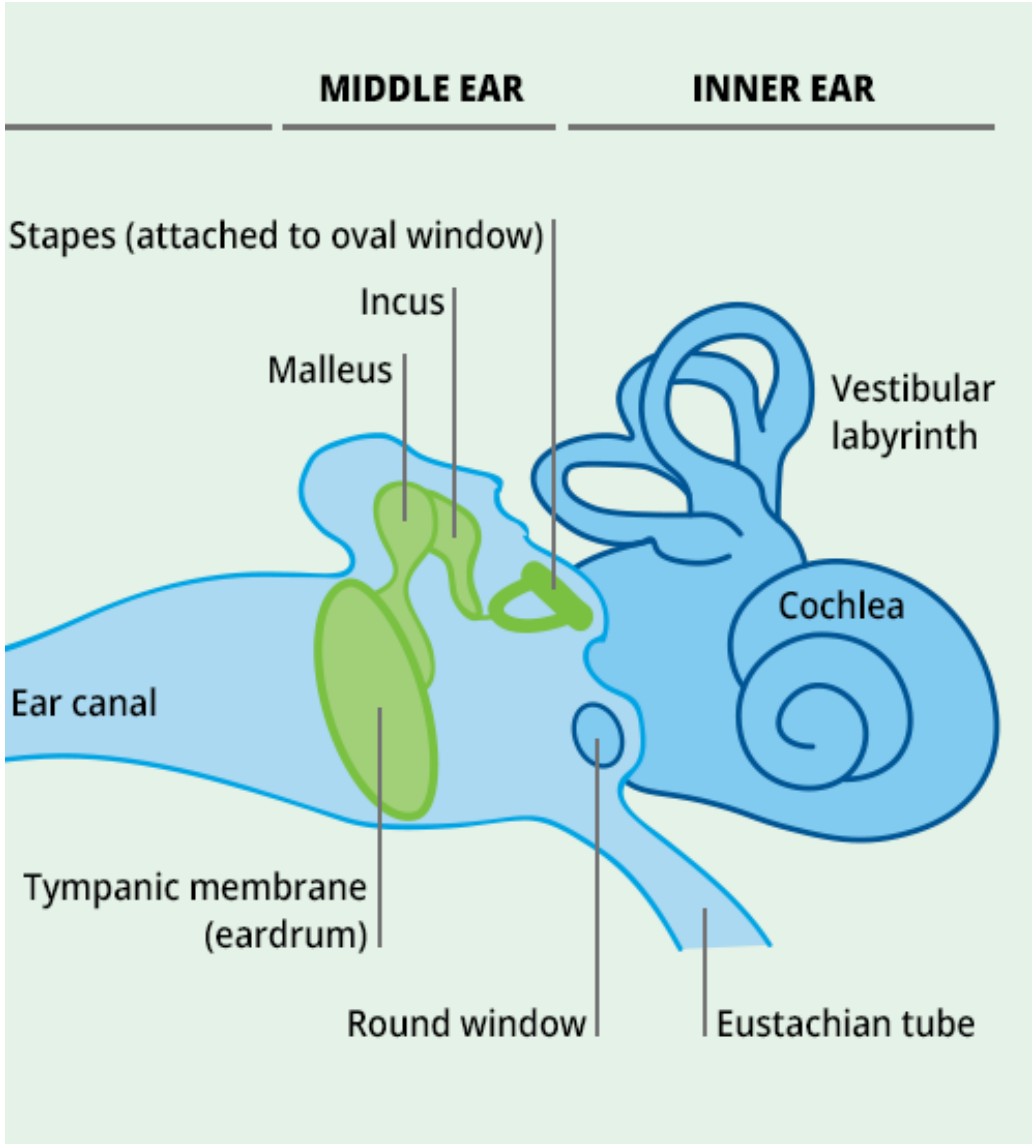








External auditory canal – sweat, sebaceous and earwax glands (apocrine)



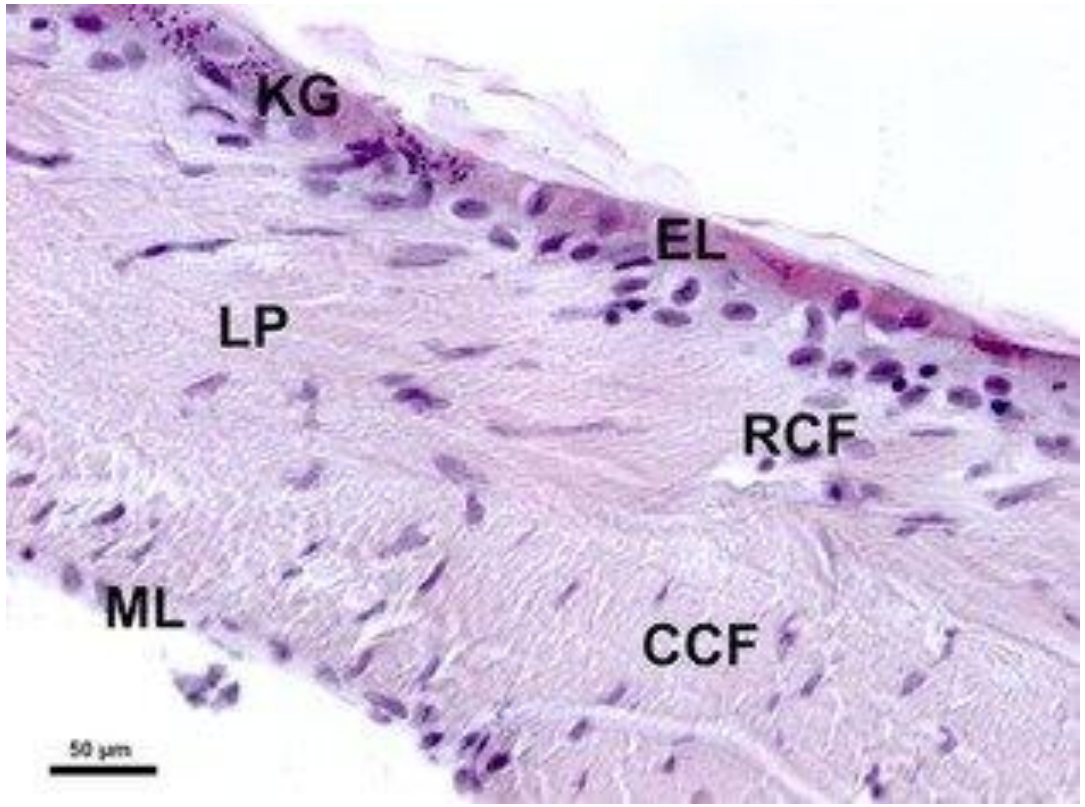
• **Middle ear (tympanic cavity located in the temporal bone)**

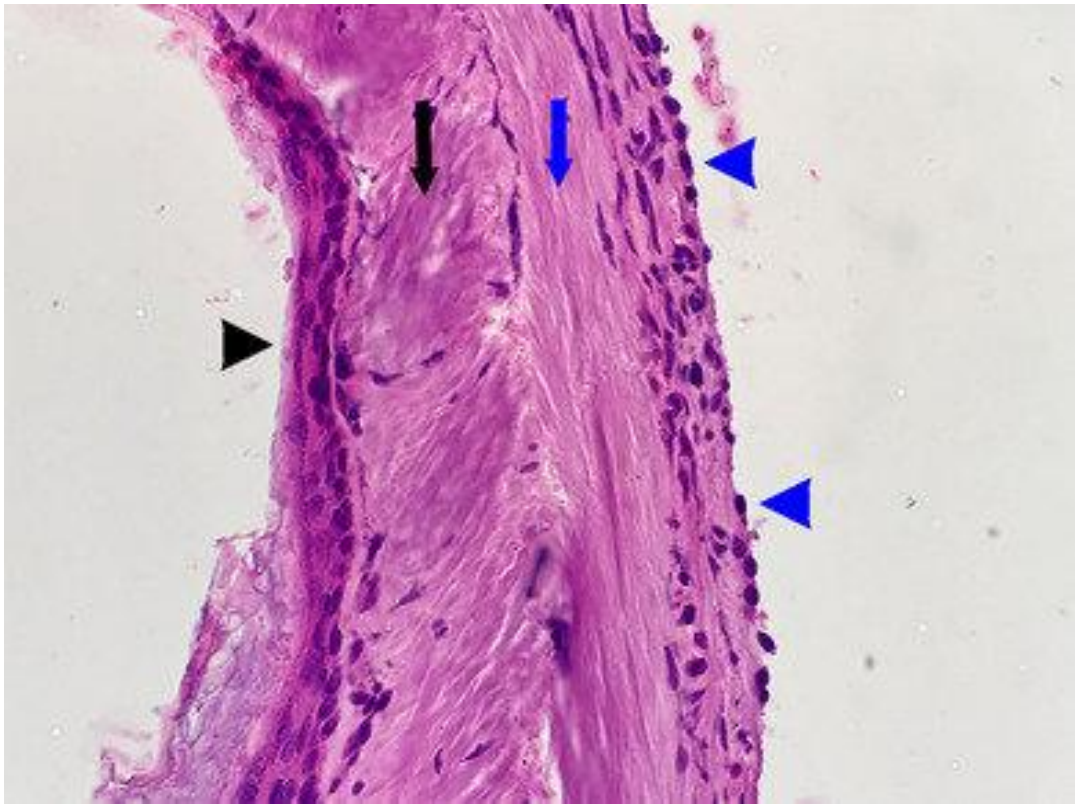
• **Eardrum (tympanic membrane)** – collagen fibers, elastin, fibroblasts; skin or mucous membrane of the tympanic cavity

•**Eustachian tube -** connection with the nasopharyngeal cavity; bone skeleton (from the tympanic side) or elastic cartilage; columnar respiratory epithelium with goblet cells; mucous glands and lymphatic nodules **(Eustachian tube tonsil)**

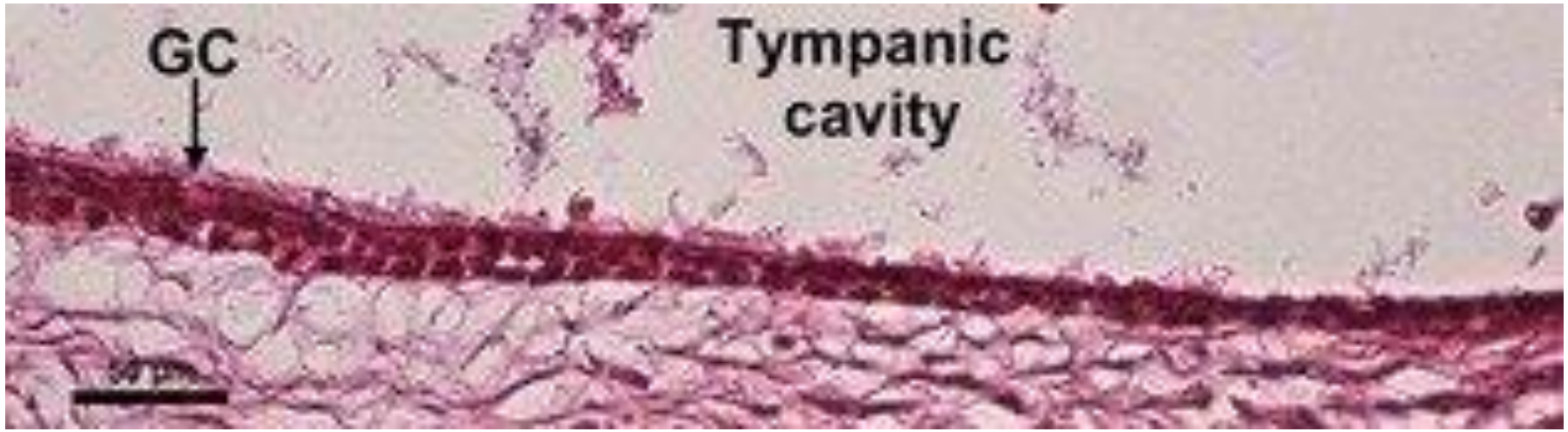
• **Auditory ossicles** (malleus, incus, stapes; covered with simple squamous epithelium)

