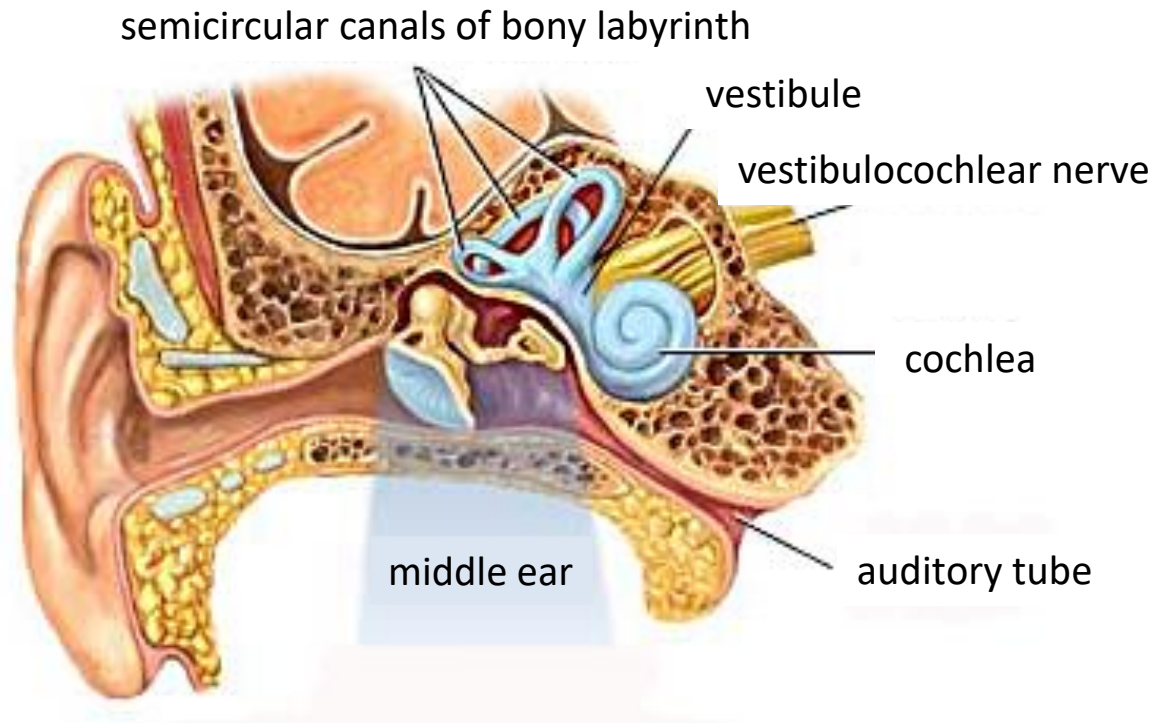


# The bony and the membranous labyrinth



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**Semmelweis University,**  
Department of Anatomy, Histology and Embryology

# The inner ear



## Location:

In the petrous part of the temporal bone.

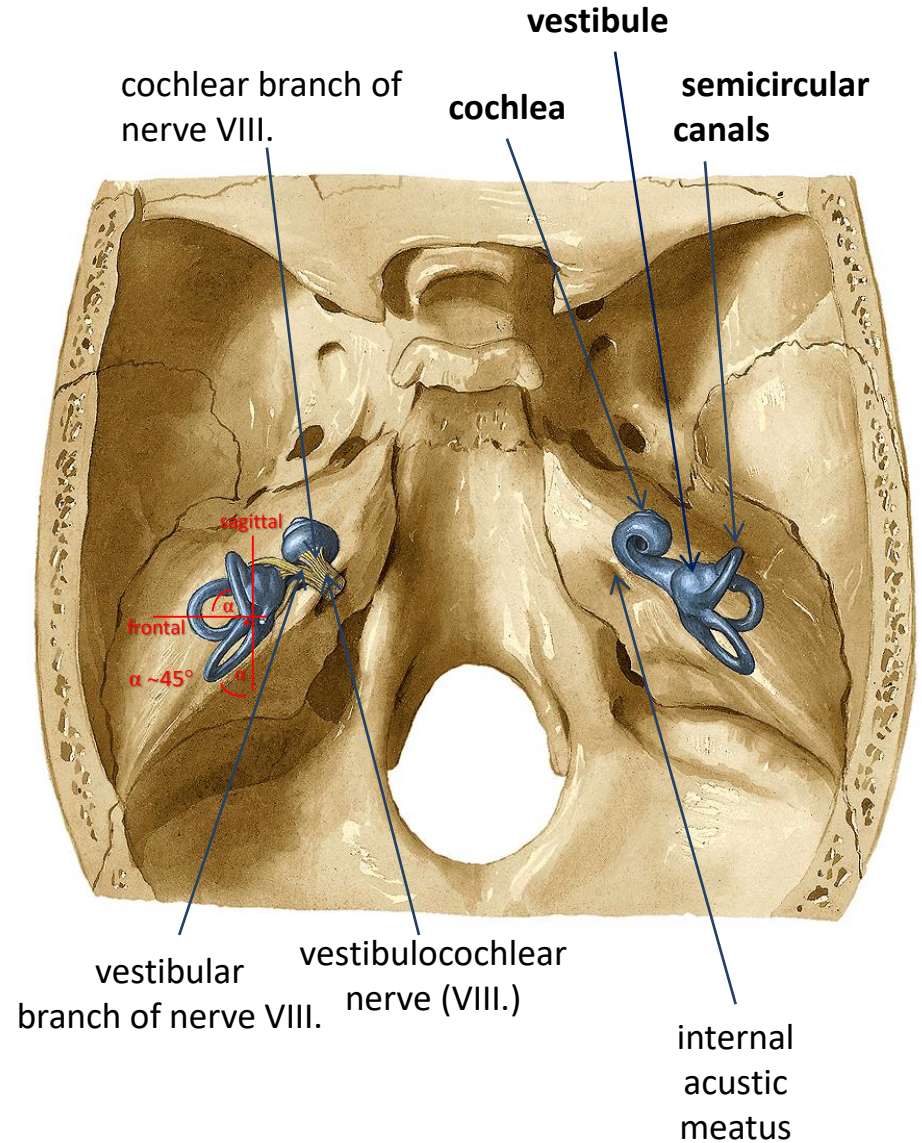
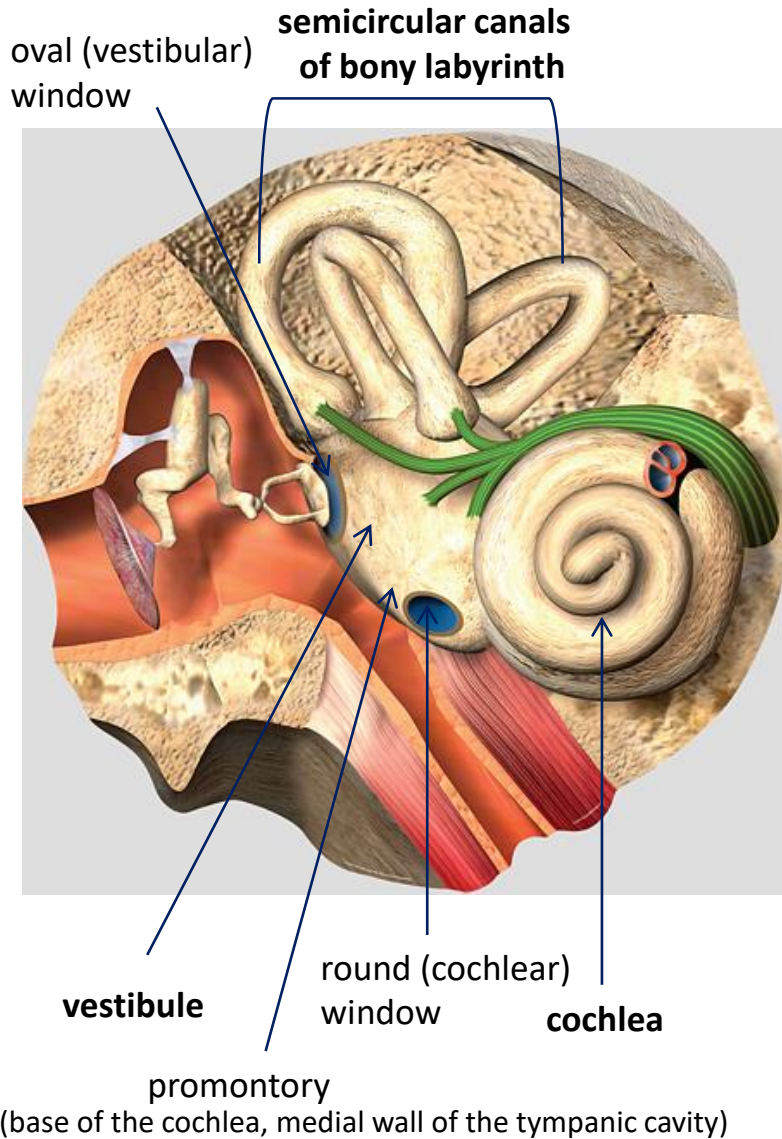
## Parts:

- bony labyrinth
- membranous labyrinth
- ganglia and final branches of the vestibulocochlear nerve (VIII.)

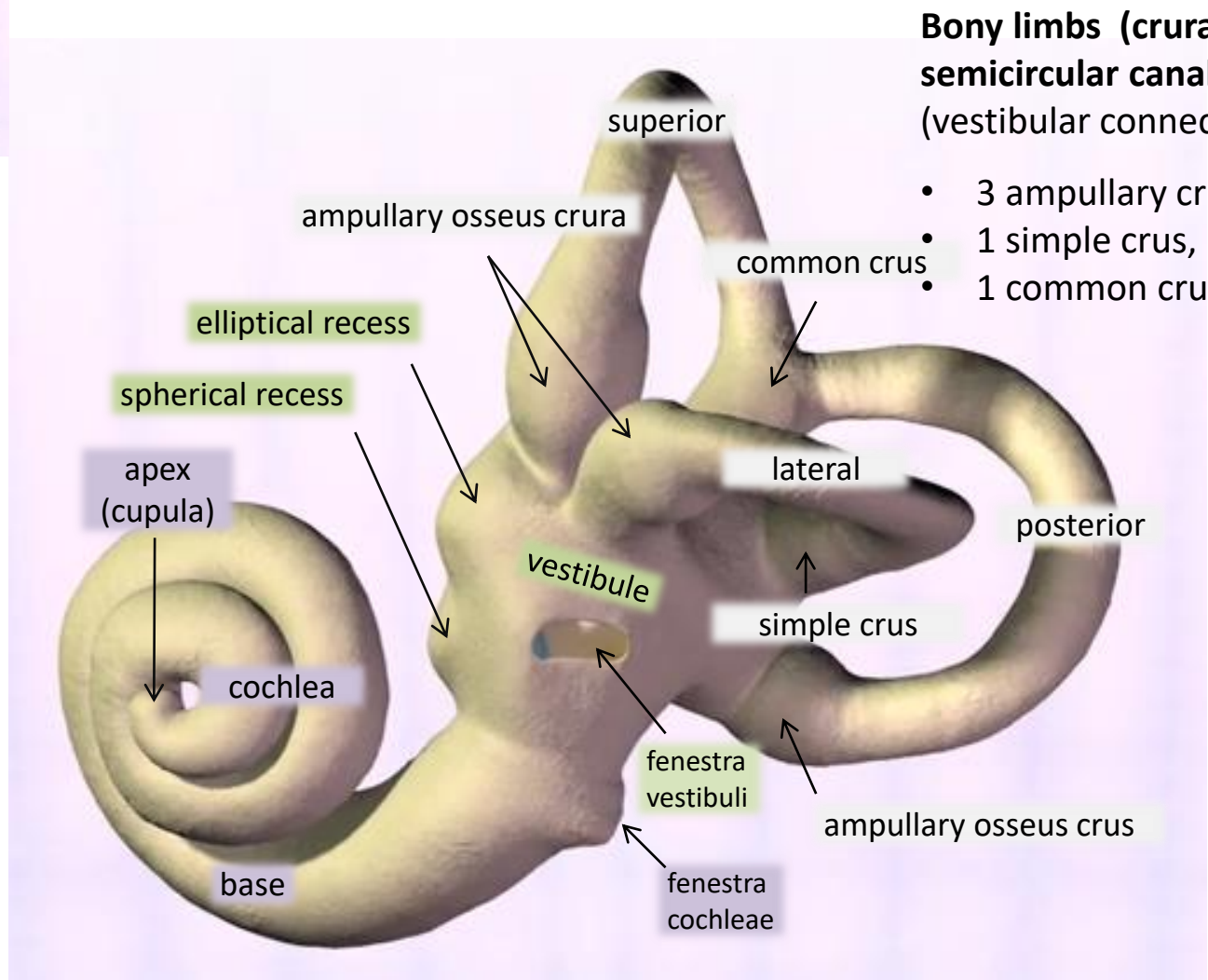
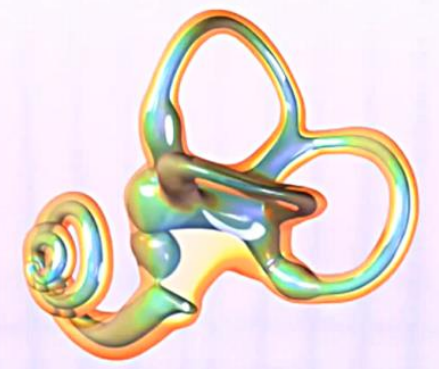
## Functions:

- hearing (cochlea, spiral organ of Corti)
- balance
- spacial orientation

# The bony (osseous) labyrinth



# Left osseous labyrinth, lateral view



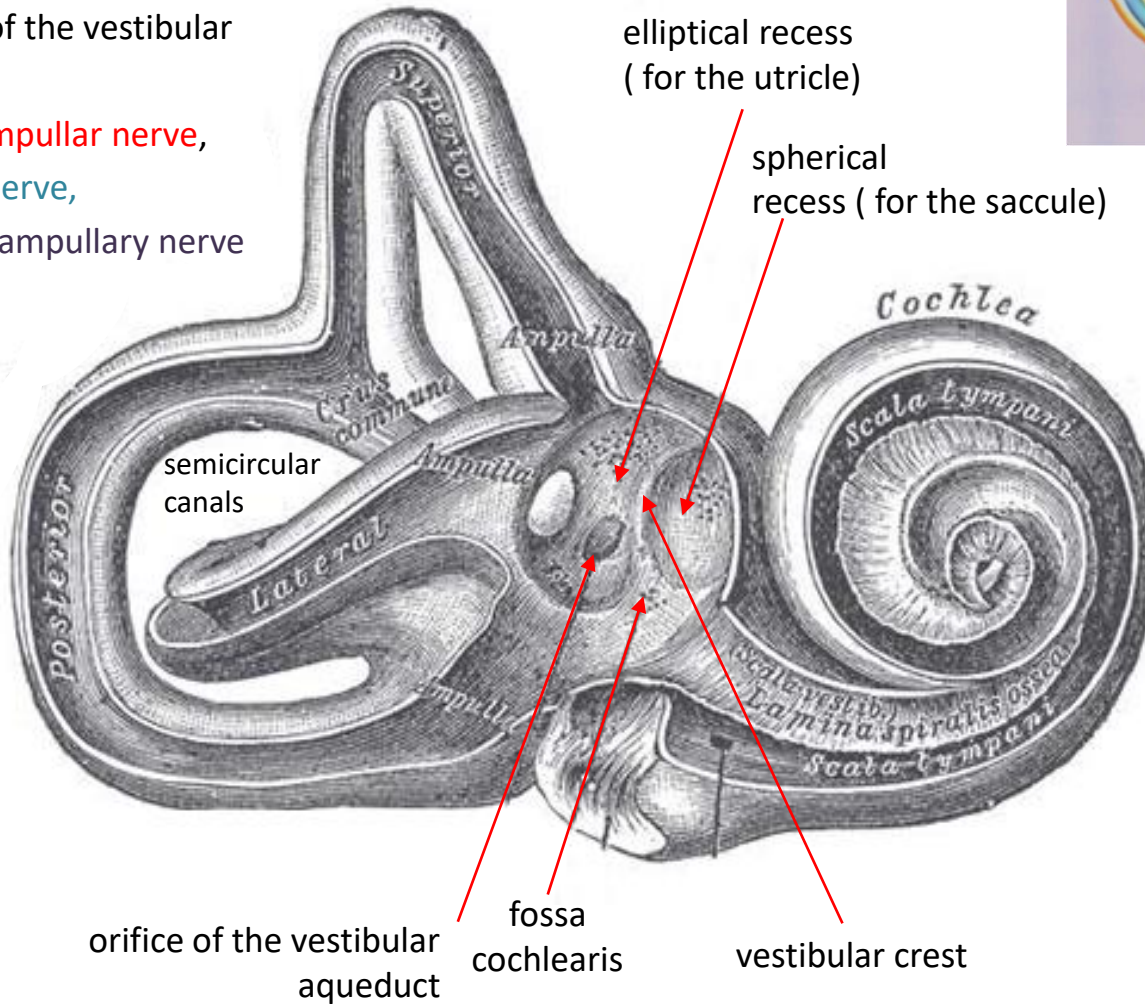
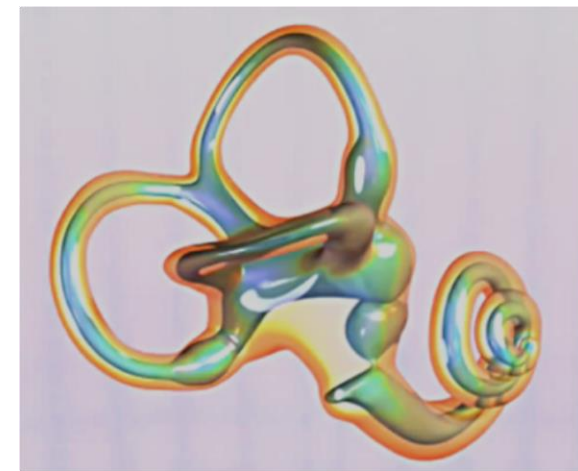
**Bony limbs (crura) of semicircular canals (5):**  
(vestibular connections)

- 3 ampullary crura
- 1 simple crus,
- 1 common crus

# Interior of the vestibule

## Maculae cribrosae:

- superior, media, inferior,
  - perforated areas for entering the branches of the vestibular nerve:
1. utriculoampullar nerve,
  2. saccular nerve,
  3. posterior ampullary nerve



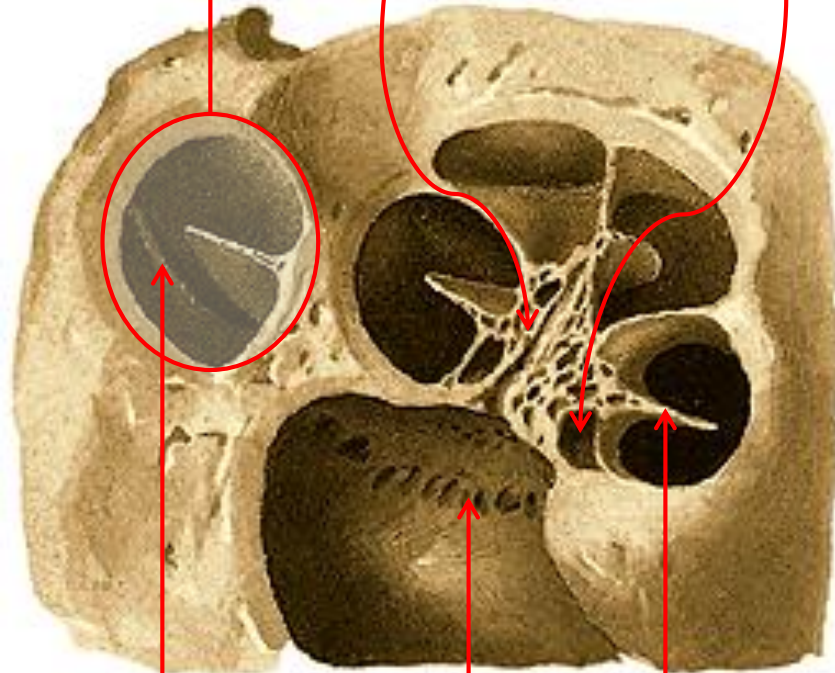
Interior of the right osseous labyrinth

# The cochlea I.

m: modiolus:

- longitudinal canals of modiolus, one bigger and several smaller channels, vessels, cochlear n.
- spiral canal of the modiolus; spiral ganglion

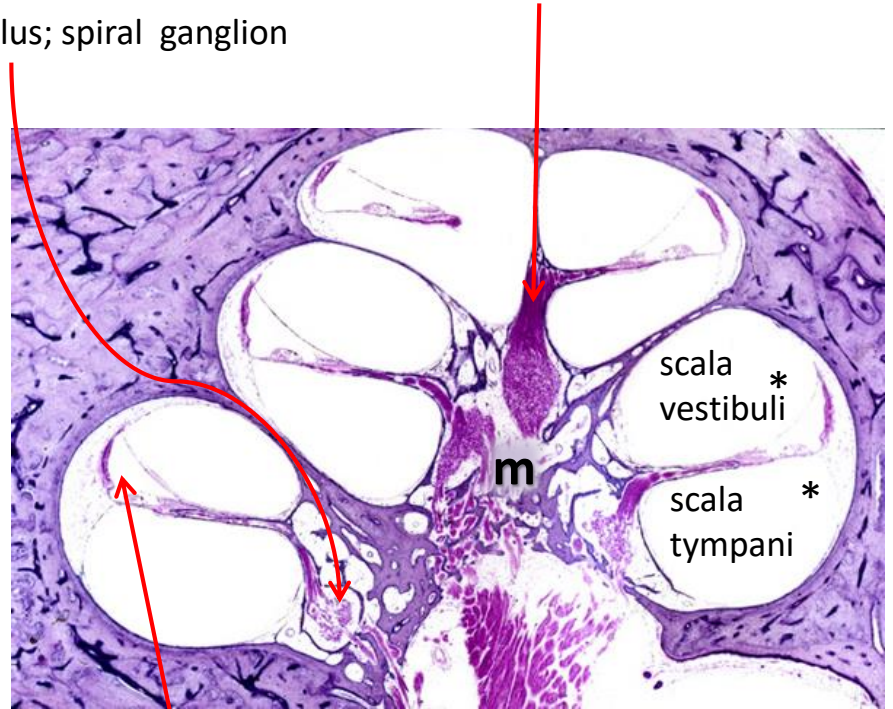
spiral canal of cochlea



secondary spiral lamina  
(at the lower part only)

osseous spiral lamina

spiral foraminous tract- filaments of the cochlear nerve exit  
(fundus of the internal acoustic meatus)



scala \*  
vestibuli

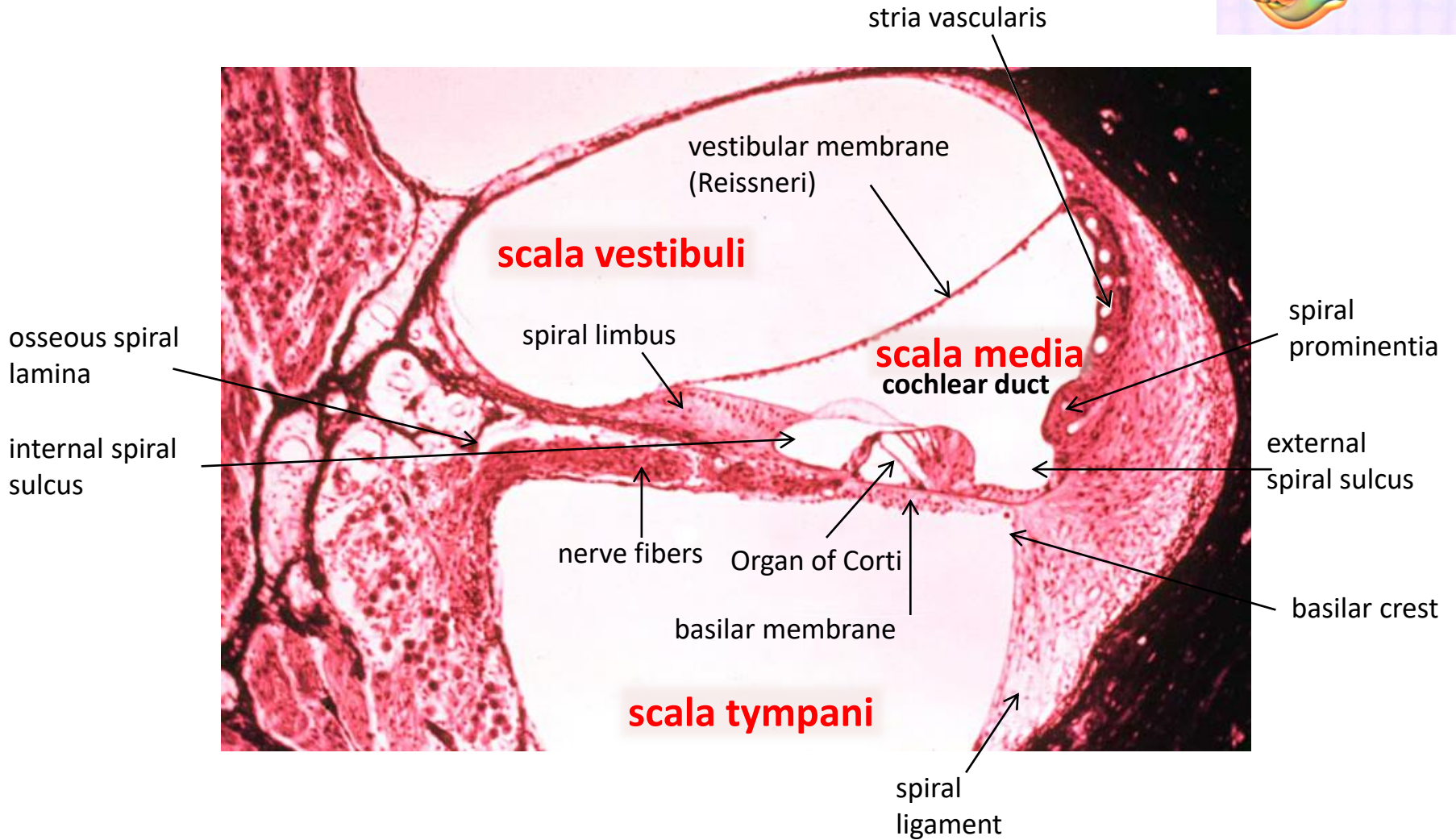
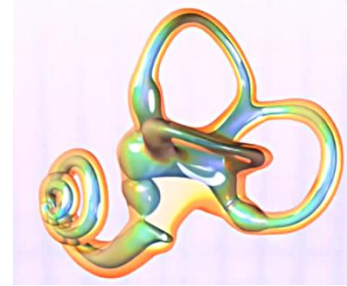
scala \*  
tympani

