# Microscopic structure of the sense organs

Aleš Hampl

November 2022

# Sense system

It serves to convey stimuli that influence organism from inside and outside

**Sensitive nerve endings**
(with simple structure)

- Simple sensory endings
- Intraepithelial sensory endings
- Sensory bodies

**Complex organs**

- Photosensitive organ - Eye
- Organ of hearing and equilibrium - Ear

# Photoreceptor organ – Eye

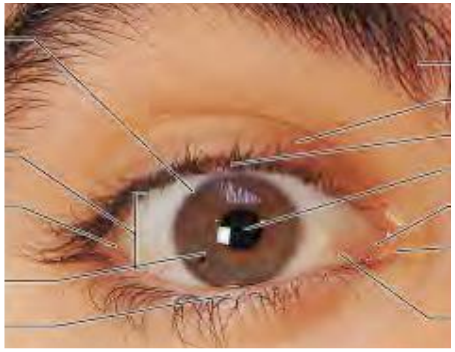
**Analyzes the form, light intenzity and colour reflected from objects**

**Eye ball**
(three-layered structure)

- tunica externa = fibrosa
- tunica media = vasculosa
- tunica interna = nervosa

**Accessory structures**

- eye lids
- conjunctiva
- lacrimal apparatus
- muscles



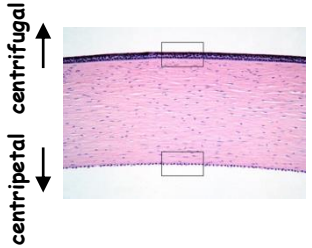
# What do we expect form the eye ?

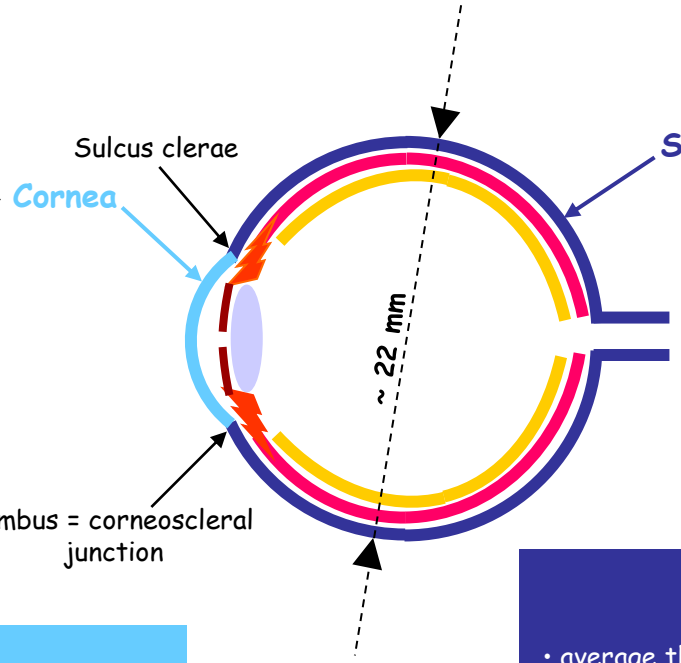
- Ability to sense signals and transfer them to CNS
- Ability to focus on objects
- Enough strength
- Ability to regenerate
- Ability to move with a minimal friction

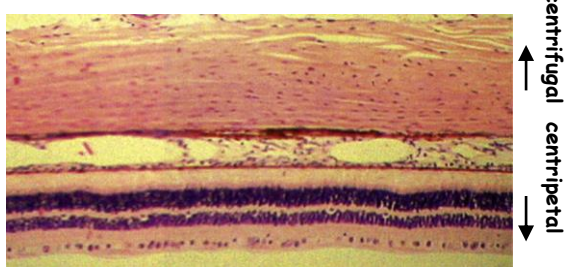
# Enough strength

Eyes sit in the protective environment of the skull, in orbits, surrounded by the fat cussions..

| Cornea | + | Sclera | = | Tunica externa oculi |
|---|---|---|---|---|
| 1/6 | + | 5/6 | = | 6/6 of the surface |




## Cornea

- average thickness 0.9-1.0 mm
- colorless
- transparent
- thoroughly avascular
- 5 distinct layers

**continues on the next slide**

## Sclera

- average thickness 0.5 mm (thicker in posterior part)
- bundles of flat collagen I fibers (intesrsecting in all directions)
- few fibroblasts, minimum ground substance
- relatively avascular
- connected by loose system of collagen fibers with **Tenon´s capsule** - **Tenon´s space** - allows for free movement of the yee
- **lamina suprachoroidea** - connection to choroid (loose connective tissue with melanocytes, fibroblasts and elastic fibers)

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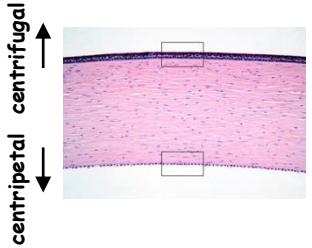


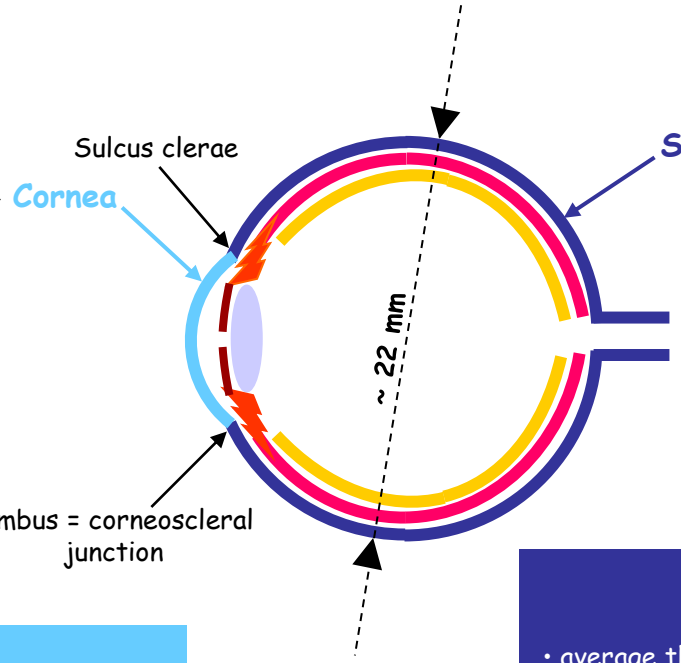


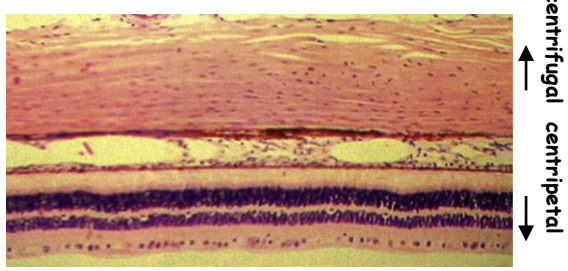


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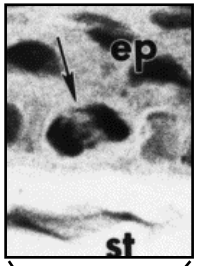
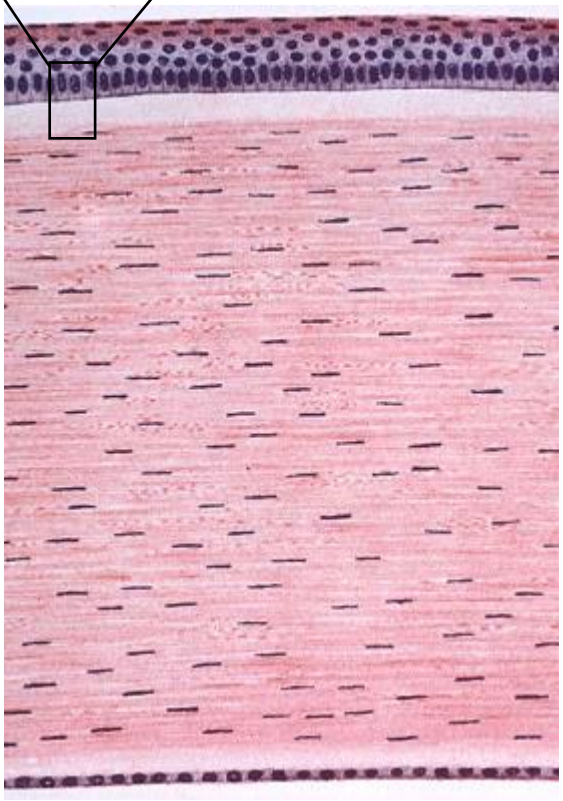
# Cornea

## (transversal section)



Anterior

Posterior

**Corneal epithelium**

- stratified + squamous (5-6 layers)
- nonkeratizing
- rich in nerve endings
- surface cells equipped with microvili
  (protrude into the space with the film of tears)

**Bowman´s membrane**

= **Lamina limitans anterior**
- thickness about 7 – 12 μm
- fine collagen fibers (intersecting in all directions)
- no cells
- provides strength

**Substancia propria corneae = STROMA**

- many layers of collagen fibers (in right angles)
- flat keratocytes in between the collagen lamellae (fibroblast-like cells)
- contains mucoid substance rich in chondroitinsulphate
- properly hydrated

KEY to the TRANSPARENCY

= **Lamina limitans posterior**
- fine collagen fibers
- fibers are arganized to 3D network

**Descemet´s membrane**

**Corneal endothelium**

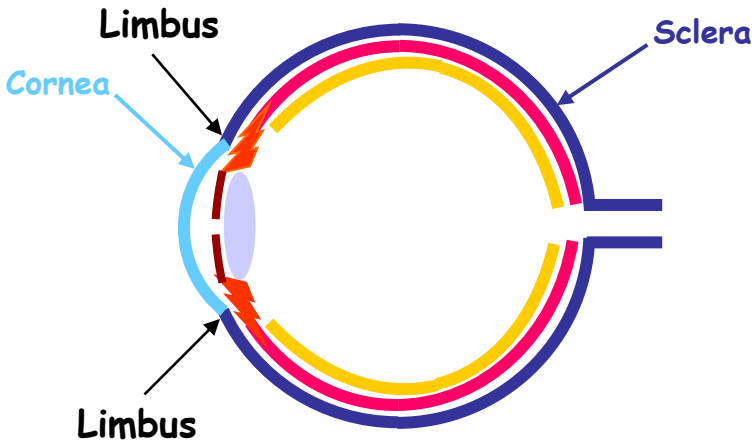
- simple + squamous
- active in transport to maintain cornea in a proper state
- continues on the frontal part of iris
  (via spongium anguli iridocornealis)

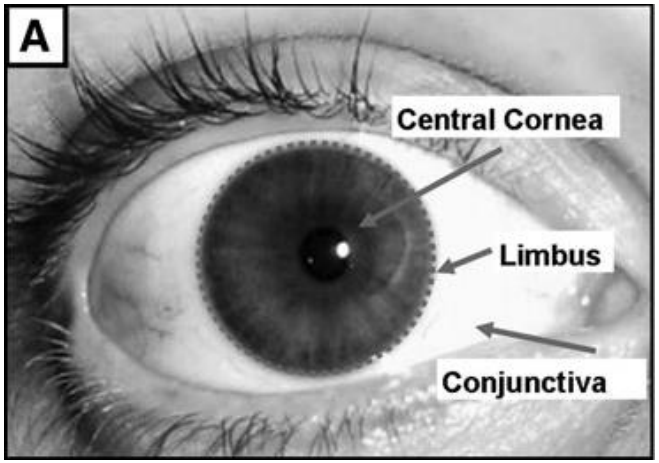
# Ability to regenerate

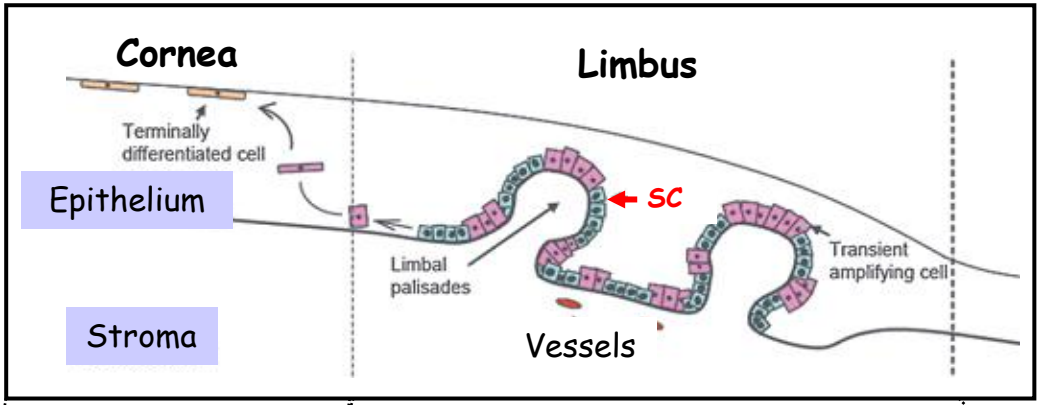
## **Limbus** – corneoscleral junction

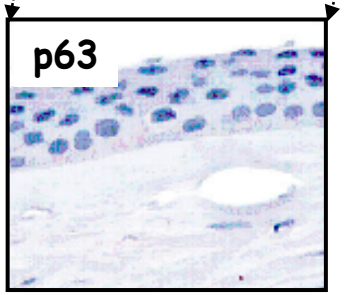
The area of transition of the transparent collagen bundles of cornea into the opaque collagen bundles of sclera.

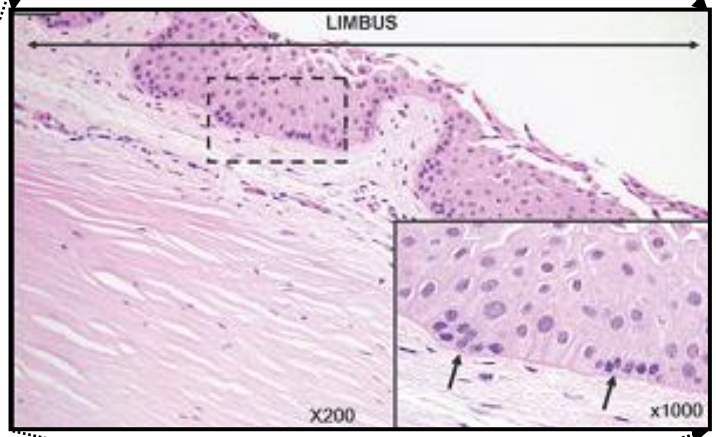
Highly vascularized – feeds avascular cornea

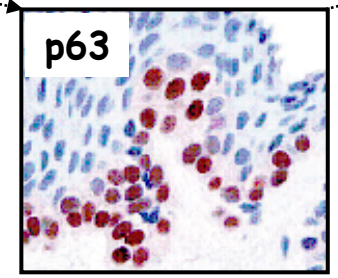


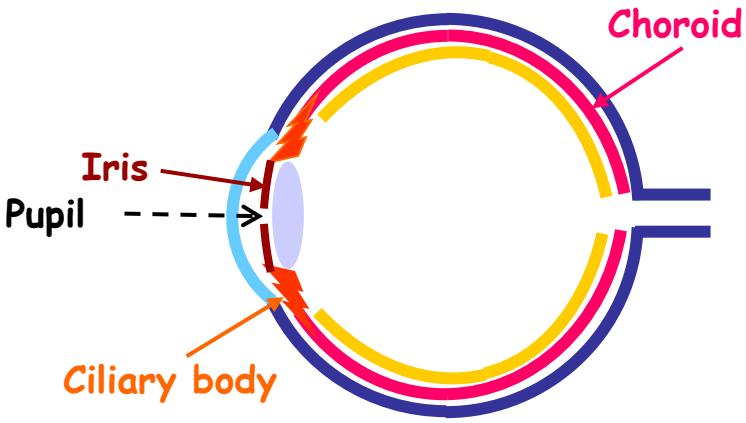






## Enough supply of resources

| Choroid | + | Ciliary body | + | Iris | = | Tunica media |
|---|---|---|---|---|---|---|
| Choroidea | | Corpus ciliare | | Iris | | T. vasculosa |

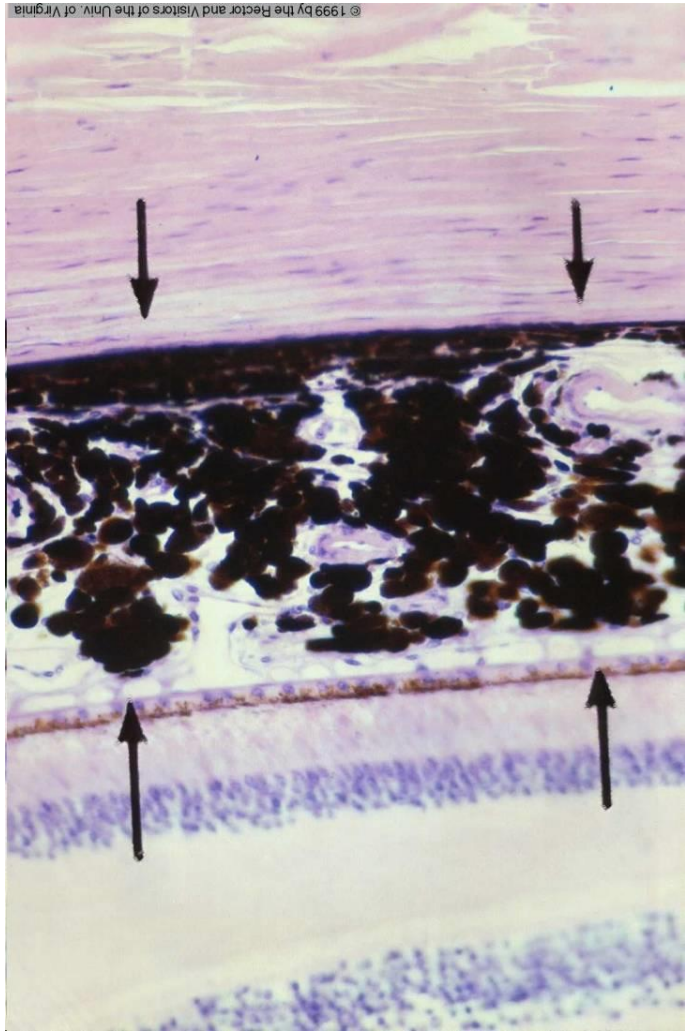
## Choroid = 4-layered structure

**Lamina suprachoroidea**
- loose connective tissue
- rich for pigment cells - melanocytes

**Lamina vasculosa**
- loose connective tissue
- rich for pigment cells - melanocytes
- contains larger vessels and nerves

**Lamina choriocapillaris**
- loose connective tissue
- network of small vessels

**Lamina vitrea = L. basalis = Bruch's membrane**
- fibers of collagenu a elastin
- averall thickness about 3-4 μm
- links together basal lamina s of Lamina choriocapillaris of choroid and pigmented epithelium of retina

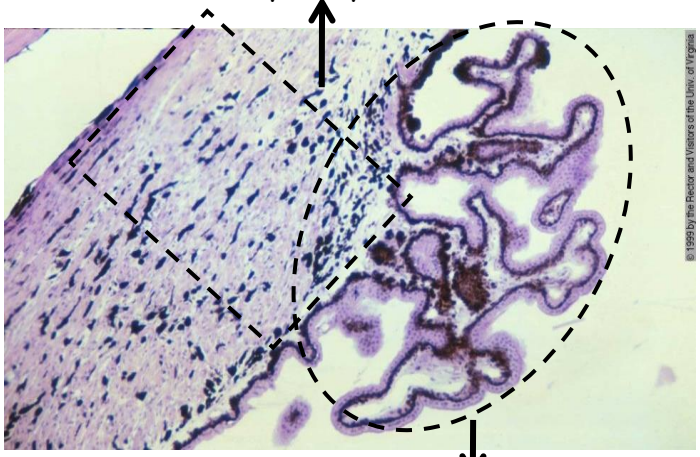


# Ability to focus on objects

## **Ciliary body** – anterior extension of the choroid

### Stroma of ciliary body

- loose connective tissue
- contains elastic fibers, vessels and melanocytes
- rich for capillaries (chamber fluid)
- bundles of smooth muscle fibers (anchored to sclera and protrude to the processes of ciliary body – *m. ciliaris*)



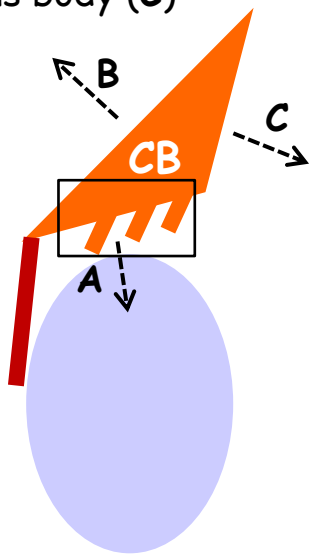
### Processes of CB (Processus ciliares)

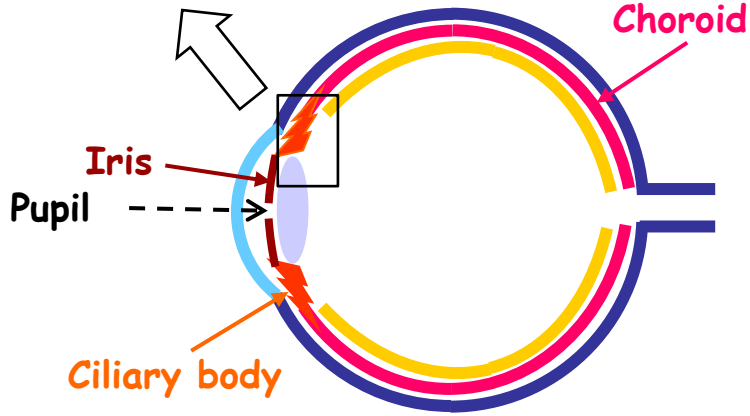
- protrude into posterir chamber
- total number of about 70-80
- rich for capilaries (chamber fluid)
- covered by two-layered epithelium (from the retina – *pars ciliaris retinae*)
- linked to the lens capsula *fibrae suspensoriae lentis* (zonulae)

