

Microscopic structure of the sense organs

Aleš Hampl

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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 intensity and colour reflected from objects

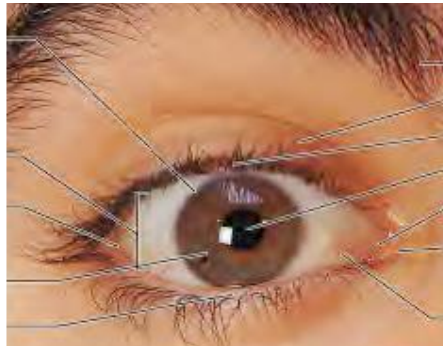
Eye ball

(three-layered structure)

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

Accessory structures

- eye lids
- conjunctiva
- lacrimal apparatus
- muscles



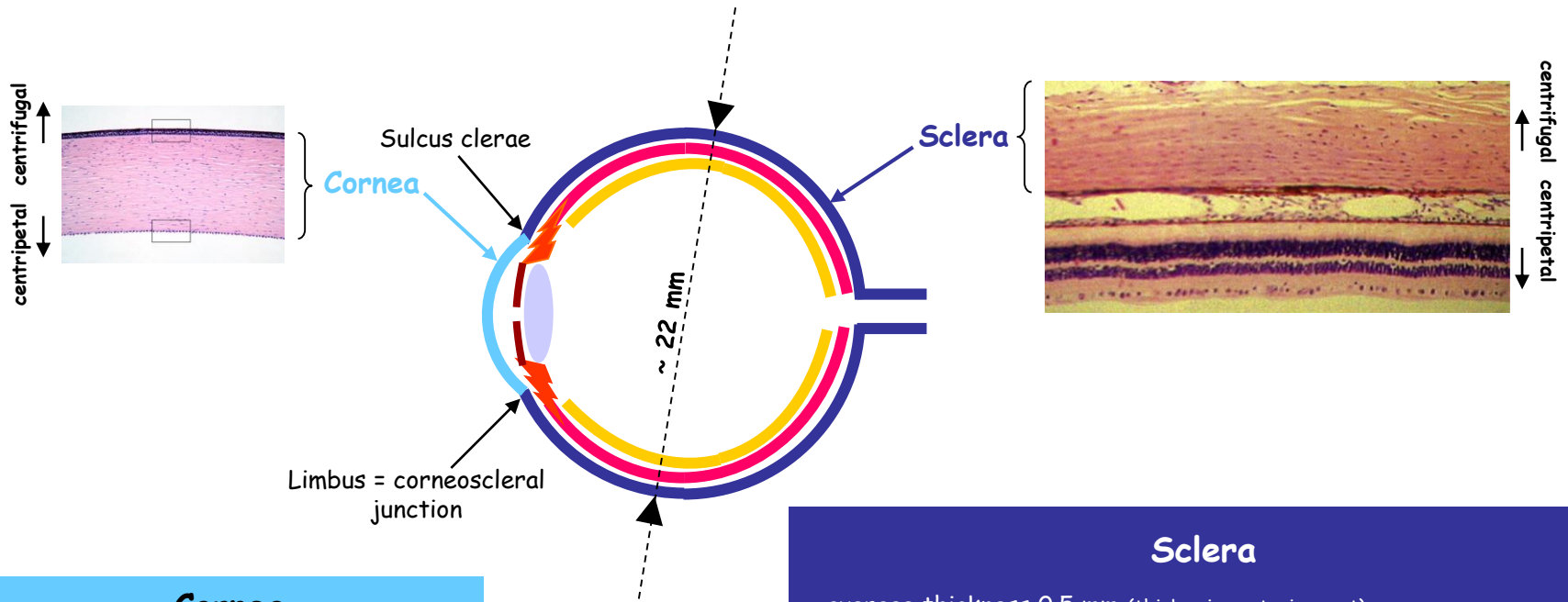
What do we expect from the eye ?

- 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 cushions..

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

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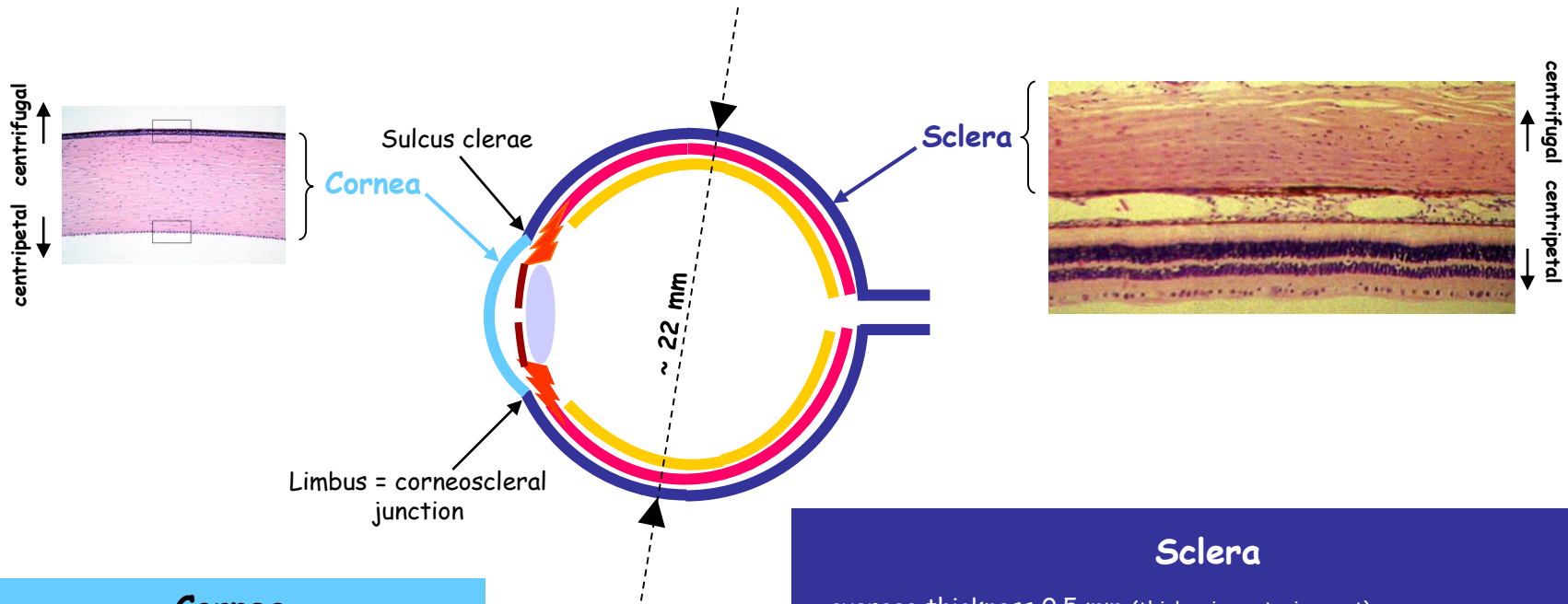
Sclera

- average thickness 0.5 mm (thicker in posterior part)
- bundles of flat collagen I fibers (intertwining 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 eye
- **lamina suprachoroidea** - connection to choroid
(loose connective tissue with melanocytes, fibroblasts and elastic fibers)