m

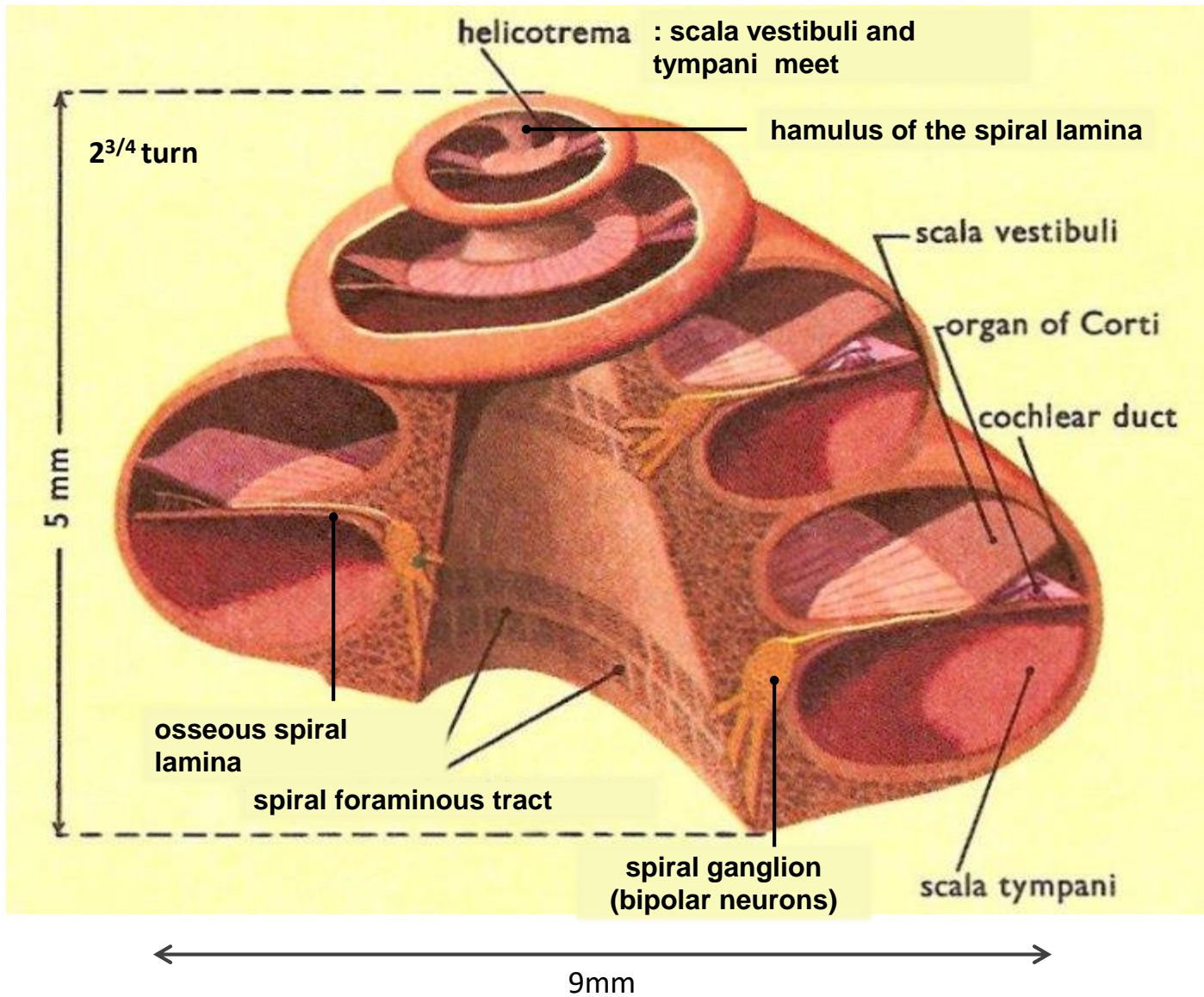
\*: perilymph

cochlear duct  
(endolymph)

# The spiral canal

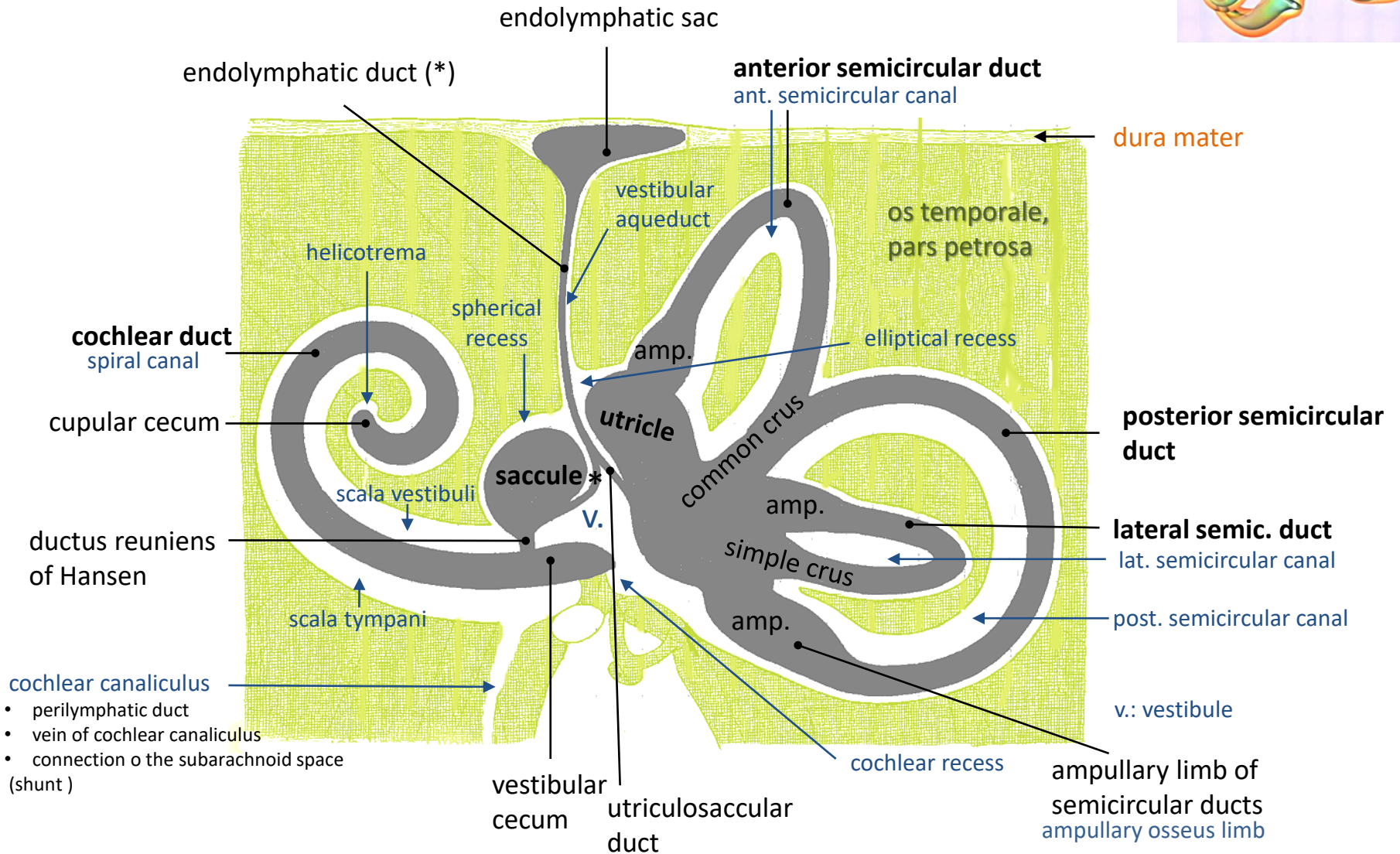
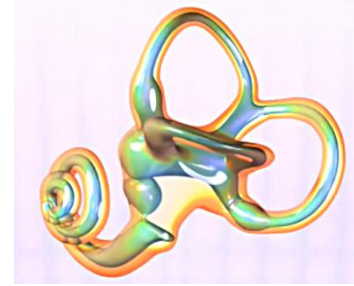


# The cochlea II.





# The membranous labyrinth



Membranous Labyrinth

S

A

P

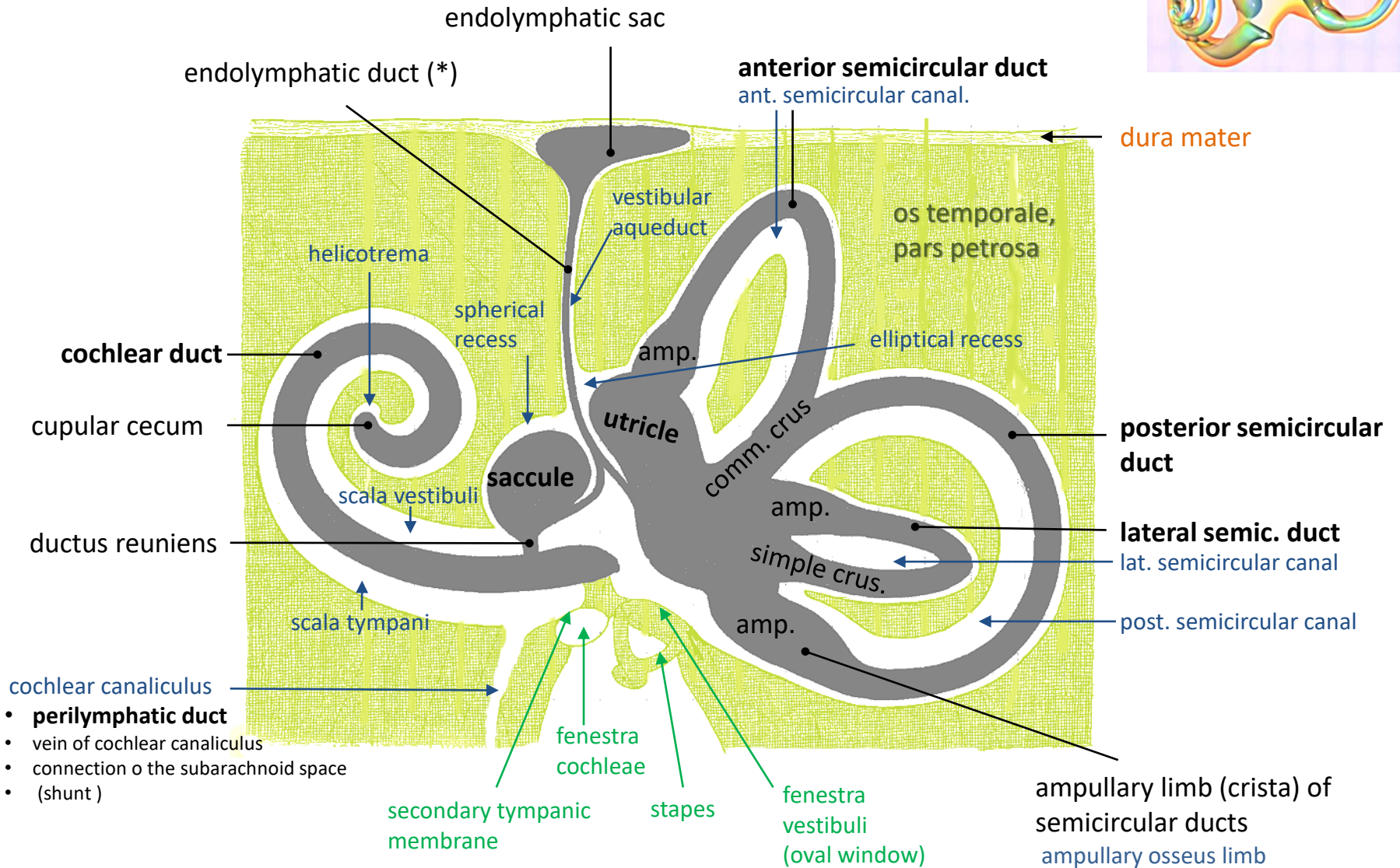
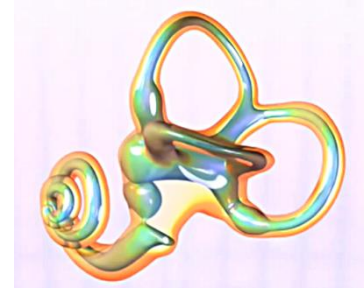
External Aperture of Vestibular Aqueduct

Extraosseous Part of Endolymphatic Sac

Sigmoid Sinus

BANIEKS<sup>®</sup>  
M.D.