### Triangular on crossection

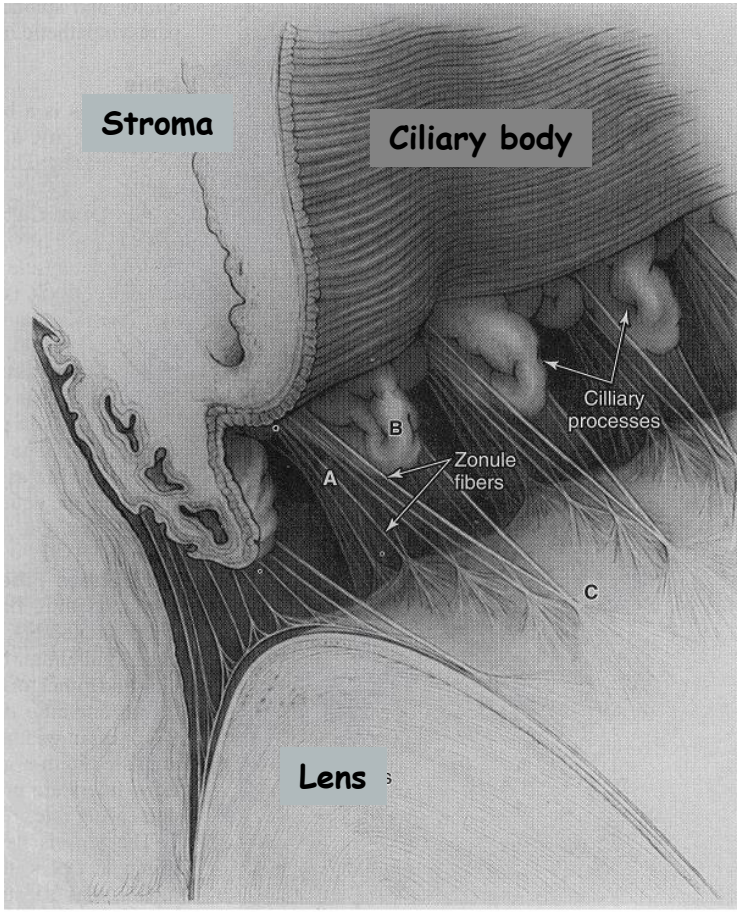
Connects to:

- lens + posterior chamber (**A**)
- sclera (**B**)
- vitreous body (**C**)

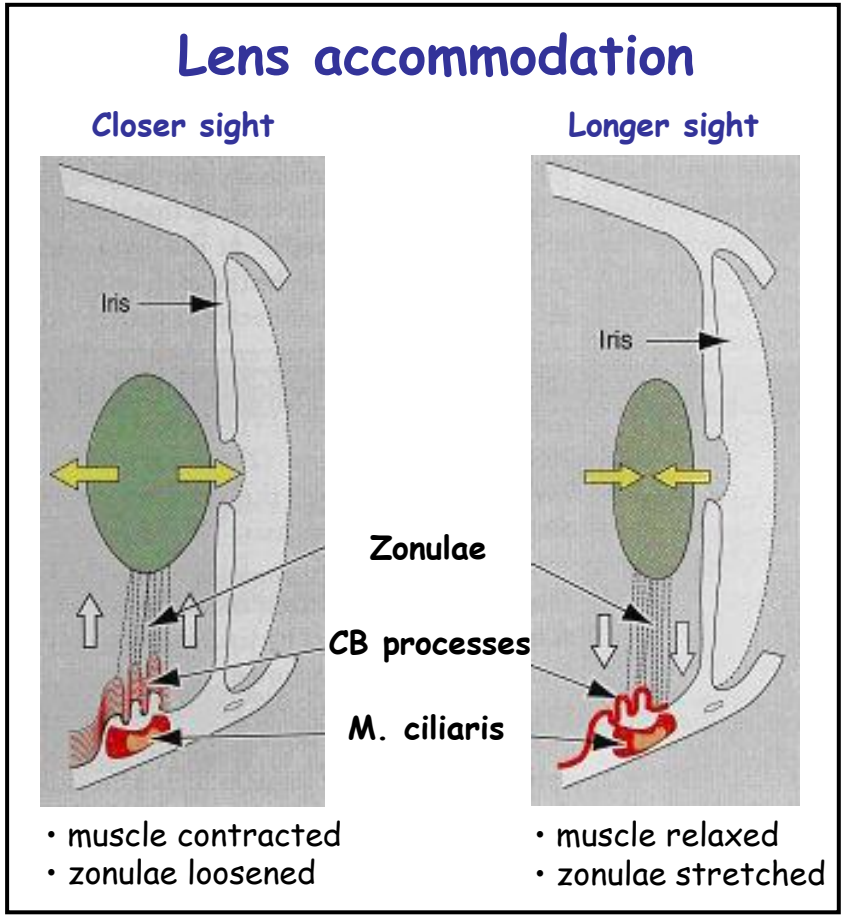


# Ciliary body

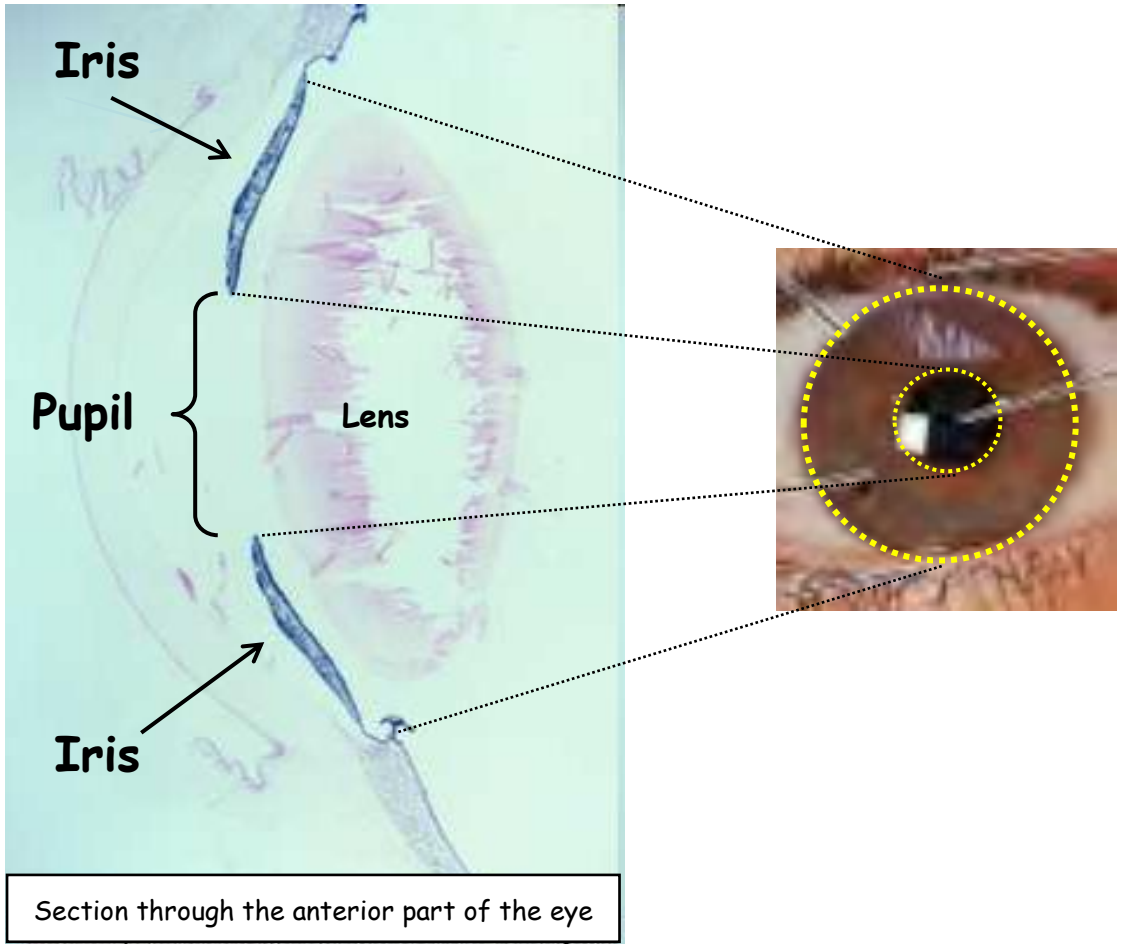



## Lens accommodation



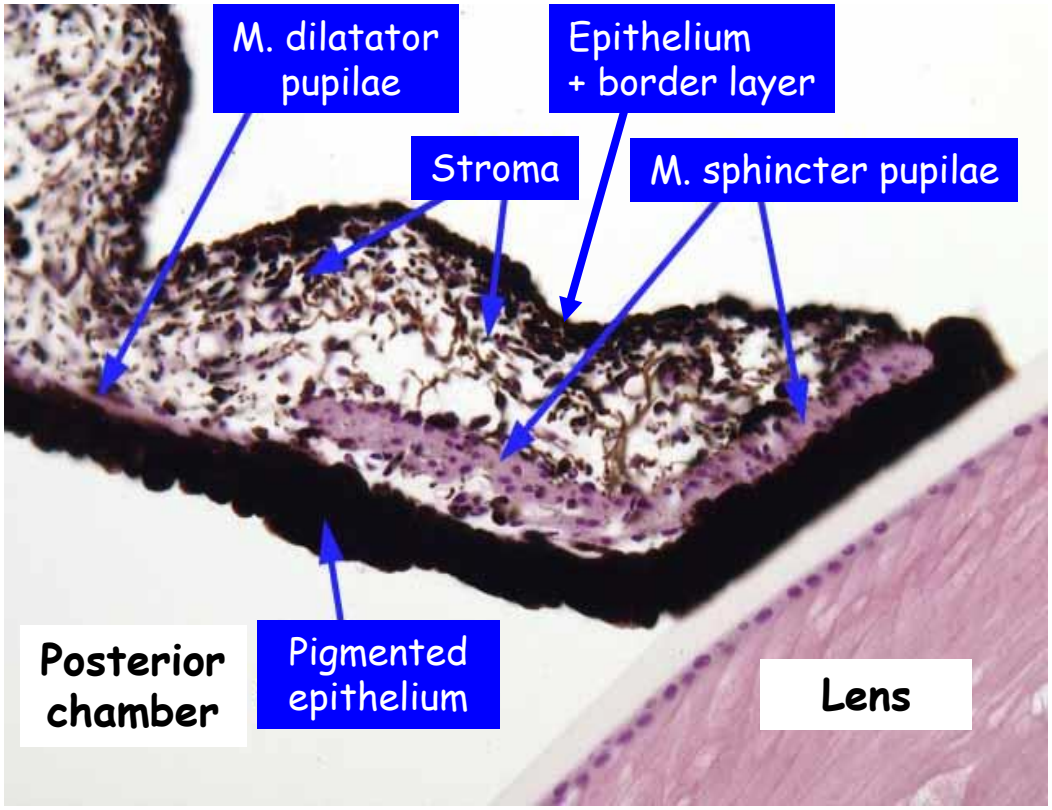
# Iris - 1

Anterior continuation of the choroid.
Partially covers the lens.




Section through the anterior part of the eye

# Iris - 2




**Iris = 4-layered structure**
Layers from outside:

1. **Anterior epithelium**
   - continuation of the posterior ep. of the cornea
   - discontinuos layer of flat epithelial cells, fibroblasts a melanocytes

2. **Anterior border layer**
   - thin layer of connective tissue
   - rich for pigmented cells - melanocytes
   - decides about eye colour

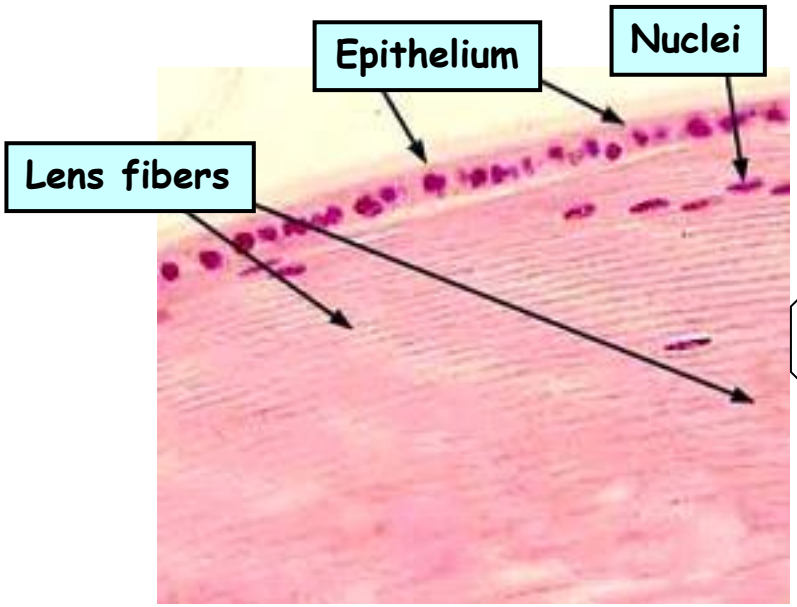
3. **Stroma**
   - loose connective tissue
   - large number of radially running vessels
   - concentrically ordered smooth muscle fibers (=musculus sphincter pupillae)

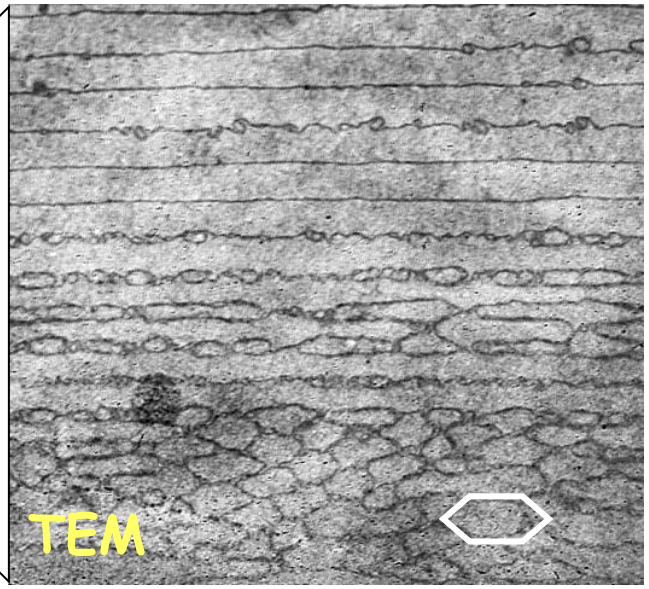
4. **Pars iridica retinae**
   - 2-layered
   - continues form ciliar body
   - layer facing the stroma contains smooth muscle fibers (=musculus dilatator pupillae)

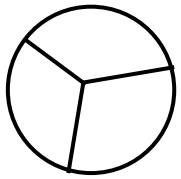
# Lens

## Capsule + Epithelium + Fibers

- 10-20 μm
- Collagen IV



Epithelium (cuboidal + low cylindrical) only on the anterior surface.

Fibrae suspensorie lentis are anchored to the equator of the lens.

# Ability to sense signals and transfer them to CNS for processing

Retina = Tunica aculi interna – Tunica nervosa

**Posterior part**
- photosensitive
- multilayered

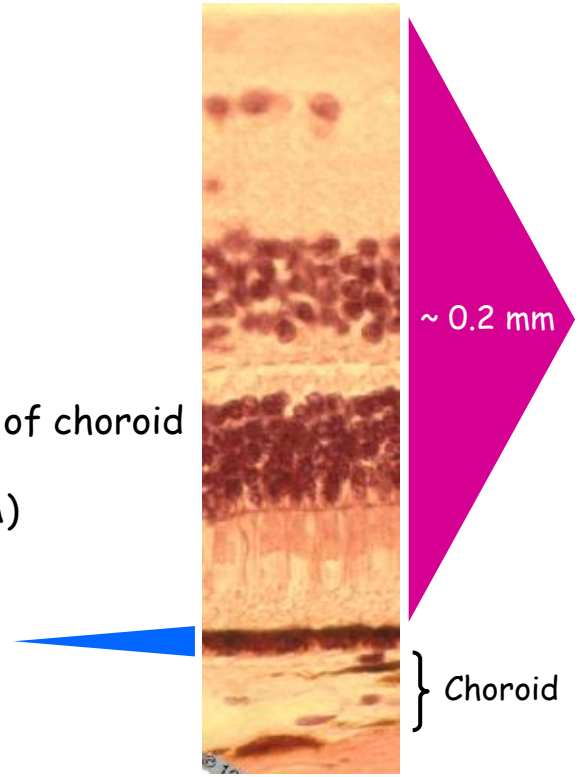
**Anterior part**
- non-photosensitive
- two-layered
- covers ciliary body and posterior part of the iris

Invagination of prosencephalon creates two-layered **optic cup.**

**Outer layer**

**Stratum pigmenti retinae**

- columnar cells
- basally located nucleus
- firm connection with lamina vitrea/basalis of choroid
- zonulae occludentes and adherentes
- rich for smooth ER (esterification of vit A)
- rich for melanin granula
- apical extensions (microvili and sheets)
- vesicles in apical parts