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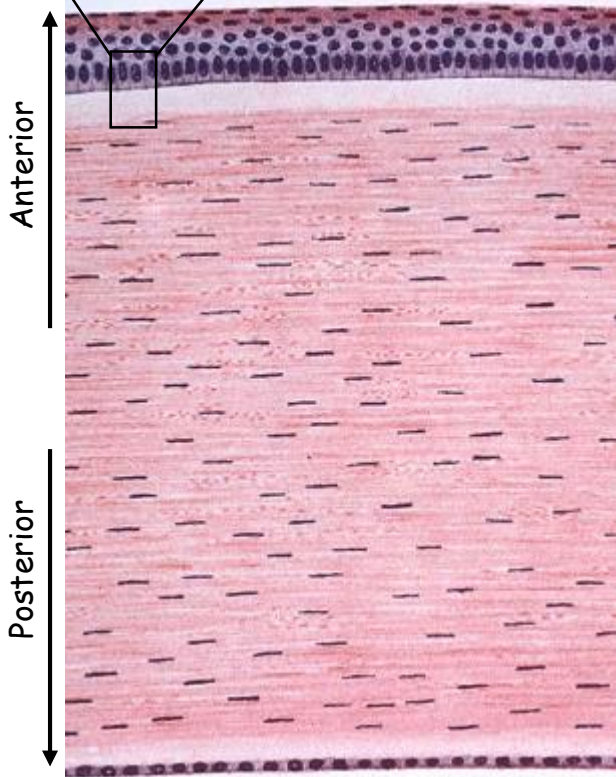
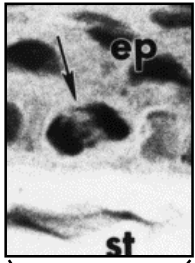
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Cornea

(transversal section)



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

Corneal epithelium

Bowman's membrane

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

Substantia propria corneae = STROMA

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

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

Descemet's membrane
Corneal endothelium

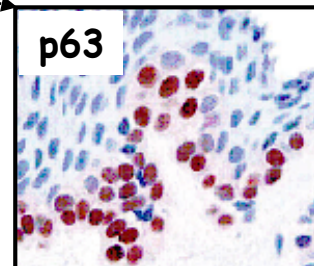
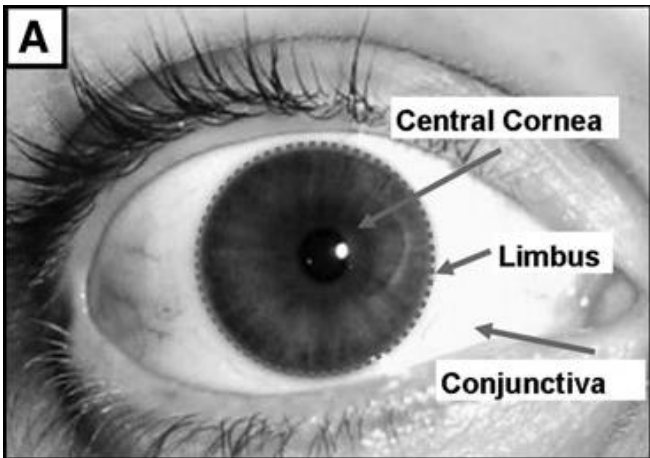
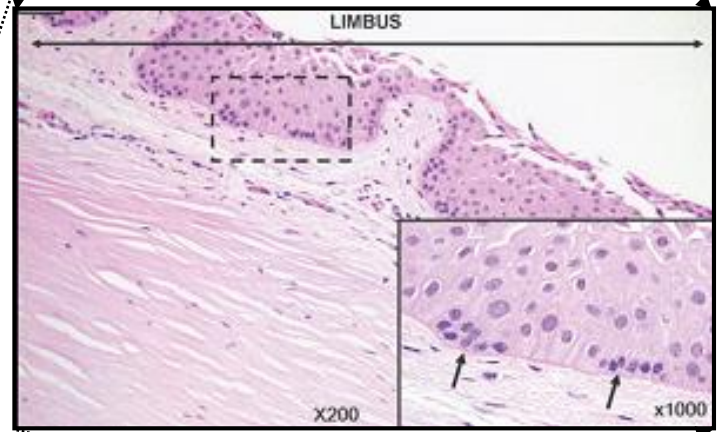
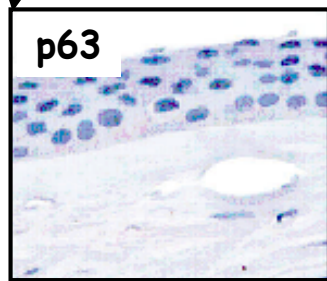
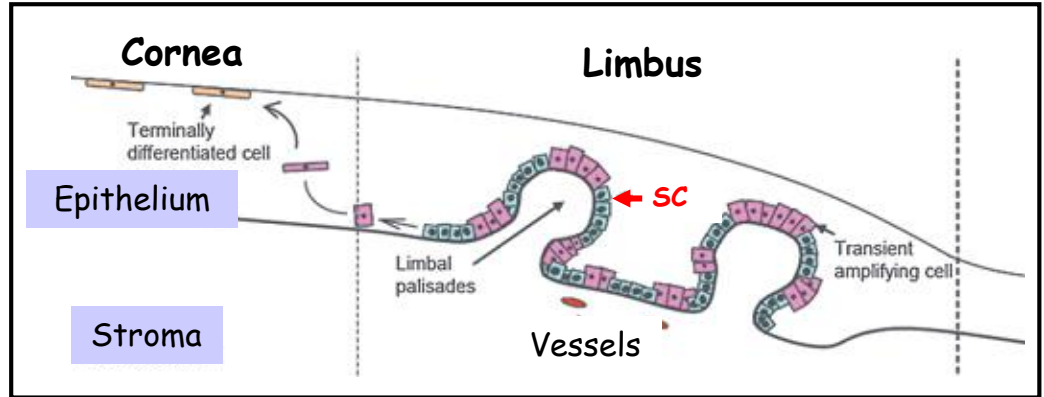
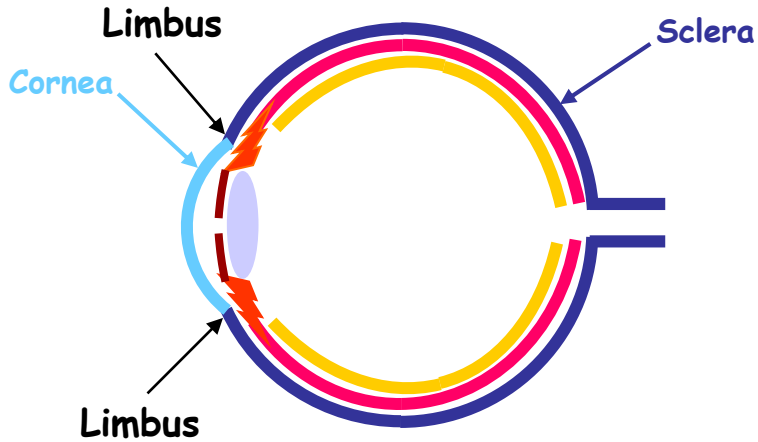
- simple + squamous
- active in transport to maintain cornea in a proper state
- continues on the frontal part of iris (via spongium anguli iridocornealis)