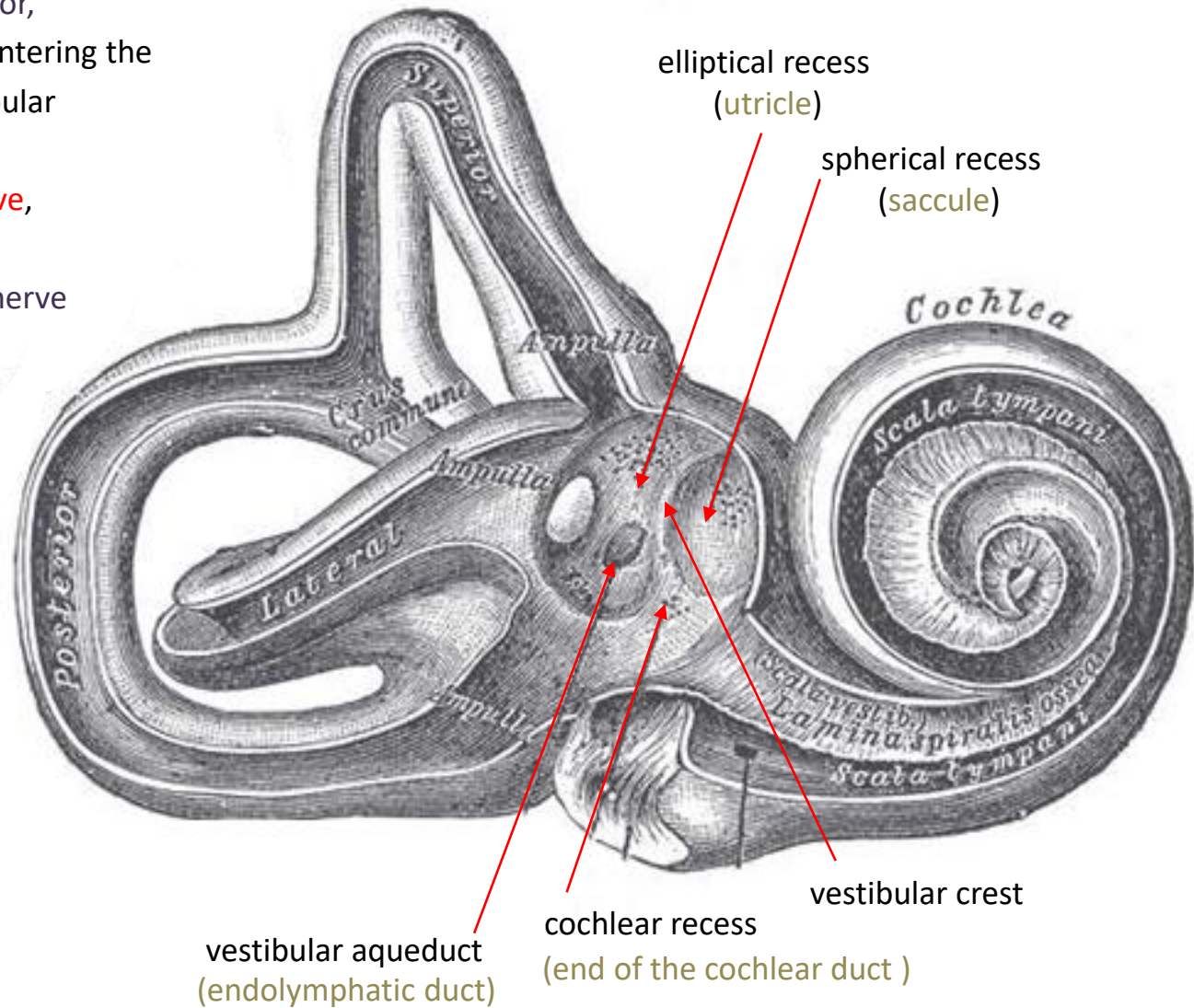
# The membranous labyrinth



# Interior of the vestibule

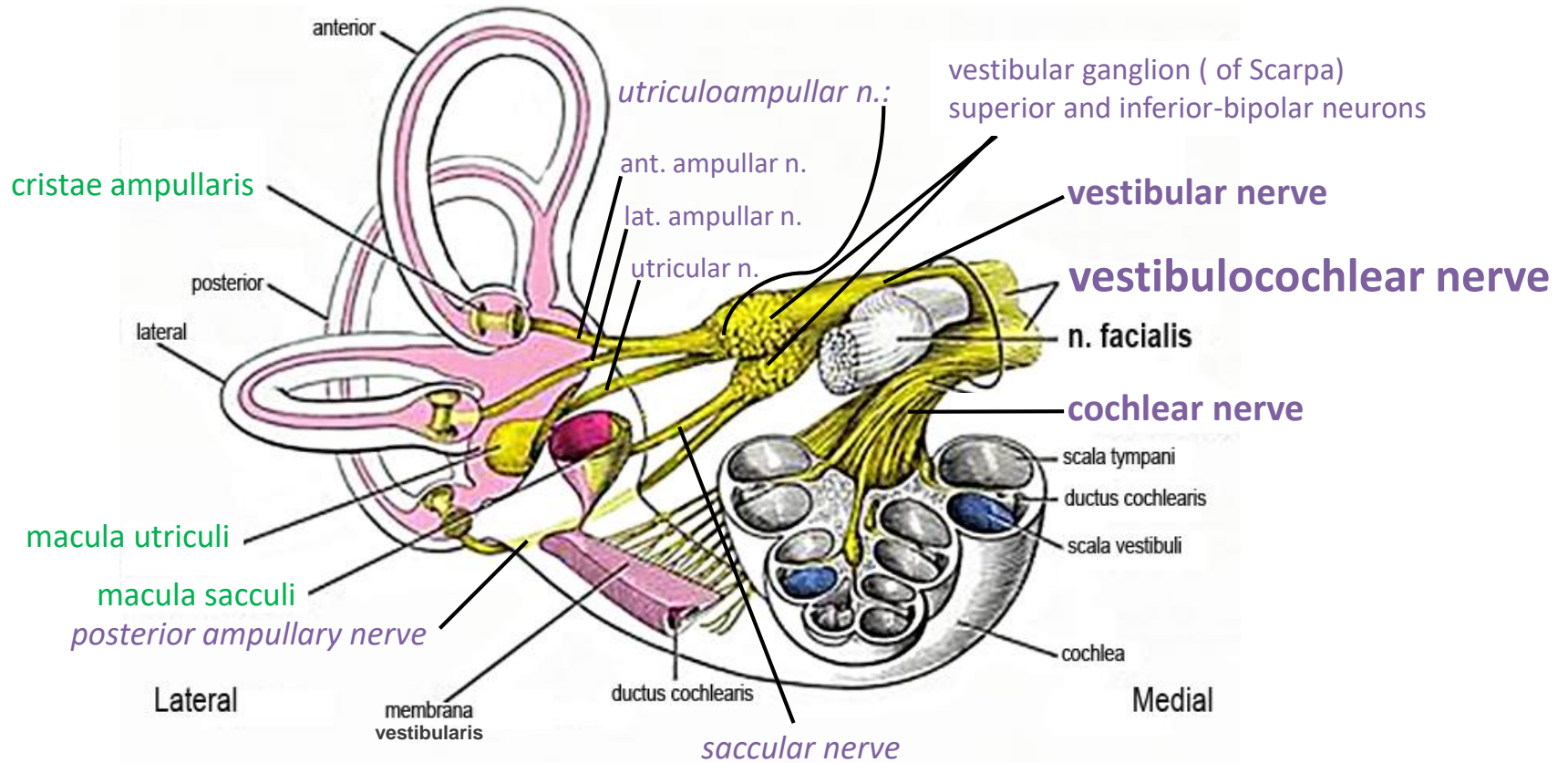
## Maculae cribrosae:

- superior, media, inferior,
  - perforated areas for entering the branches of the vestibular nerve:
1. utriculoampullar nerve,
  2. saccular nerve,
  3. posterior ampullary nerve



Interior of the right osseous labyrinth

# The membranous labyrinth-sensory epithelia, nerves, blood supply



## Blood supply:

basilar artery

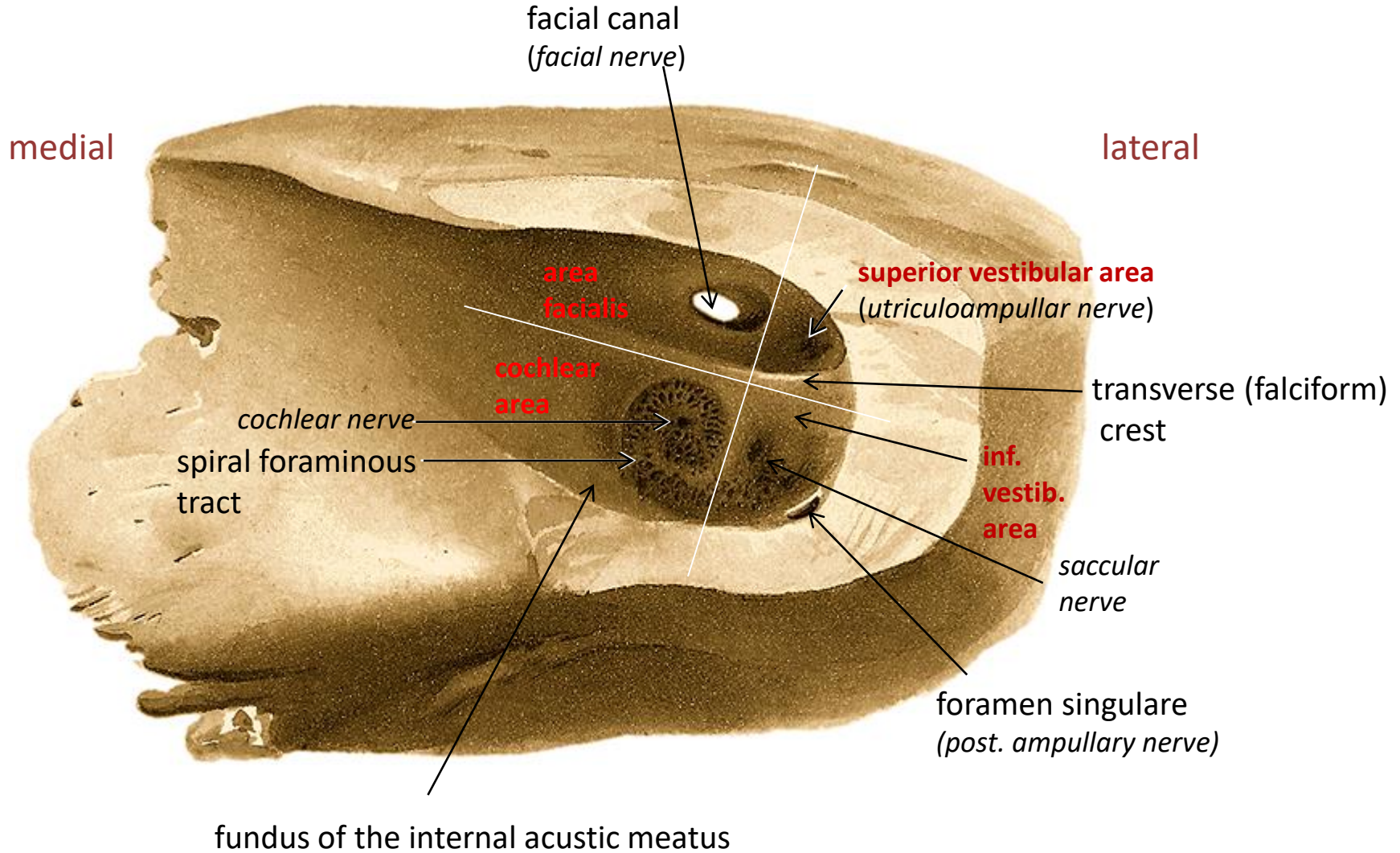
→ labyrinthine arteries

→ common cochlear artery

→ anterior vestibular artery

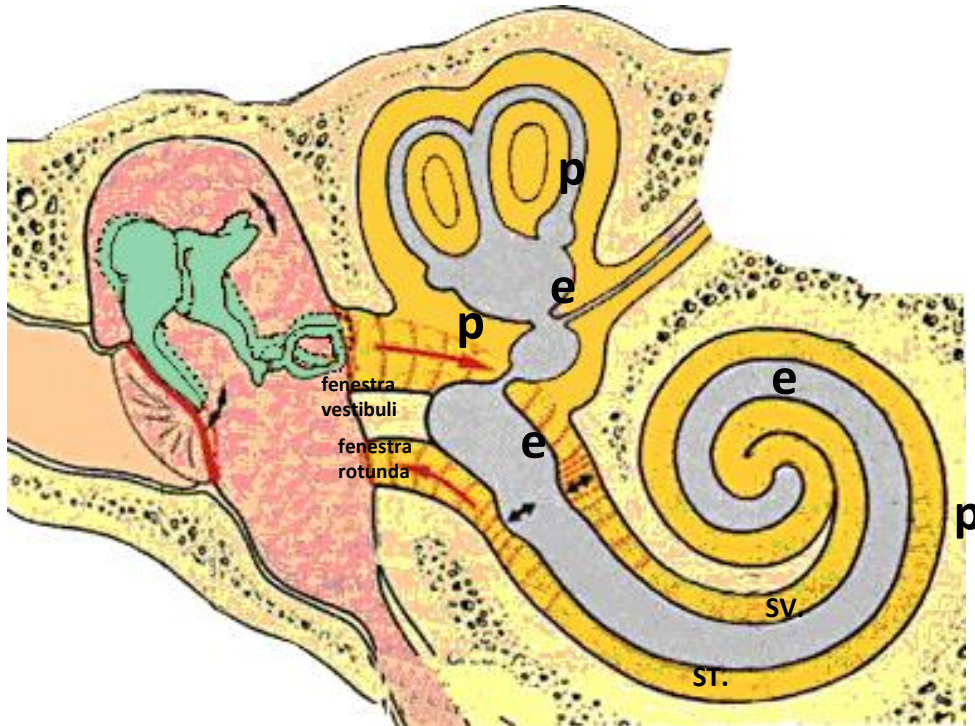
labyrinthine veins, v. of aqueduct of vestibule, v. of aqueduct of cochlea → inf. petrosal sinus → sigmoid sinus

# The internal acoustic meatus



The right internal acoustic meatus and its fundus, medial view. The posterior wall has been partially removed.

# The endo- and perilymph



## Perilymph:

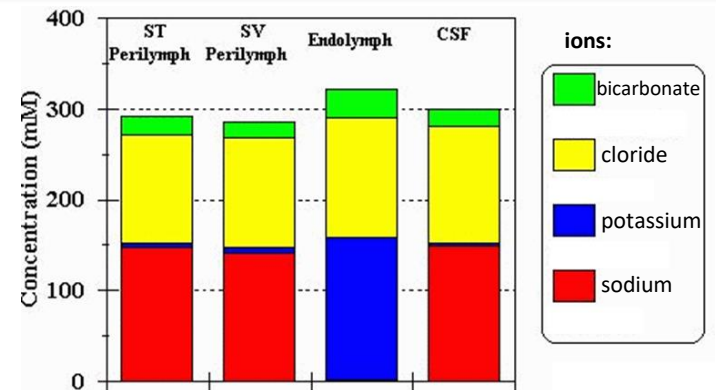
- fills the bony labyrinth protecting the membranous one
- is produced by the microvasculature of the periosteum
- is drained by the perilymphatic duct into the subarachnoidal space
- similar to the extracellular fluid or the CSF