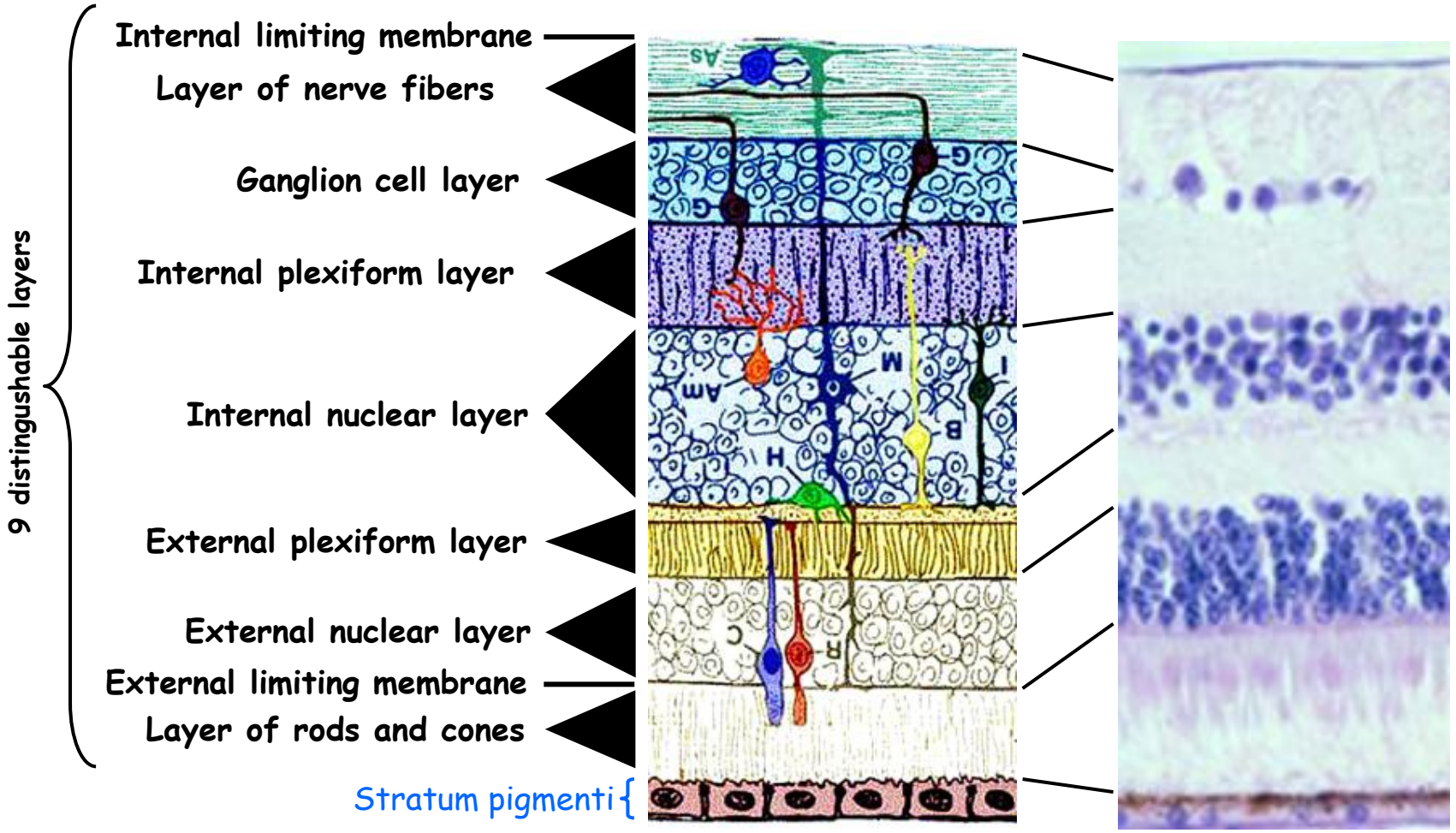



**Inner layer**

**Neural retina**

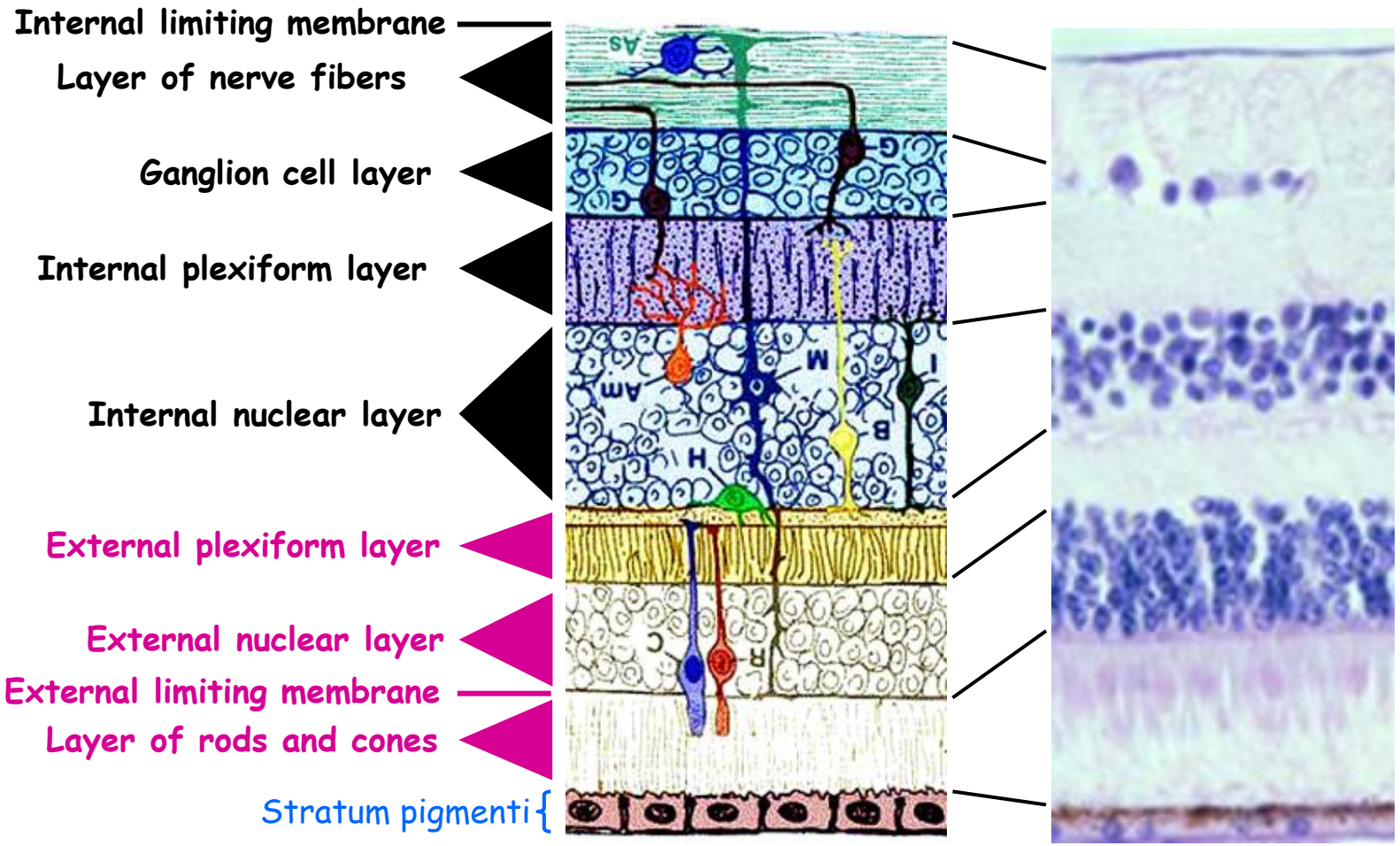
# Neural (optical) retina

minimum 15 different types of neurons with tens of interactions (synapses)



# Photoreceptors = Rod and cone cells 1

## I. Neurones of the optical path



# Photoreceptors = Rod and cone cells 2

## I. Neurones of the optical path

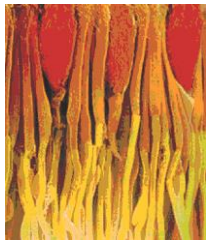
External plexiform layer

External nuclear layer

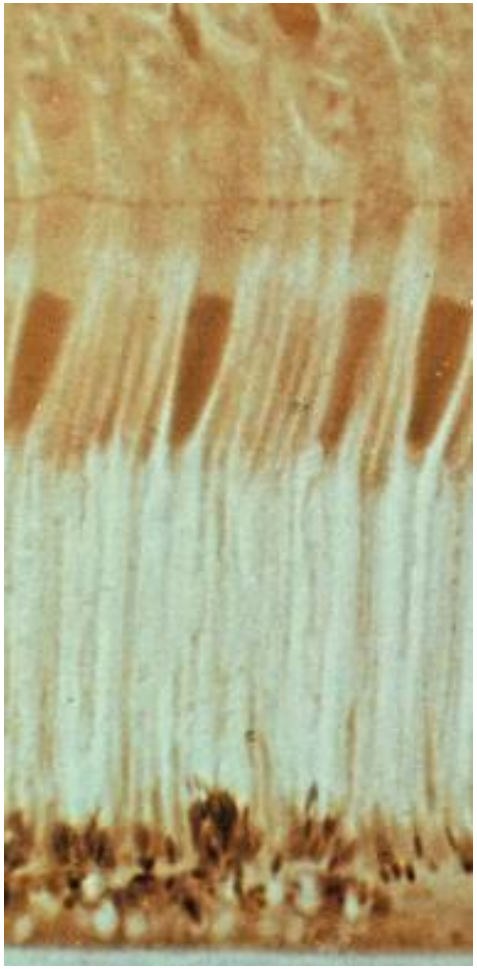
Membrana limitans externa

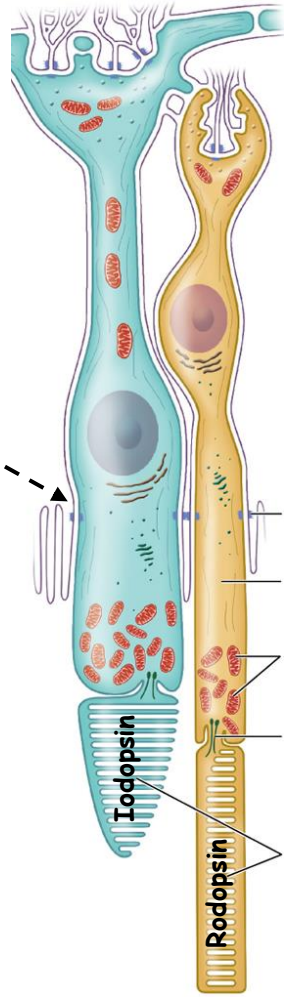
(series of junctional complexes between photoreceptors and glial Muller cells)

Layer of rods and cones



SEM






Synaptic region

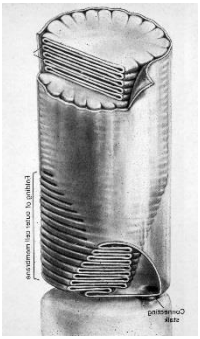
Nuclear region

Central part

Inner segment

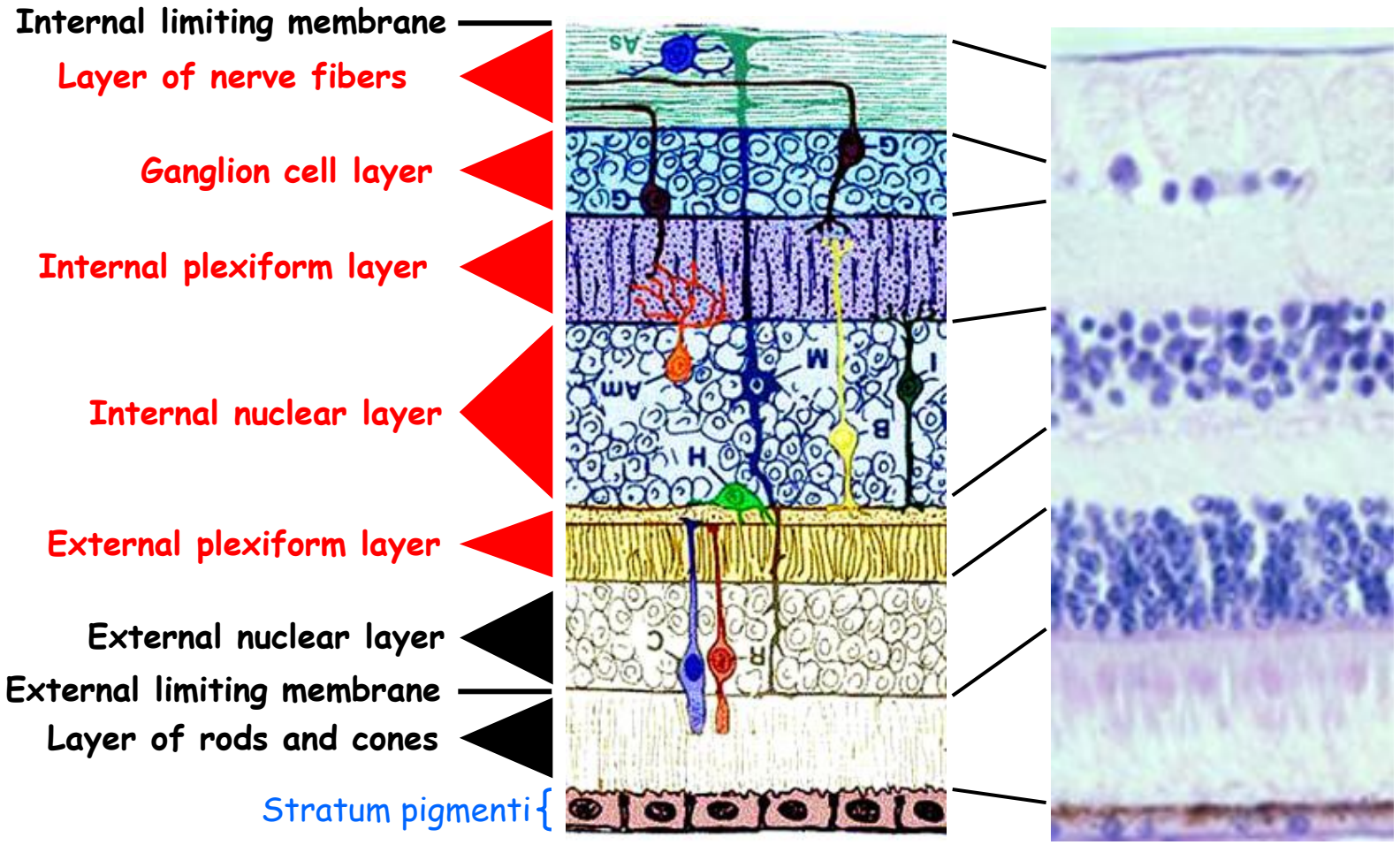
Outer segment

Peripheral part



Rod cells: 100-150 mil.
Cone cells: 7 mil. (méně citlivé)

# Other neurons of the optical path 1



# Other neurons of the optical path 2

## II. neuron
## Bipolar cells

**Diffuse**
- Synapses with two or more receptors

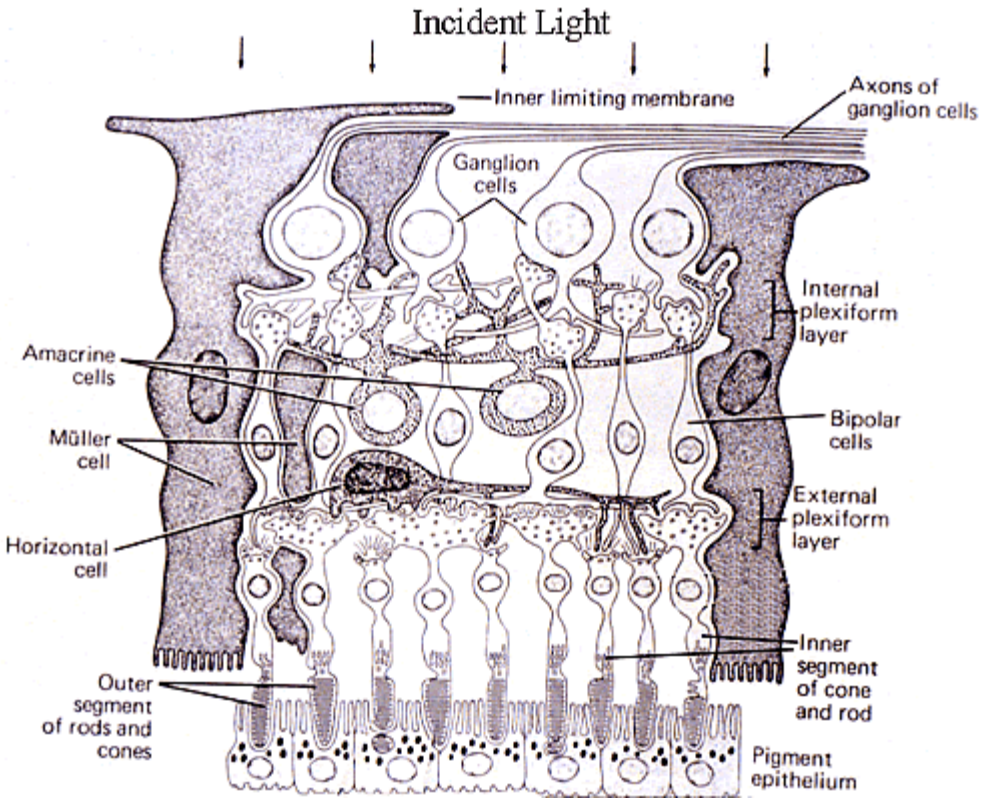
**Monosynaptic**
- Synapses with only one receptor
- Direct transfer of impulses from some rods

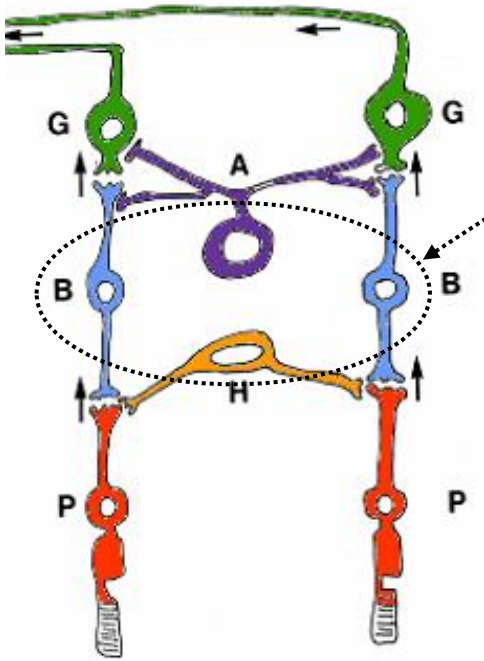
## III. neuron
## Ganglion cells (multipolar)
- Large cells
- Nuclei mainly in one layer
- Dendrites connect to neurites of bipolar and amakrine cells
- Neurites run in 9. layer of the retina and come together to form optic nerve

## Asociating + integrating neurons

**Horizontal cells**
- Small
- Multipolar

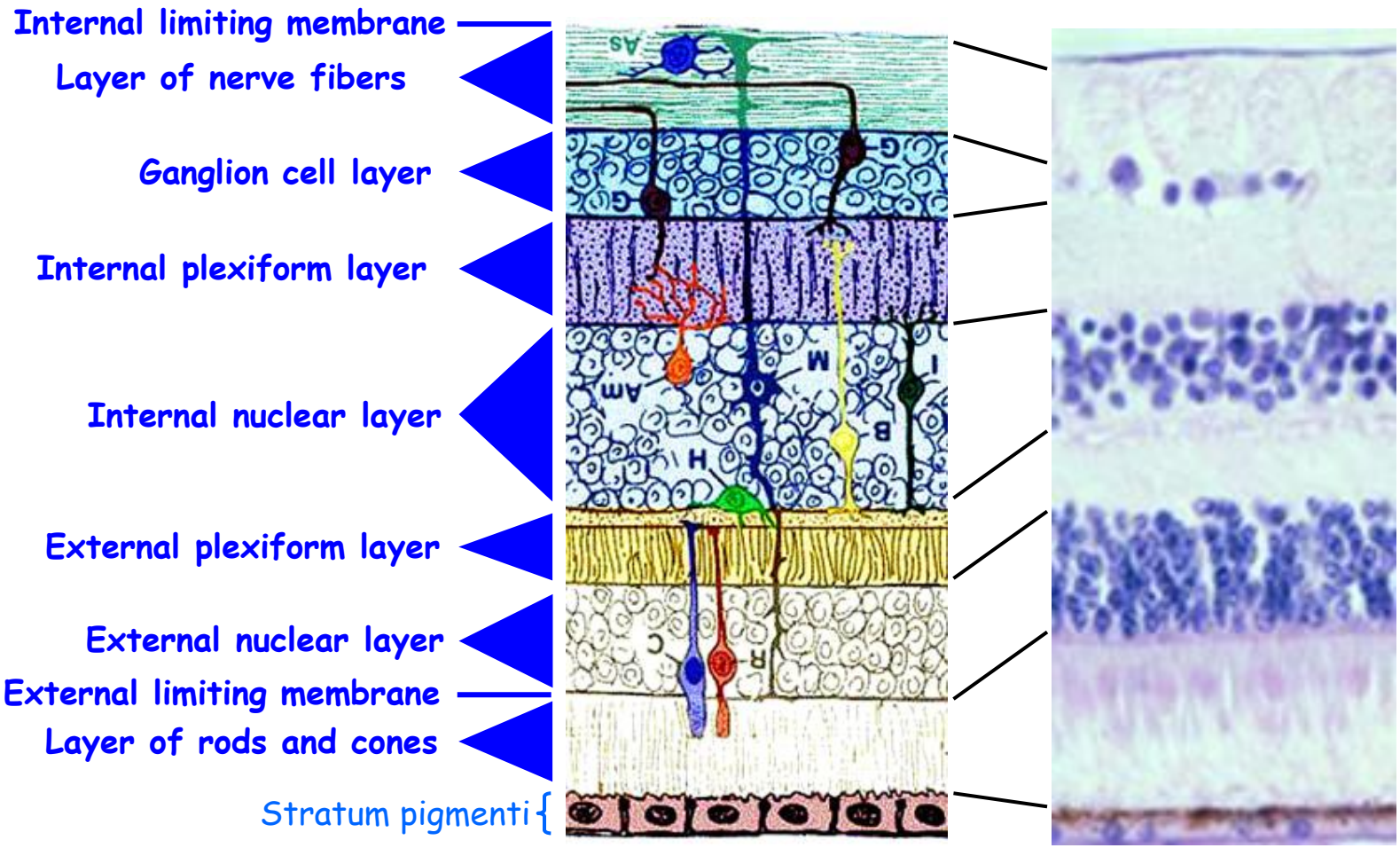
**Amacrine cells**
- They don´t have neurite