Middle ear – tympanic membrane

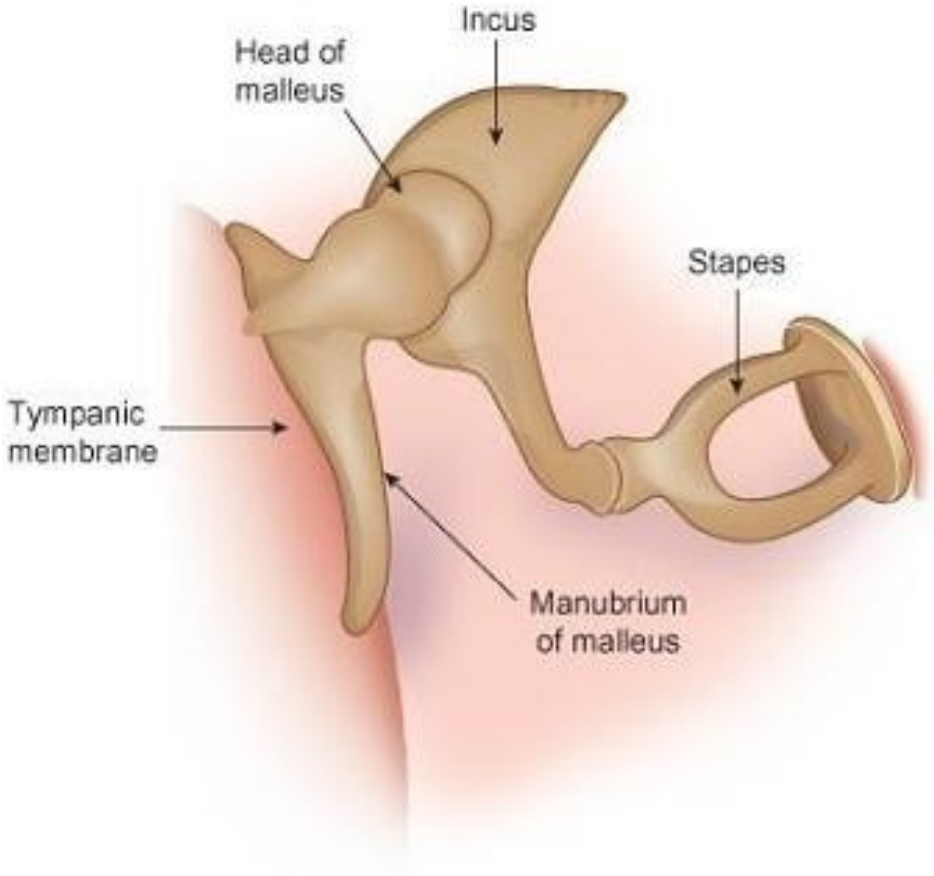


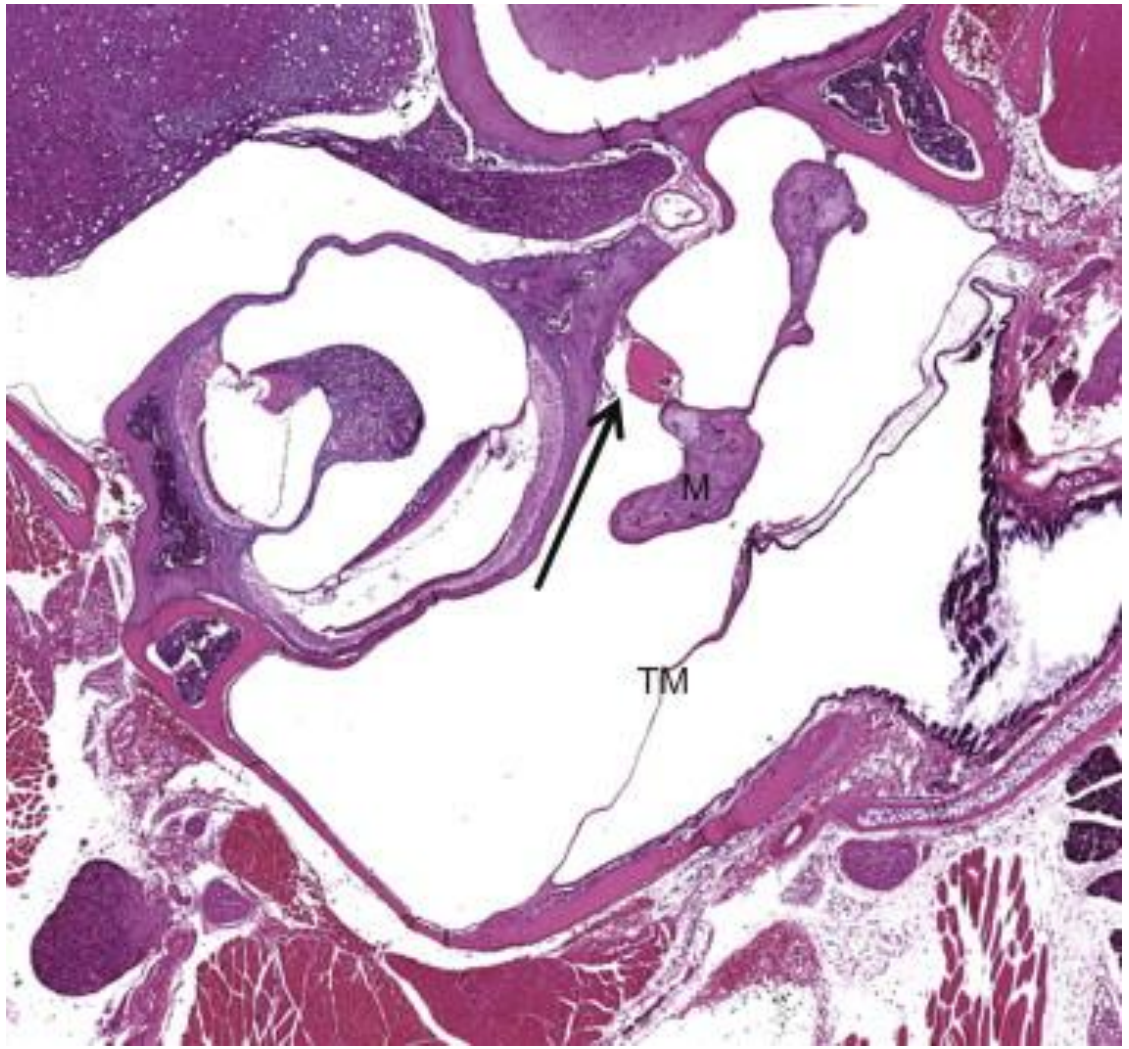


Middle ear – tympanic cavity



Middle ear – auditory ossicles



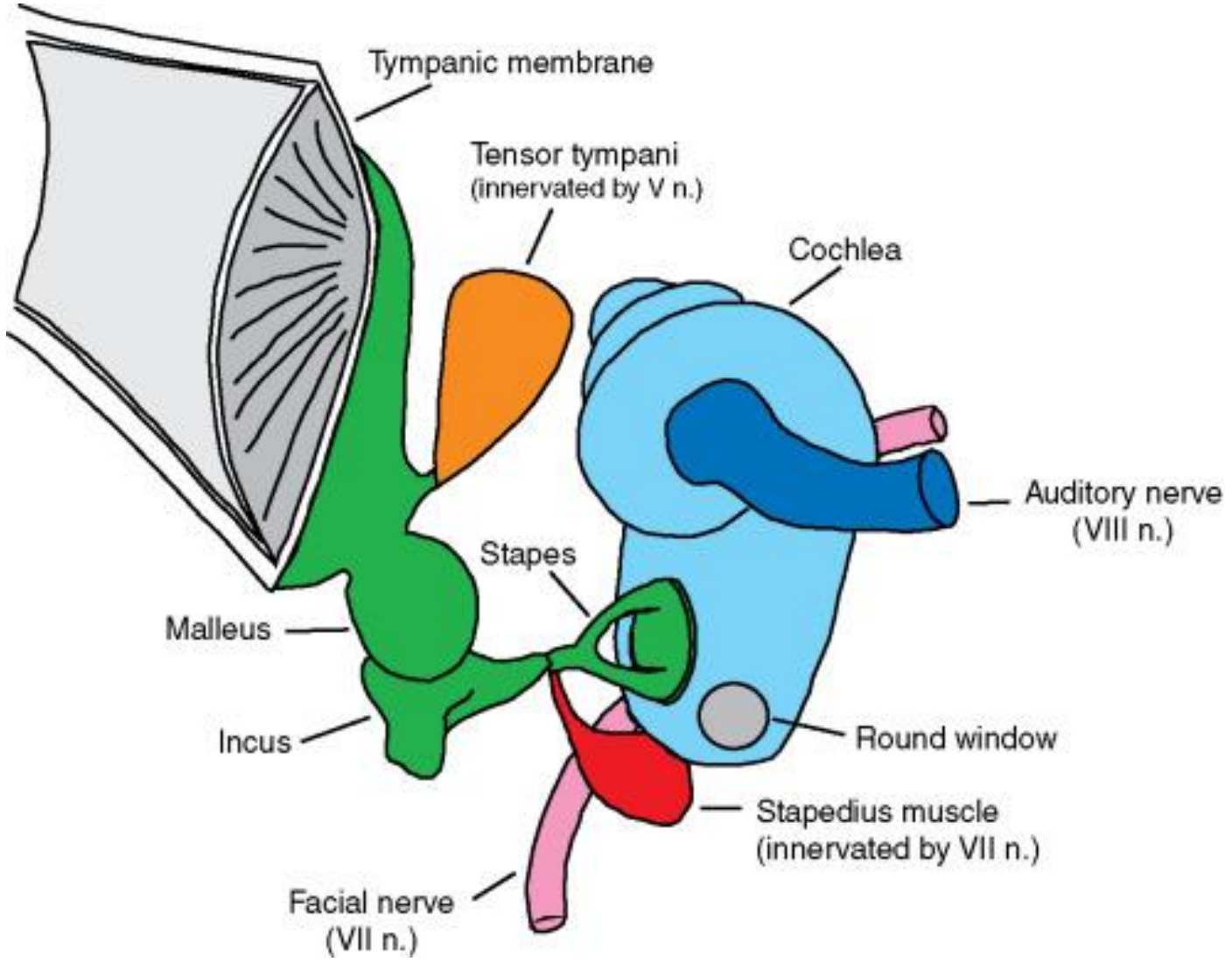


Middle ear – nerves and muscles

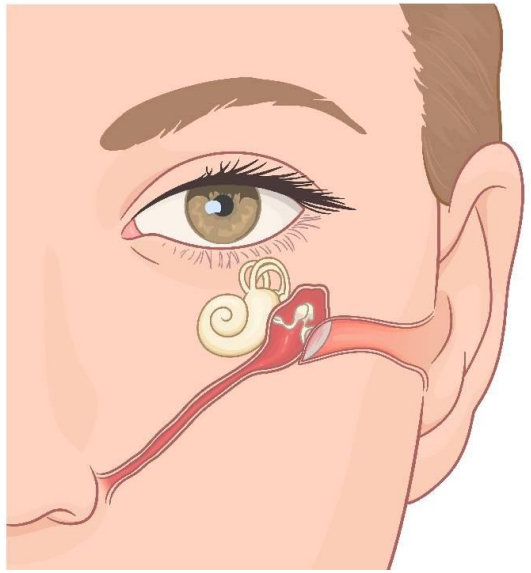
Tensor tympani muscle

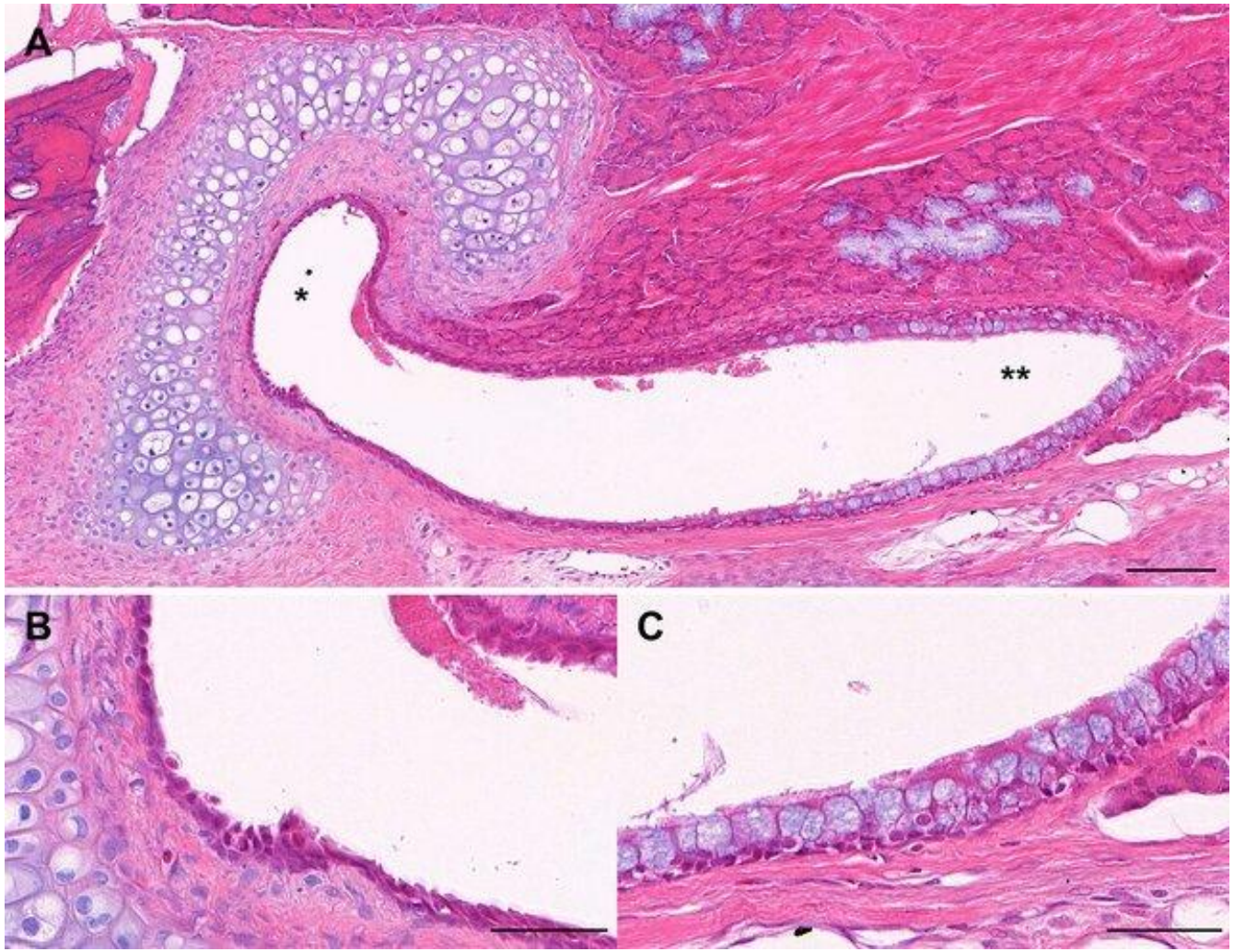
Stapedius muscle

Chorda tympani

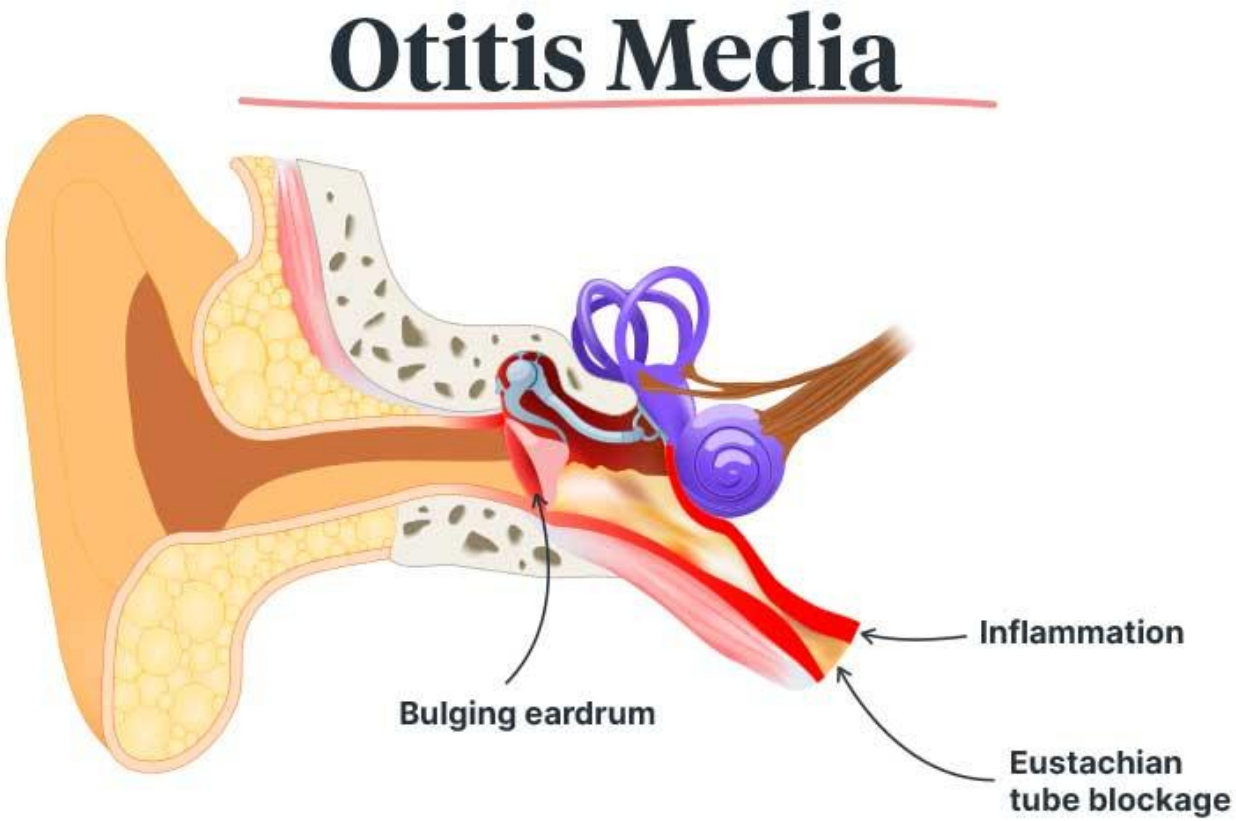


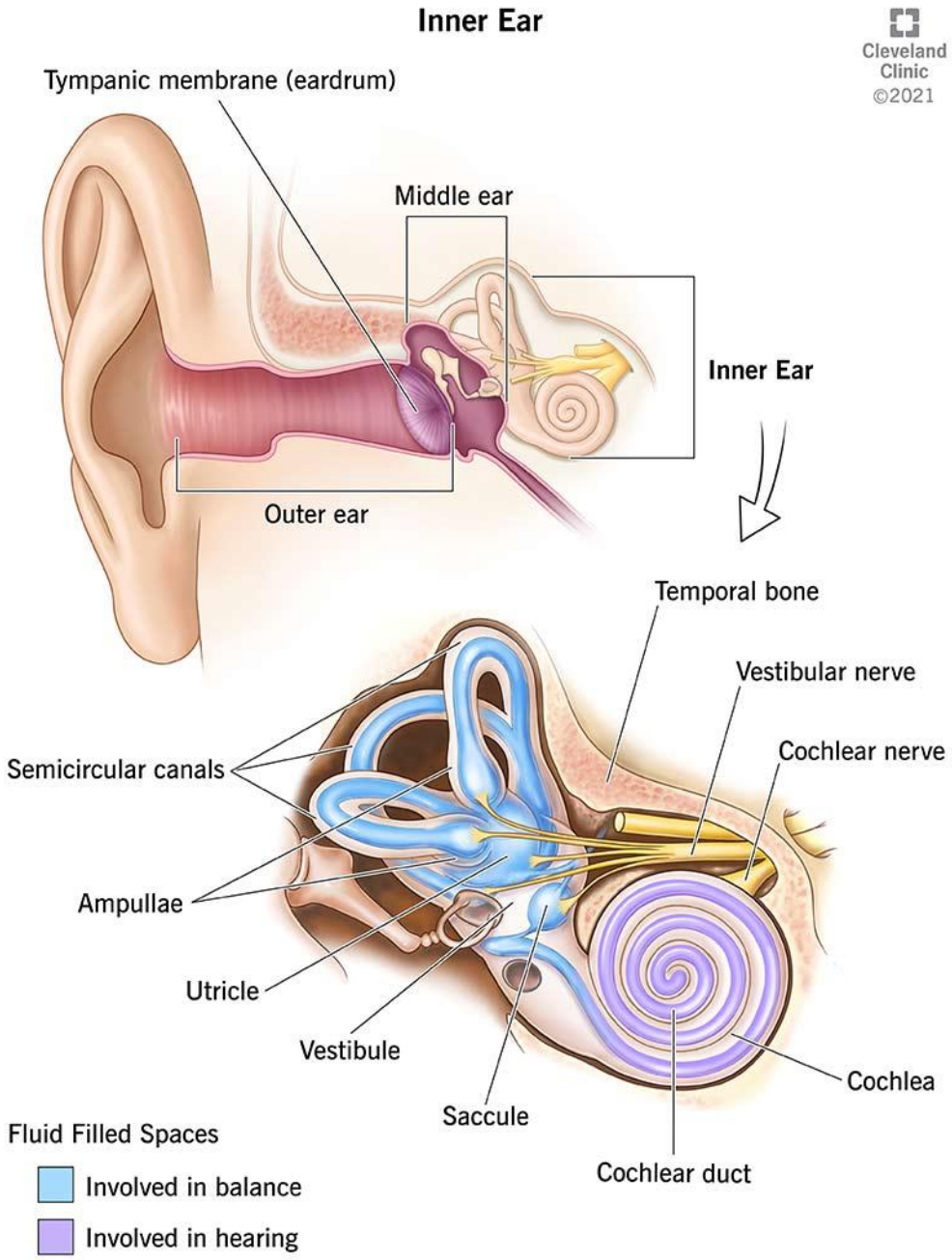
Eustachian tube






WiscMed
WiscMed
WiscMed


Otitis Media
Inflammation
Bulging eardrum
Eustachian
tube blockage

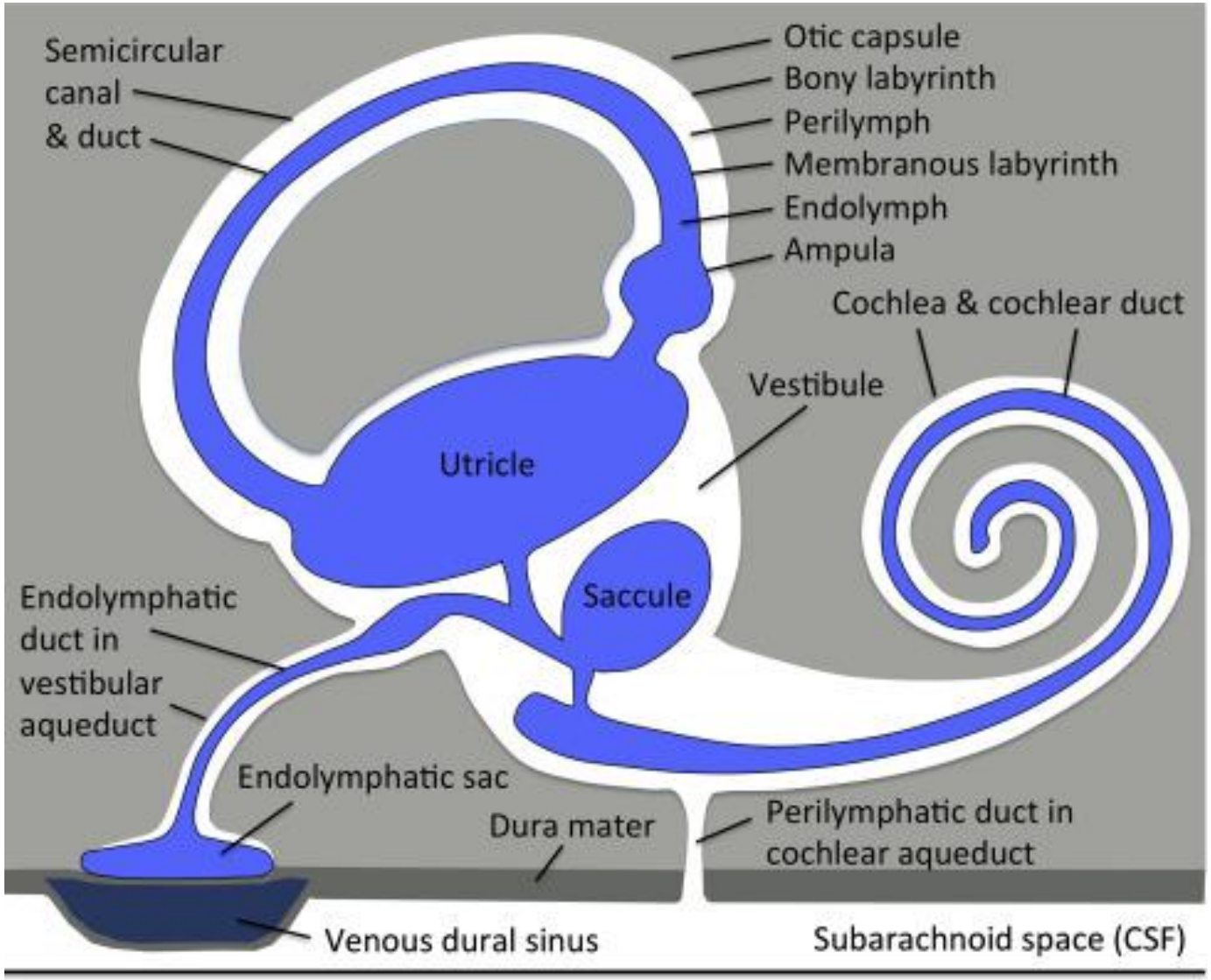


Inner ear