## Endolymph:

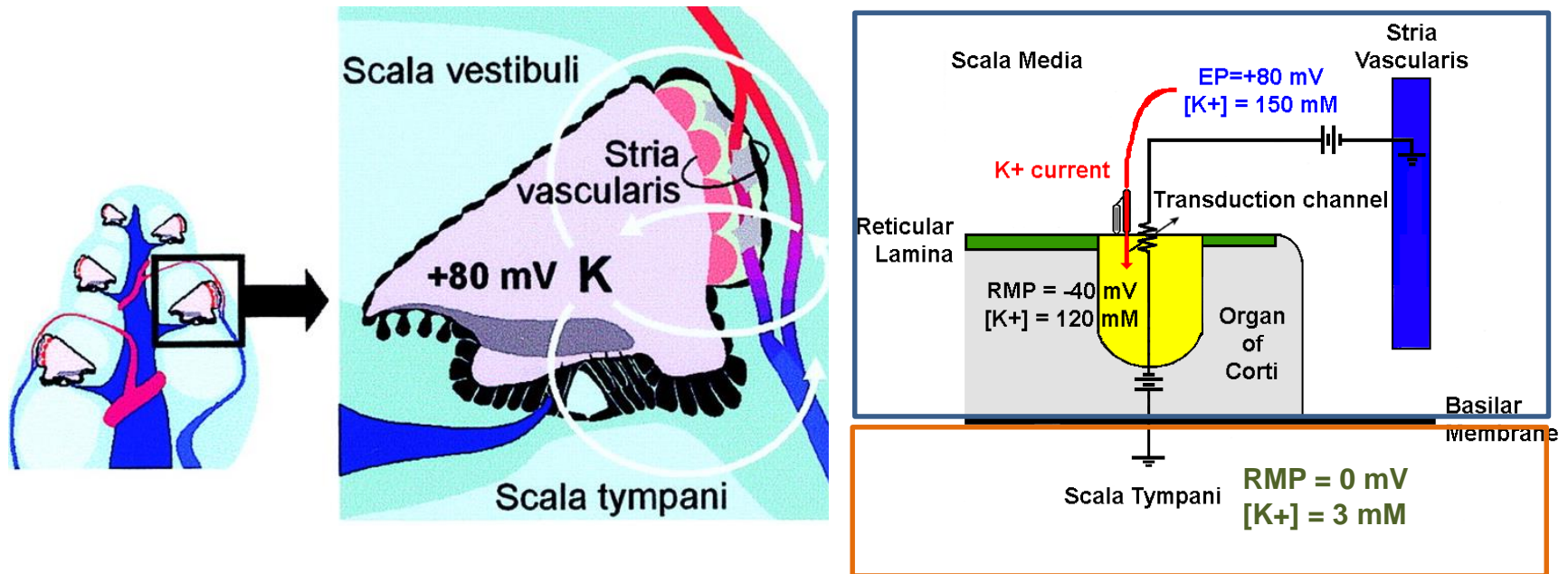
- fills the membranous labyrinth,
- is produced by the stria vascularis (cochlea) and by the dark cells in semicircular duct
- is drained by the endolymphatic duct into the dura mater venous sinuses
- similar to the intracellular fluid

## Sound waves in the perilymph, pressure equilibration:

base of the stapes → fenestra vestibuli → scala vestibuli perilymph  
 → cochlear duct and helicotrema → scala tympani perilymph →  
 fenestra rotunda → secondary tympanic membrane



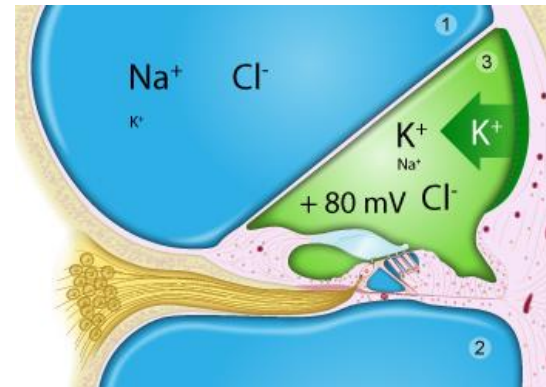
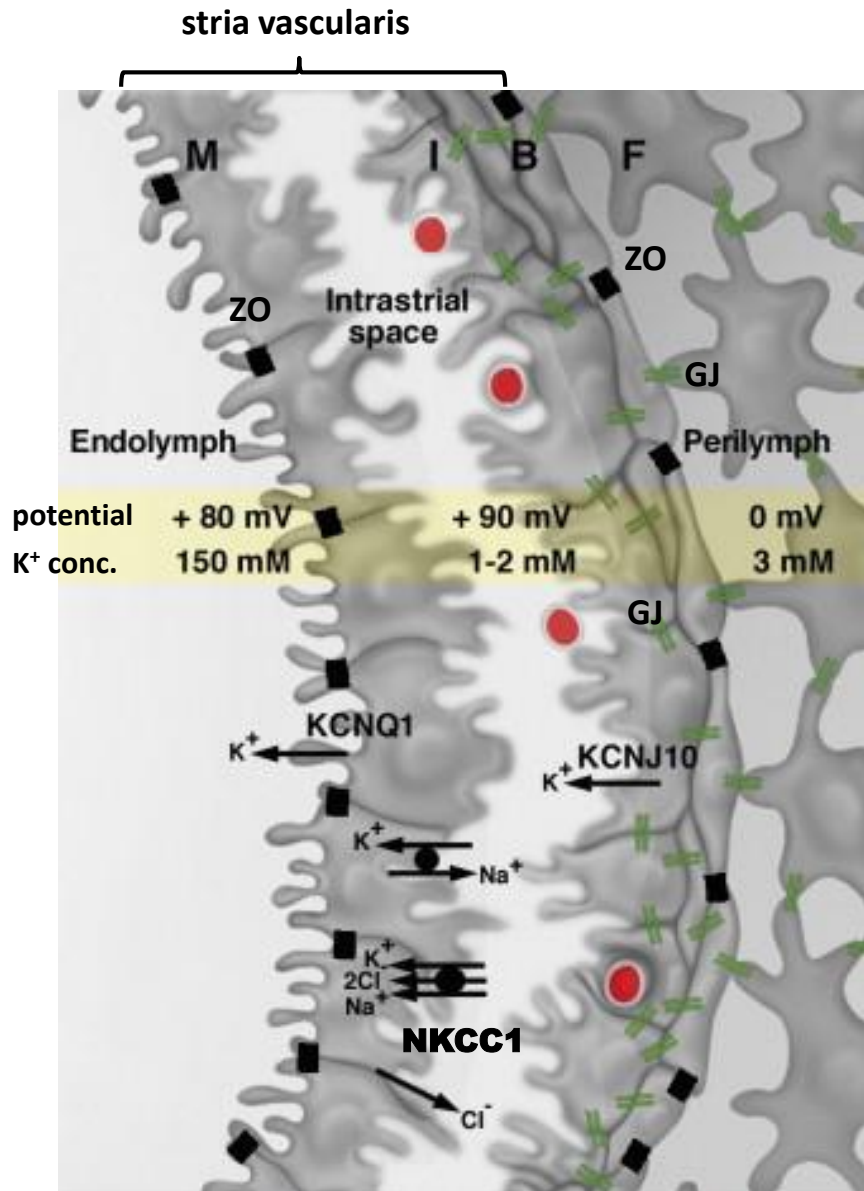
# Special features of the endolymph are necessary for the sensory functions



- endolymph: very high (150mM) K<sup>+</sup> and low (1mM) Na<sup>+</sup> content
- **endocochlear potential (EP)**: scala media is +80mV relative to scala tympani
- EP is generated by the stria vascularis.
- A strong driving force exists for K<sup>+</sup> to flow into the receptor (hair) cells (120mM K<sup>+</sup>, -40mV) during stimulus - depolarization.
- The large driving force for K<sup>+</sup> entry contributes to extremely low threshold of auditory hair cells.
- A recycling system allows returning of K<sup>+</sup> to the stria vascularis.
- Energy (ATP) saving for hair cells: K<sup>+</sup> enters end exits the cell according to the concentration gradient.

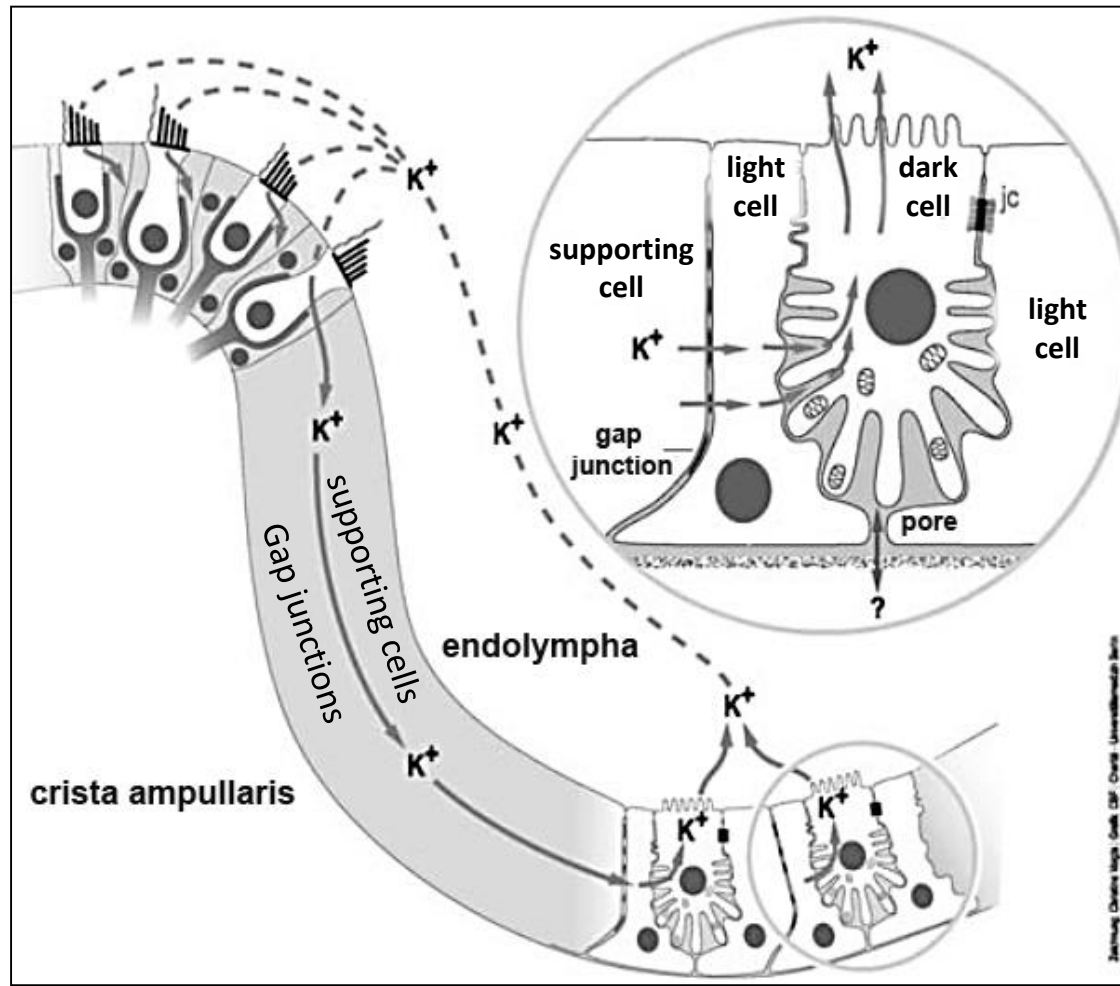


# Stria vascularis - generation of the endocochlear potential



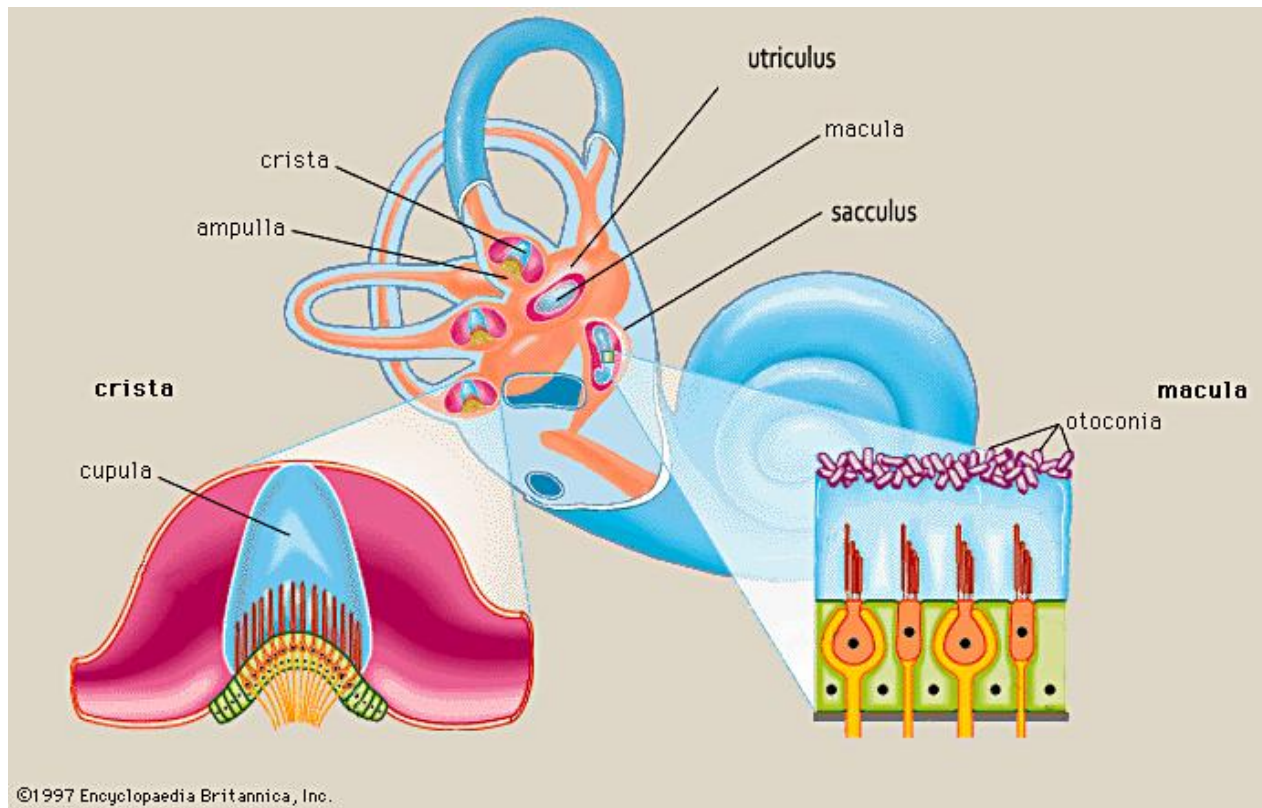
- epithelial barriers between the endo- and perilymph:
  1. basal (B) and intermediate cells
  2. marginal (M) cells
- supported by tight junctions (ZO)
- communication: gap junctions (GJ) between B, I cells and fibroblasts (F) in the spiral ligament
- intrastrial space: an extracellular fluid compartment with a dense capillary network
- endocochlear potential generation: B cells, KCNJ10 potassium channels-mutation: EAST syndrome
- K<sup>+</sup> ion concentration gradient generation: M cells, no further EP generation because of Cl<sup>-</sup> ion co-transport

# Production of the endolymph and $K^+$ ion transport in the semicircular ducts



There is no potential, only concentration gradient.