**Cells with their nuclei in internal nuclear layer**

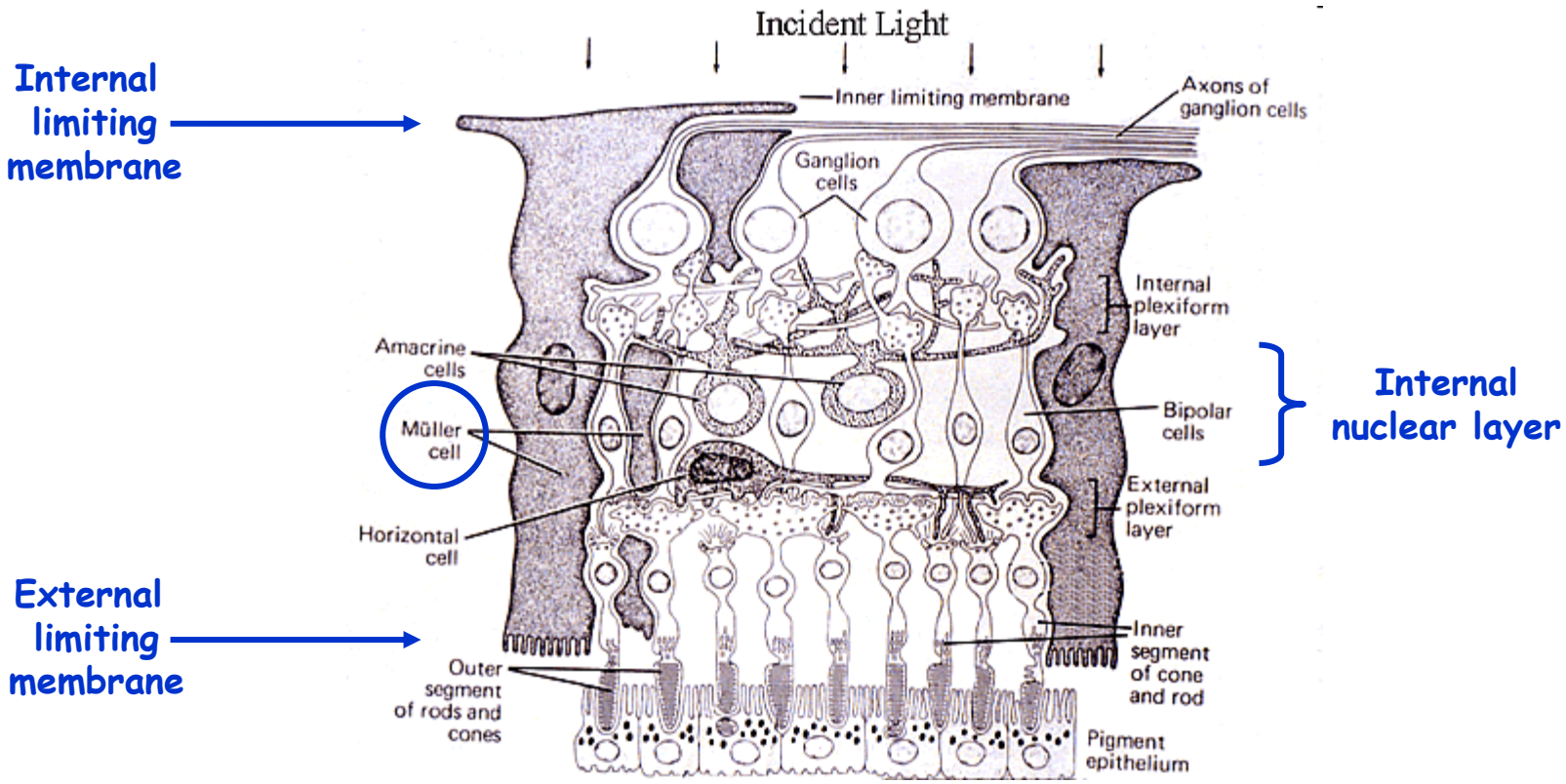
# Supporting cells of the retina 1



# Supporting cells of the retina 1

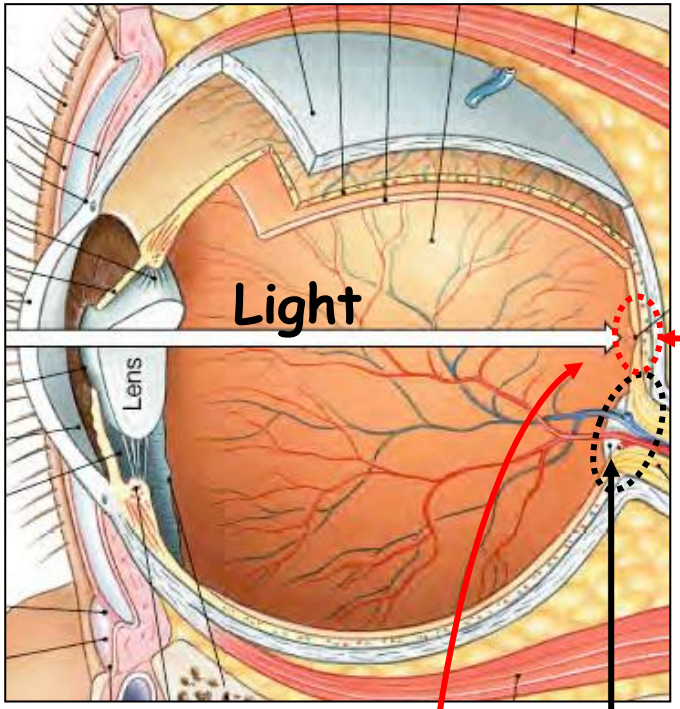
## Muller cells

= modified glial cells of the CNS

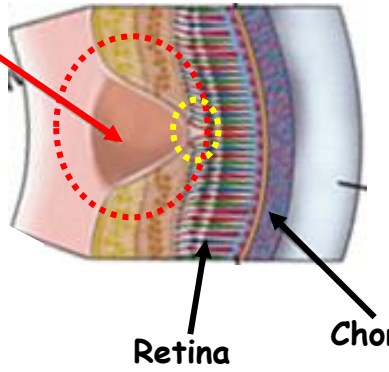


„Does the retina see the same in all its areas"

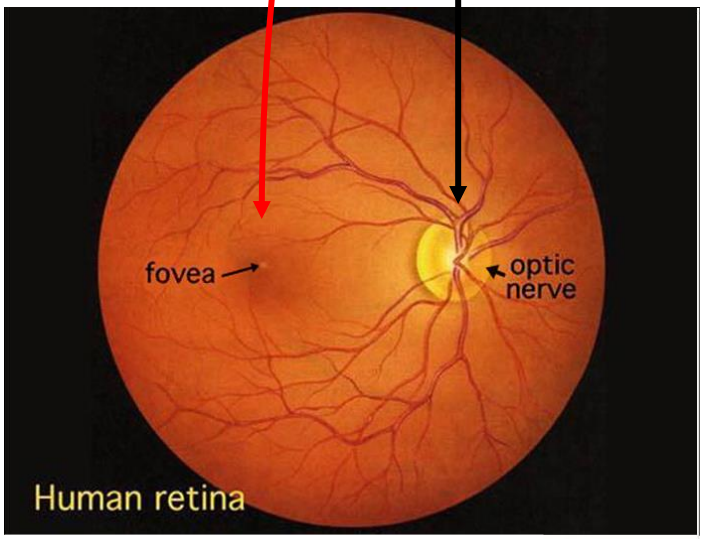
Central x Peripheral vision



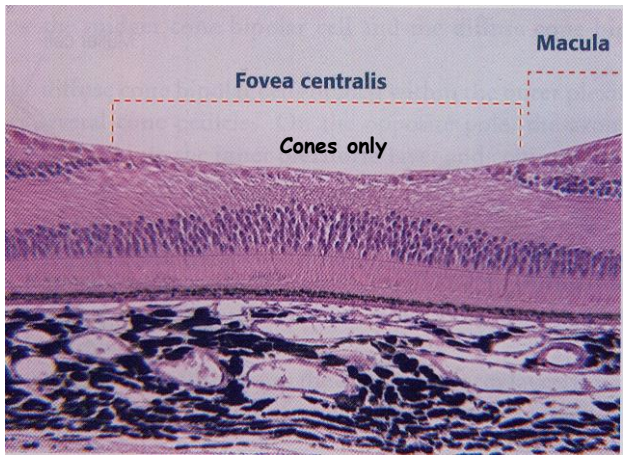

Macula lutea



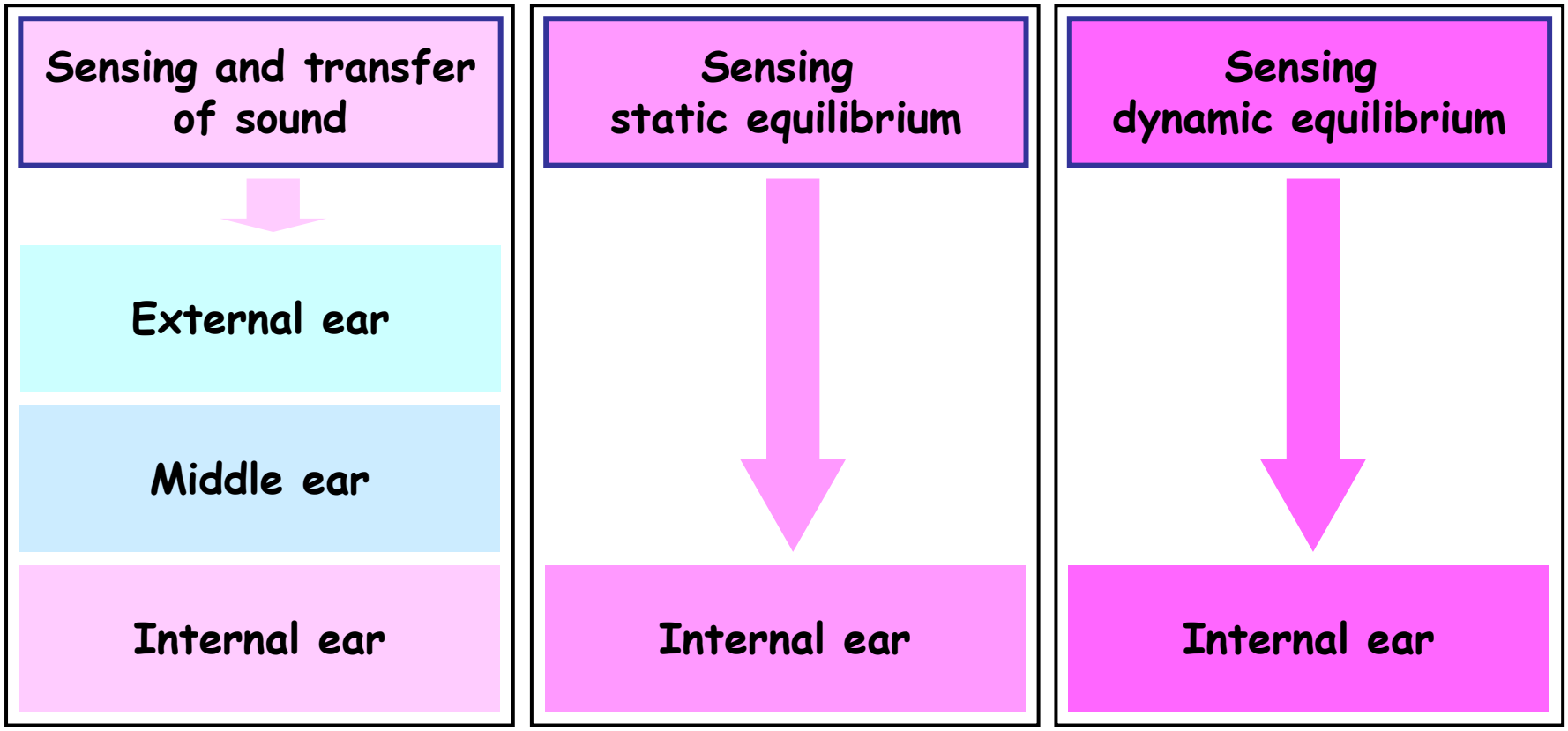

Papilla of the optic nerve




Fovea centralis of the macula lutea = the sharpest vision

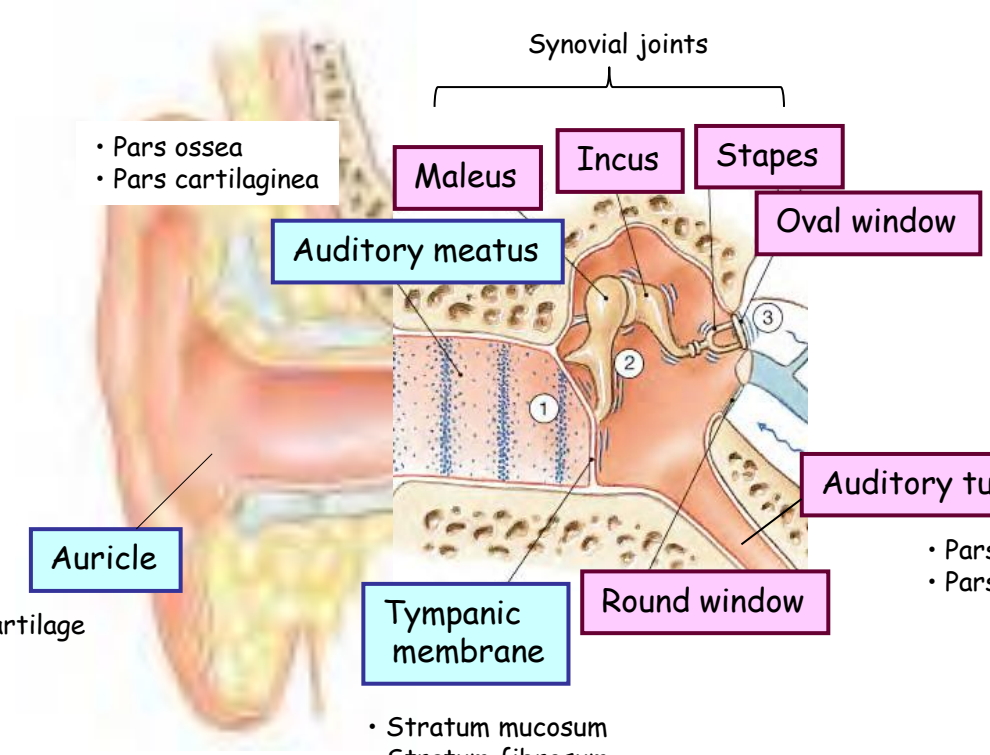


# Audioreceptor system
# =
# Vestibulocochlear apparatus

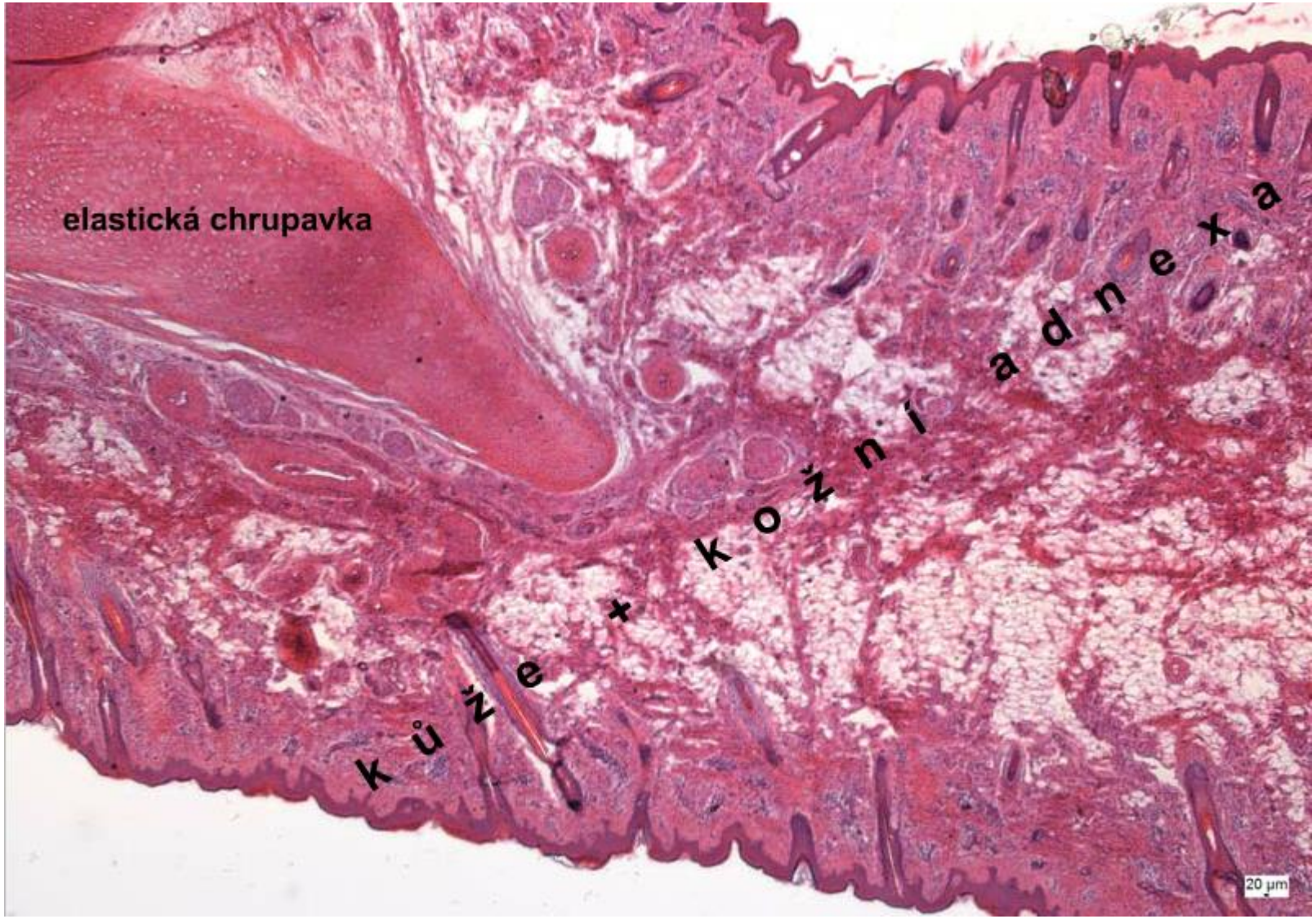


# External + Middle ear – Organ of hearing

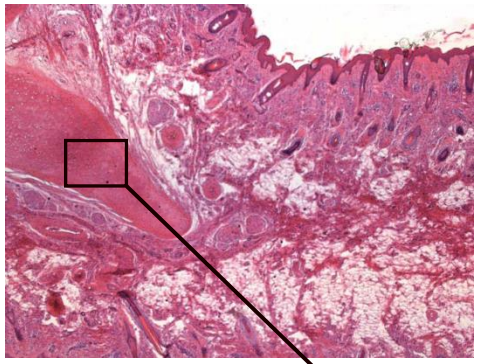
Middle ear – fitted in the cavities of **temporal bone** along with internal ear – osseous labyrinth.

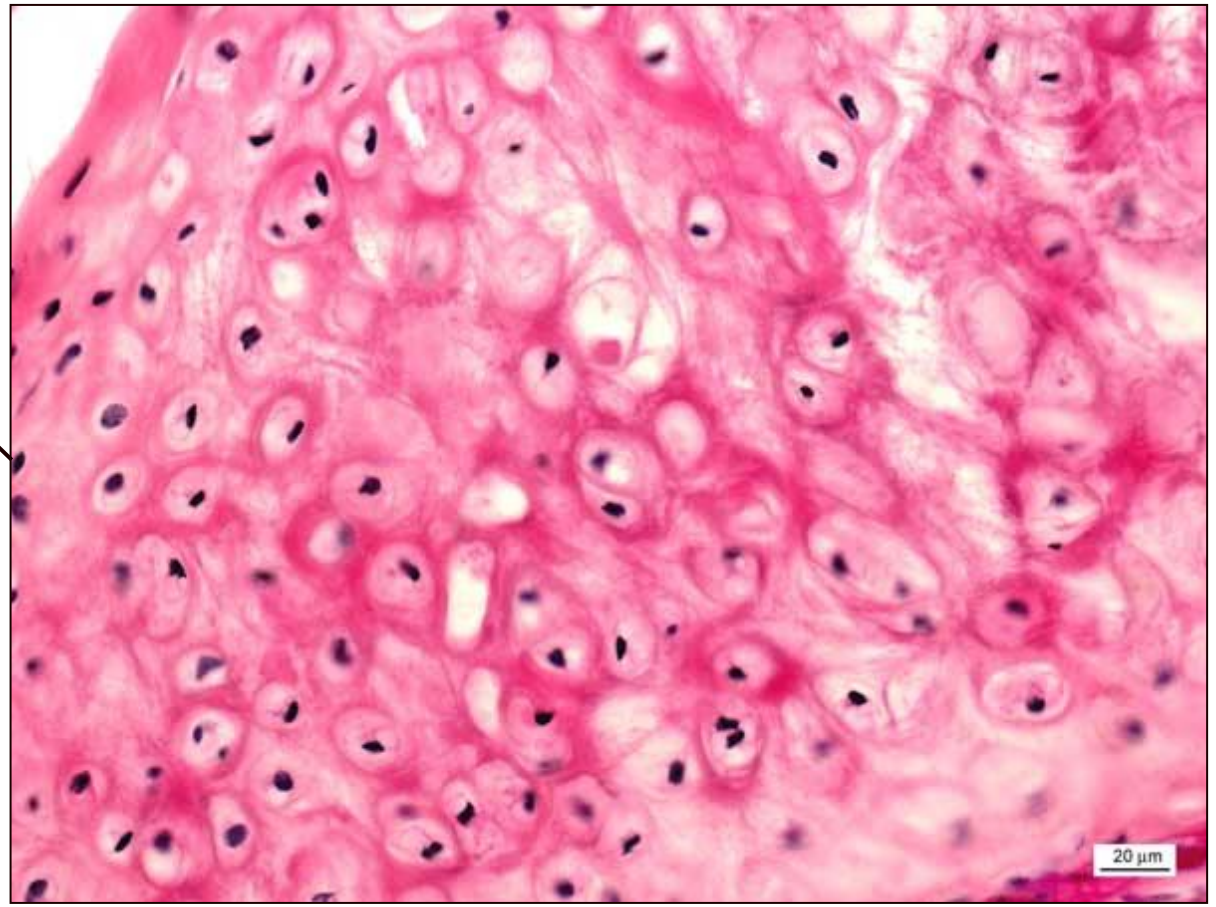


# Extrenal ear - Auricle



# Extrenal ear – Auricle – Elastic cartilage





# Internal ear

## Bony labyrinth

- series of cavities
- petrous portion of temporal bone

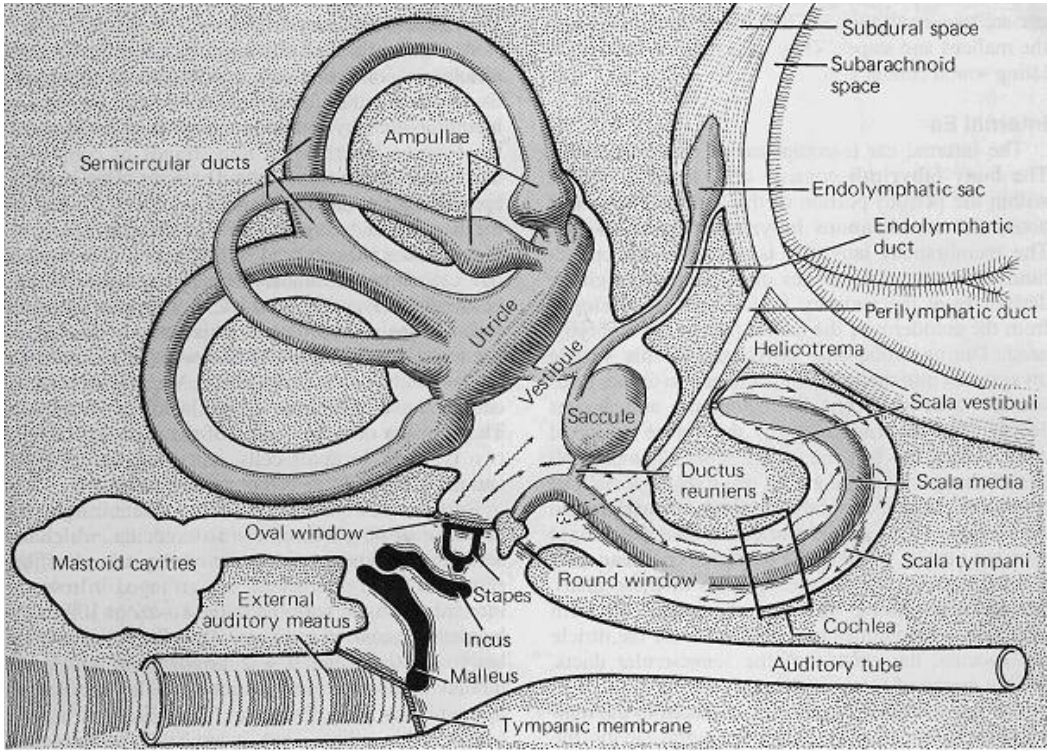
**Vestibulum** | **Cochlea** | **Semicircular canals**