Ability to regenerate

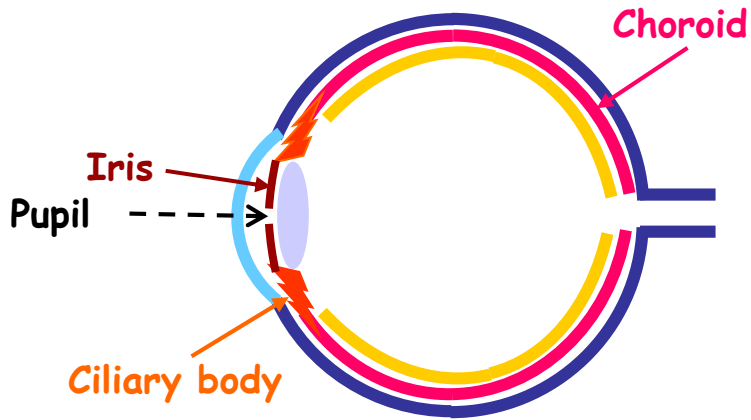
Limbus - corneoscleral junction

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 Choroidea	+	Ciliary body Corpus ciliare	+	Iris Iris	=	Tunica media T. vasculosa
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Choroid = 4-layered structure

Lamina suprachoroidea

- loose connective tissue
- rich for pigment cells - melanocytes

Lamina vasculosa

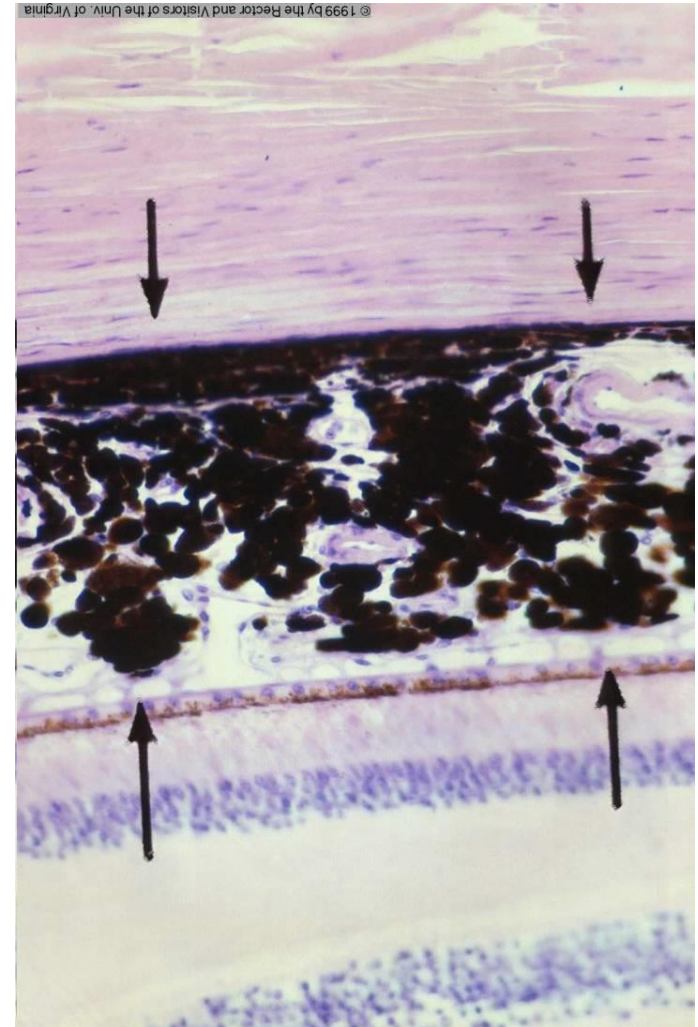
- loose connective tissue
- rich for pigment cells - melanocytes
- contains larger vessels and nerves

Lamina choriocapillaris

- loose connective tissue
- network of small vessels

Lamina vitrea = L. basalis = Bruch's membrane

- fibers of collagen and elastin
- overall thickness about 3-4 μm
- links together basal laminae of Lamina choriocapillaris of choroid and pigmented epithelium of retina



Choroid

Sclera

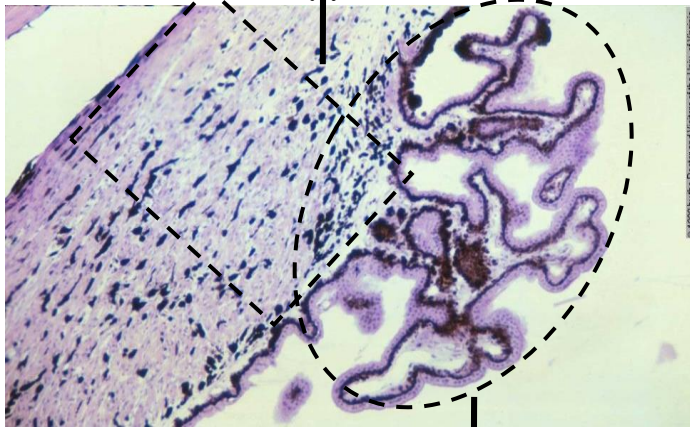
Retina

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*)



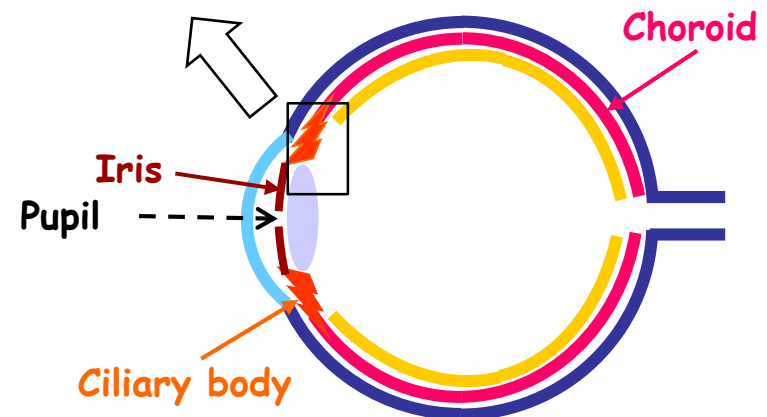
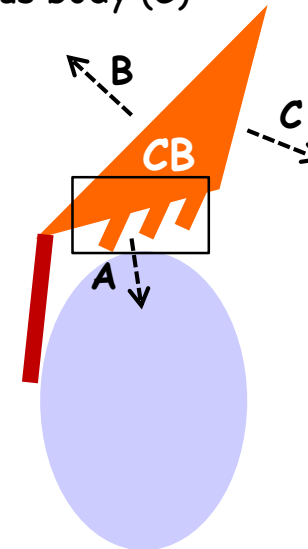
Processes of CB (Processus ciliares)