# The vestibular system



## 1. Cristae ampullares :

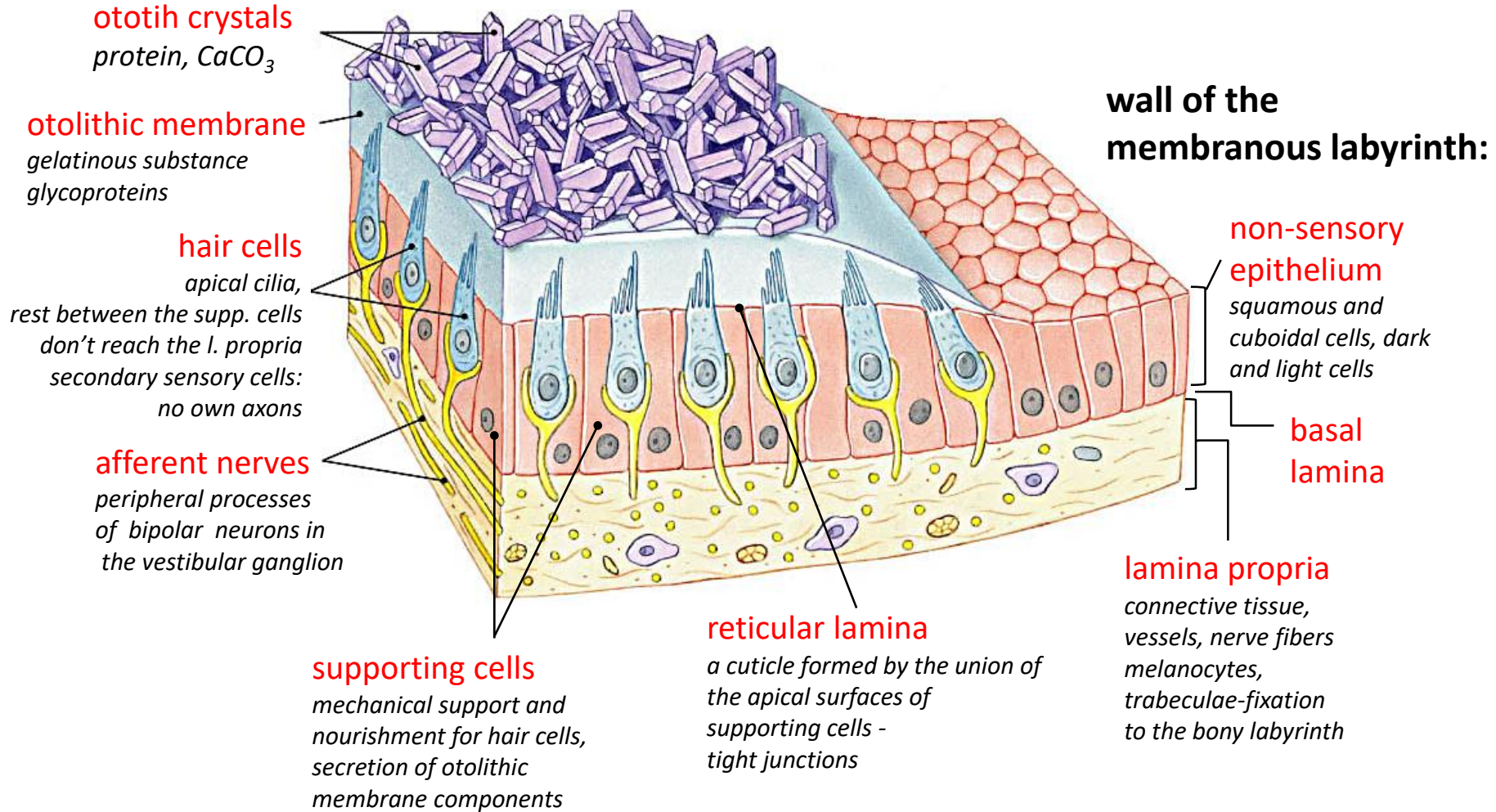
- in the ampullae of semicircular ducts
- the ridge of the crista is always perpendicular to the long axis of the duct
- *detect angular acceleration of the head.*

## 2. Maculae staticae:

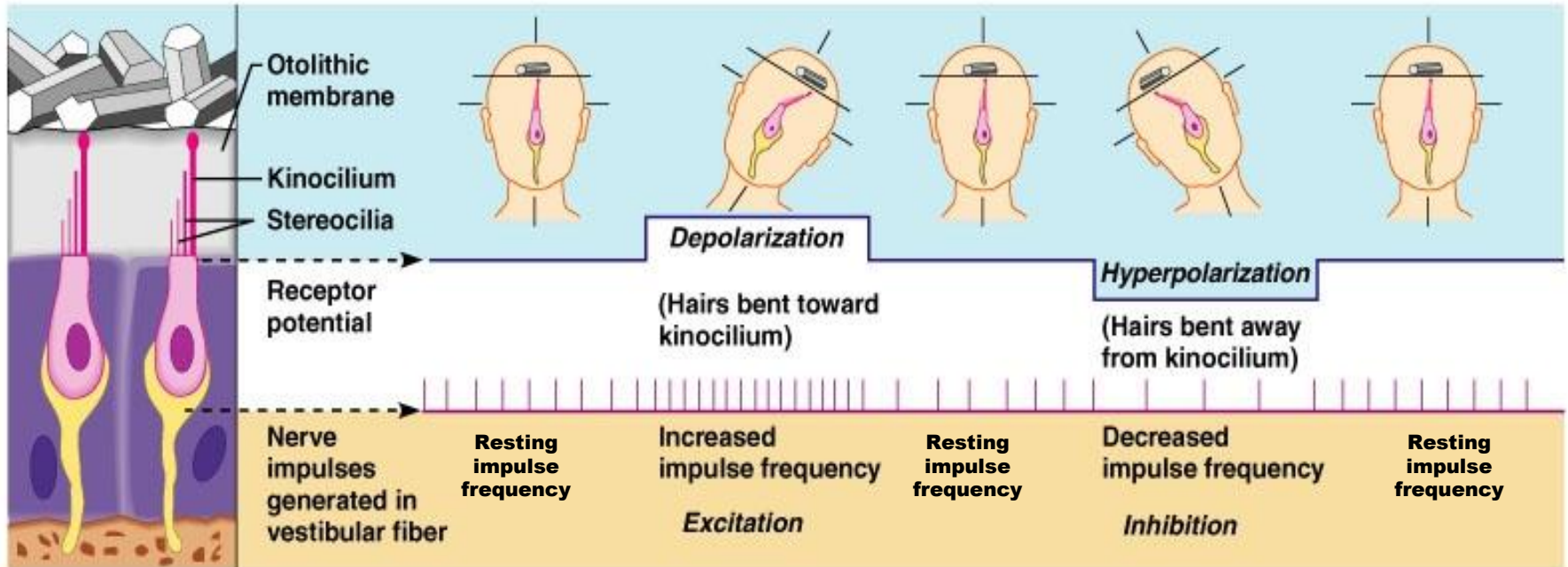
- in the utricle and saccule
- they lie in a perpendicular plane to each other
- *detect linear acceleration, tilt of the head and gravity*

# The structure of the macula

## sensory epithelium:



# Pattern of membrane potential and firing of the hair cells



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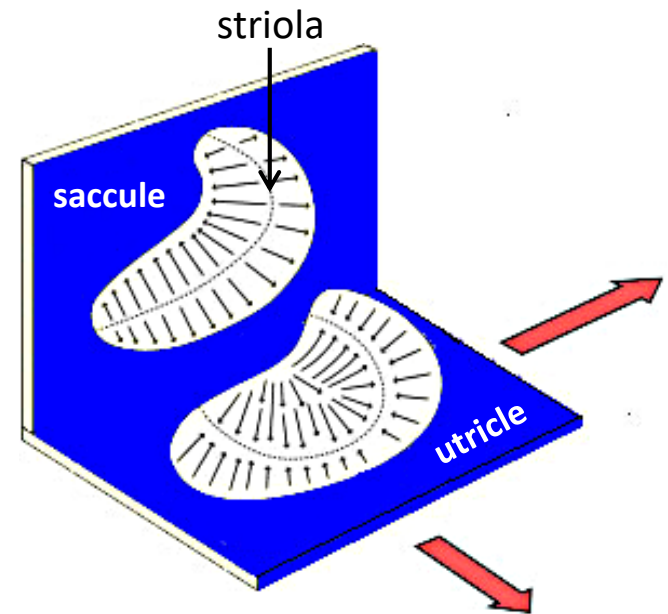
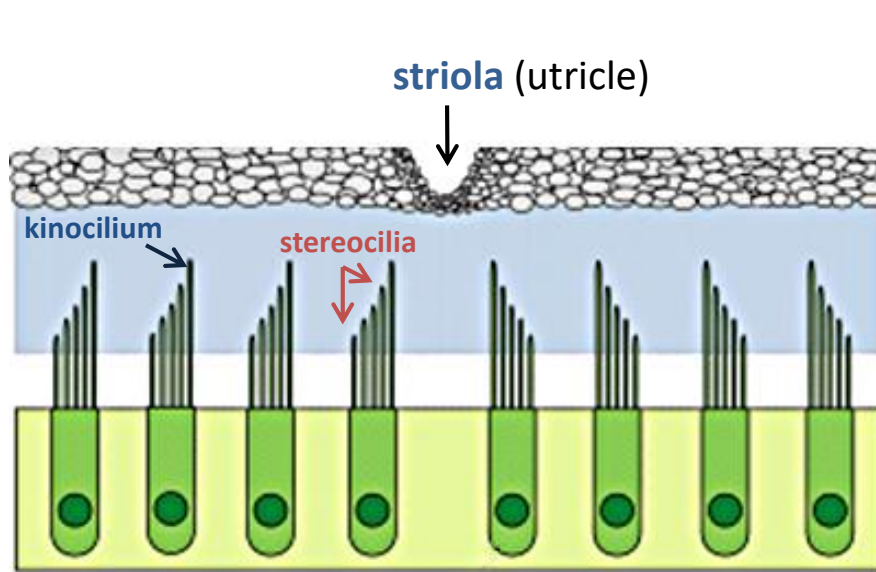
## Stereocilia:

- 30-300pcs/ hair cell,
- large microvilli,
- arranged by size,
- contain actin filaments,
- contain fimbrin -rigidity.

## Kinocilium:

- 1pc/ hair cell
- a real cilium: 9 + 2 array of microtubules
- taller than the stereocilia

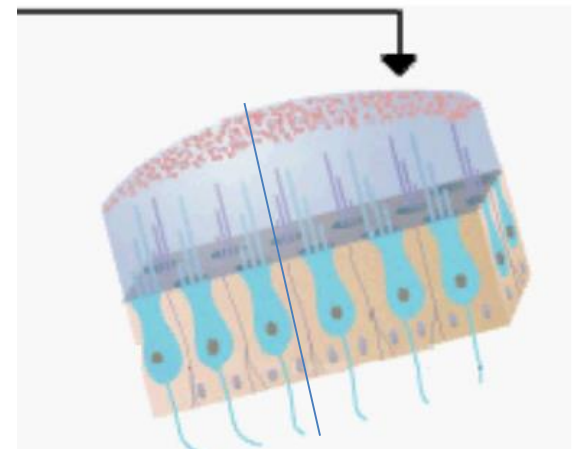
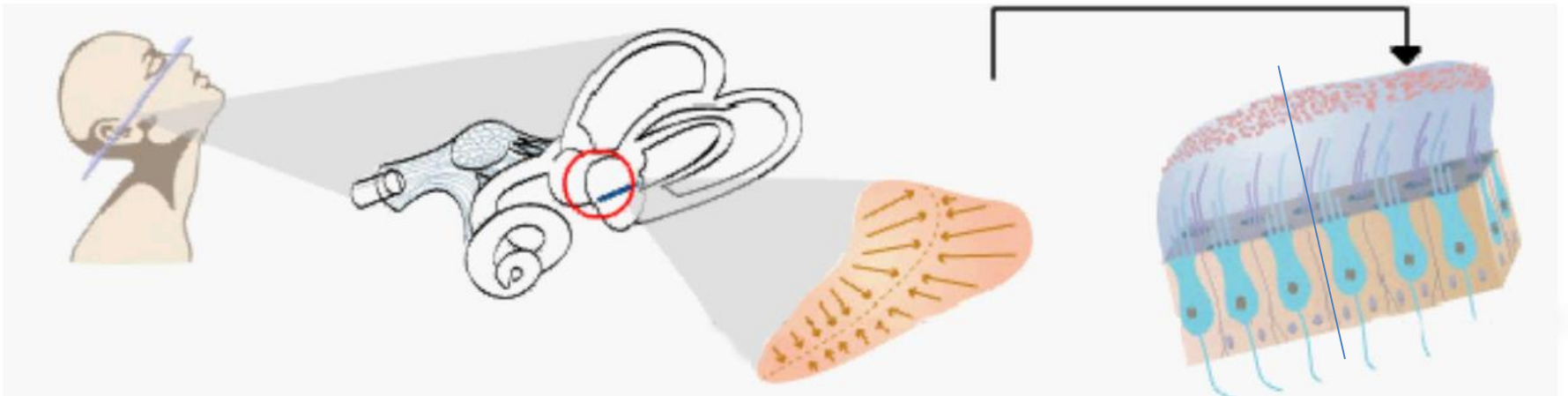
# Orientation of cilia - a key of sensitivity to multiple directions



## Orientation of kinocilia:

- kinocilia are oriented in opposite direction on each side of the striola
- utricle - kinocilia are facing the striola
- saccule- kinocilia are facing away from the striola
- this arrangement allows sensing linear acceleration in every directions