## Membranous labyrinth

- series of interconnected tubes and vesicles
- lined by epithelium
- positioned in bony lybrinth

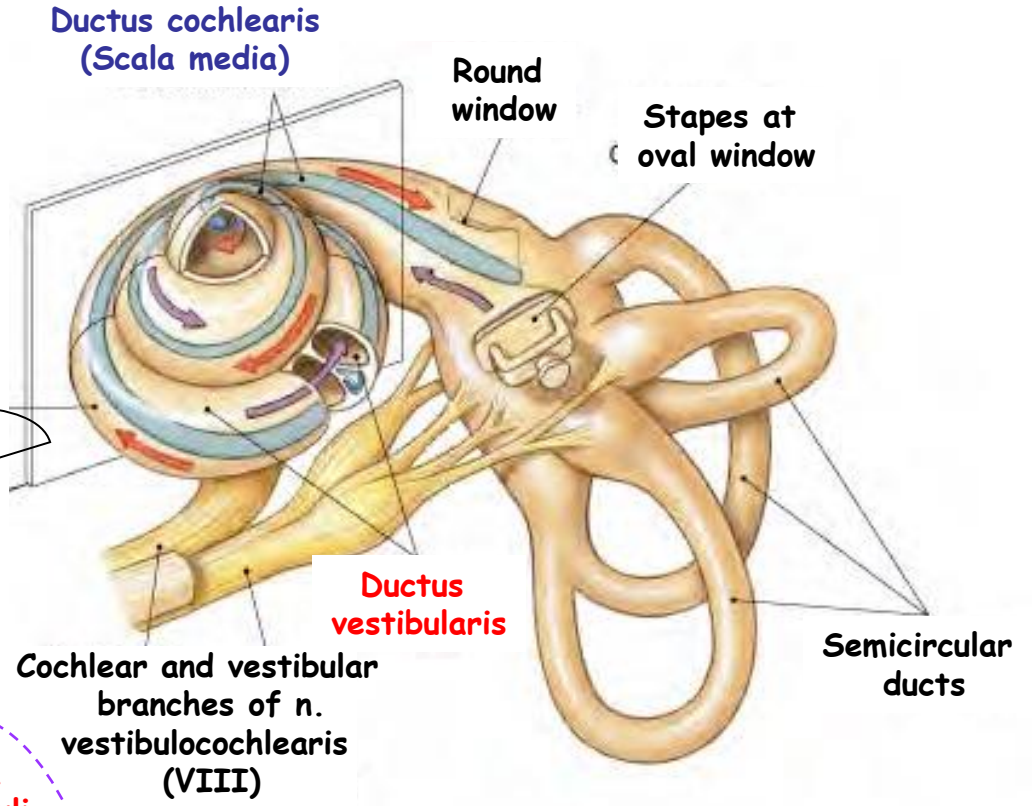
**Utricle** → **Semicircular ducts**

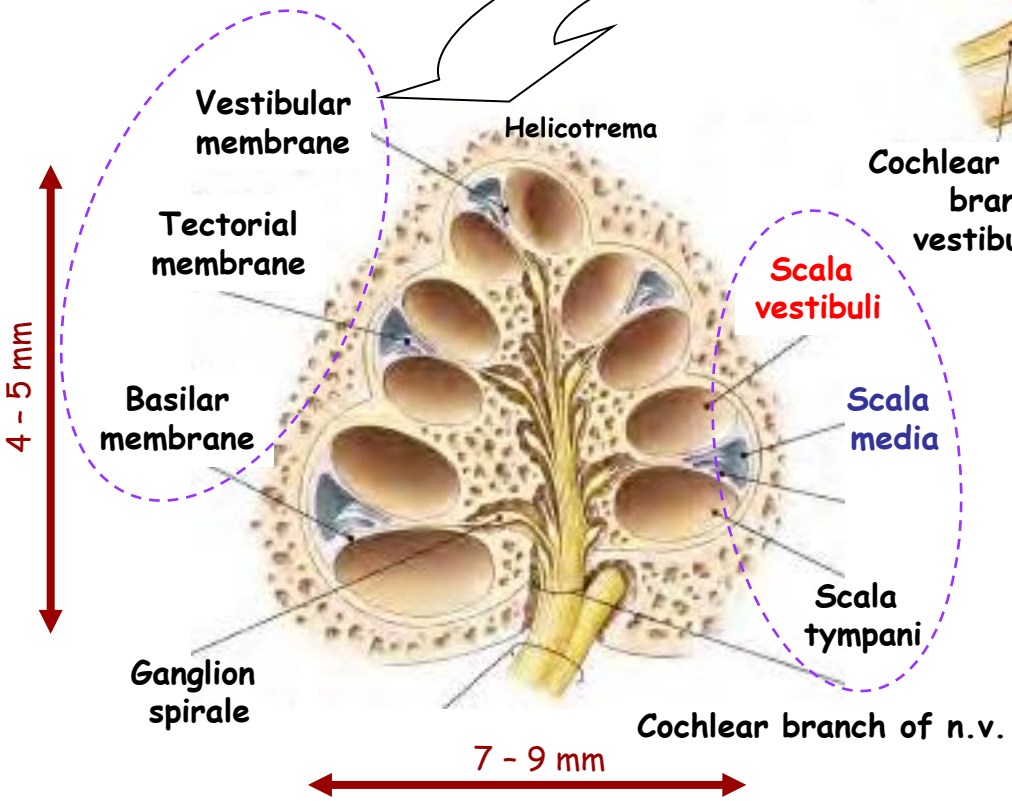
**Saccule** → **Cochlear duct**



# Internal ear – Organ of hearing

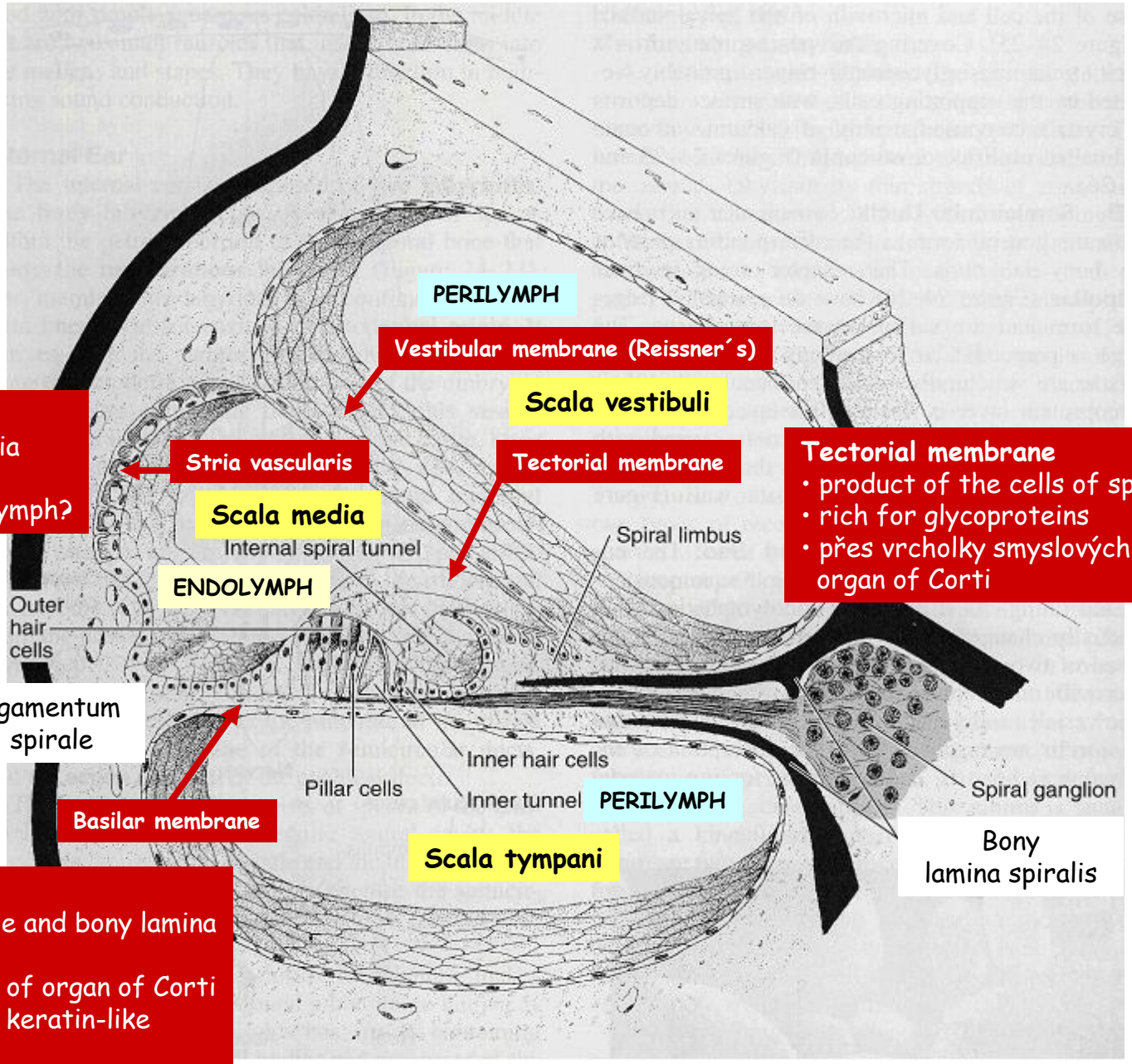
**Cochlea**
- 2,5 turns around modiolus
- total length about 35 mm




**Modiolus (bony core)**
- central axis of cochlear duct
- contains ganglion spirale cochleae, nervus cochlearis and vessels

# Internal ear – Detail of cochlear duct



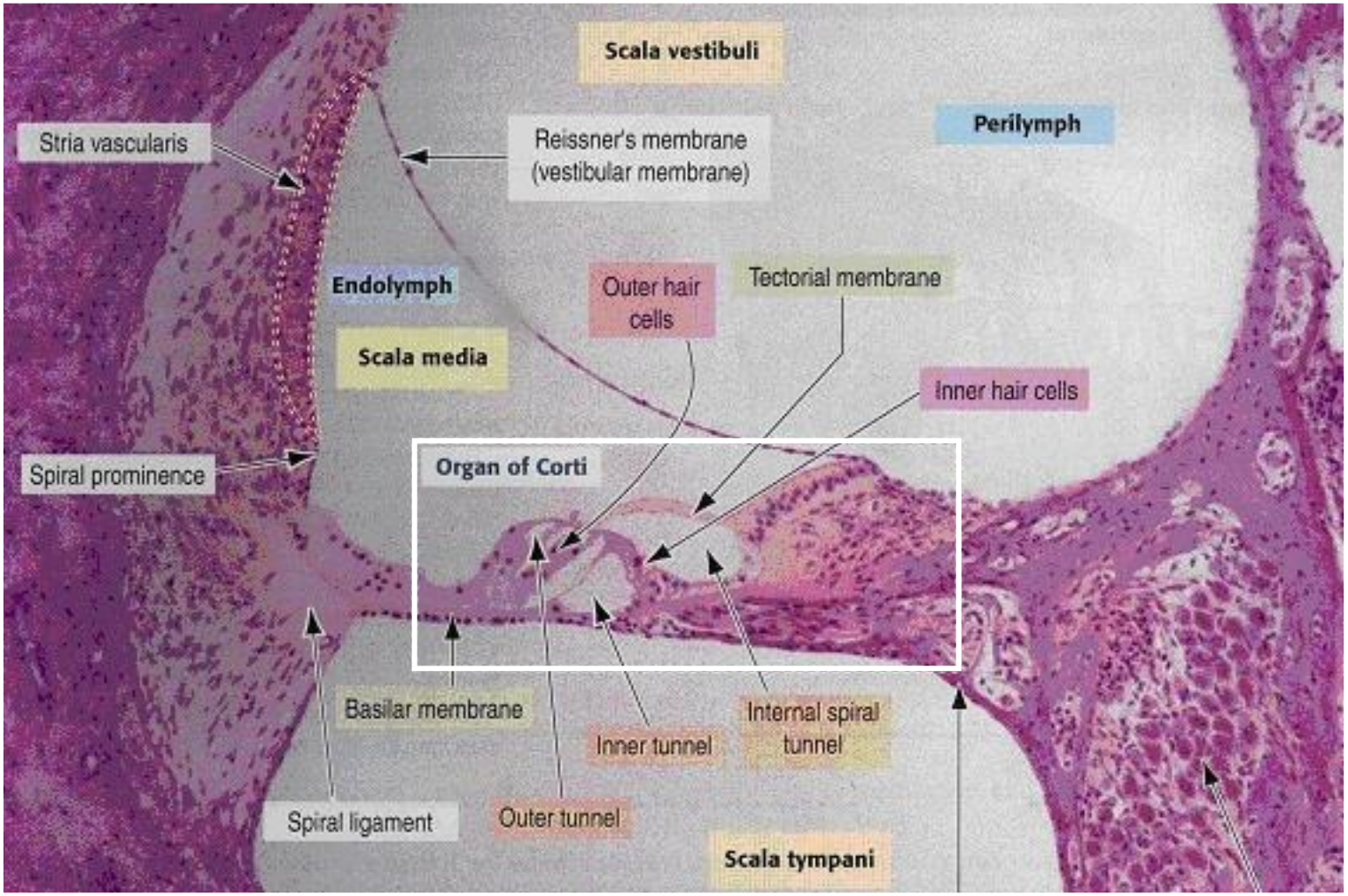

**Stria vascularis**
- vascularized epithelia
- responsible for the composition of endolymph?

**Tectorial membrane**
- product of the cells of spiral limbus
- rich for glycoproteins
- přes vrcholky smyslových buněk organ of Corti

**Basilar membrane**
- between lig. spirale and bony lamina spiralis
- supports the cells of organ of Corti
- made of fibrils of keratin-like proteins

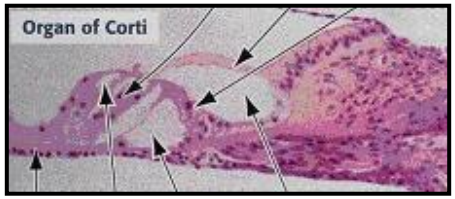

Scala media = Ductus cochlearis
20 µm

# Internal ear – Organ of Corti - 1




Ganglion spirale


Inner hair cells
Outer hair cells
20 µm




# Internal ear – Organ of Corti - 2

## Secondary receptor cells

- hearing hairs – stereocilia
- in contact with tectorial membrane
- bases wraped by dendrites of bipolar cells of ganglion spirale

**Outer hair cells**
- 3-5 rows, ~12 000, no axonema

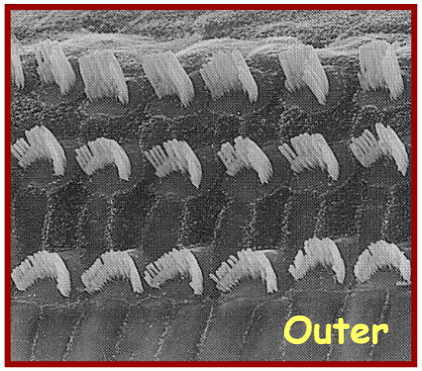
**Inner hair cells**
- 1 row, ~3 500, no axon.

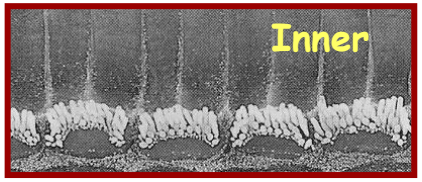
## Supporting cells

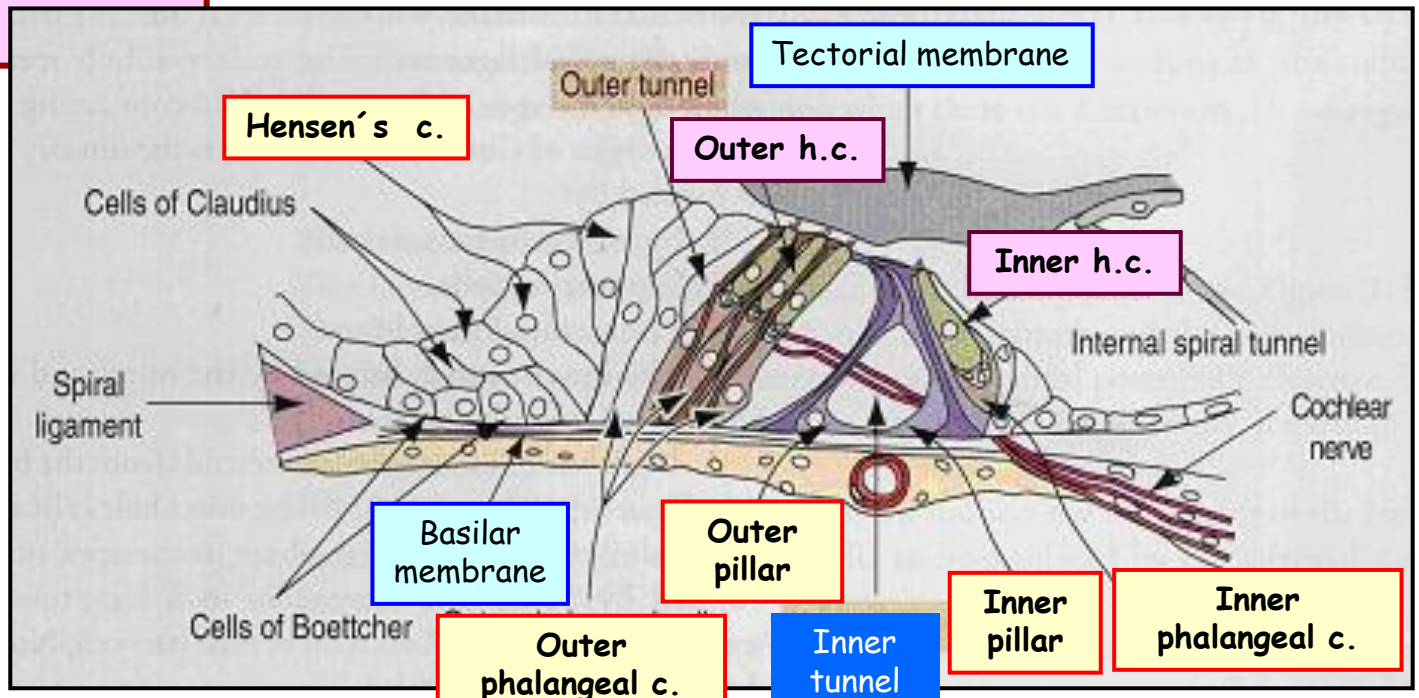
**Hensen´s cells**
**Outer phalangeal cells**
- support to hair cells, which run through the spaces between ph.