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

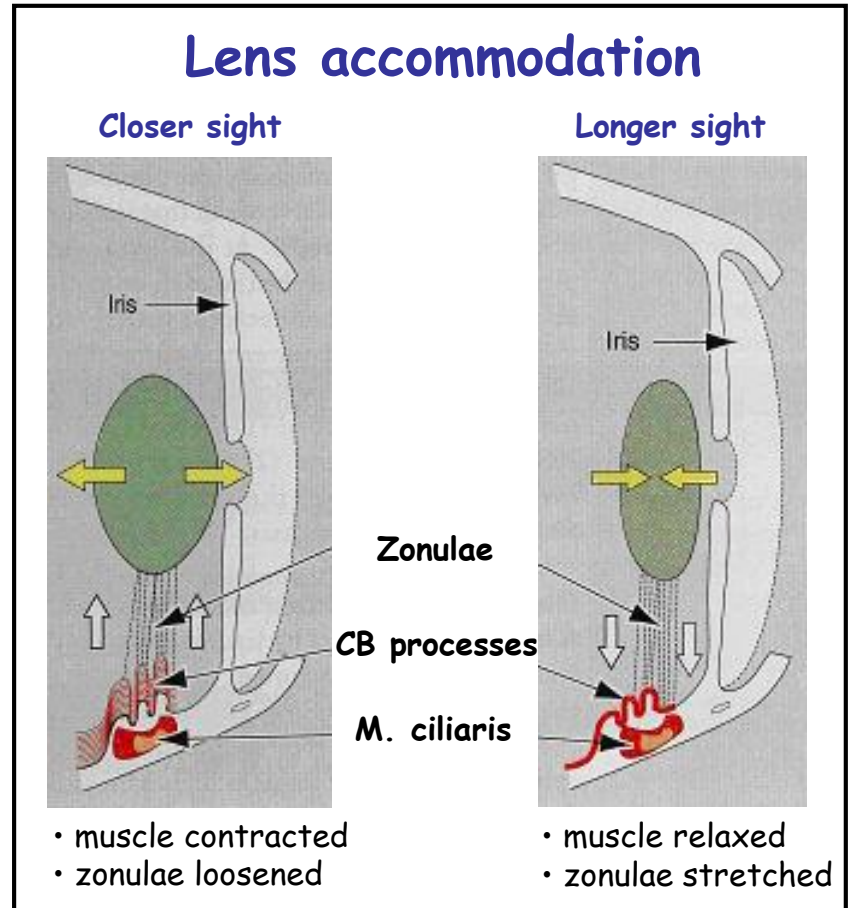
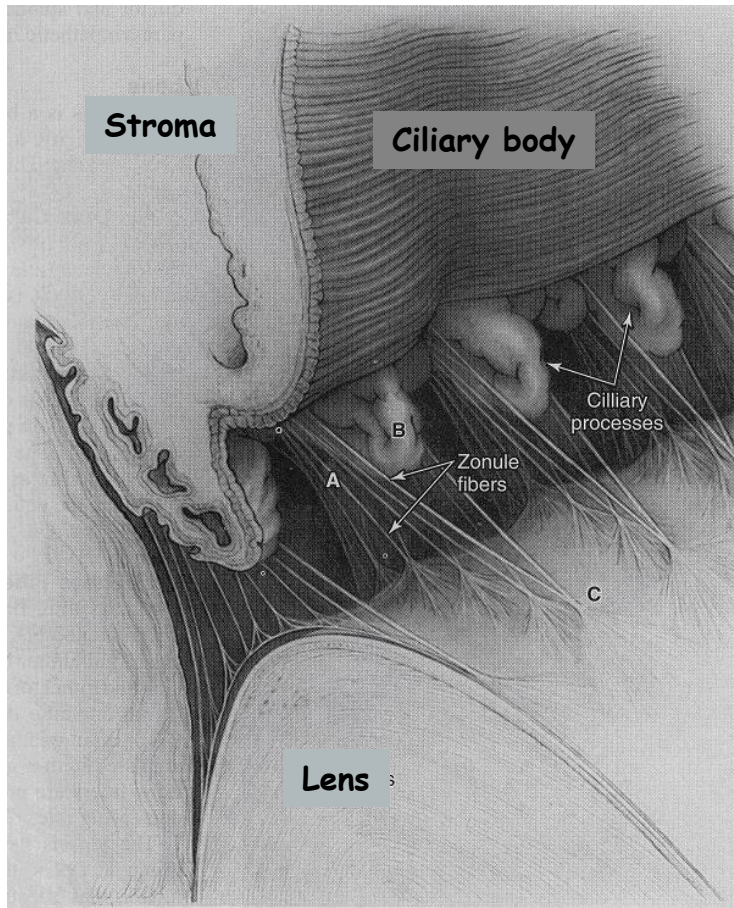
Triangular on crosssection

Connects to:

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

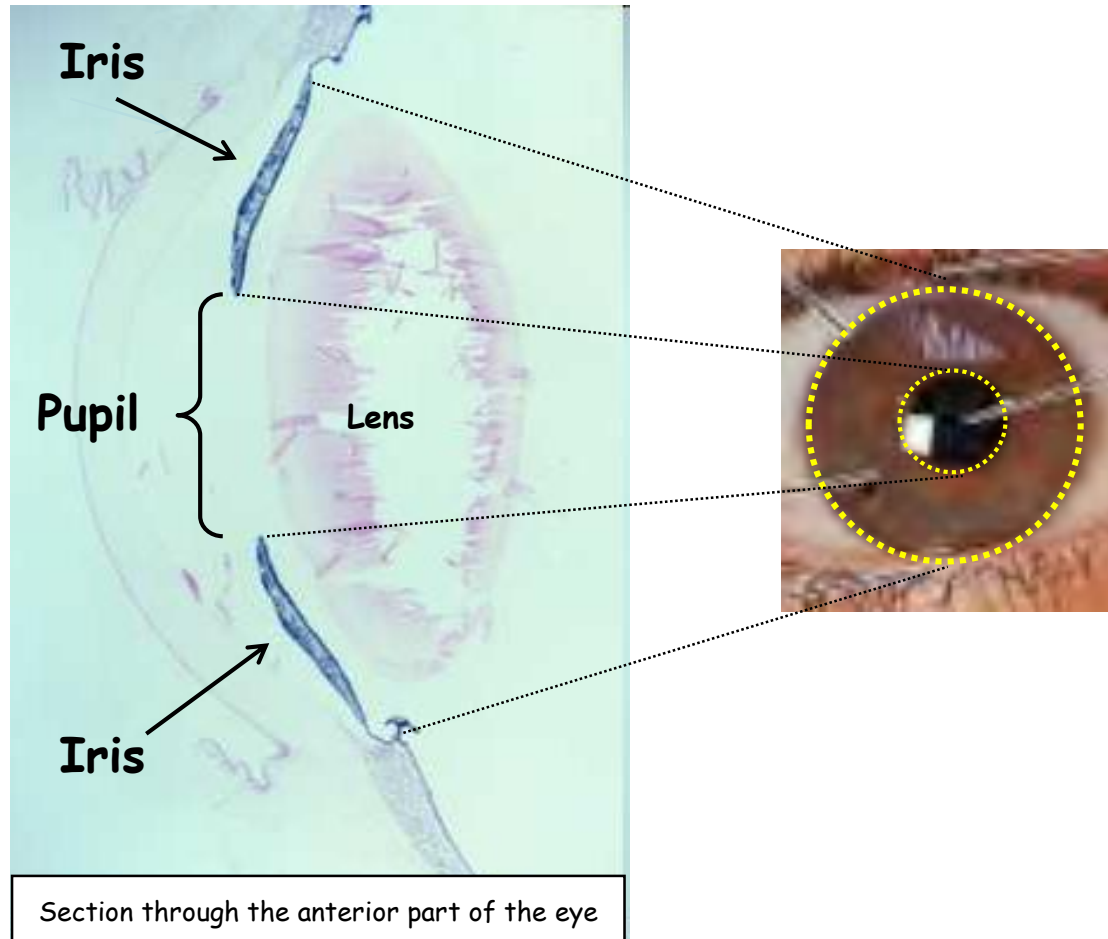


Ciliary body

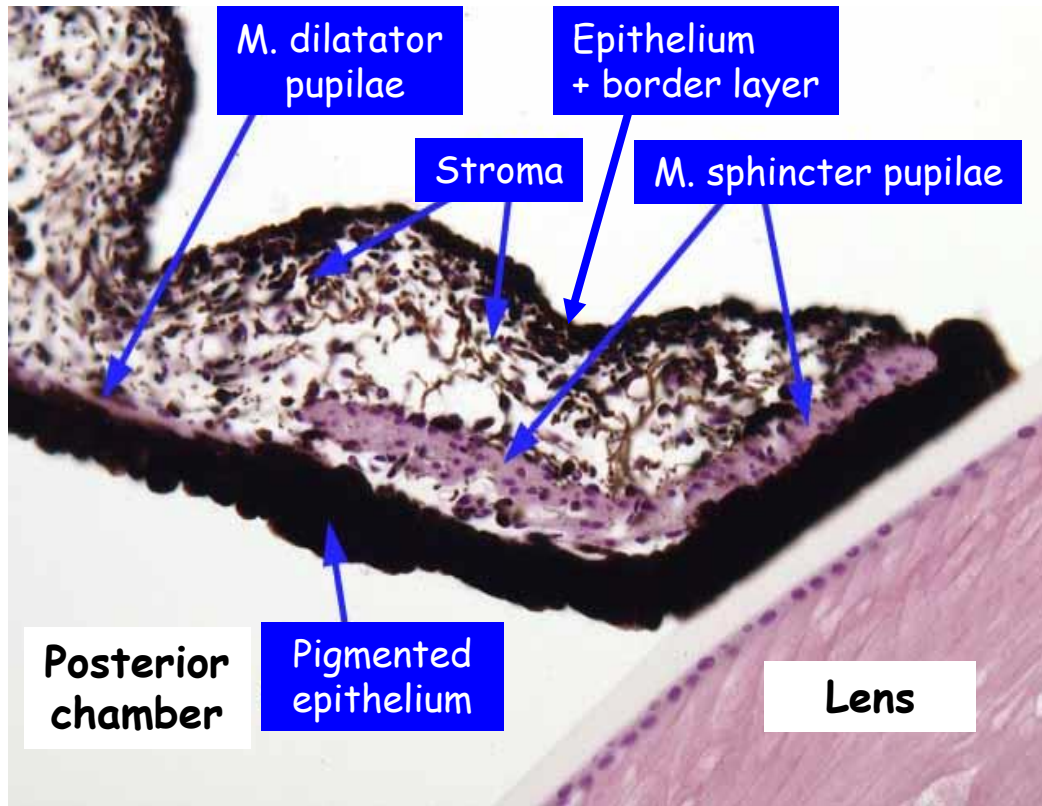


Iris - 1

Anterior continuation of the choroid.
Partially covers the lens.



Iris - 2



Iris = 4-layered structure

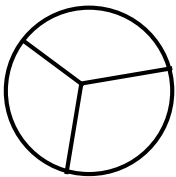
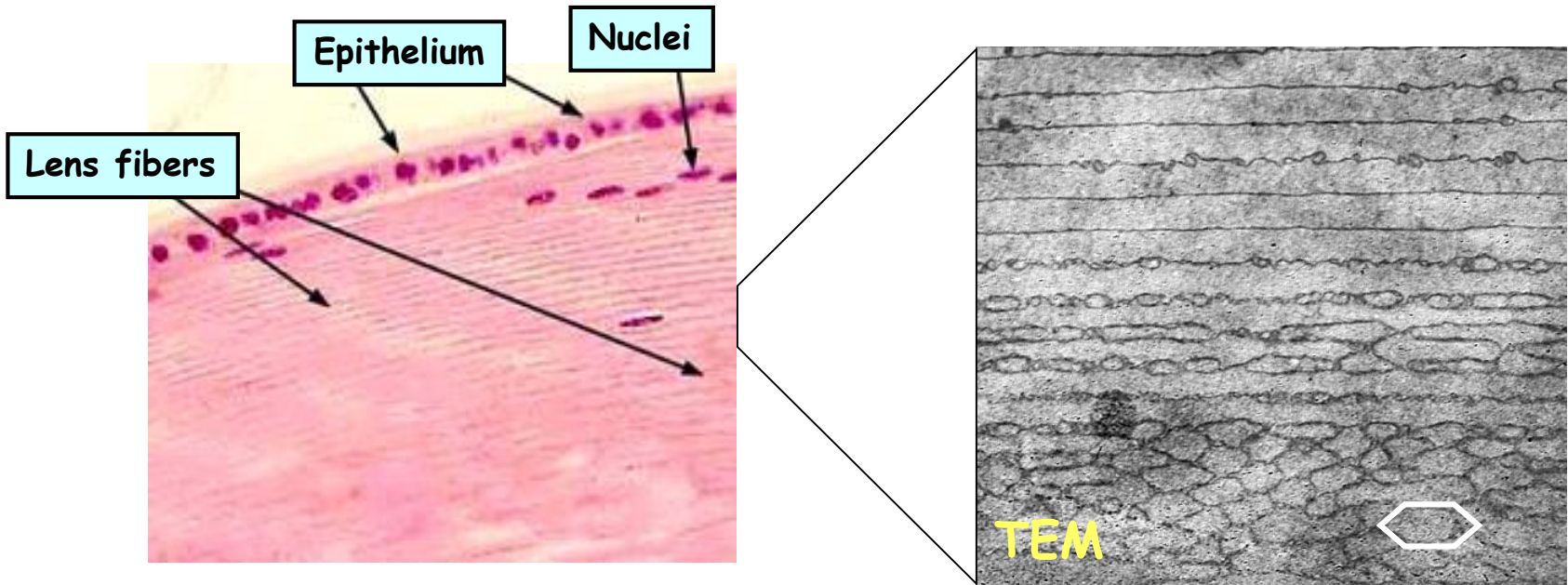
Layers from outside:

- 1. Anterior epithelium**
 - continuation of the posterior ep. of the cornea
 - discontinuous layer of flat epithelial cells, fibroblasts and 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 from ciliary 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

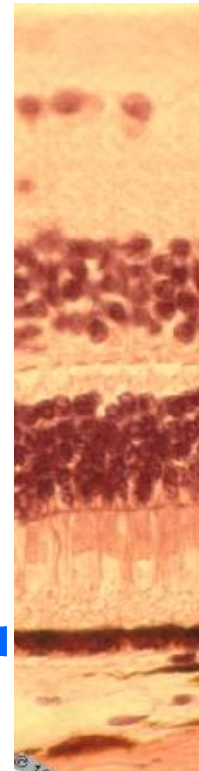
- non-photosensitive
- two-layered
- covers ciliary body and posterior part of the iris