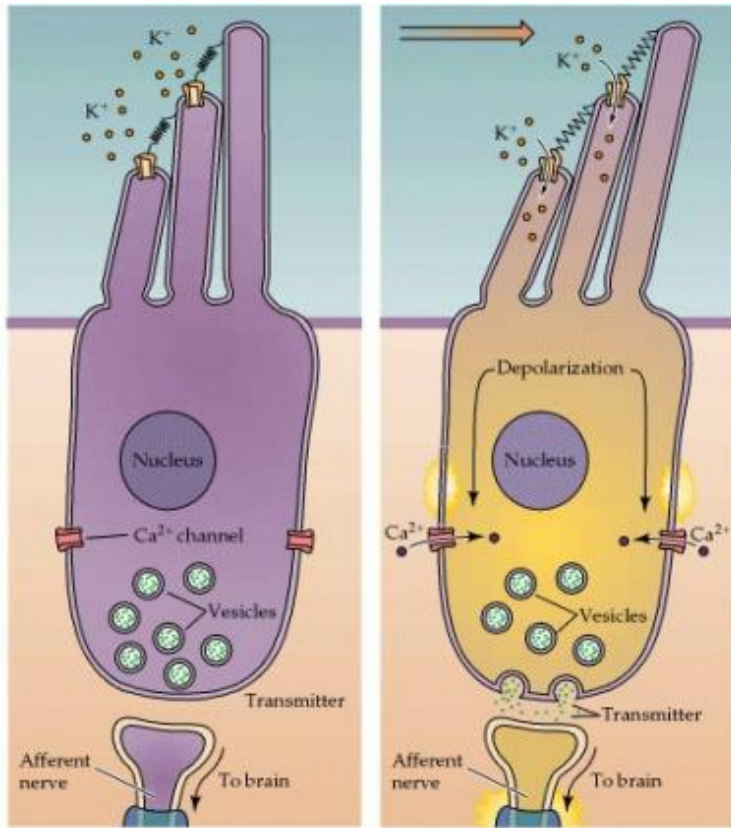
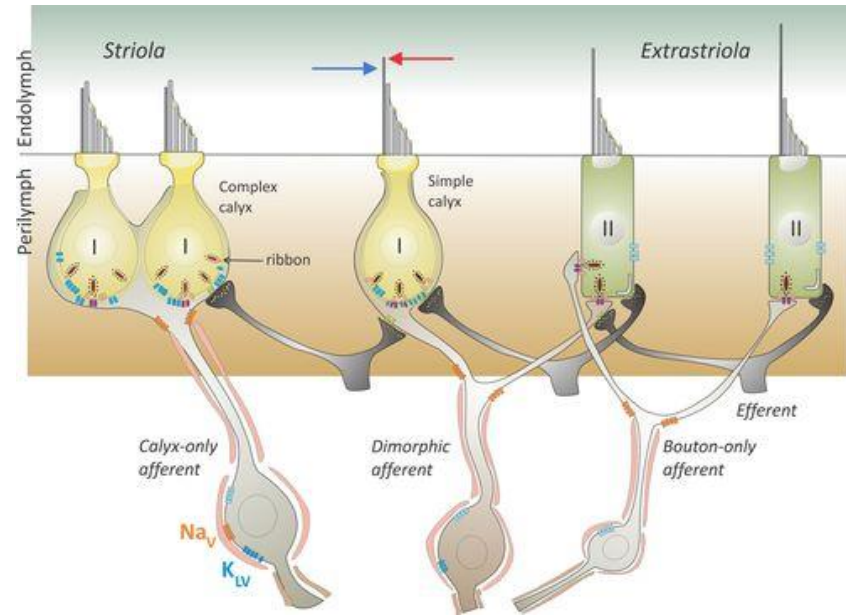
# Utricule



# Signal transmission, types of hair cells

## Hair cell:

- secondary sensory cell
- basal cell nucleus, synaptic vesicles (glutamate)
- ribbon synapses facing the afferents of the vestibular nerve
- efferent fibers; central modulation, modulation of sensitivity



## Type I. hair cell:

- flask shaped,
- striolar,
- calyx endings of afferent nerve,
- 1 afferent / hair cell,
- fast signaling

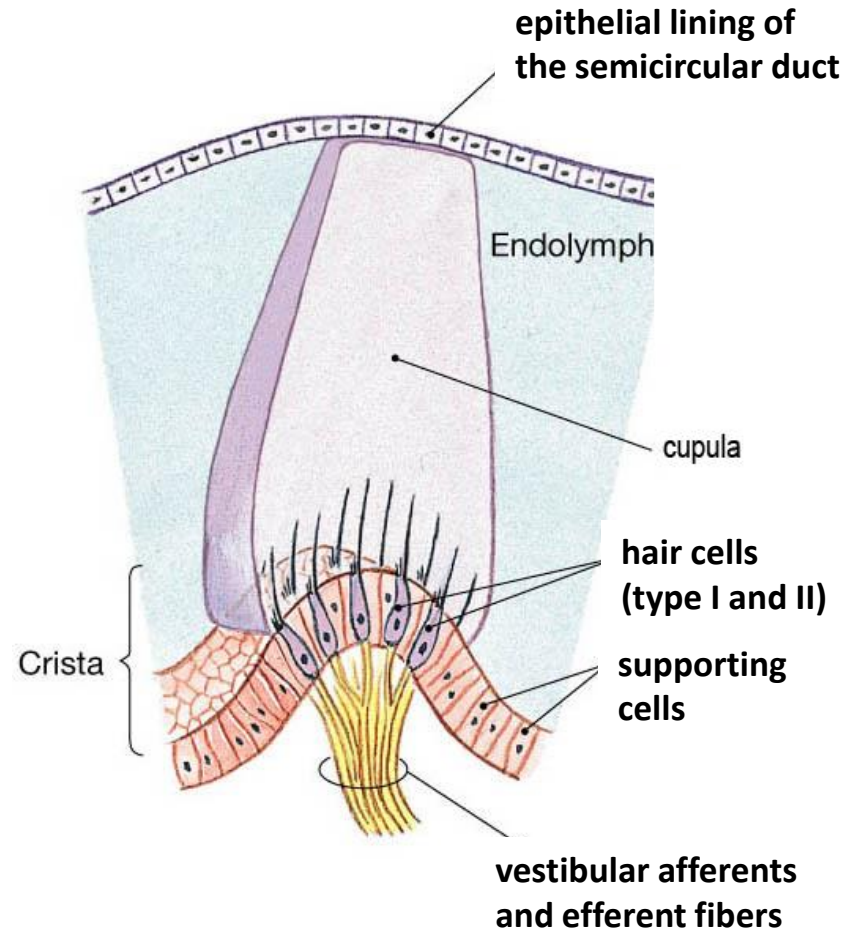
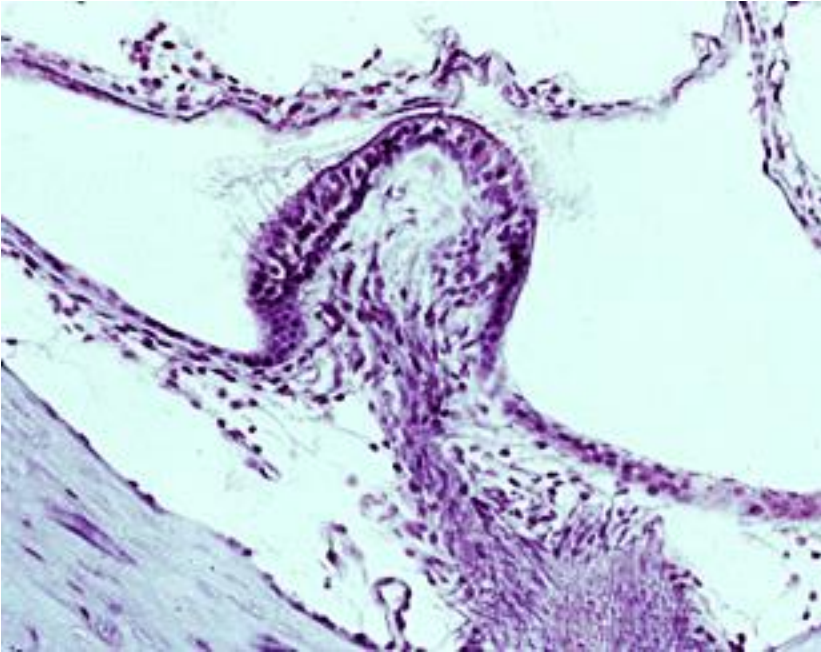
## Type II. hair cell:

- narrow, cylindrical,
- extrastriolar,
- bouton-like synapses,
- more afferent / hair cell,
- slower signaling,
- better signal to noise ratio



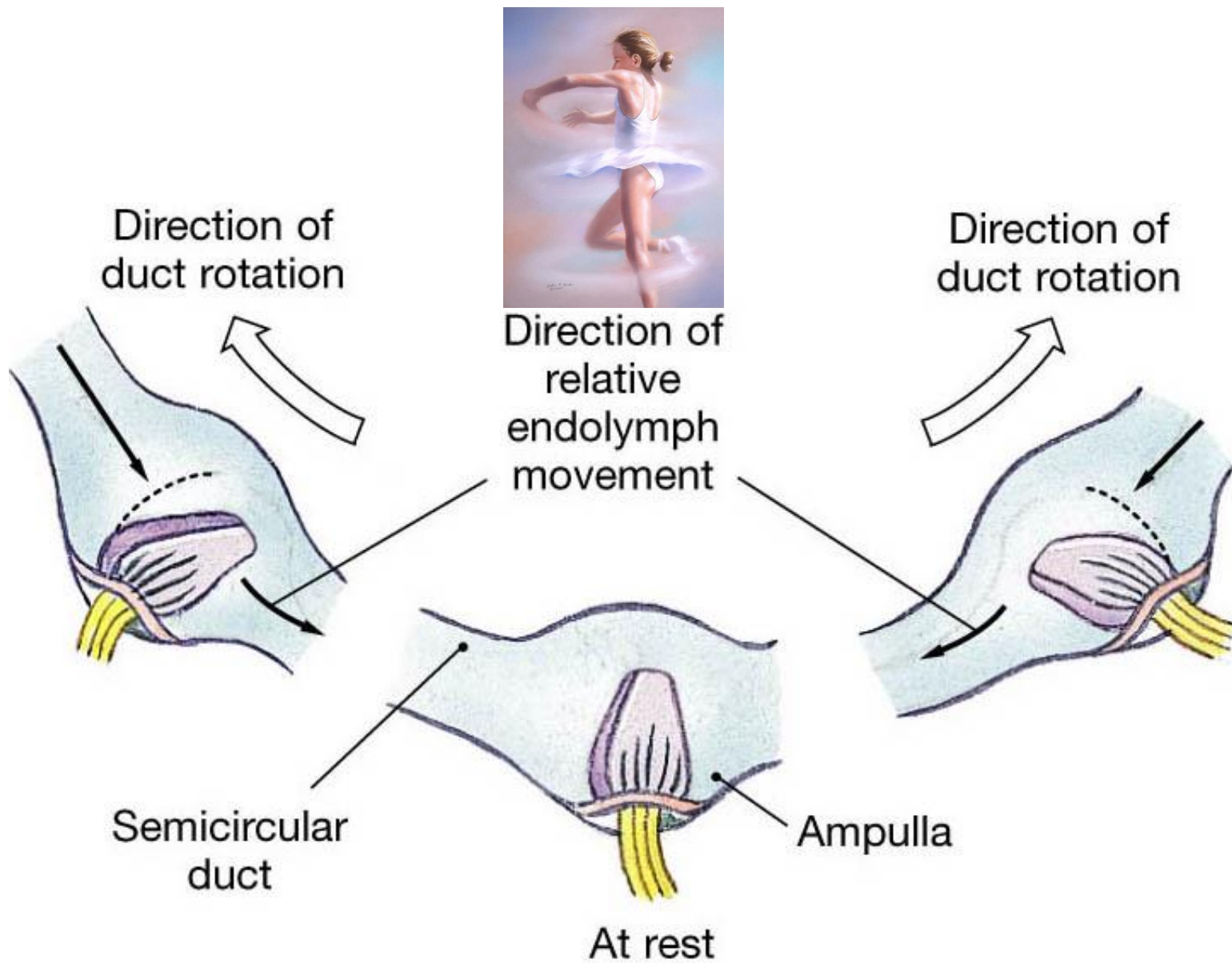
# The structure of the ampullary crest

cross section

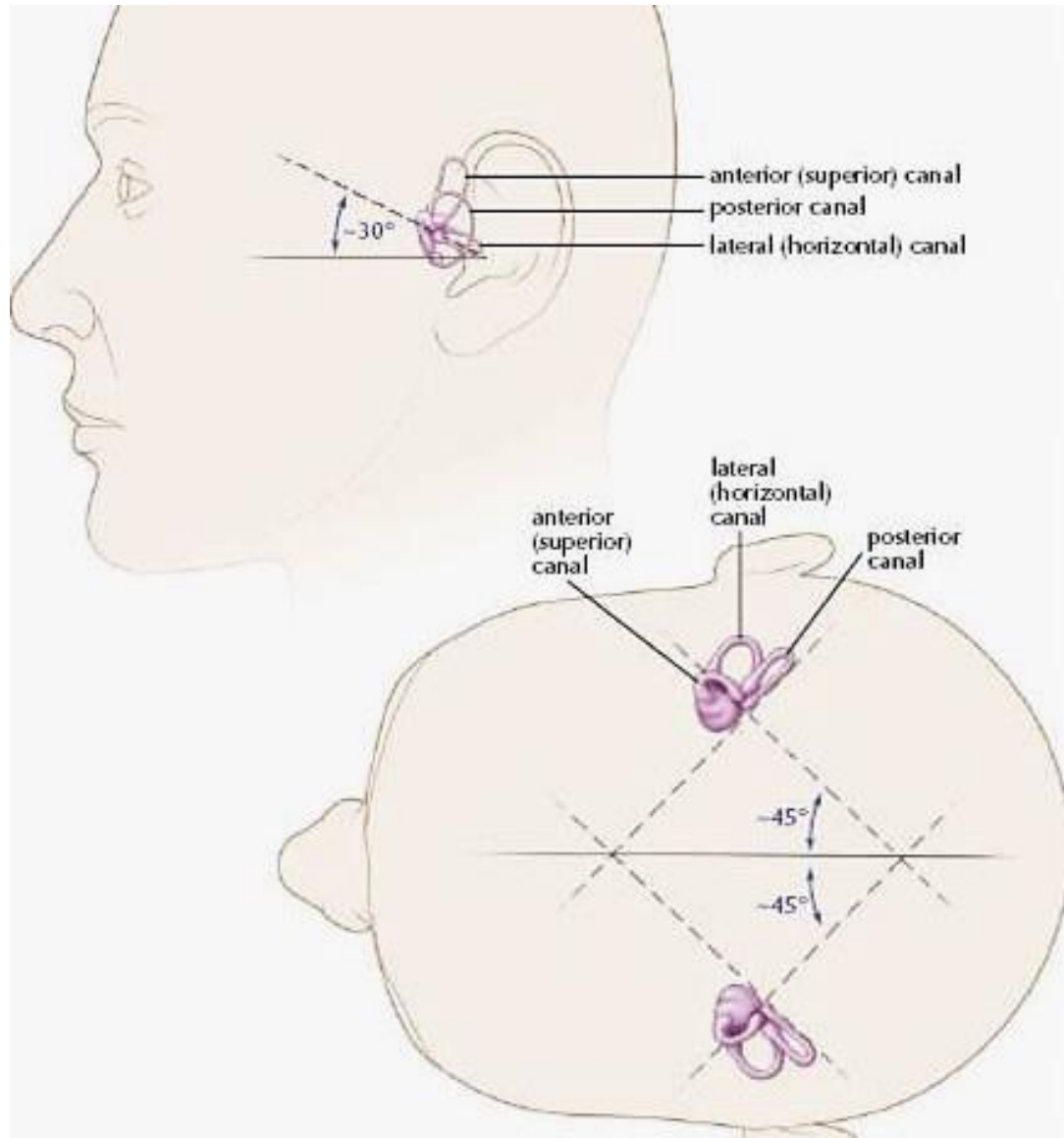


It is similar to the macula, but there are no striolas or otoliths. Kinocilia are arranged in one direction.