**Outer pillar of Corti**
**Outer pillar of Corti**
**Inner phalangeal cells**
- same as inner ph. cells

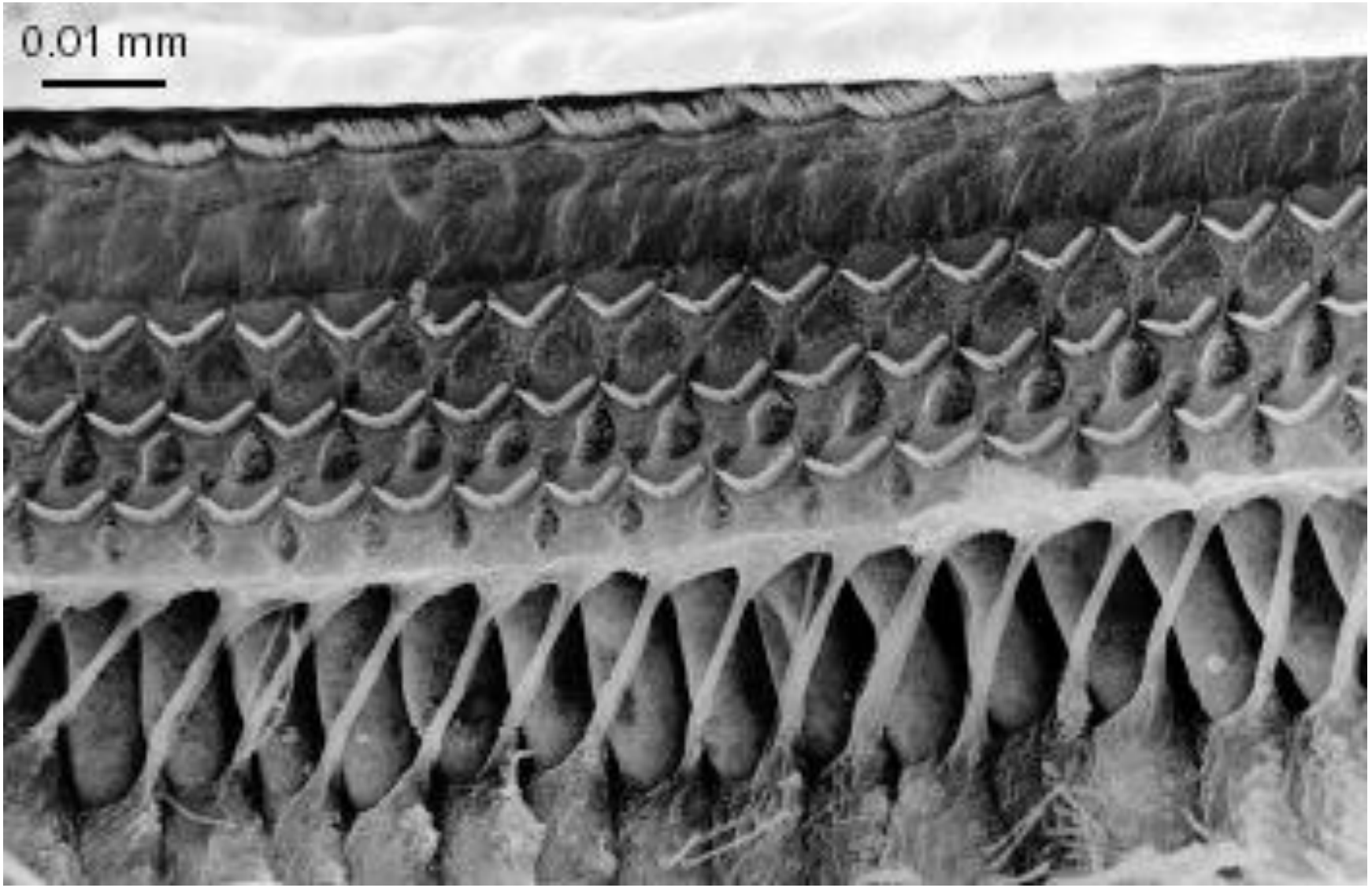
**Border cells**



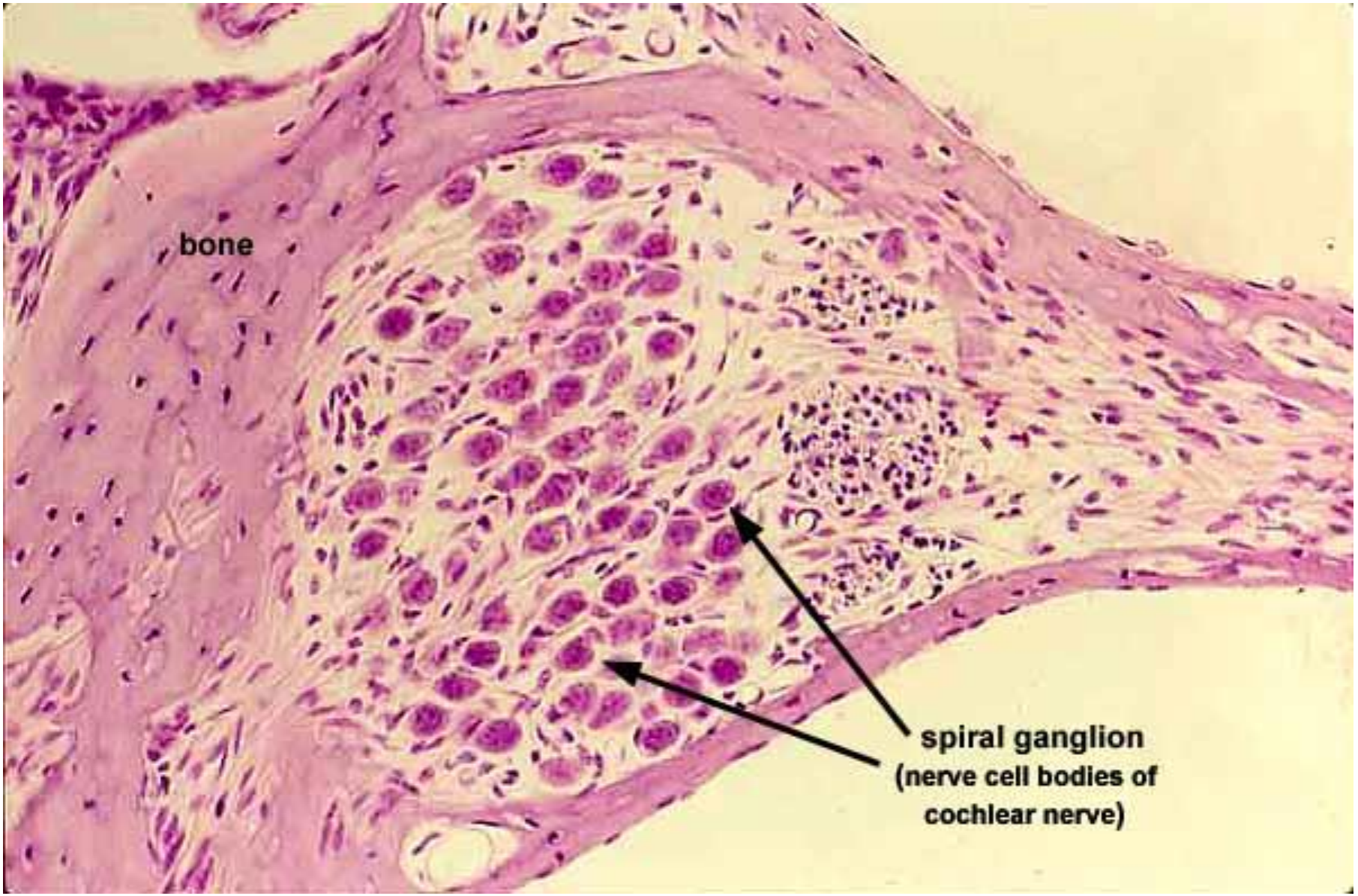



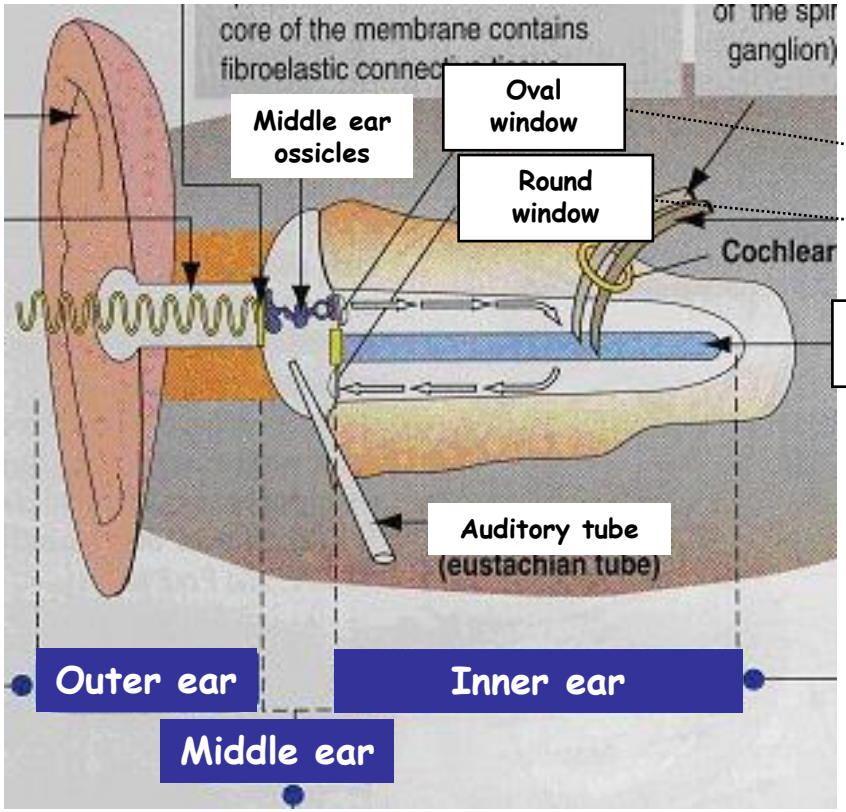
# Hair and phalangeal cells

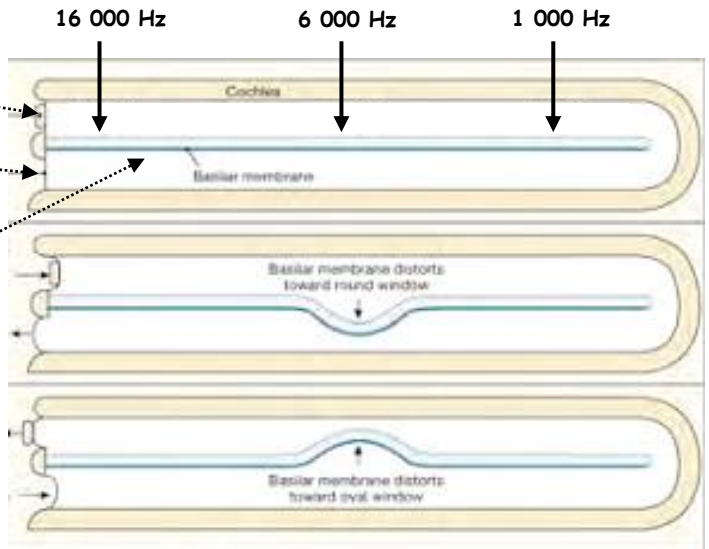


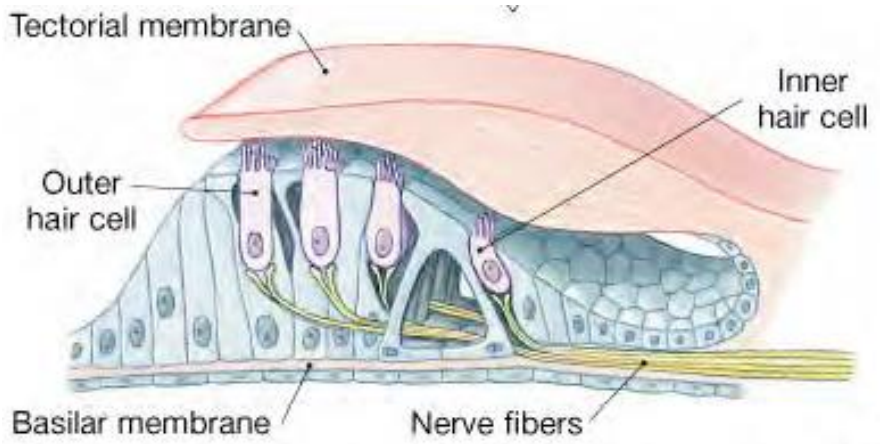
# Spiral ganglion



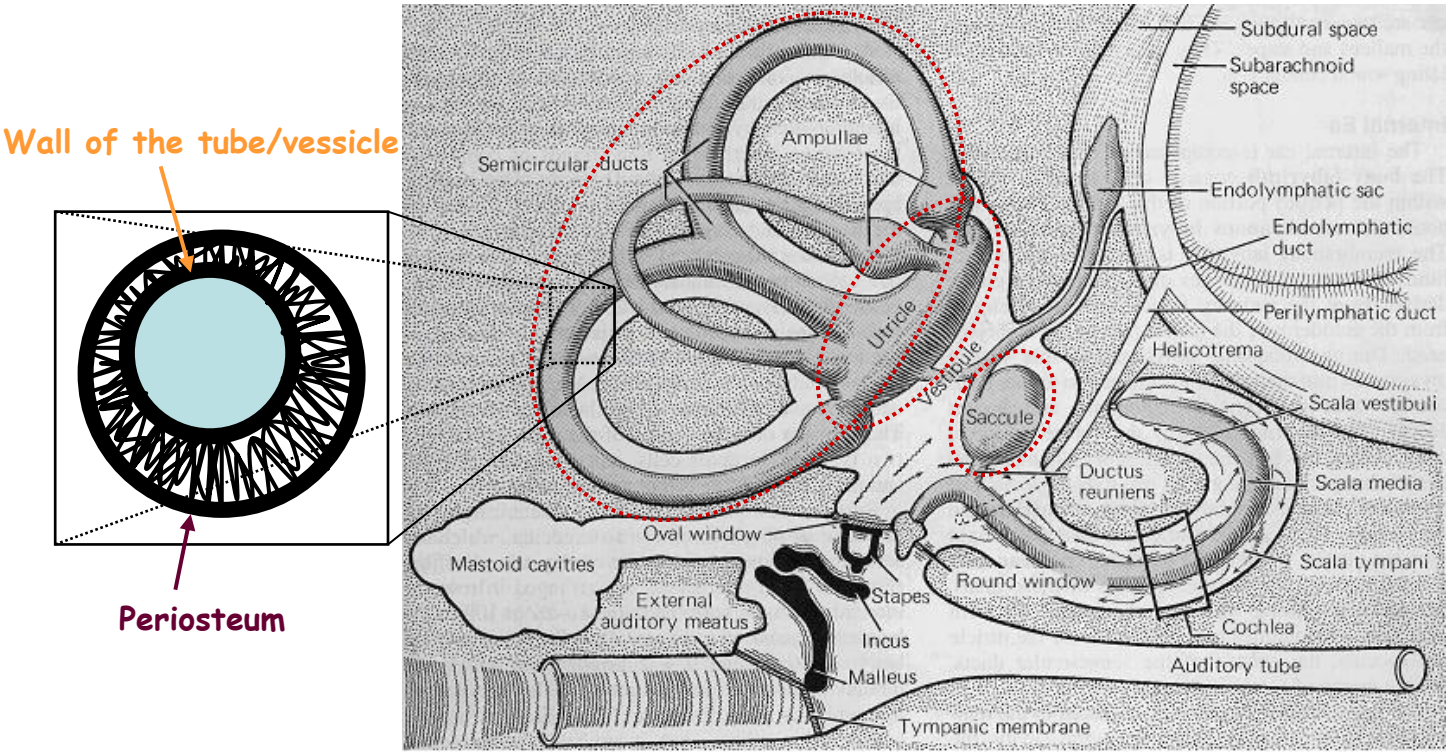
# Inner ear – Principle of hearing



# Inner ear – Statokinetic / Vestibular organ - 1




**Uniform composition of the wall** (vessicles and tubes)
Thin layer of connective tissue + single-layer squamous/cuboidal epithelium.

**Unifying concept of the composition of sensing elements**
(vessicles – **maculae**; tubes – **cristae ampullares**)
Thickening of the wall with neuroepithelial cells inervated by branches of n. vestibularis.

# Inner ear – Statokinetic / Vestibular organ - 2

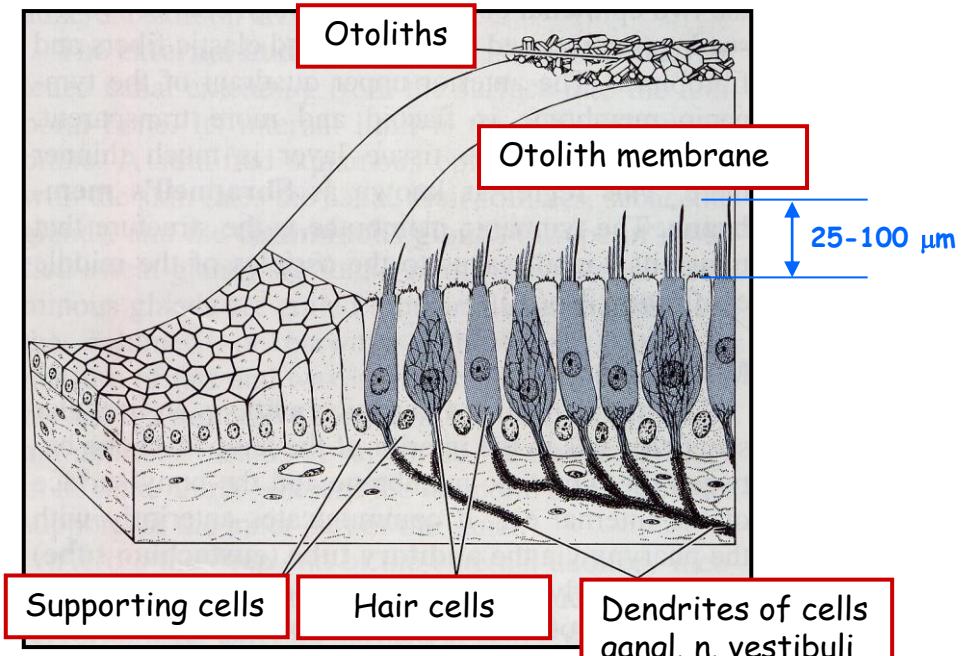
## Sensing of static equilibrium (maculae = static spots)

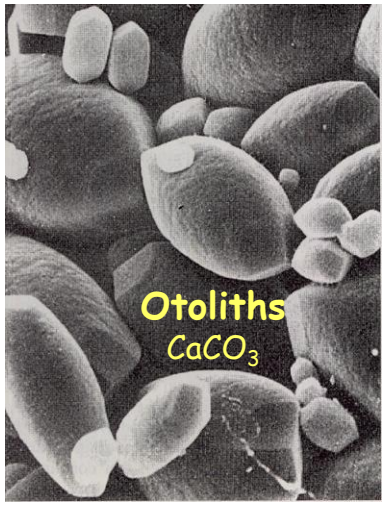
Deviation from the gravity force
(gravity force of otoliths)
max. pressure – max. pull