Bone labyrinth- Vestibule, semicircular canals, cochlea;

Membranous labyrinth– structures made of connective tissue and epithelium

Perilymph and endolymph



- **Perilymph** - cerebrospinal fluid, rich in **sodium ions**
- **Endolymph**– rich in **potassium ions**

- In the vestibule of **membranous labyrinth:**
  - **Utricle and saccule**– connective tissue, simple squamous epithelium (columnar epithelium in **maculae**)

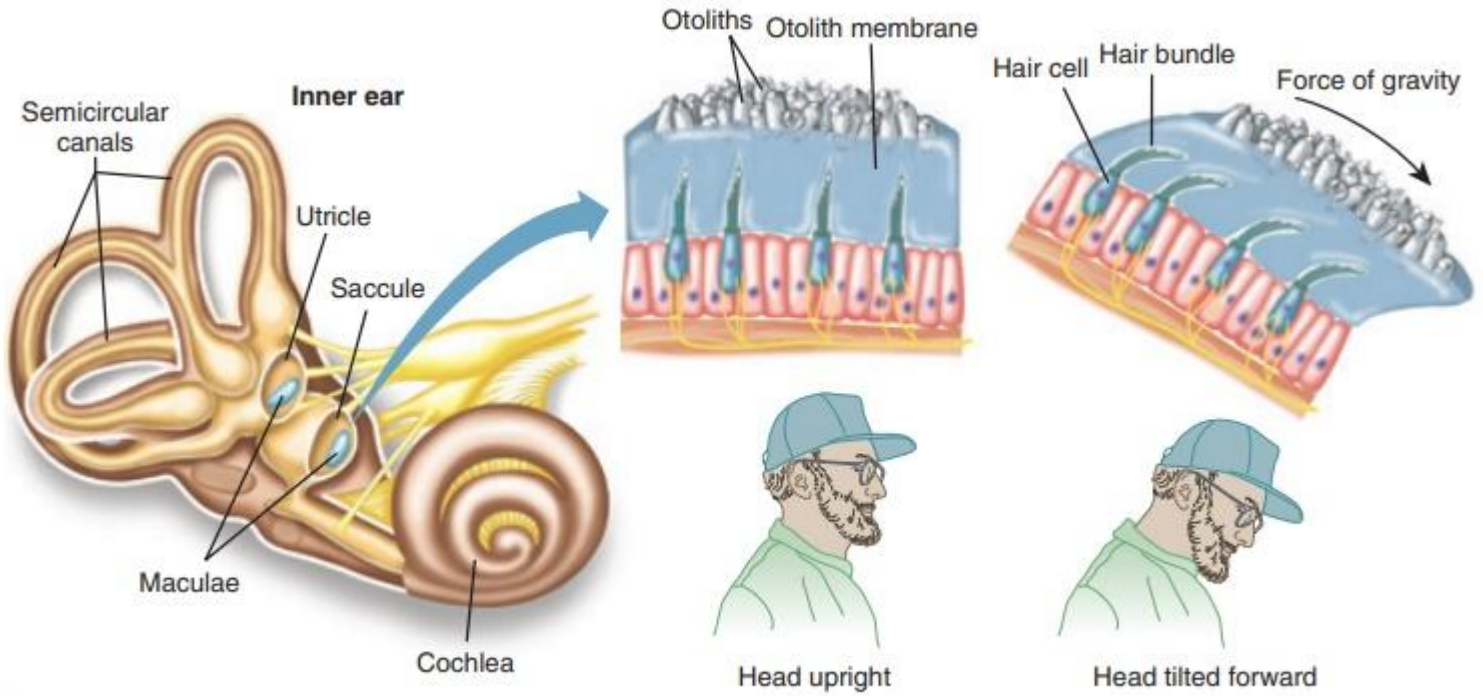
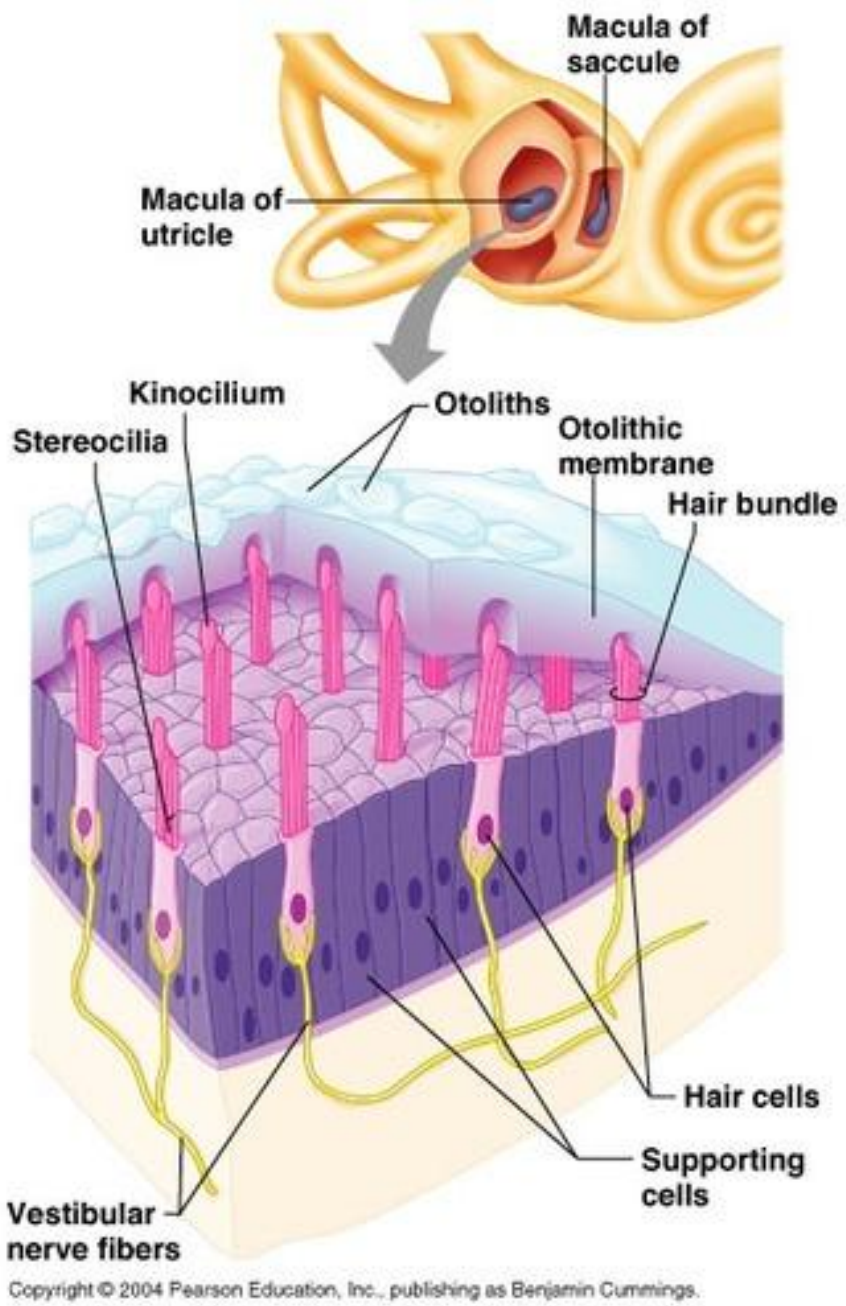
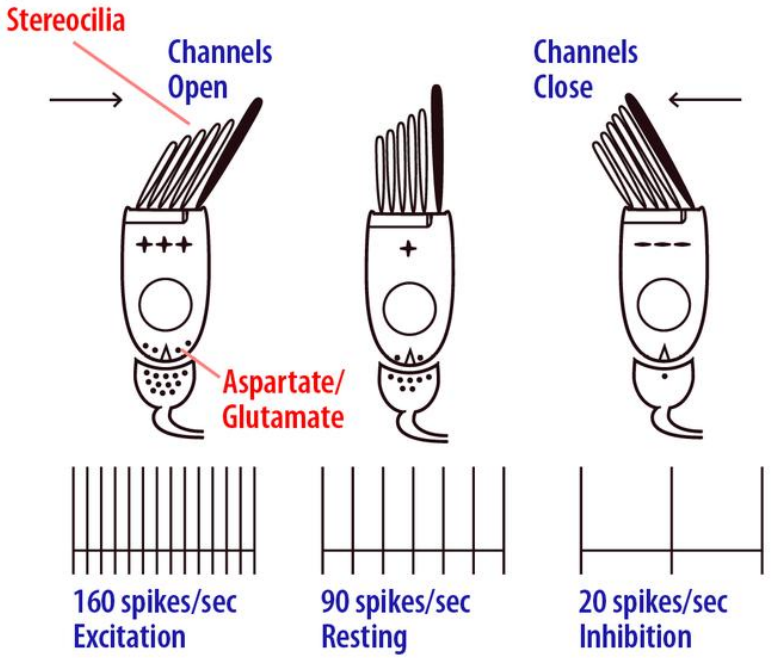


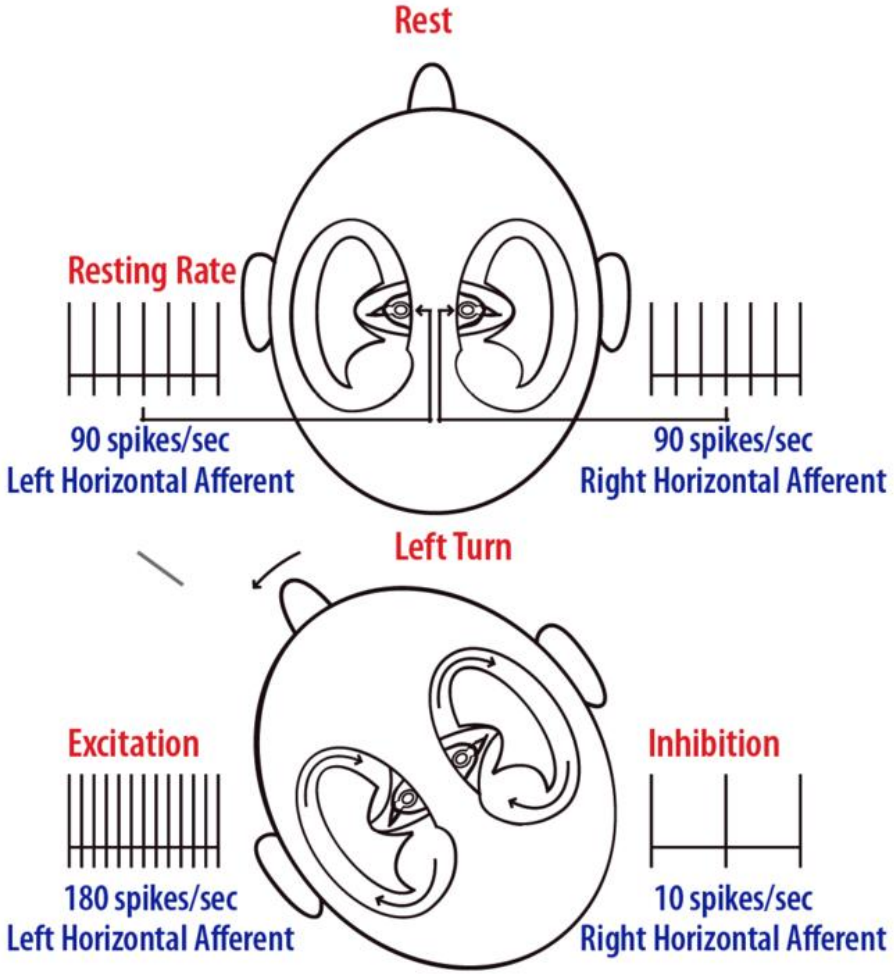
FIGURE 15-6 How the maculae respond to changes in the head position.