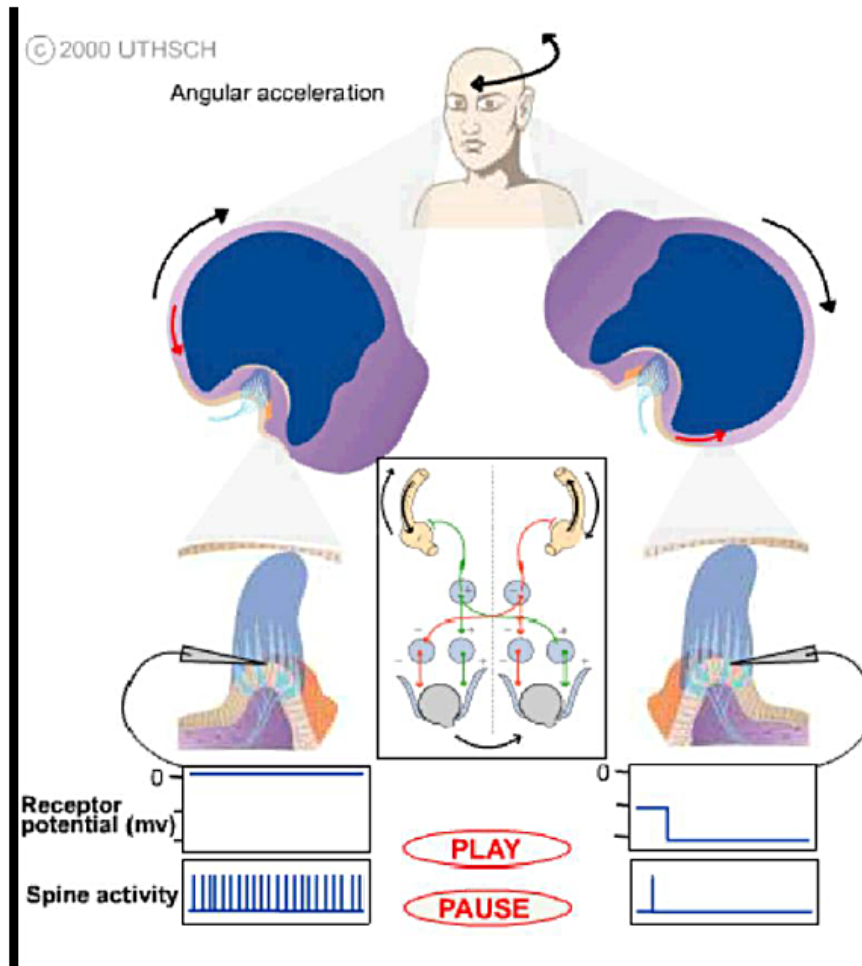
# Angular acceleration and movements of the endolymph



# Semicircular canals are paired bilaterally



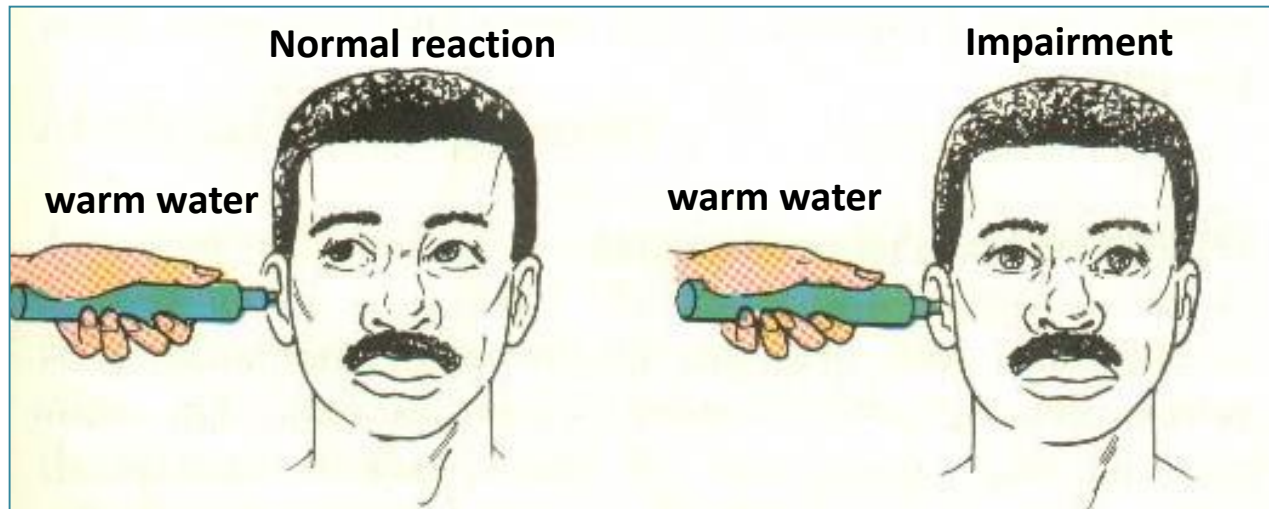
# Coordinated firing of the ampulla partners



Vestibulo-ocular reflex (VOR)- keeps the eyes focused on target when the head moves.

Disharmony of vestibular and visual information causes dizziness, nausea and vomiting (ie.: motion sickness).

# Bárány's caloric test



- Robert Bárány, Nobel prize, 1914
- a test of the vestibulo-ocular reflex
- cold or warm water is irrigated into the external auditory canal
- the temperature difference creates a current in the endolymph of the nearby horizontal semicircular canal, the vestibular sensation is in disharmony with the visual information
- vertigo, nystagmus (cold and hot causes nystagmus in opposite directions, COWS: cold-opposite, warm-same)
- lack of the reaction indicates impaired vestibular functioning

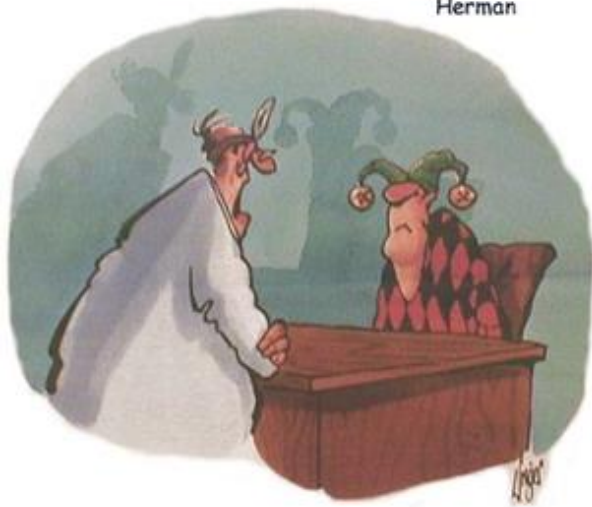
# Ménière's disease



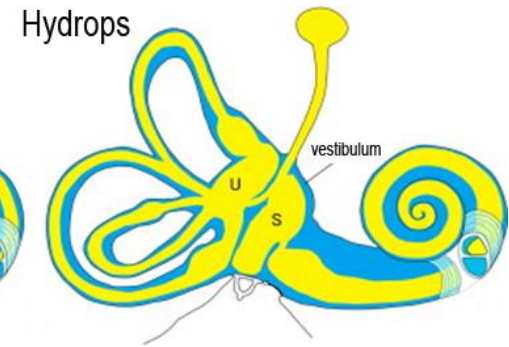
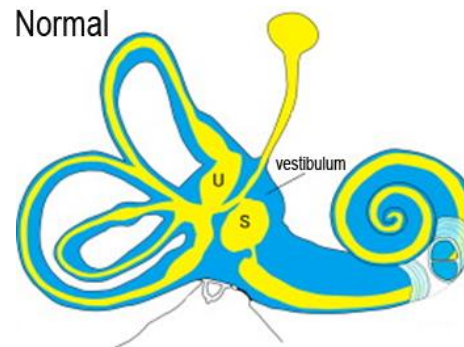
( 1799 – 1862)

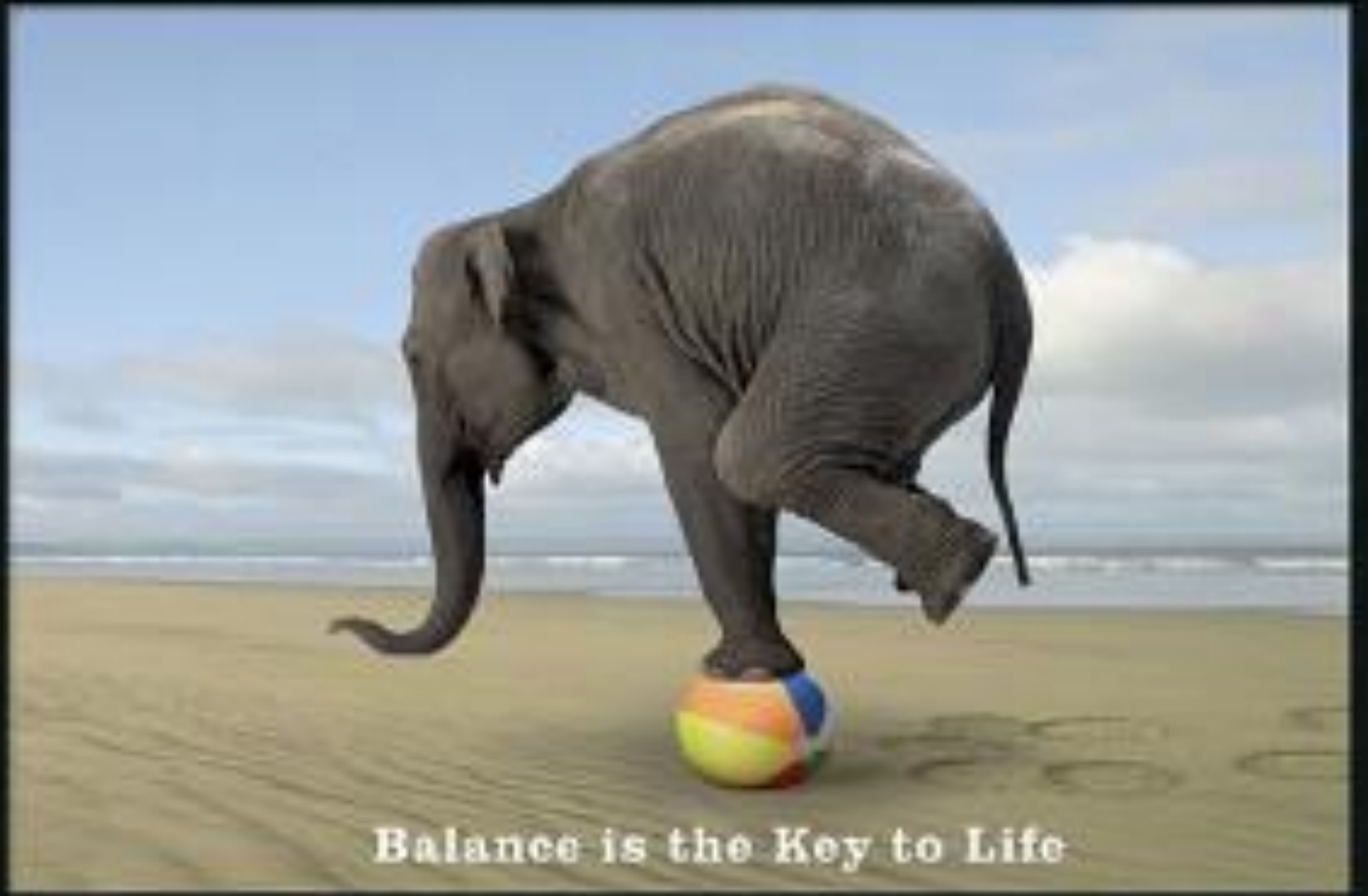


- symptoms happen in attacks
- episodic rotational vertigo, sometimes vomiting
- fluctuating, progressive, sensorineural deafness
- tinnitus
- frequency of the attacks is unpredictable, and they last from minutes to hours
- idiopathic
- increased hydraulic pressure within endolymphatic systems because of the excessive accumulation of fluid (endolymphatic hydrops)



„You say you have ringing in your ears...?“





Balance is the Key to Life