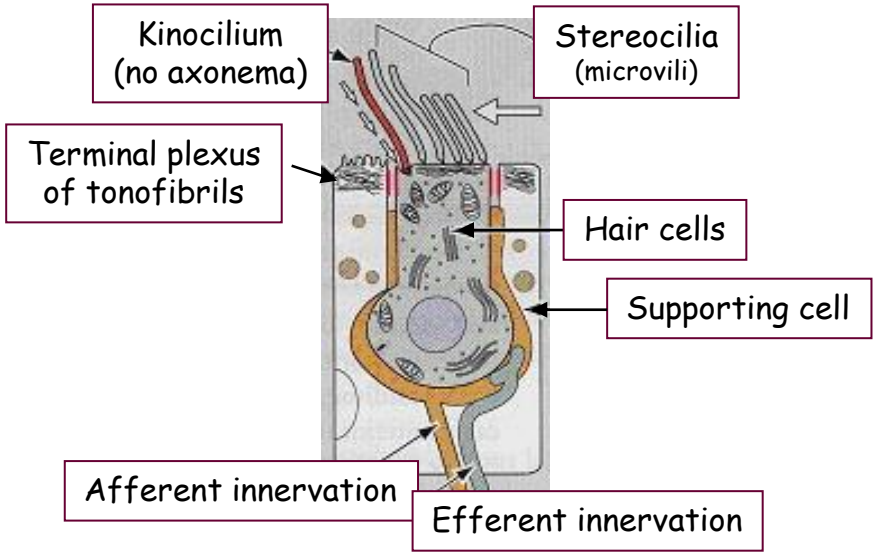
**Position of maculae**

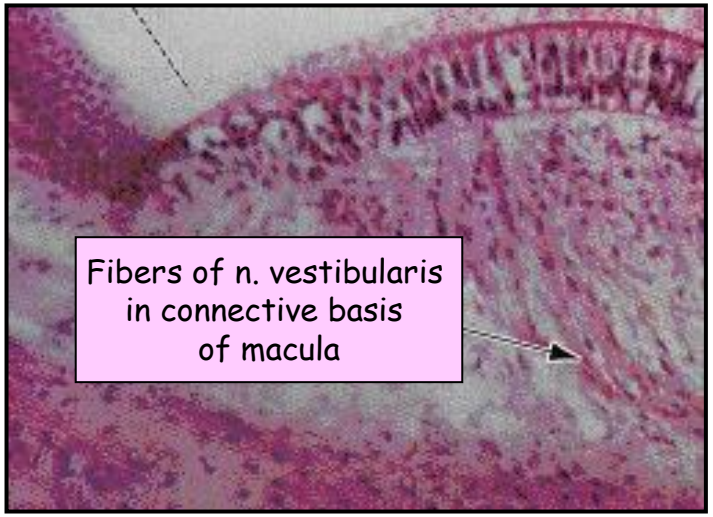
**Saccule**
bottom

**Utricle**
lateral wall



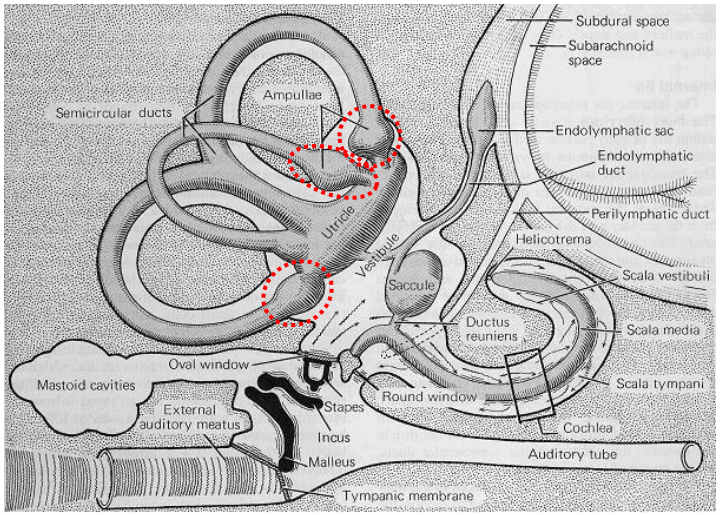



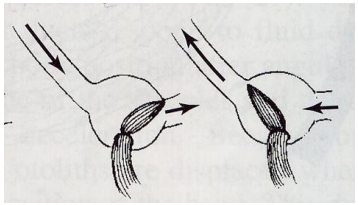



# Inner ear – Statokinetic / Vestibular organ - 3

## Sensing of dynamic equilibrium (cristae ampulares)

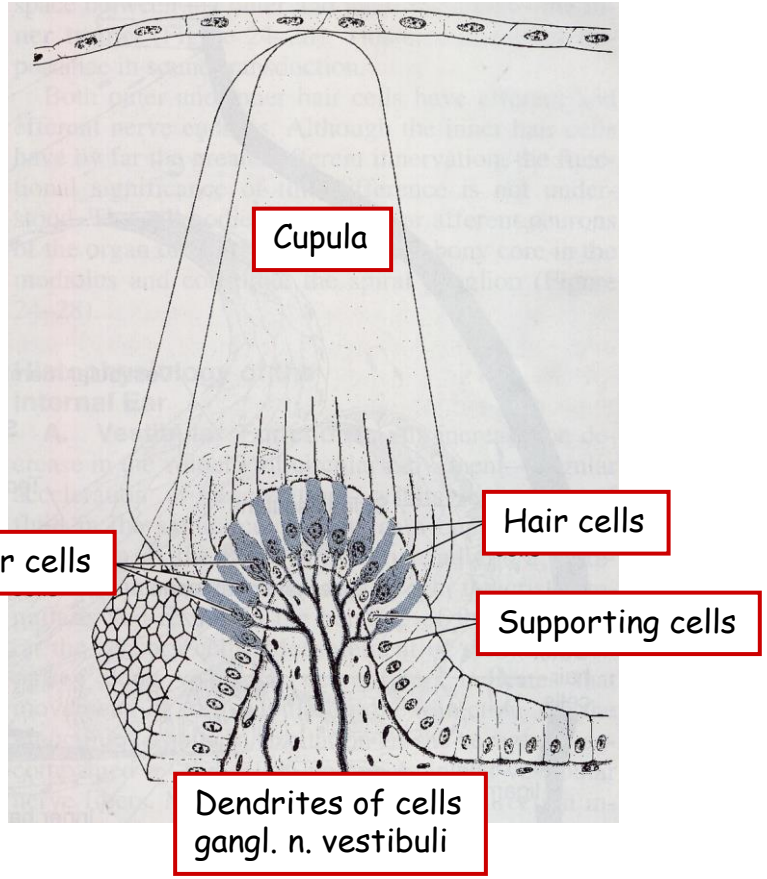


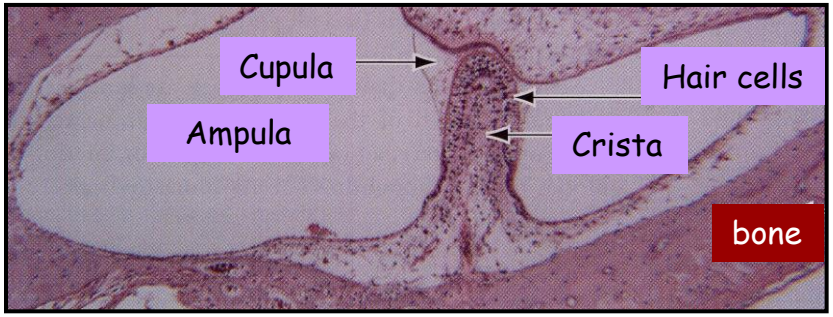

**Reaction on acceleration/deceleration**
(movement of endolymph)



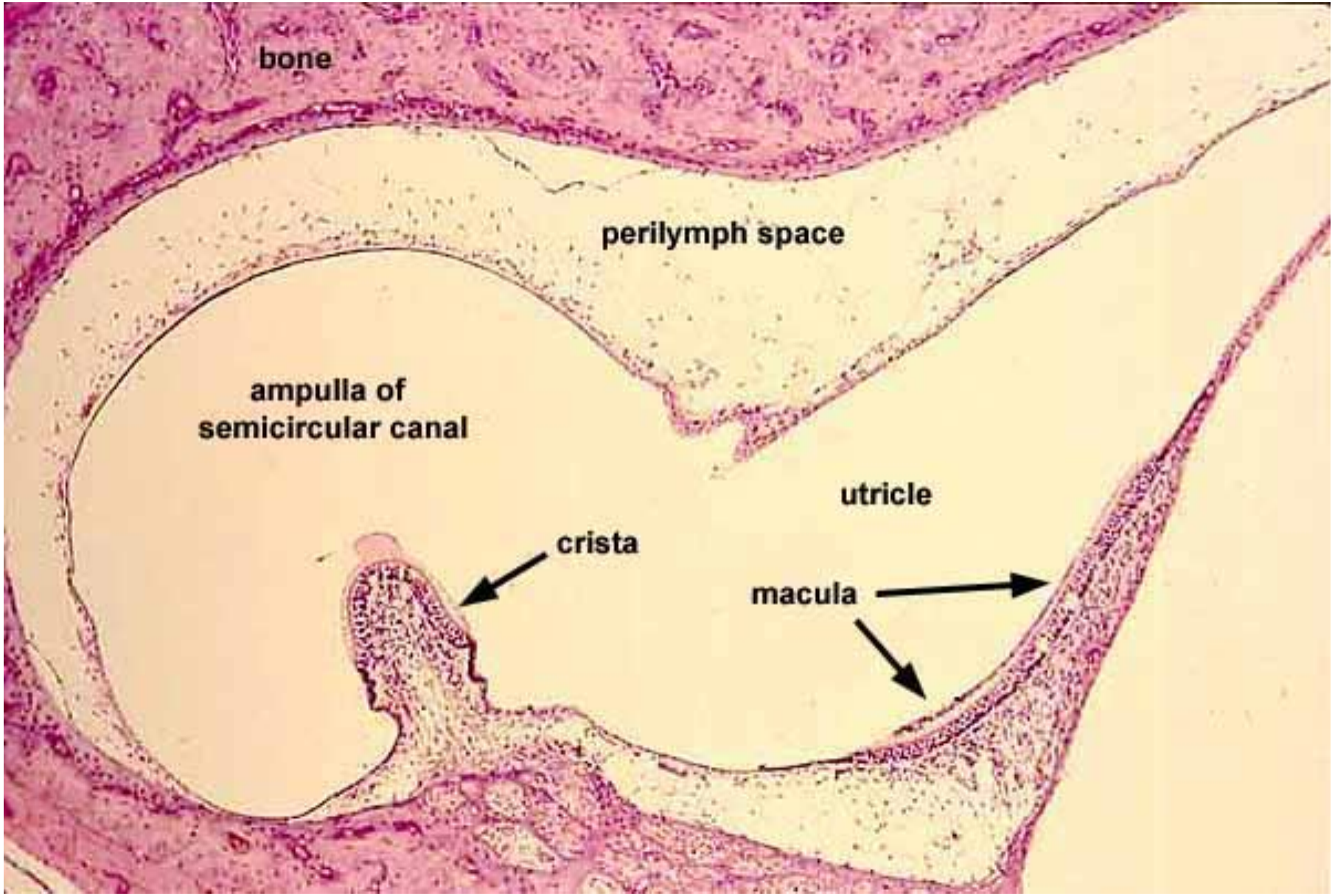
**Position of cristae amplulares**

- in ampules of semicircular ducts
- ridges perpendicular to axis of SDs

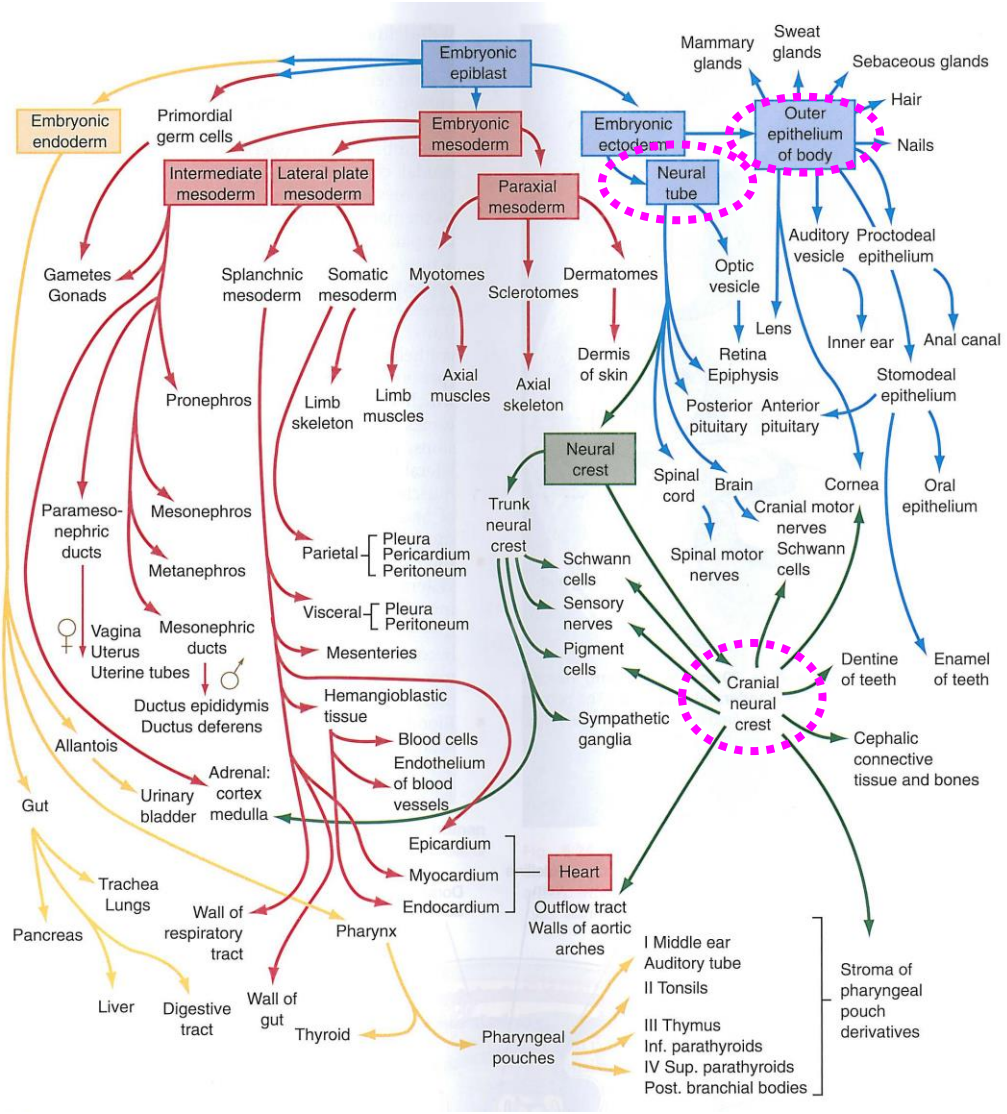


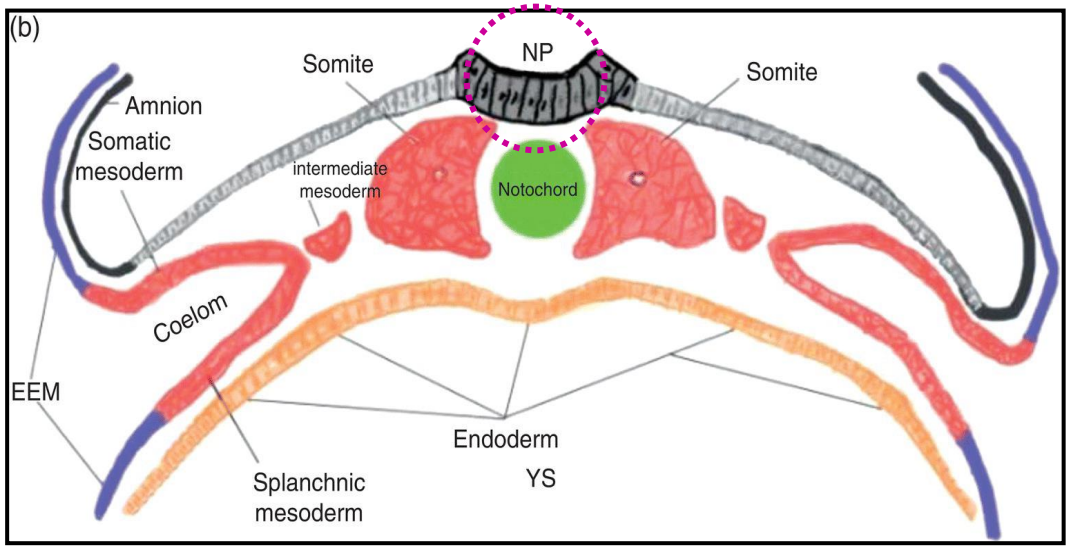
# Membranous labyrinth

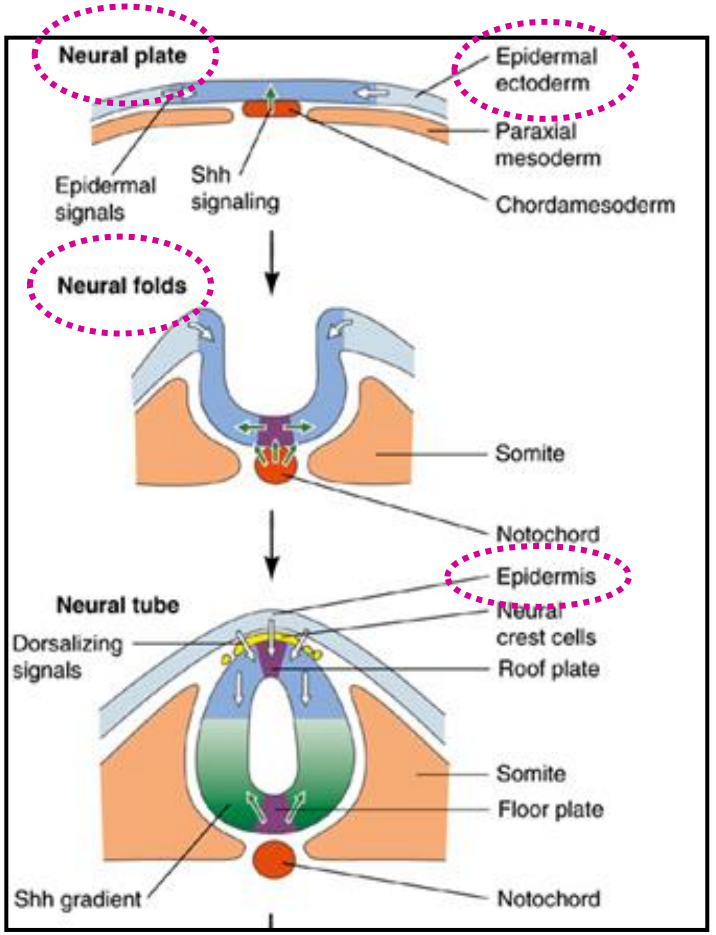


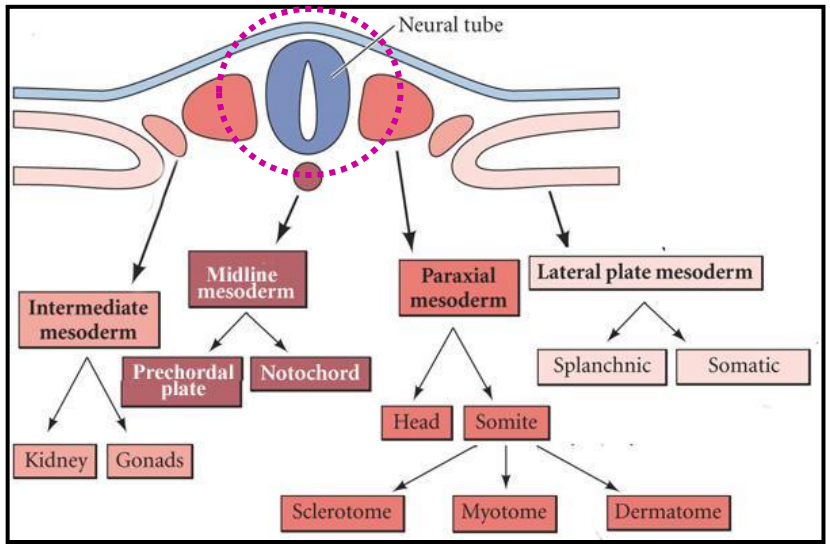
# Development of sense organs – Overall picture

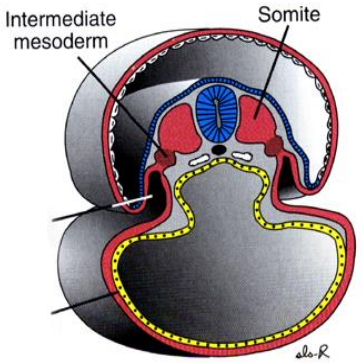


# Sense organs – Reminder – Neural tube

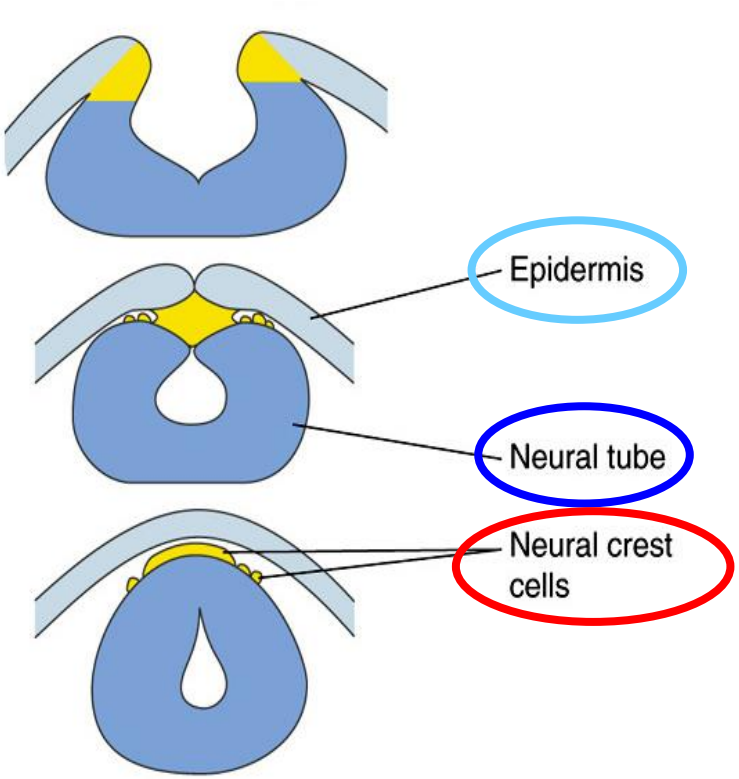


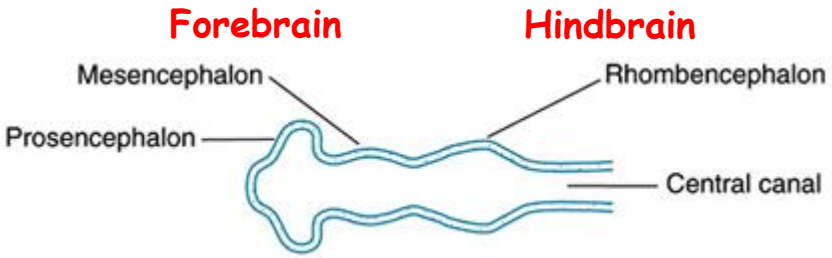



# Sense organs – Reminder – Neural crest



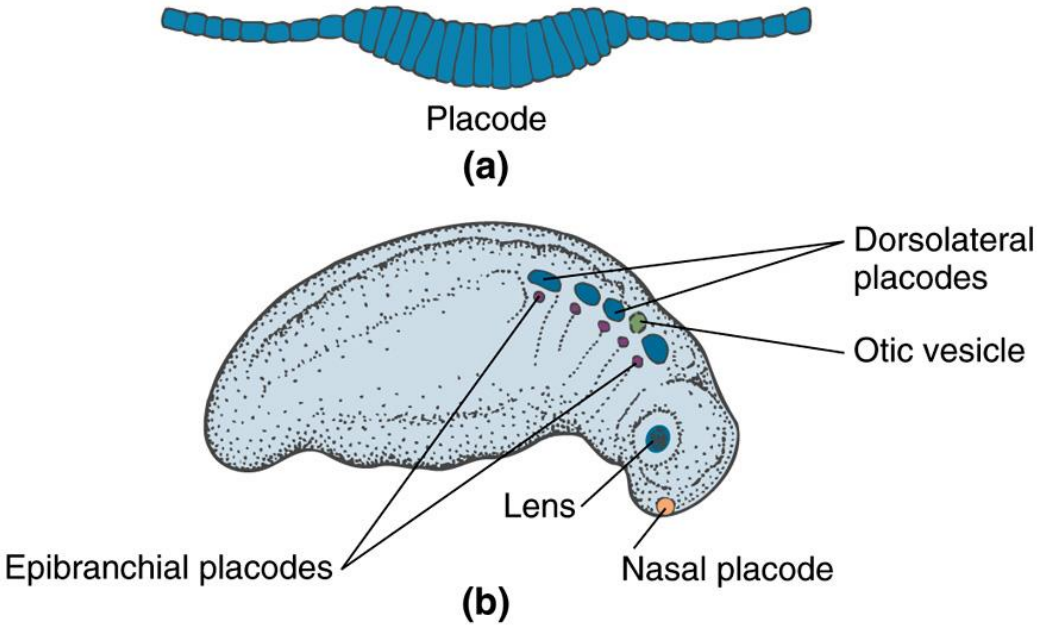

Arise from both
dorsal epidermis and neural plate

# Sense organs – Cranial neural tube + Placodes




**Brain after 4 weeks of development**

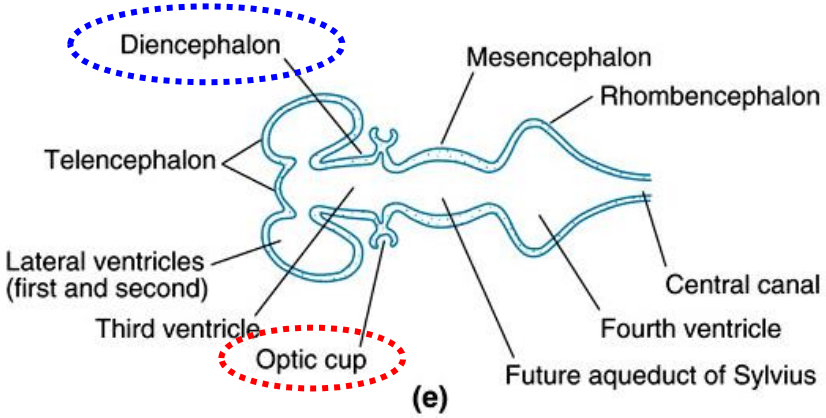
**Placodes:** **patches of dense culumnar epithelium in the epidermis covering the head – their formation is induced by underlying brain and mesenchymal tissue – develop in week 4**