Macula of saccule and utricle

- Gelatinous otolithic membrane and calcium otoliths
- Columnar epithelium:
  - Supporting cells
  - Type I and II sensory cells with kinocylium (cilia) and stereocilia (microvilli)





At rest, hair cells release the neurotransmitter at intervals, which regularly triggers cell depolarized

When the **stereocilia bend towards the kinocilium**, the cell depolarizes more rapidly

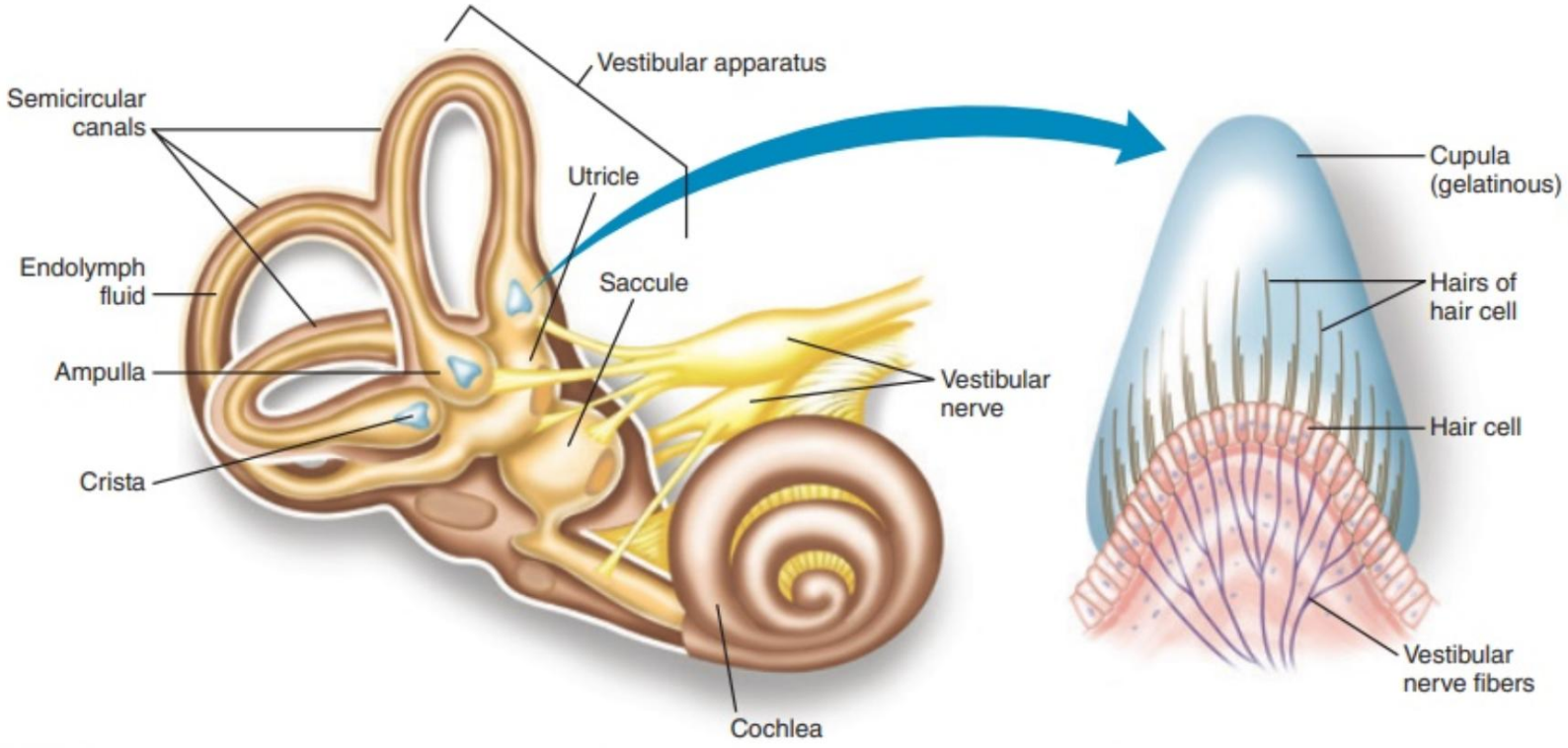
When the **stereocilia bend from the kinocilium,** the cell becomes hyperpolarized

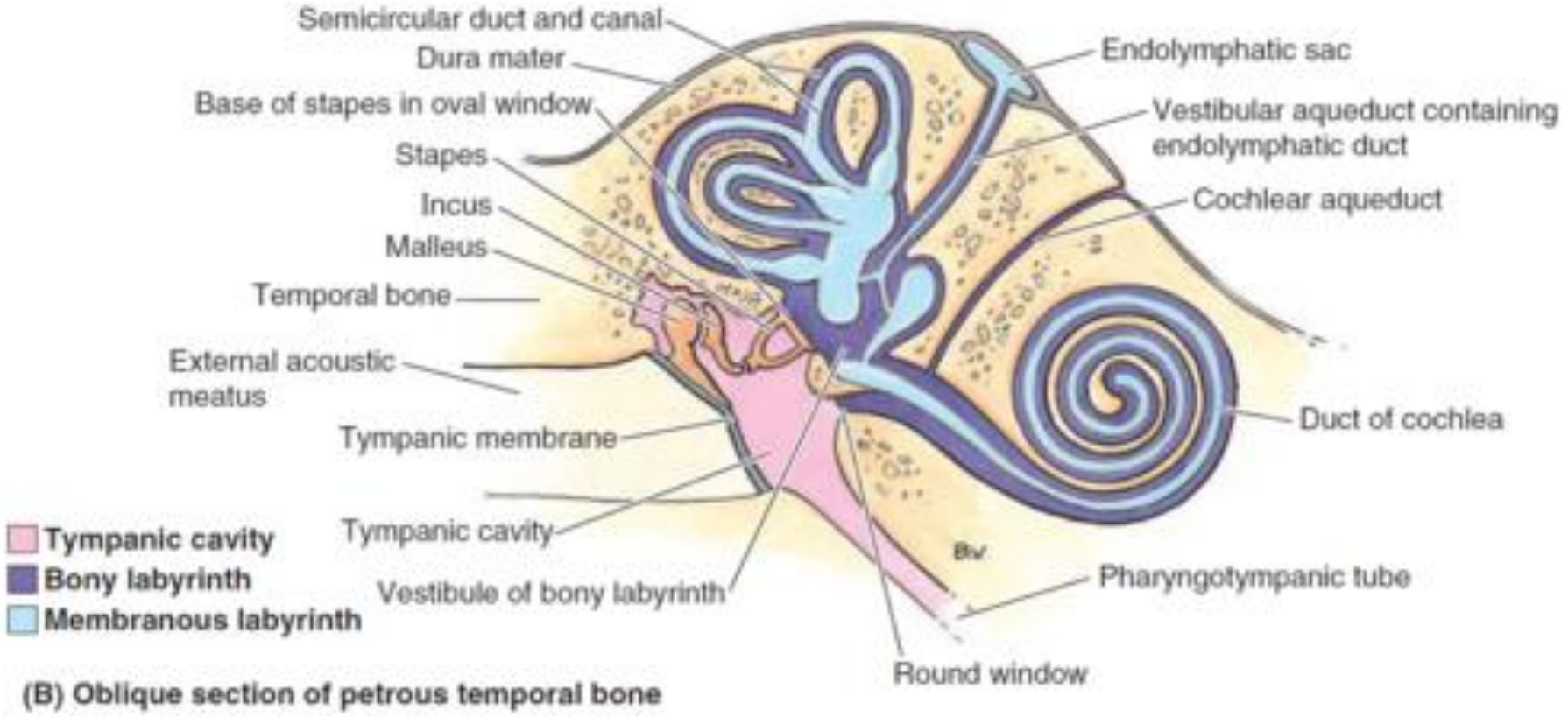
Semicircular canals – ending with the ampulla opening into vestibular apparatus

Canals – simple squamous epithelium

Cristae of ampulla – simple columnar epithelium

- Support and hair cells (sensory)
- Thick layer of gelatinous substance– cupula; no otoliths





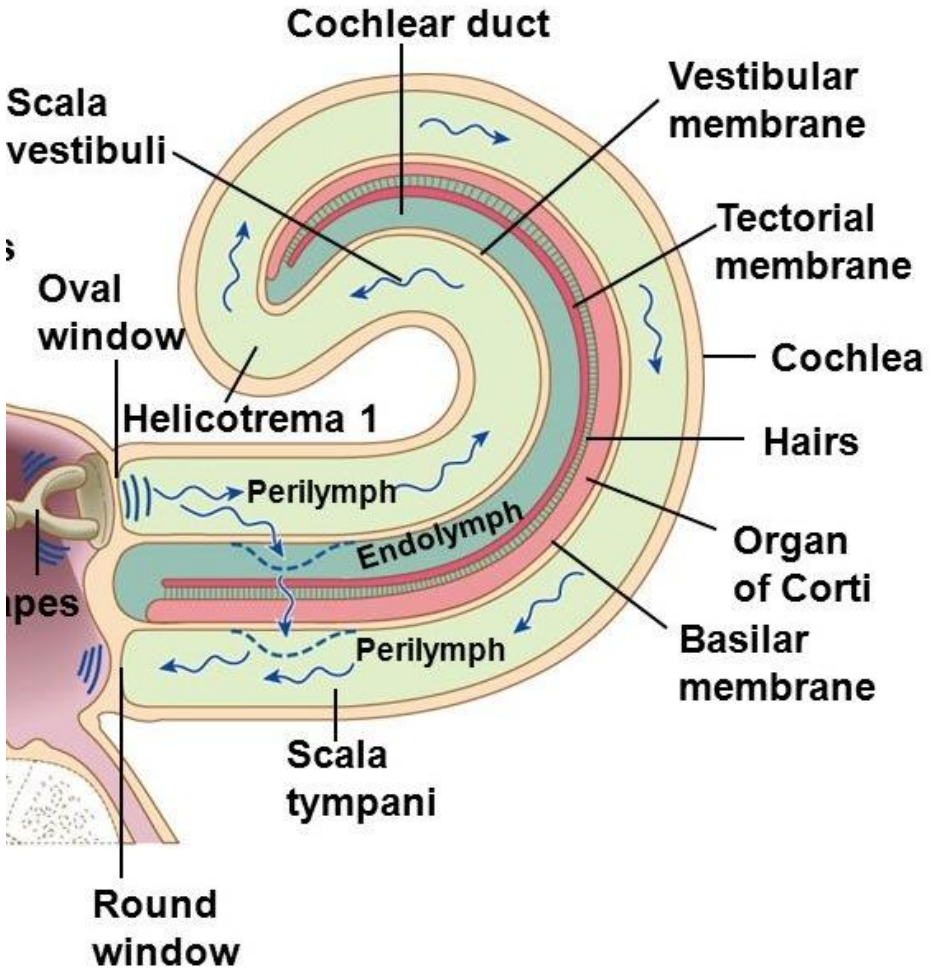
(B) Oblique section of petrous temporal bone

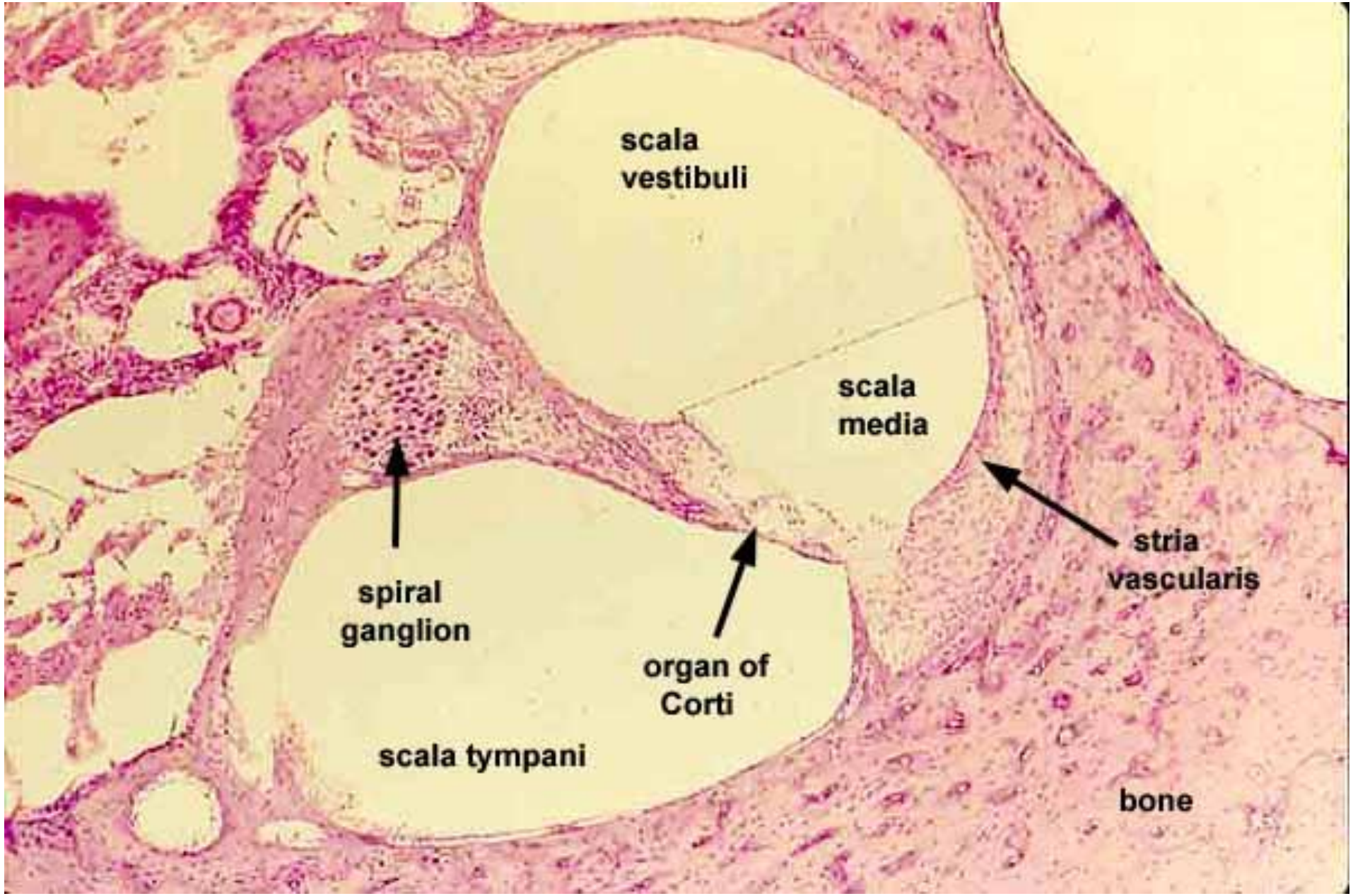
Endolymphatic duct and sac

- Wall – connective tissue proper
- Duct - simple squamous epithelium
- Sac – simple columnar epithelium – here endolymph is absorbed

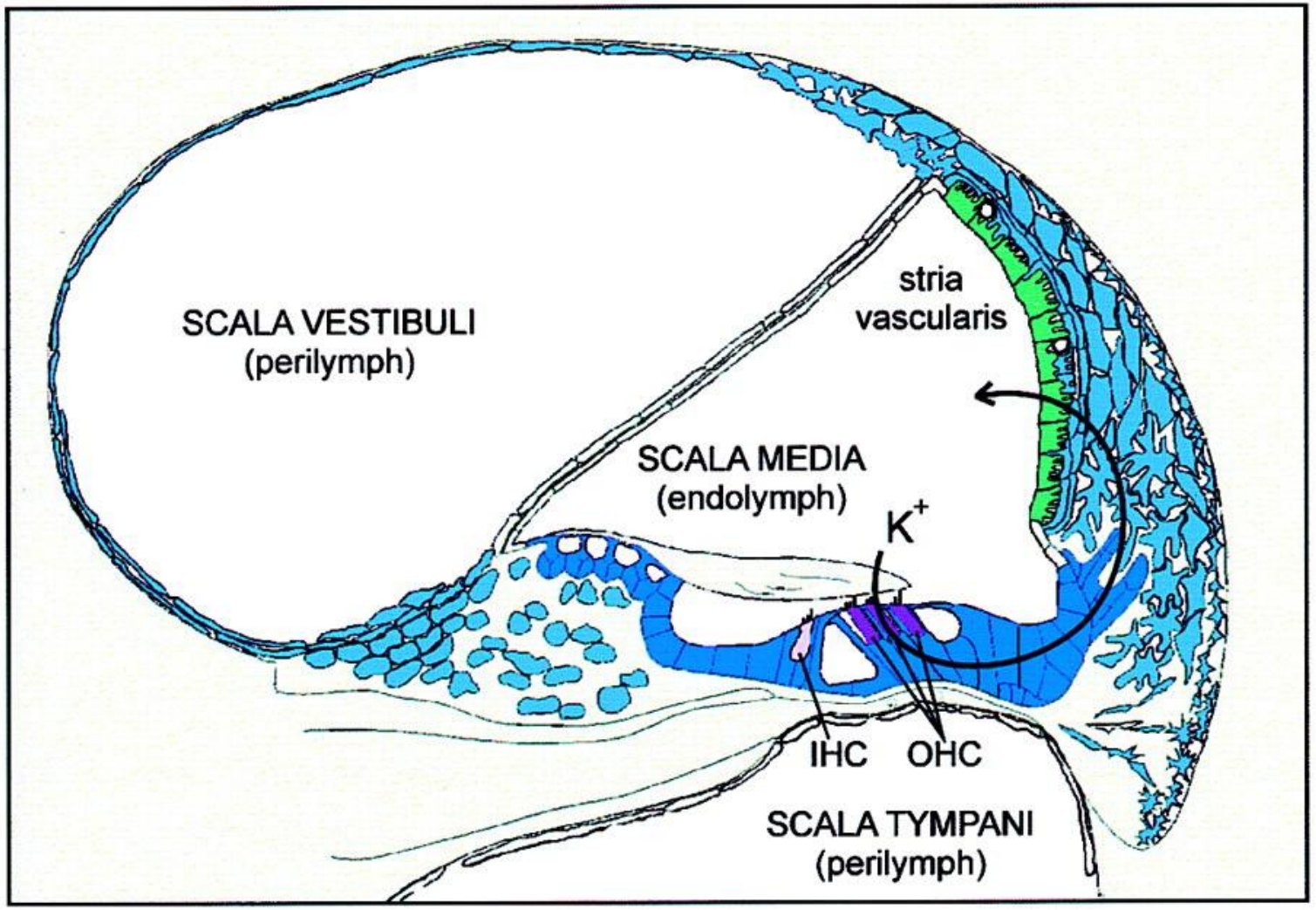
Cochlea

- **Scala vestibuli** and **scala tympani** - simple squamous epithelium on connective tissue fused with the periosteum
- **Scala media (cochlear duct)** separated from scala vestibule and scala tympani with vestibular membrane (Reissner membrane) – organ of Corti and stria vascularis




scala
vestibuli
scala
media
spiral
ganglion
organ of
Corti
stria
vascularis
scala tympani
bone