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



~ 0.2 mm

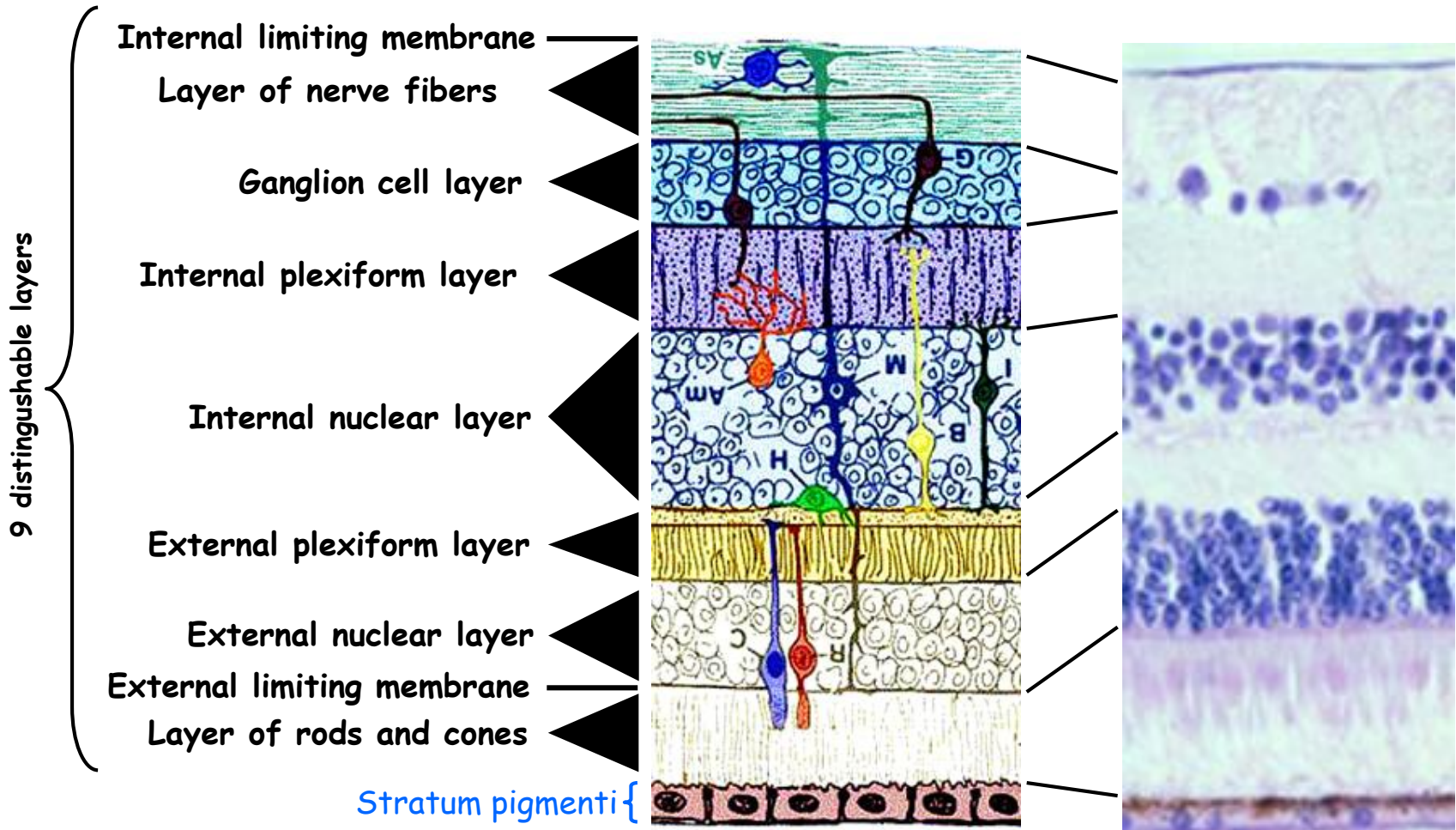
} Choroid

Inner layer

Neural retina

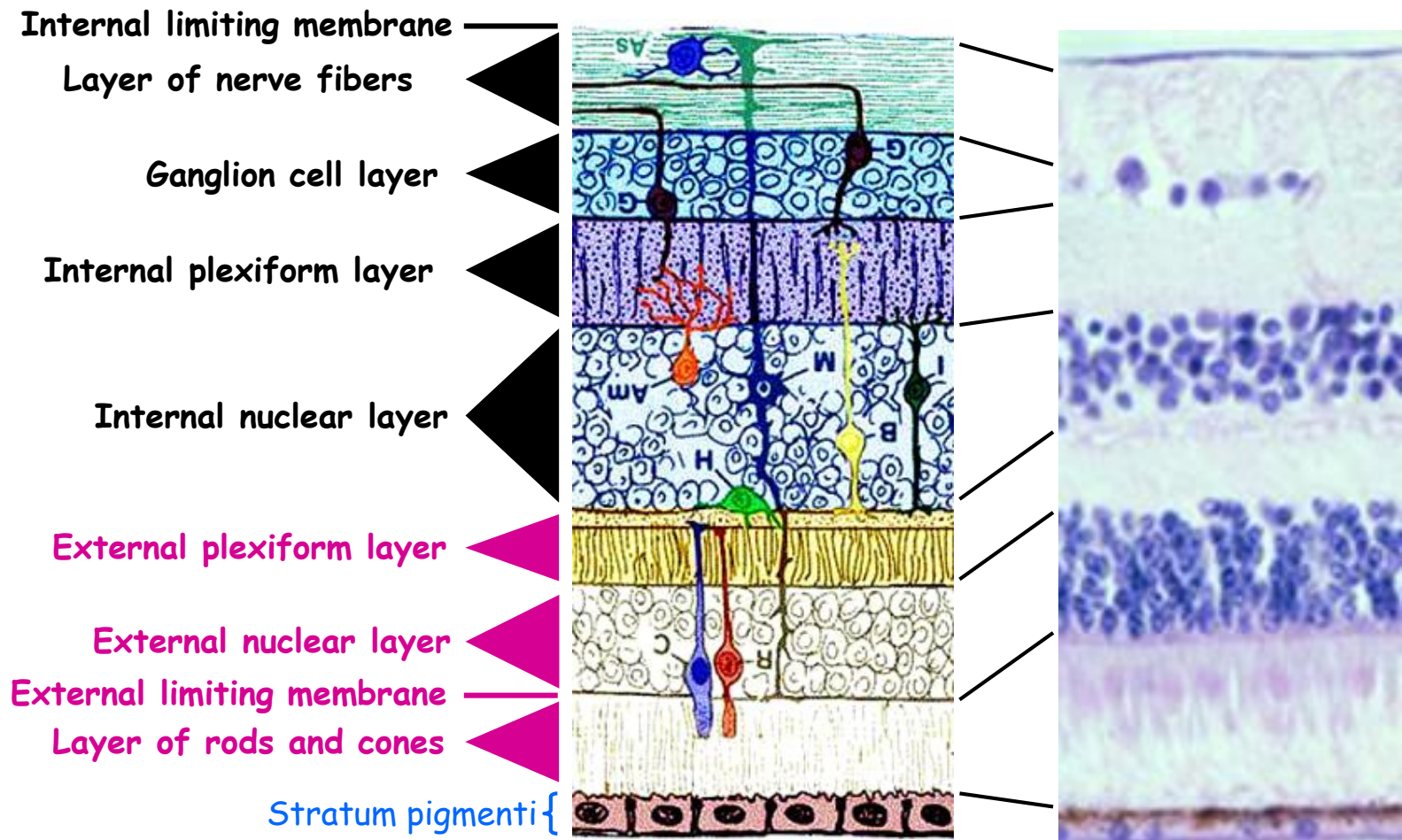
Neural (optical) retina

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

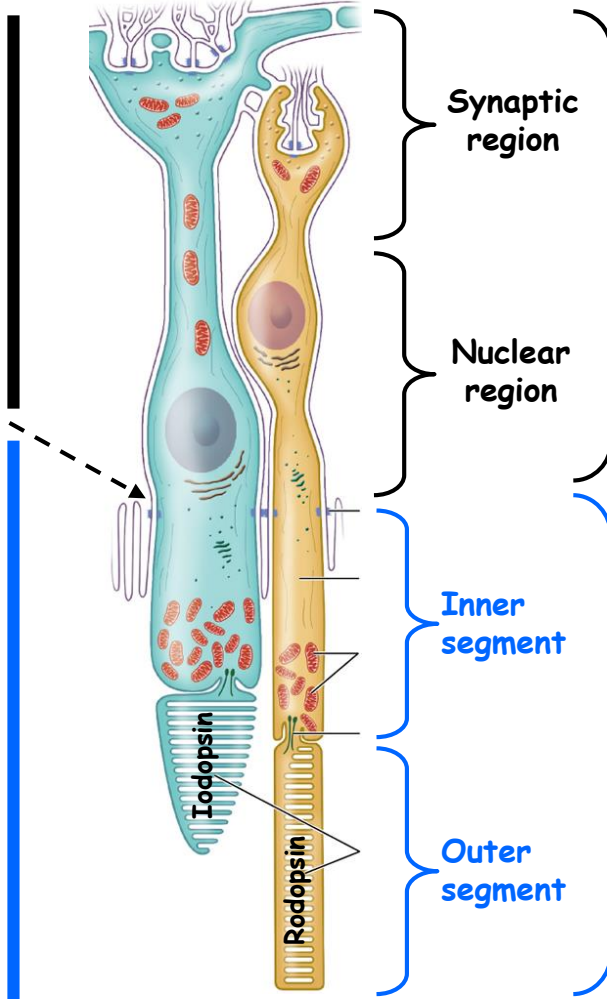
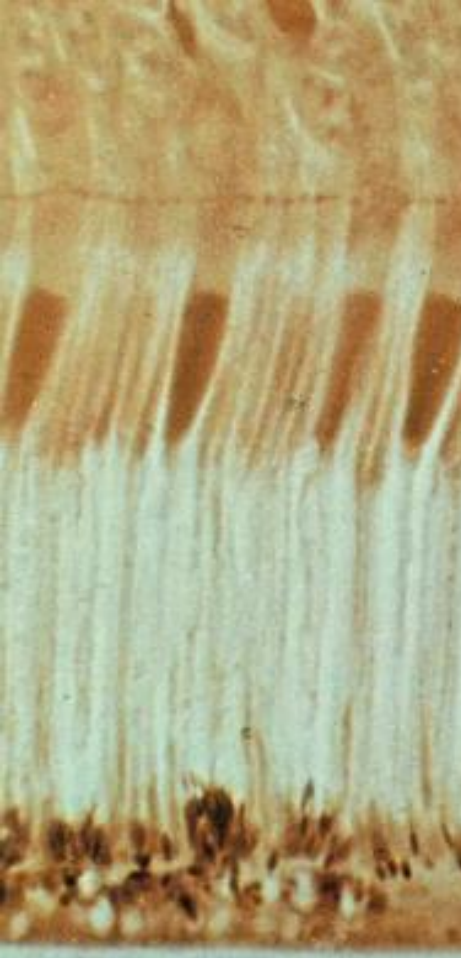