**Dorsolateral placodes**
Contribute to:
- eye – lens placode
- ear – otic placode
- nose – nasal placode
- sensory ganglia

**Epibranchial placodes**
Develop into:
- sensory ganglia of cranial nerves (V, VII, IX, X)

# Sense organs – Eye development 1



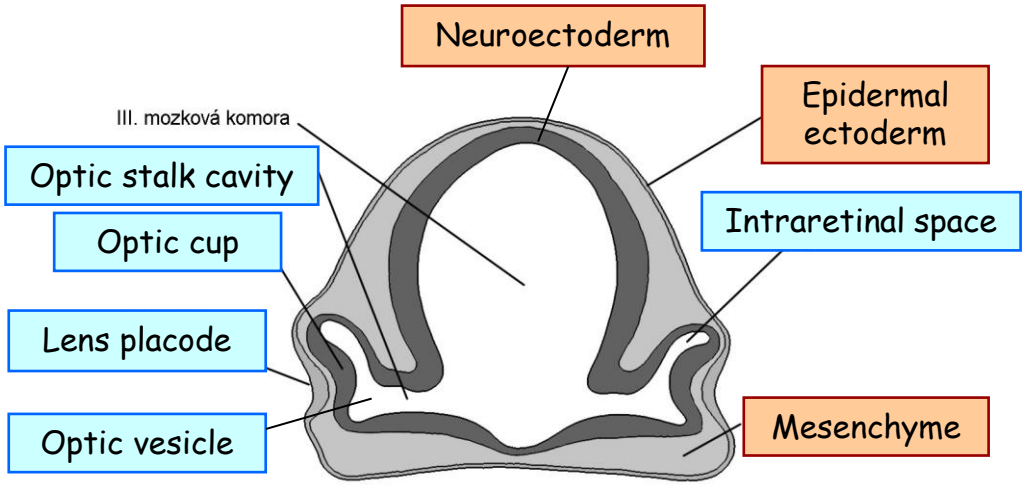

**Brain after 5 weeks of development**

Neural plate ectoderm -> prosencephalon (forebrain) **eye fields** ->

-> neural plate growth carries eye field region forward ->

-> eye field invaginates forming **optic grooves (sulci)**

# Sense organs – Eye development 2




Prosencephalon – transversal section – about 30 days

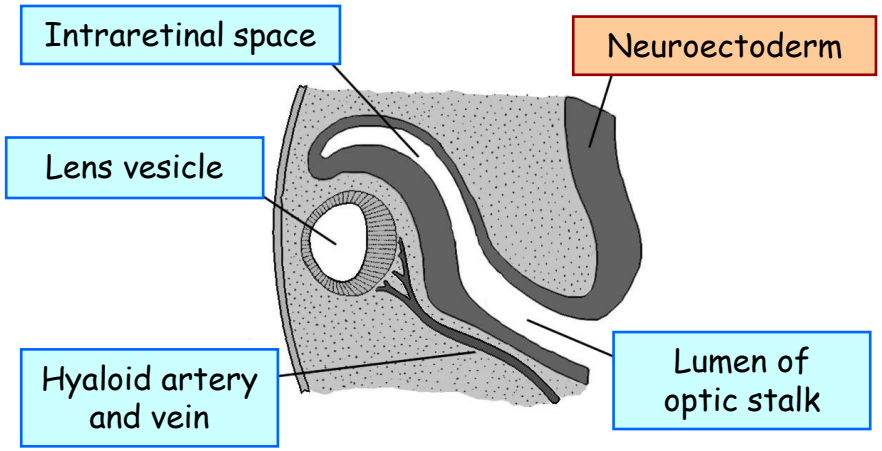
**Lens placode:** the ectoderm invaginates in response to signals from the optic cup underneath. It then pinches off as a lens vesicle. Cells elongate to fill the vesicle and start to synthesize crystallins.

**Optic cup:** forms from the neural tube by invagination. The opening (choroid fissure) closes forming a round optic cup, an extension of the brain.

**Optic stalk:** connection to the brain that is filled with neurons to form the optic nerve.

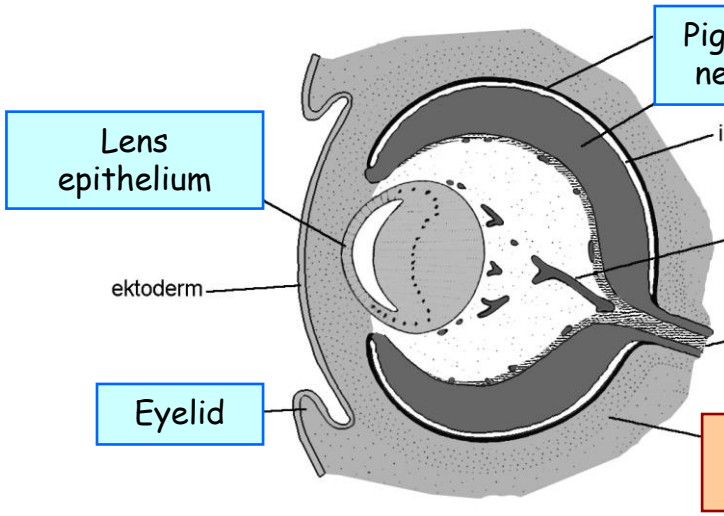
**Reciprocal interaction:** the lens induces the formation of the optic cup and the cup regulates formation of the lens.

# Sense organs – Eye development 3




Diencephalon – transversal section – 6 weeks

# Sense organs – Eye development 4

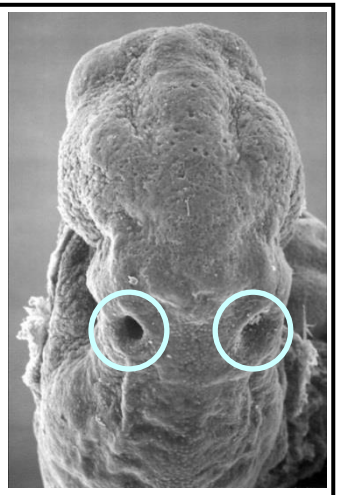



Histogenesis of retina ends in 8 month.

- m. ciliaris
- proc. ciliares
- stroma iridis
- choroid
- sclera
- vitreous

About 7 weeks

# Ear development – Inner ear 1

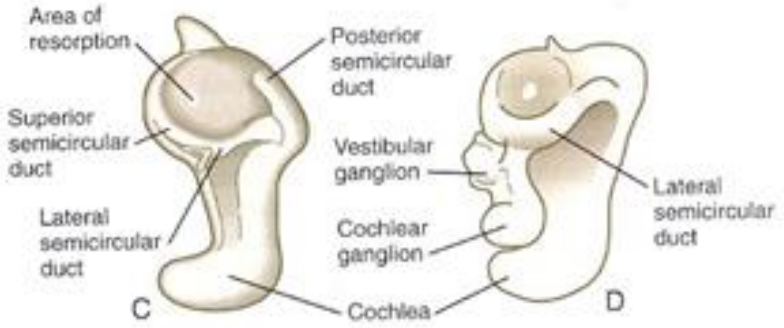


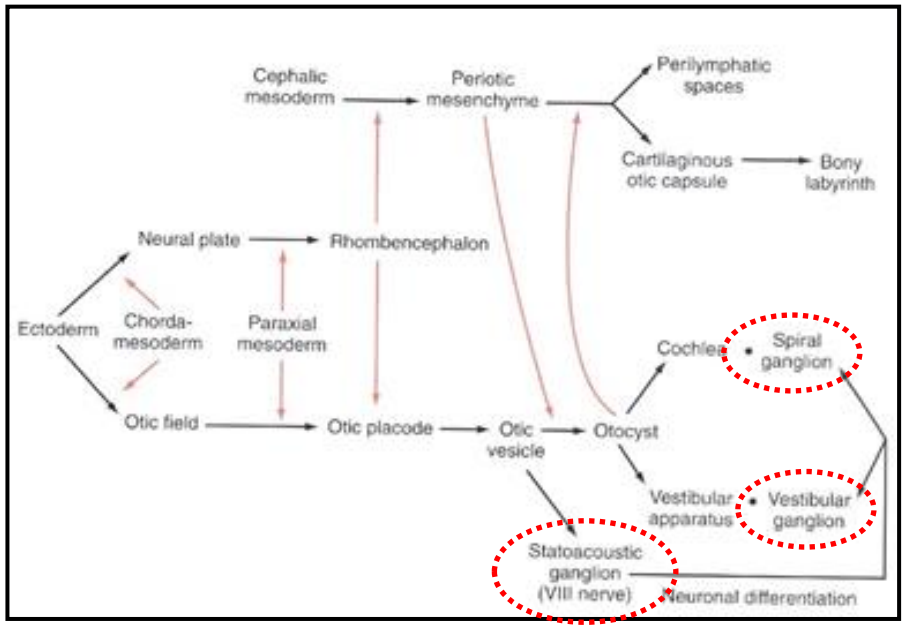



Rhombencephalon – transversal section

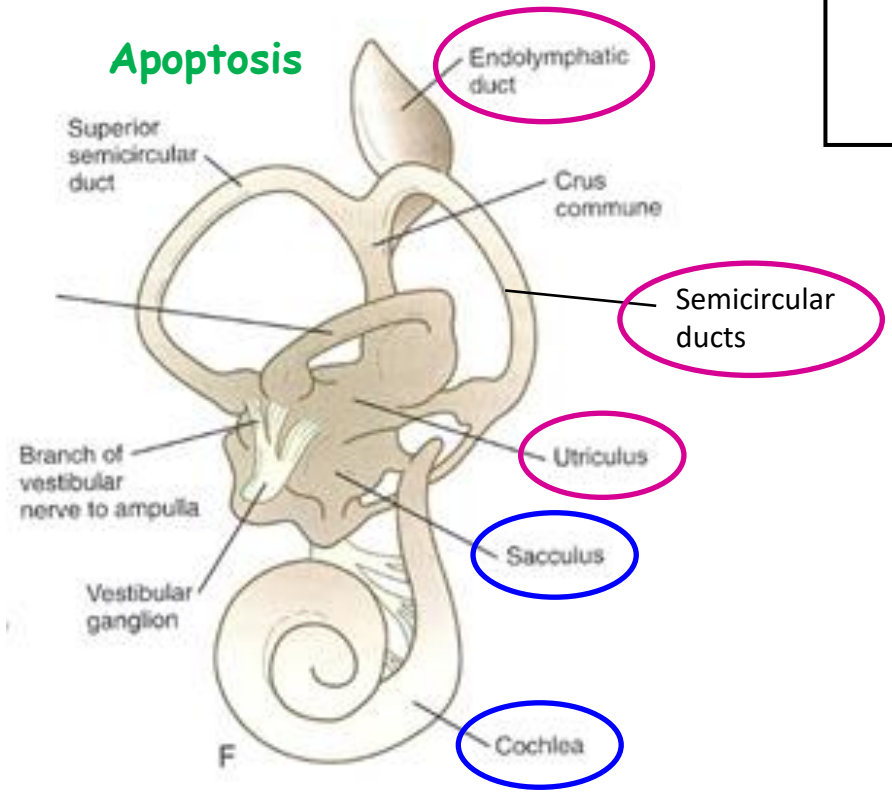
# Ear development – Inner ear 2

## Elongation



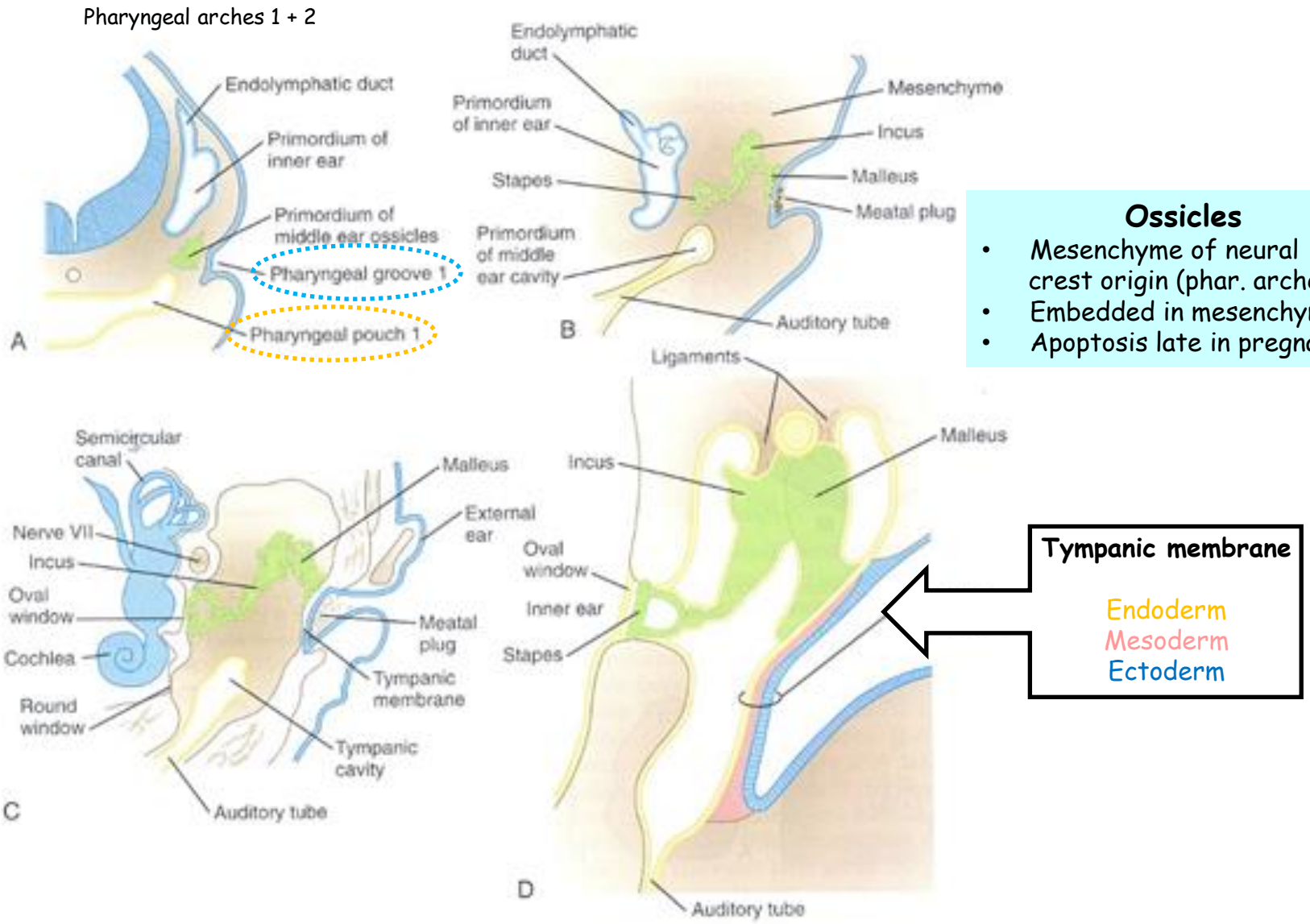

## Apoptosis




**Dorsal part**

**Ventral part**

# Ear development - Middle ear



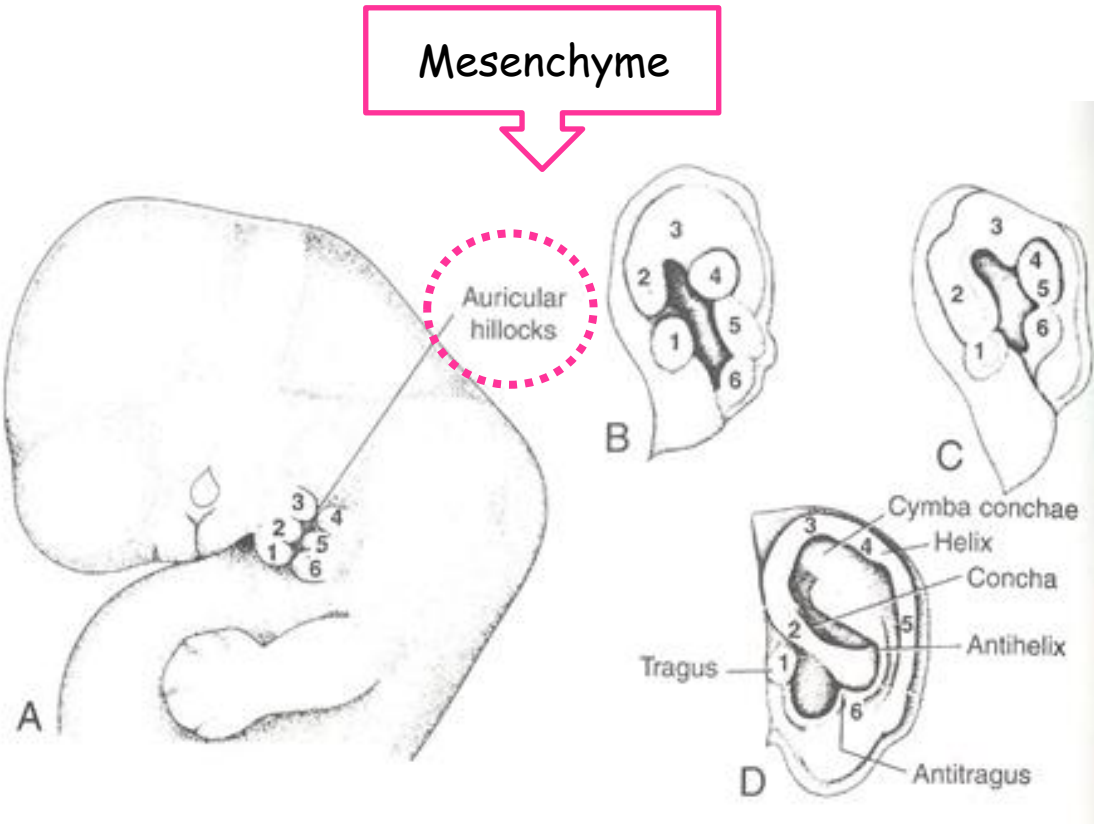

**Ossicles**

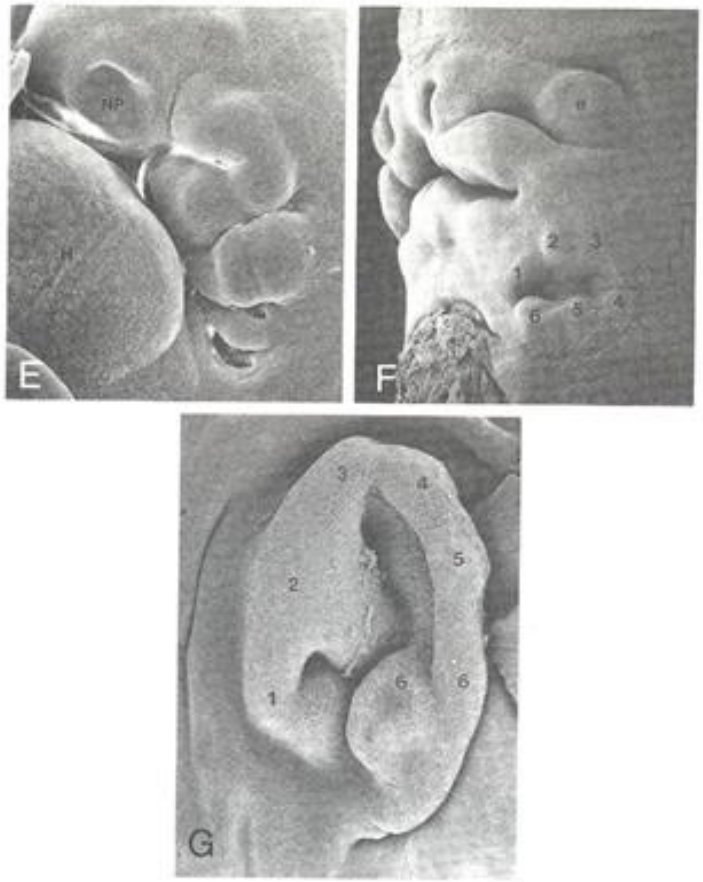
- Mesenchyme of neural crest origin (phar. arches 1+2)
- Embedded in mesenchyme
- Apoptosis late in pregnancy

**Tympanic membrane**

Endoderm
Mesoderm
Ectoderm

# Ear development – External ear




External auditory meatus - ectoderm

Thank you for your attention !