Stria vascularis

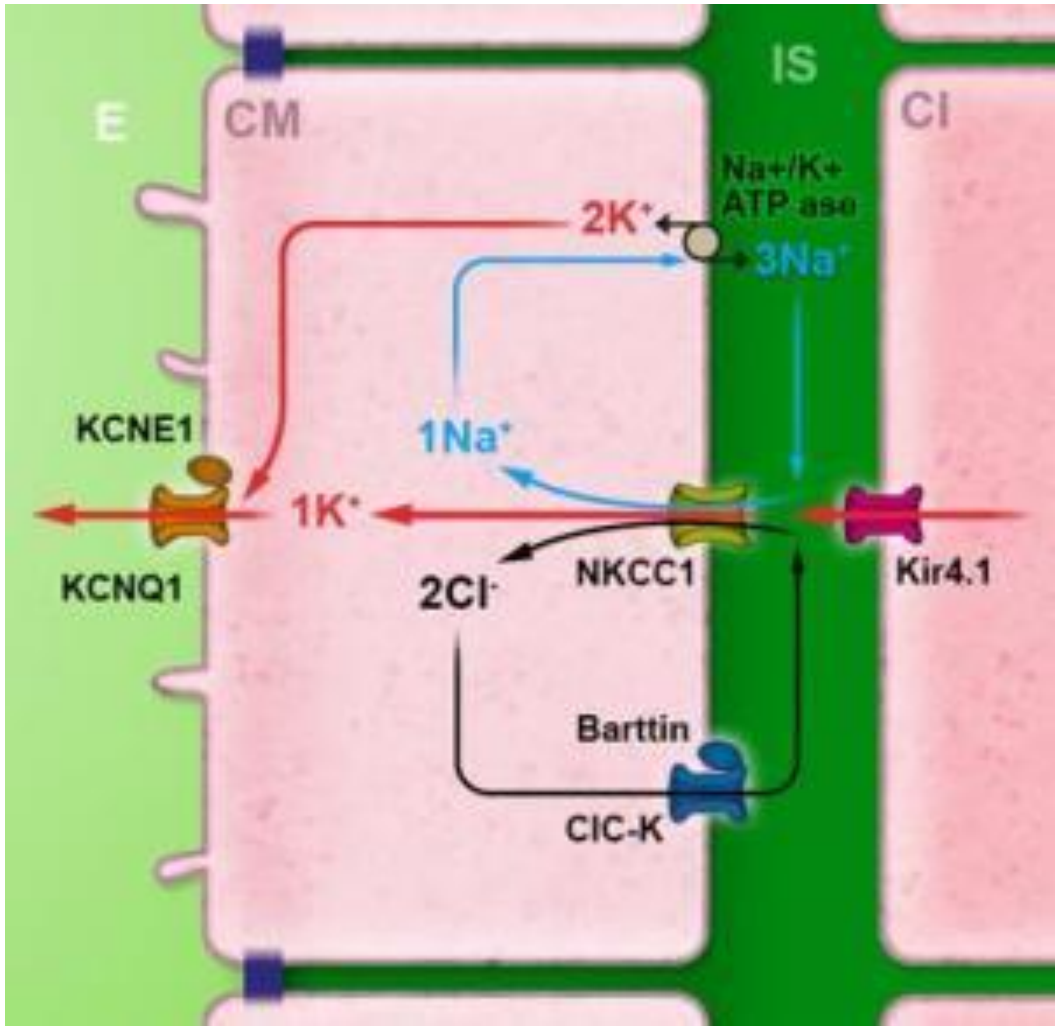


marginal cells of stria vascularis
(KCNQ1 & KCNE1)

connective tissue system
(GJB2)

epithelial cell system
(GJB2)

outer hair cells
(KCNQ4)



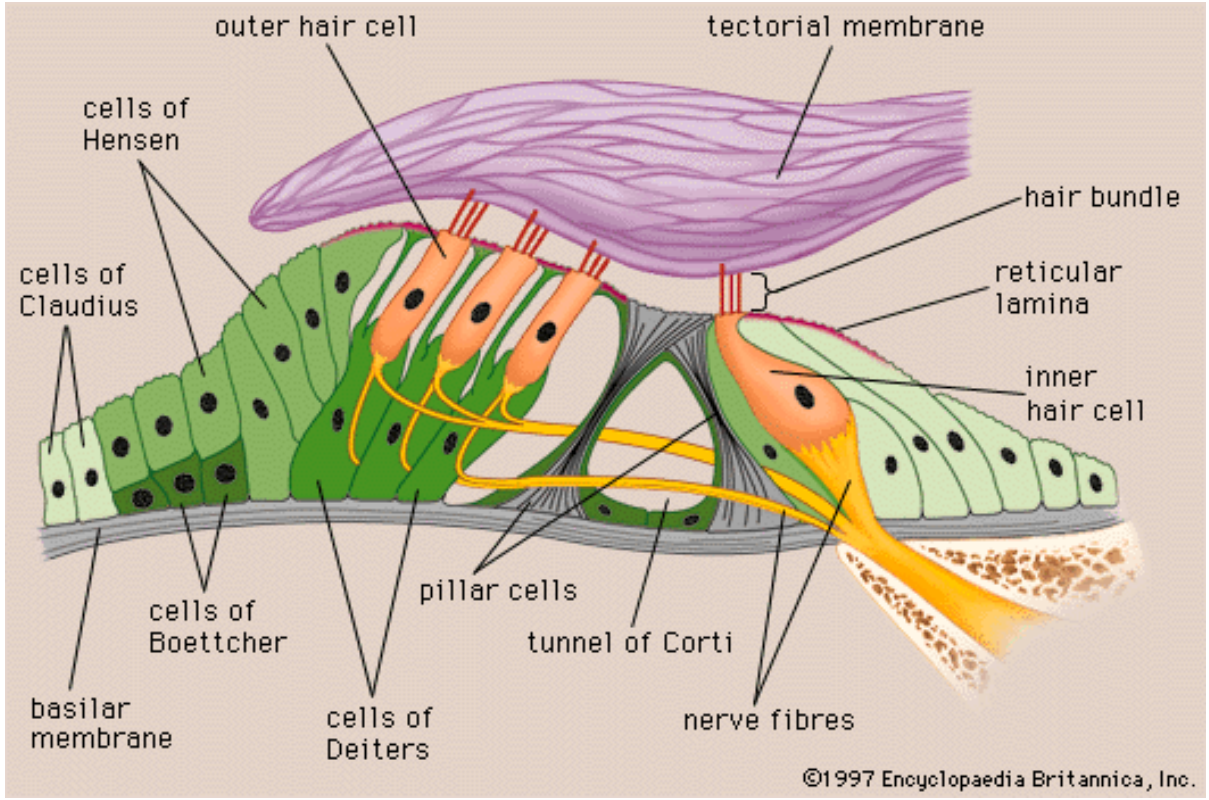
Potassium is transported from the basal cells to marginal cells through a series of channels – passive and active

Kir4.1 – the mutation causes **EAST syndrome** (Epilepsy, Ataxia, Sensorineural deafness and Tubulopathy)

Sodium-potassium pump– transports potassium to marginal cells

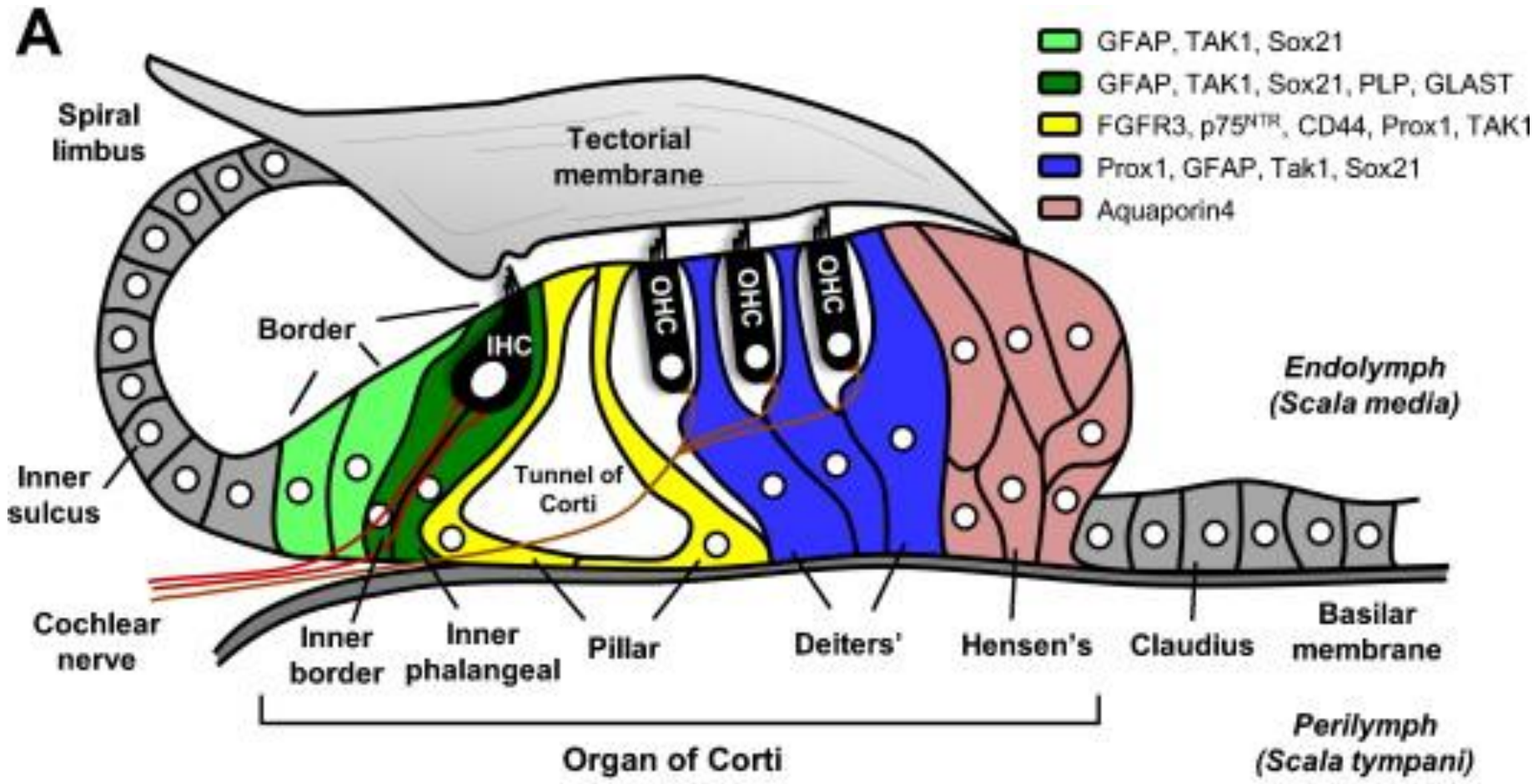
Symport **NKCC1** (sodium, chlorine, potassium) in the membrane of marginal cells – uses a gradient of sodium ions to transport potassium

Channel **KCNQ1** for potassium - releases potassium into the endolymph – the mutation causes **Lange-Nielsen syndrome** (hearing loss, cardiac arrhythmias)



- **Organ of Corti**
  - **Supporting cells** (external and internal pillar cells, internal phalangeal cells (cells of Dieter – house sensory cells, Hensen, Claudius, Boettcher cells)
  - **Sensory cells – hair cells**
  - **Tectorial membrane -** gel-like structure containing 97% water. Its dry weight is composed of collagen (50%), non-collagenous glycoproteins (25%) and proteoglycans (25%)