External plexiform layer

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

Inner segment

Outer segment

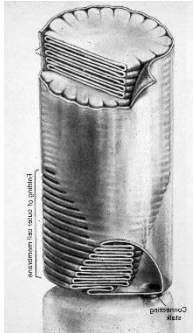
Central part

Peripheral part

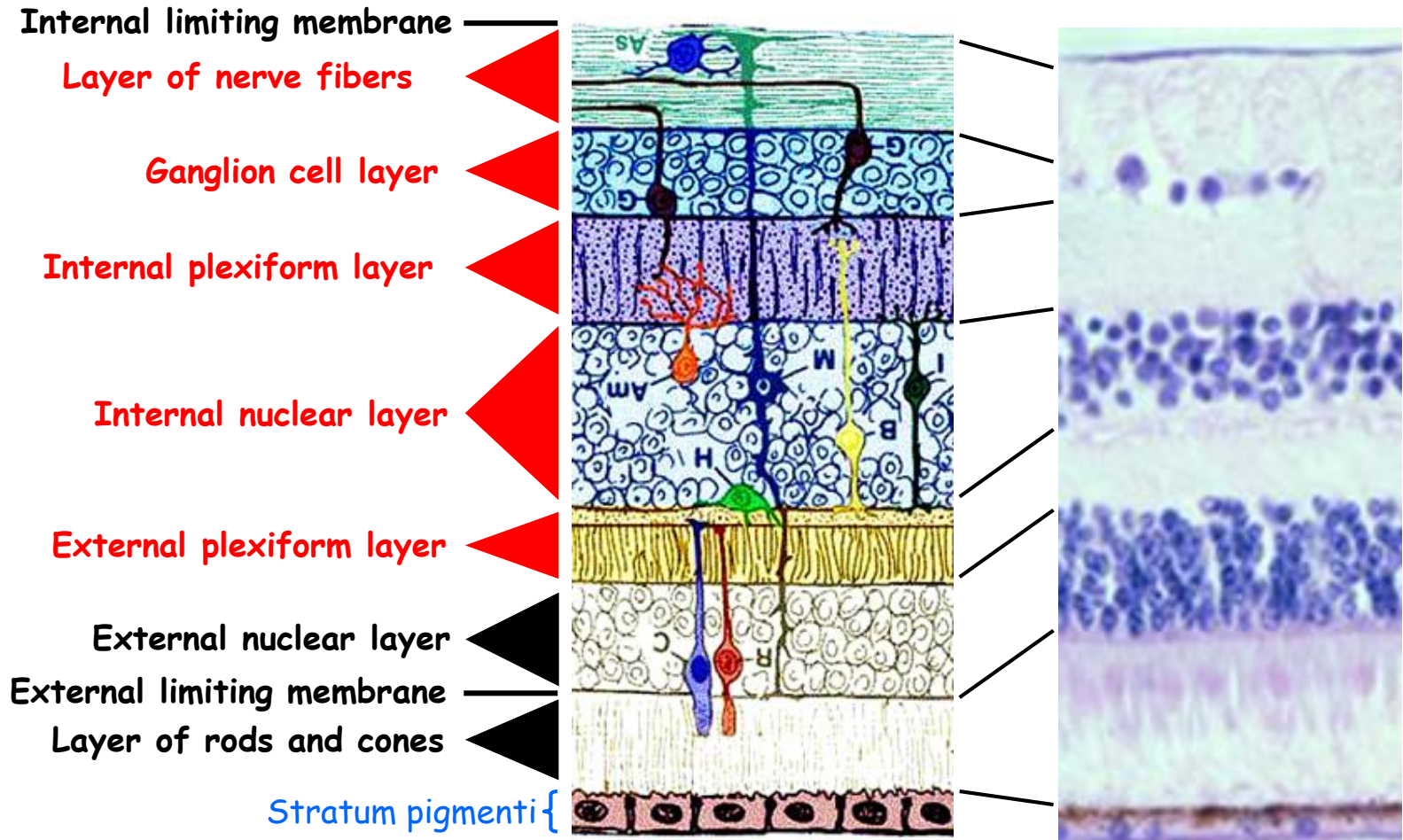
Rodopsin

Rodopsin

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