Support cells

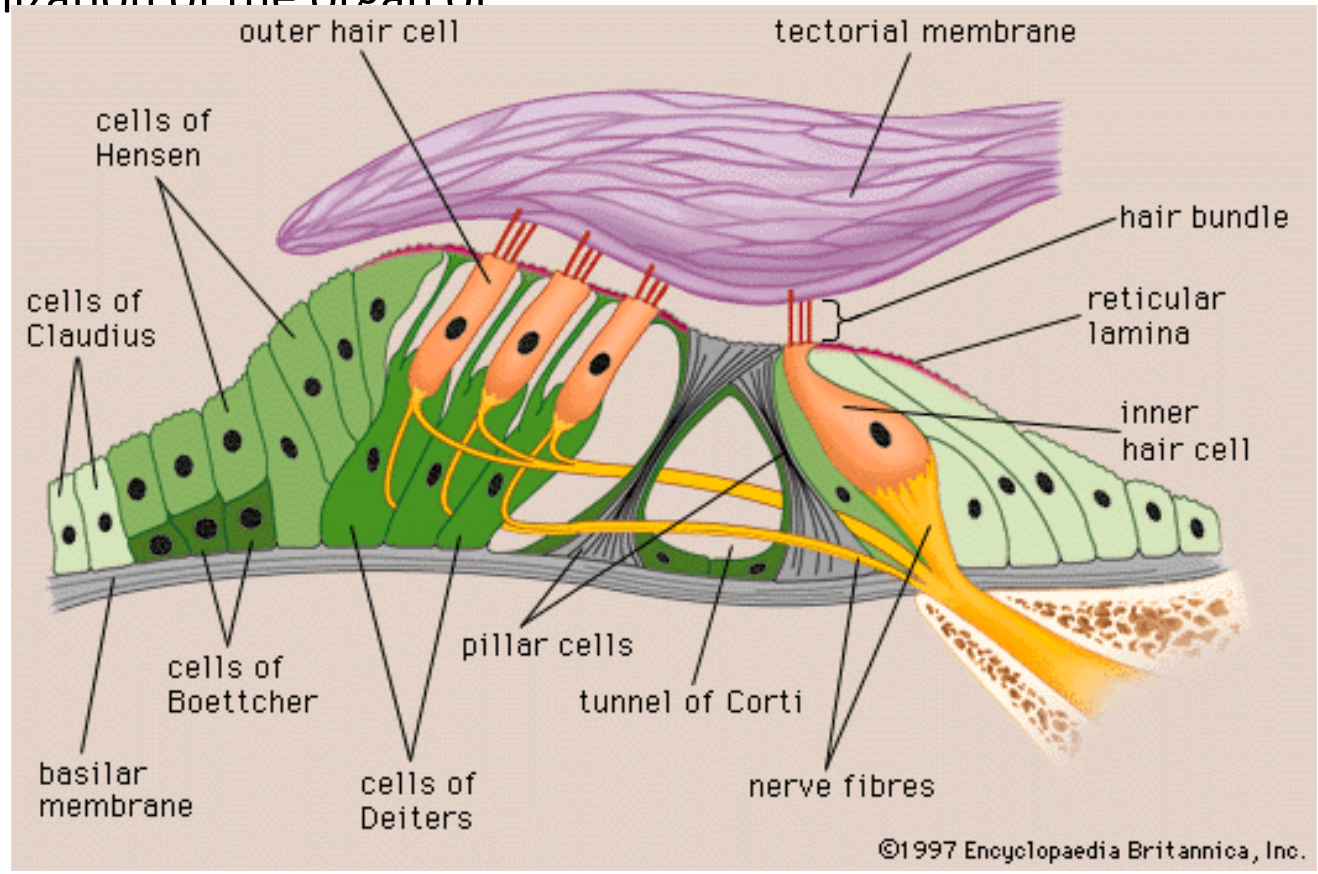


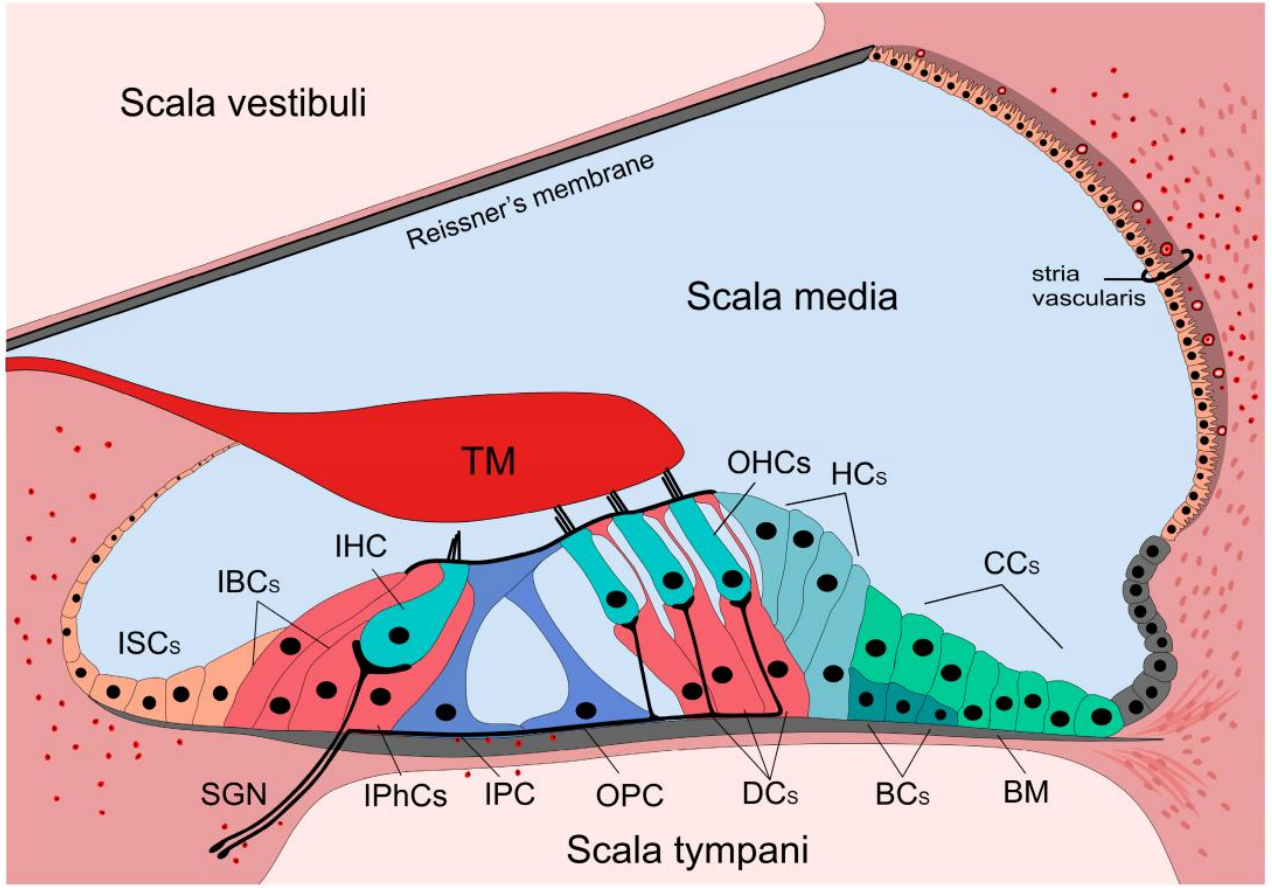
Hensen cells – cubic
Cells of Dieter and **pillar cells** – well developed cytoskeleton, long processes – they maintain the structures of the tunnel of Corti

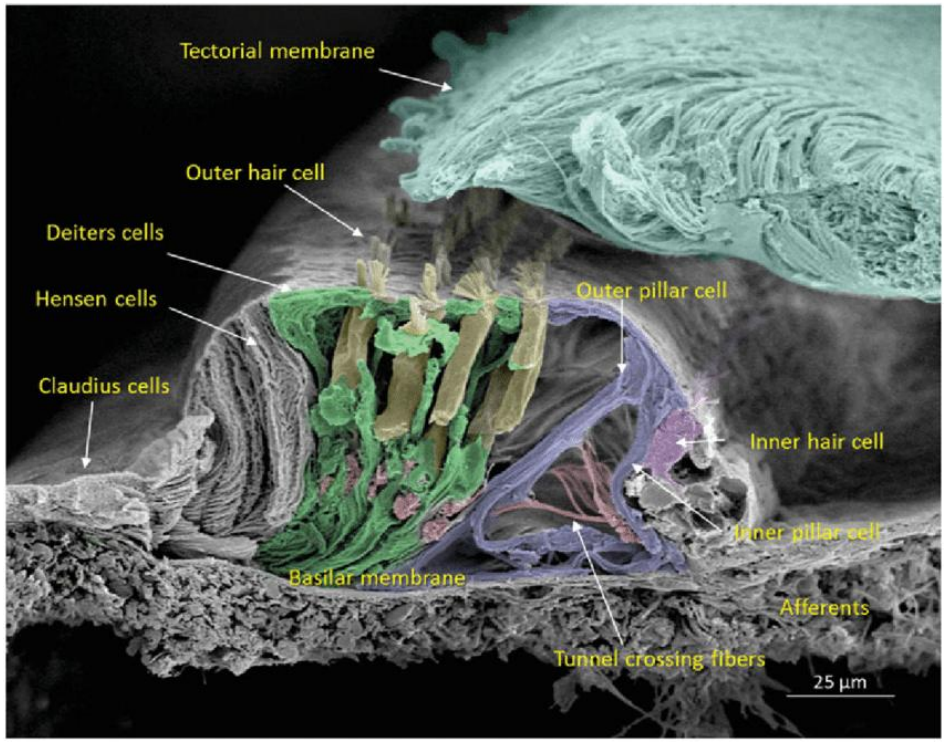
Functions of support cells:

During the development of the ear – the organization of the organ of Corti, the development of hair cells

In the mature ear:
- Maintaining hair cells
- Maintaining the integrity of the Corti organ
- Homeostasis of ions and neurotransmitters
- Participation in mechanotransduction
- Extracellular matrix production
– **reticular membrane**



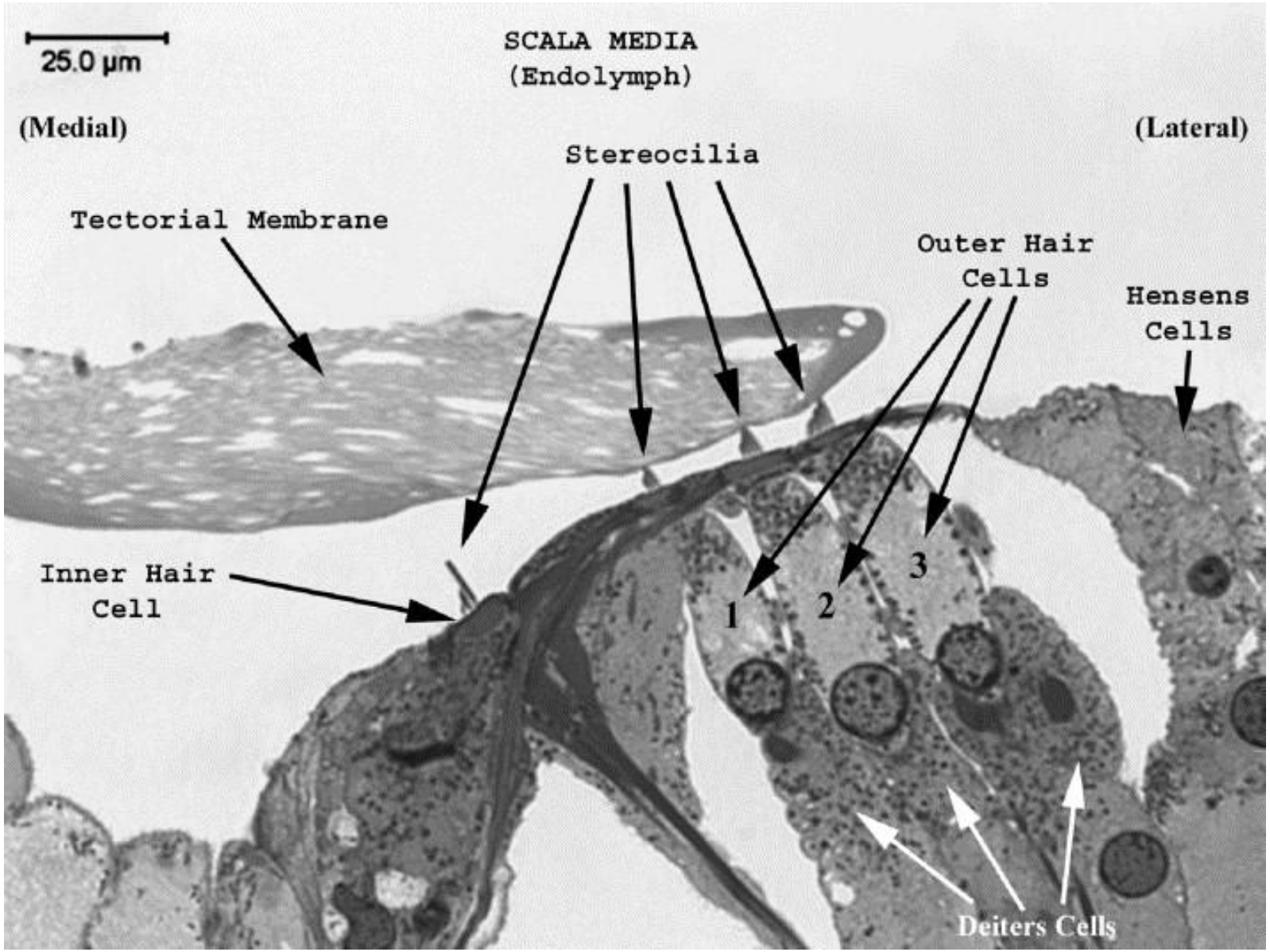




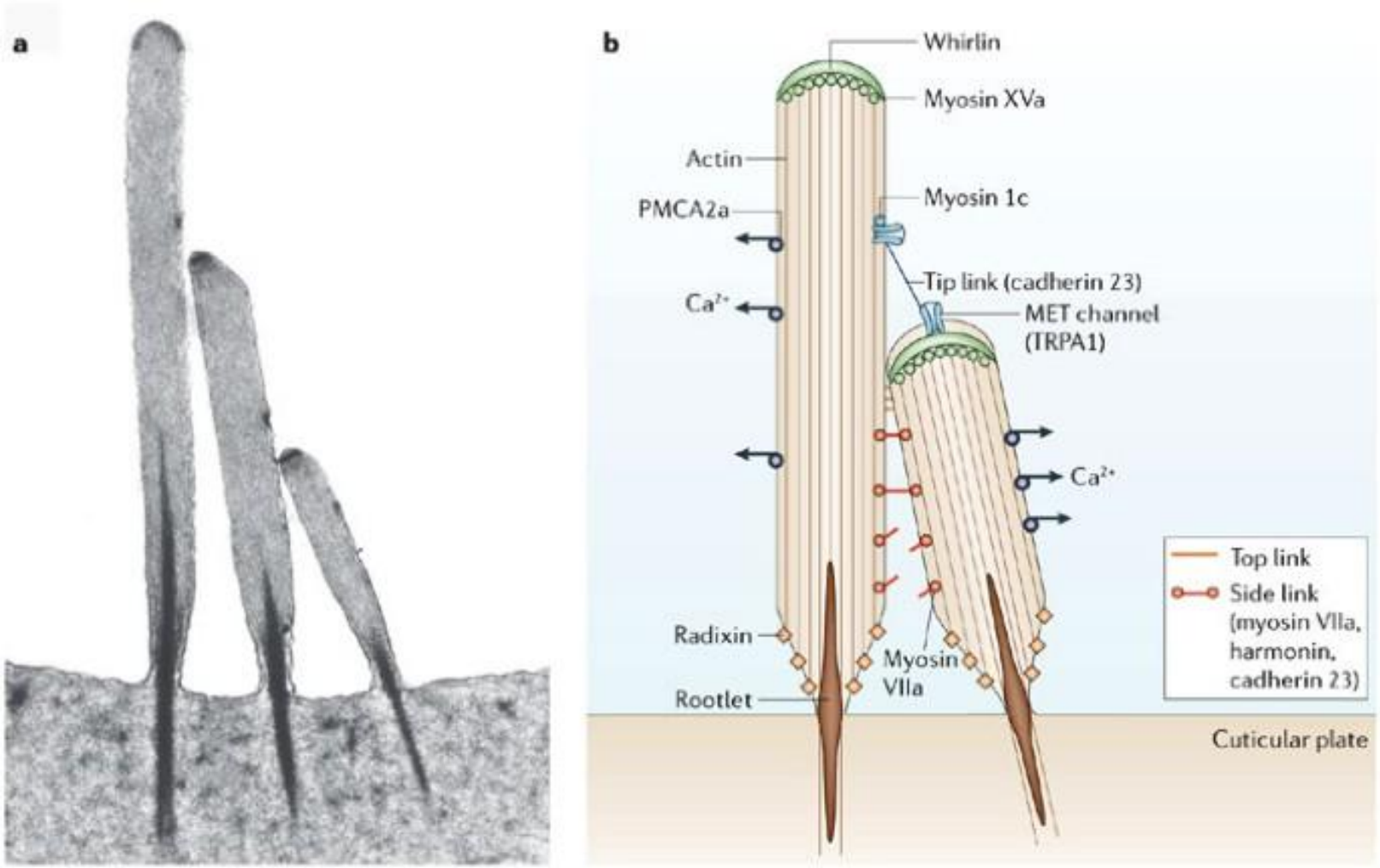
Sensory cells

inner hair cells (type I) with stereocilia

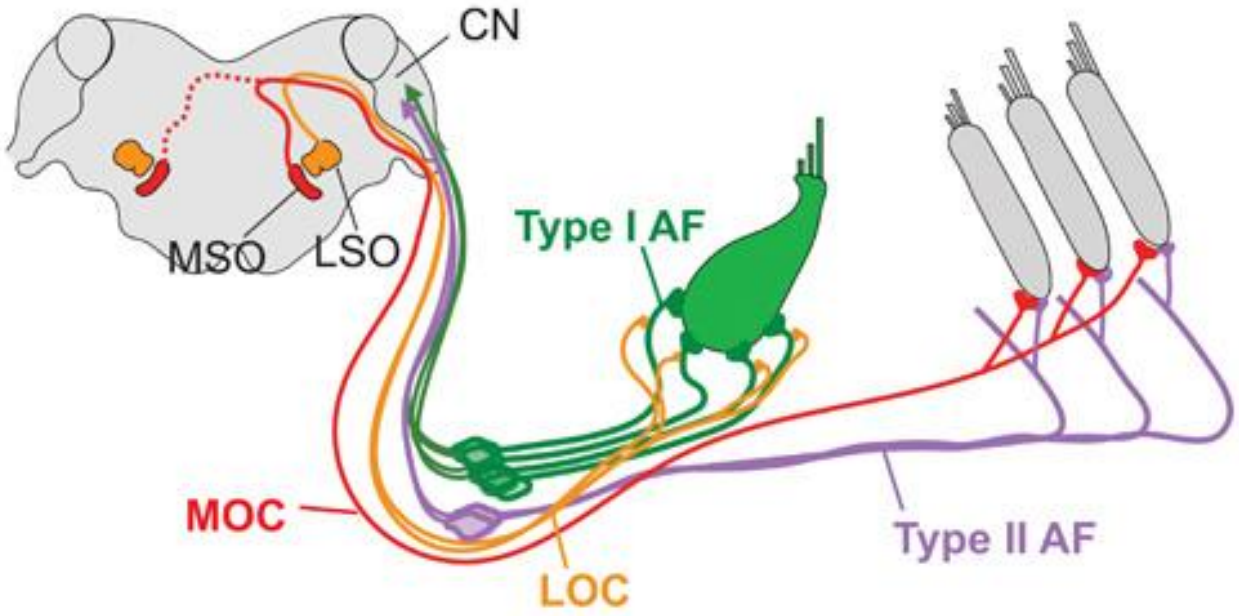
outer hair cells (type II) with stereocilia

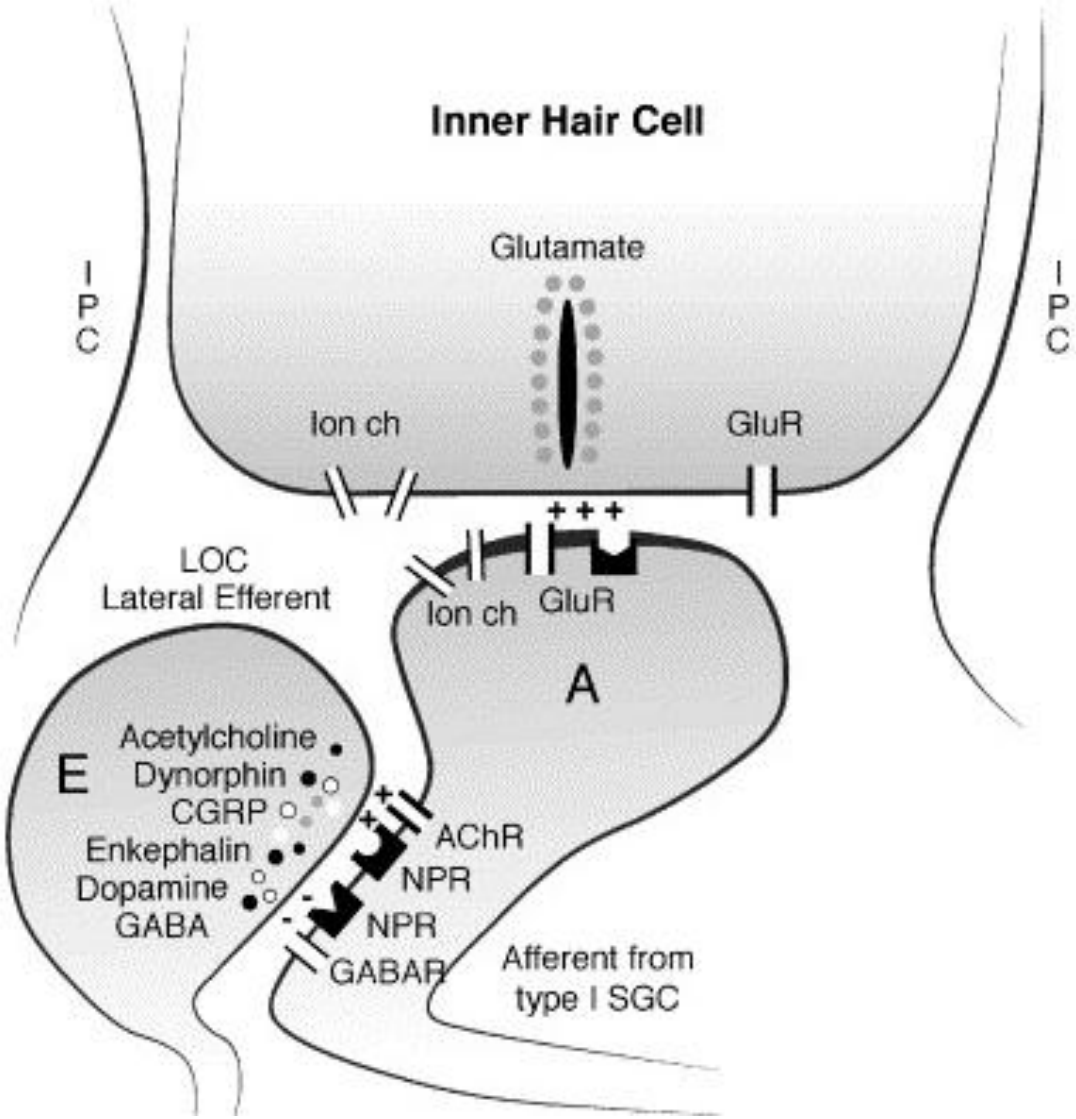

25.0 µm
SCALA MEDIA
(Endolymph)
(Medial)
(Lateral)
Stereocilia
Tectorial Membrane
Outer Hair
Cells
Hensens
Cells
Inner Hair
Cell
1
2
3
Deiters Cells

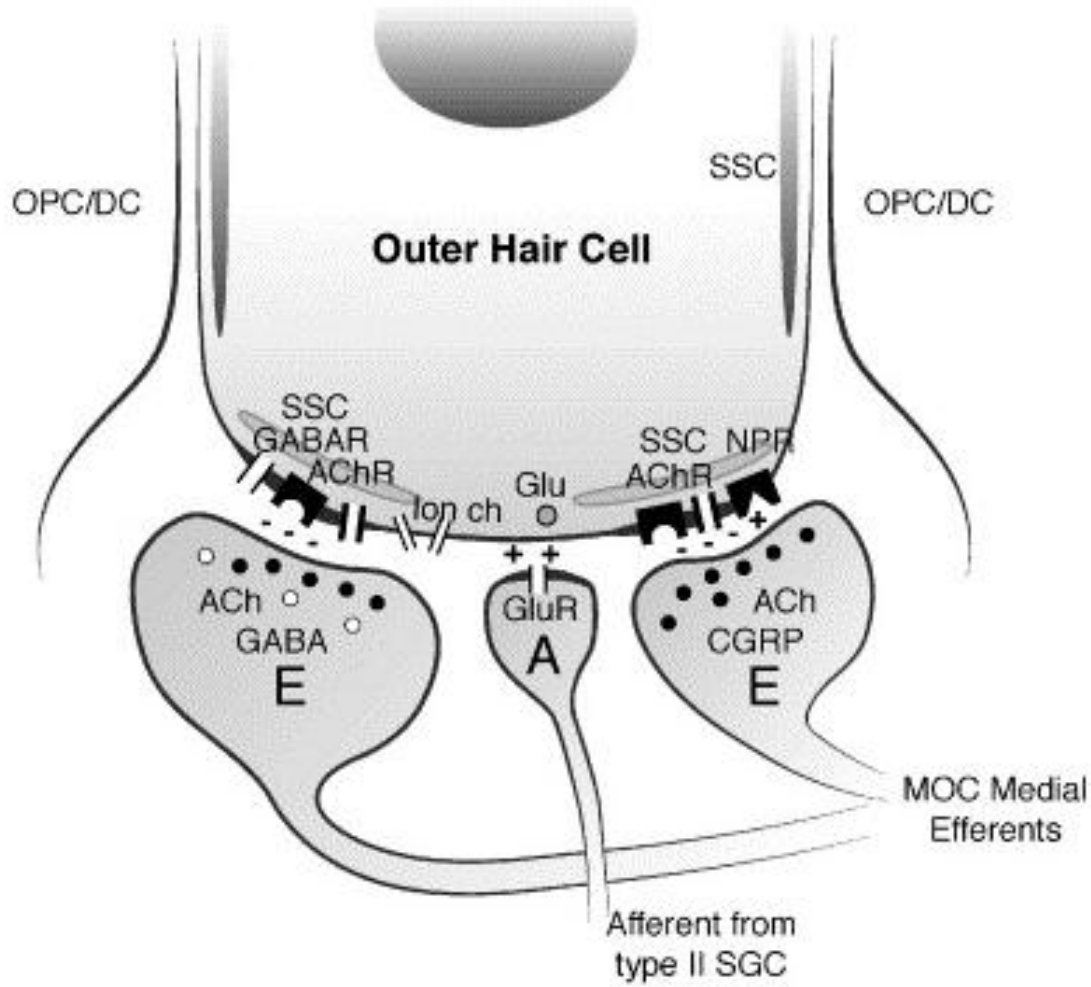
Hair cells



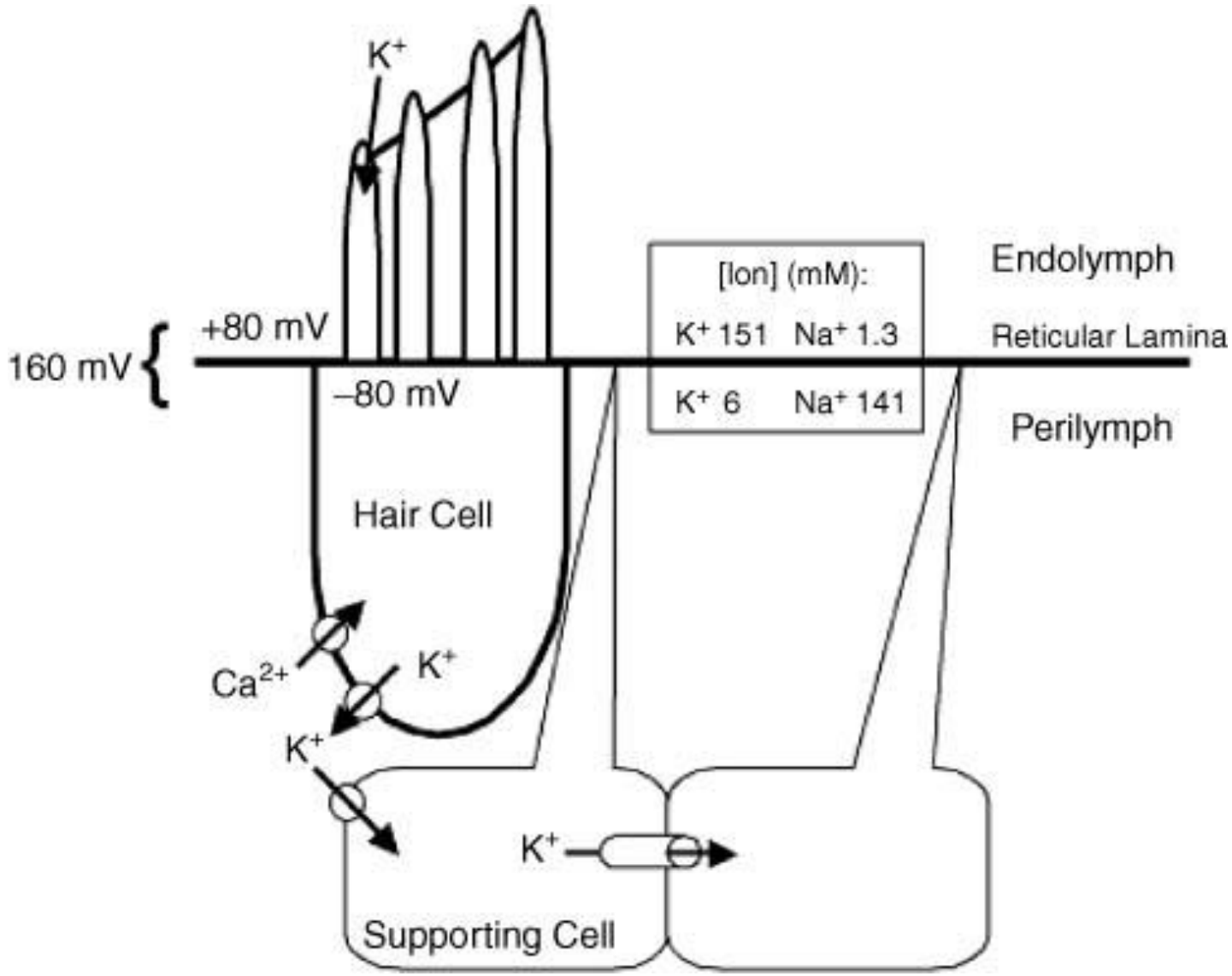
- **Afferent acoustic fibers** (AF type I and II) - dendrites of bipolar spiral ganglion cells– reach the hair cells
- **Efferent acoustic fibers** (LOC, MOC) – upper ganglion of the olivary nucleus – Innervates support and hair cells




Inner Hair Cell
IPC
IPC
Glutamate
Ion ch
GluR
LOC
Lateral Efferent
Ion ch
GluR
A
E
Acetylcholine
Dynorphin
CGRP
Enkephalin
Dopamine
GABA
AChR
NPR
NPR
GABAR
Afferent from
type I SGC

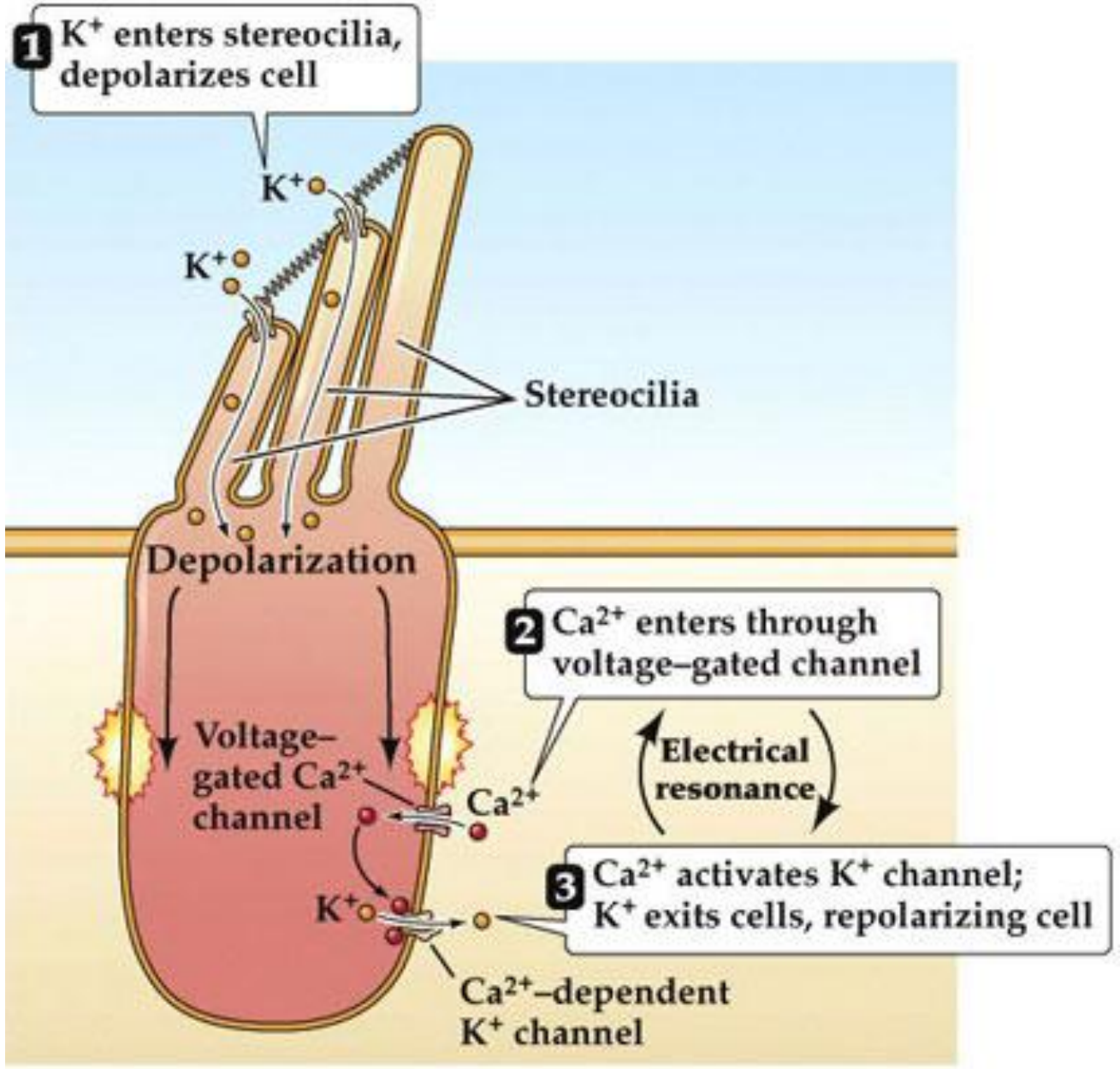

OPC/DC
SSC
OPC/DC
Outer Hair Cell
SSC
GABAR
AChR
Ion ch
Glu
SSC NPR
AChR
ACh
GABA
E
GluR
A
ACh
CGRP
E
MOC Medial
Efferents
Afferent from
type II SGC

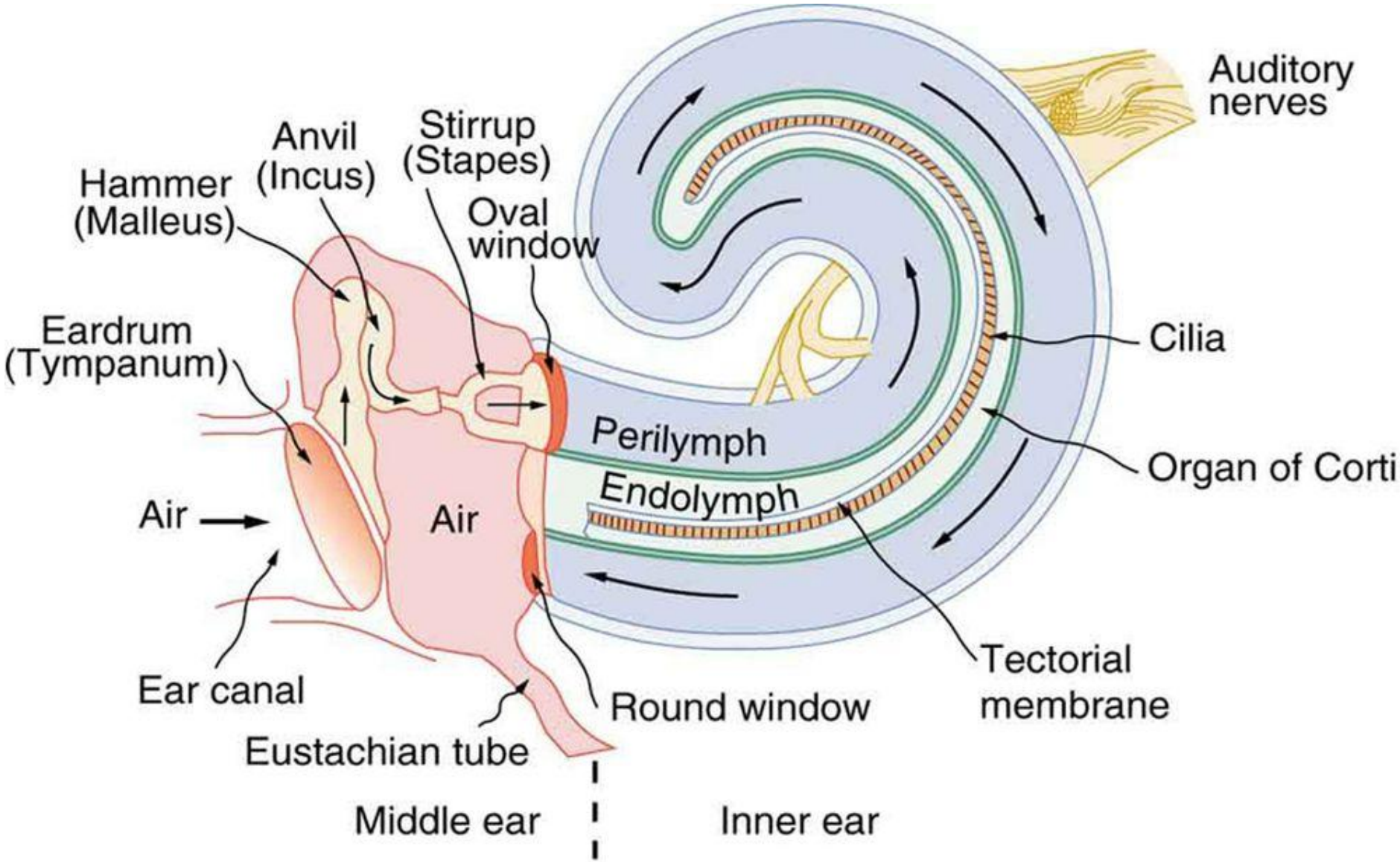
Cochlear potential



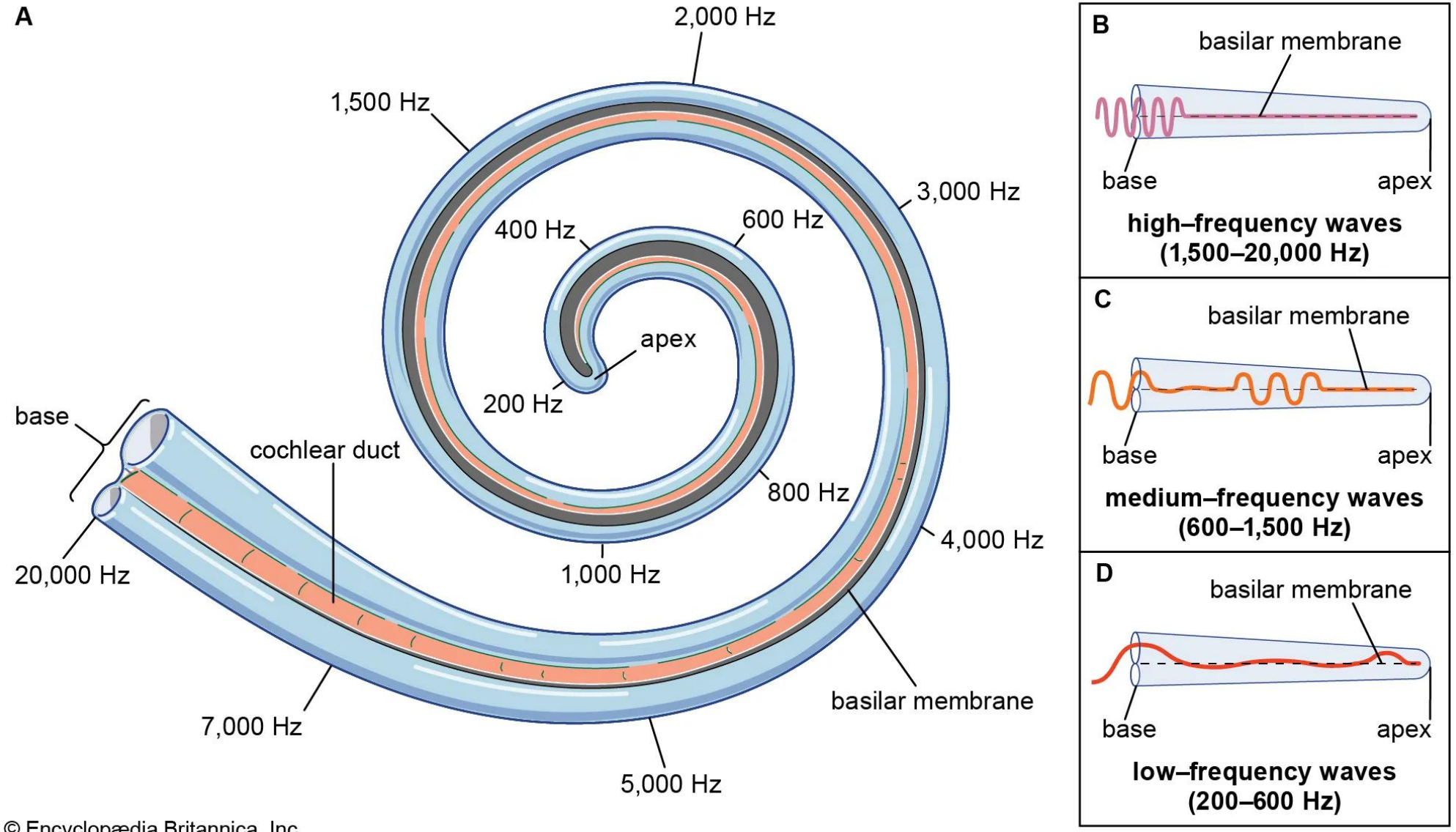
Potassium flow– a way to depolarize and repolarize without ATP expenditure

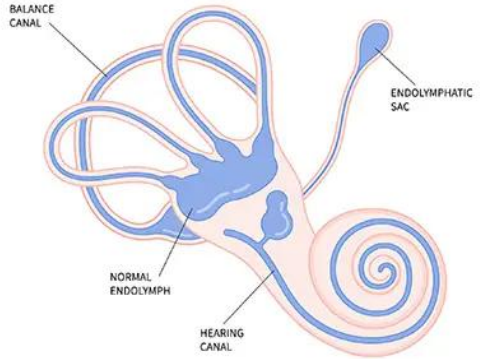
Potassium flows into the cell passively (**ENDOLYMPH** – high concentration of K+), causing depolarization and then exits the cell according to a gradient in the basal portion that is immersed in the **PERILYMPH** (low concentration of K+)



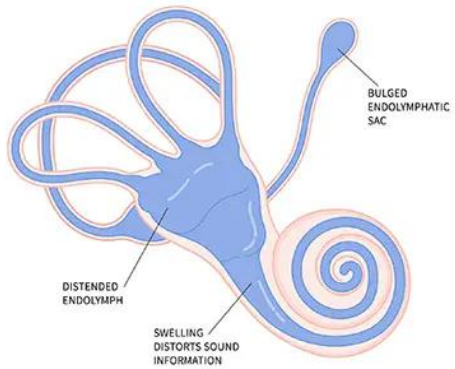


https://socratic.org/questions/what-part-of-the-ear-contains-the-sensory-receptors-for-hearing





HEALTHY INNER EAR

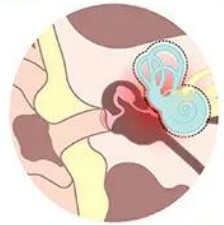


MENIERE'S DISEASE

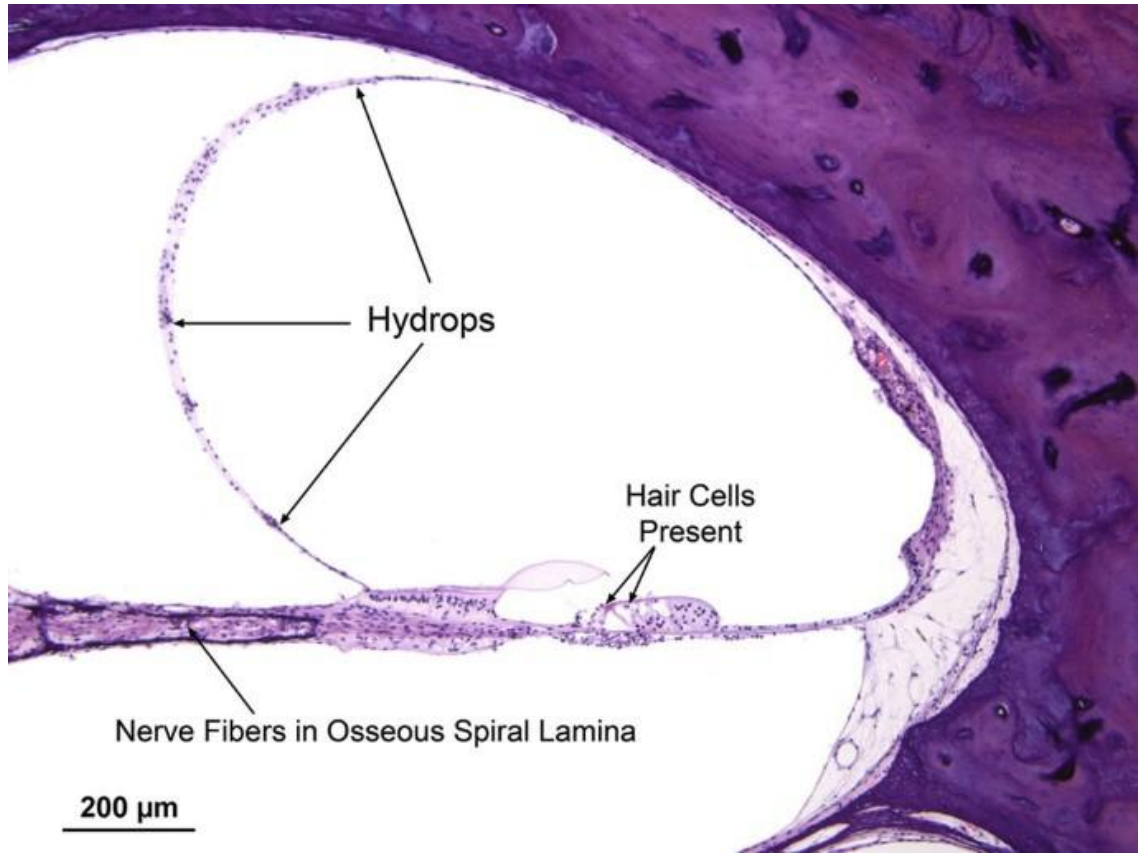
MENIERE'S DISEASE

HEARING LOSS

TINNITUS



AURAL FULLNESS

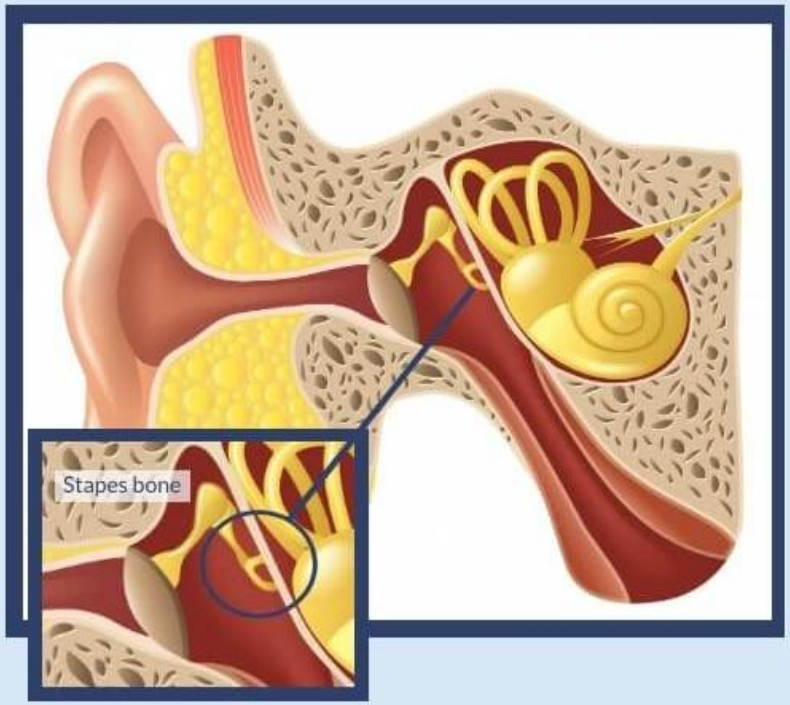


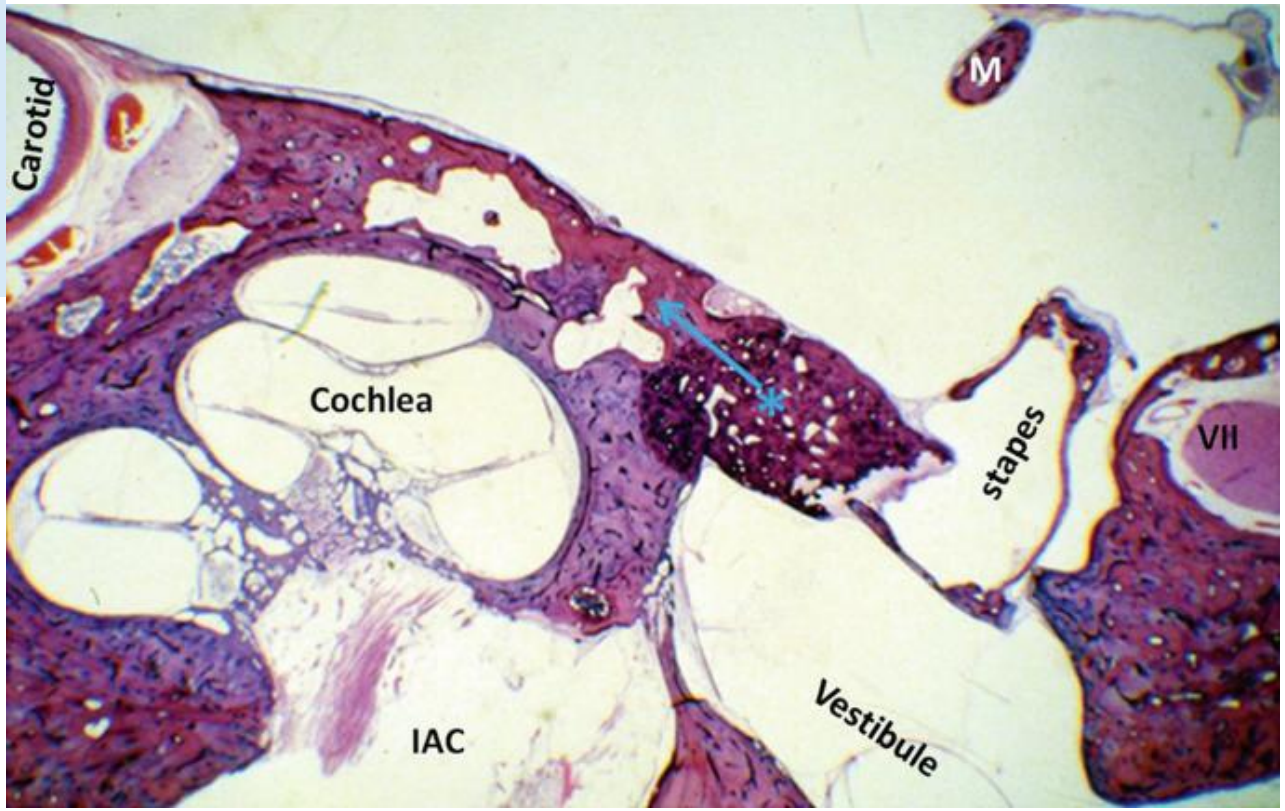
What is otosclerosis?

Otosclerosis is a condition that affects the tiny middle ear bone known as the stapes.

The stapes can become stuck, limiting its ability to vibrate.

These vibrations are crucial for hearing.





Cochlear implant