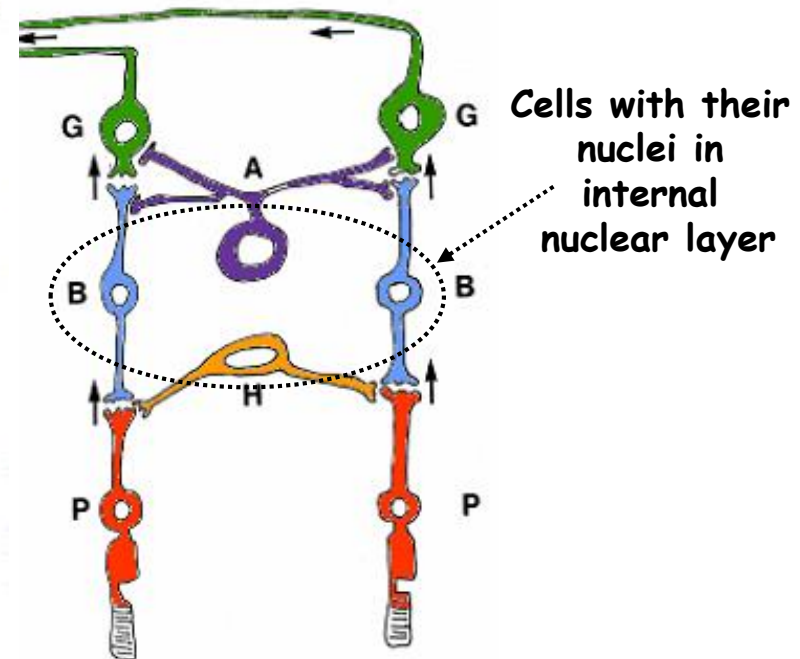
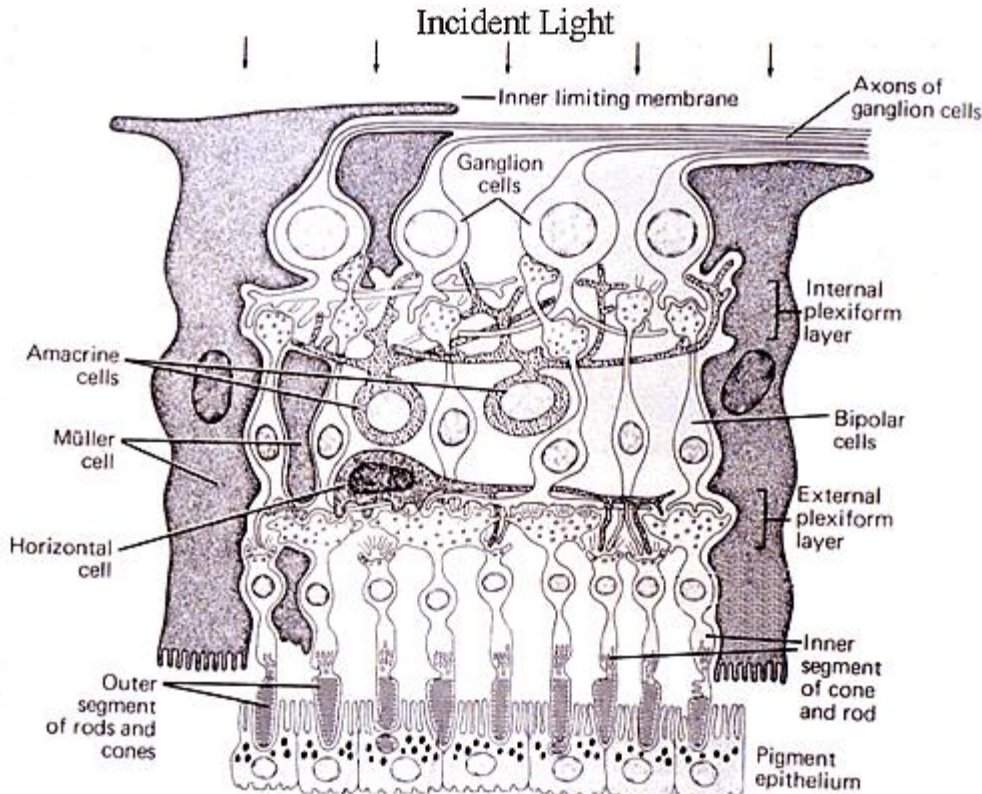
Asociating + integrating neurons

Horizontal cells

- Small
- Multipolar

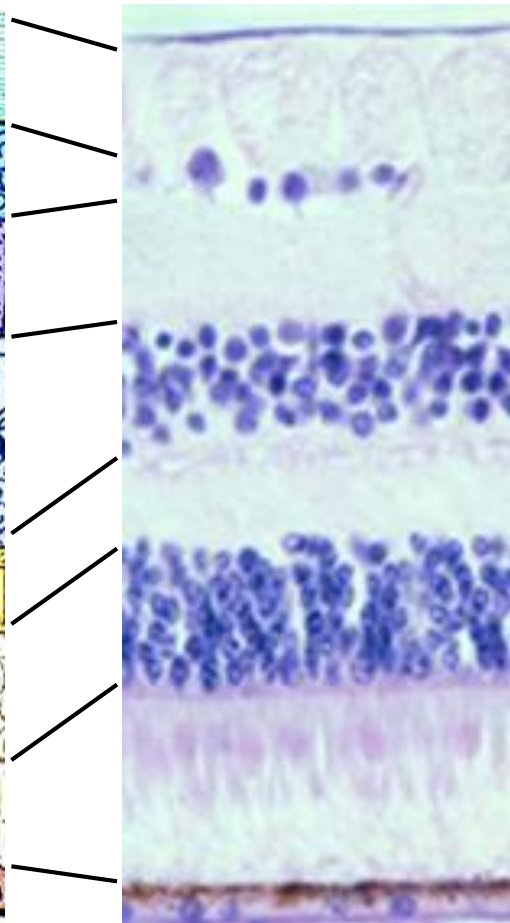
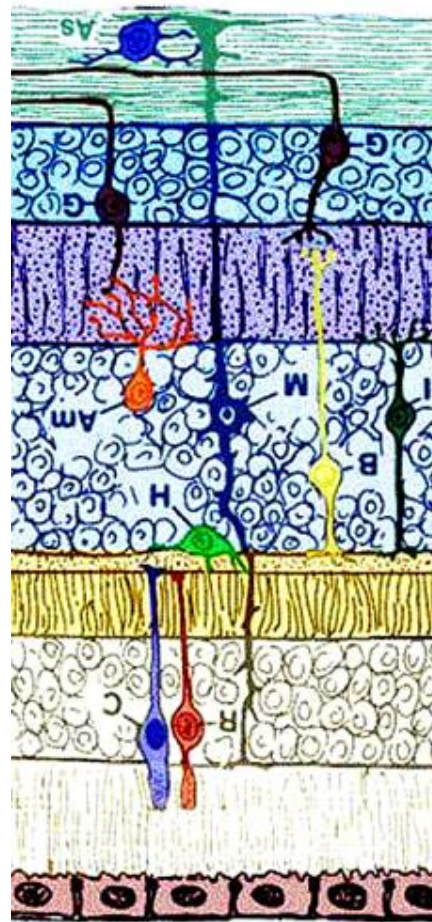
Amacrine cells

- They don't have neurite



Supporting cells of the retina 1

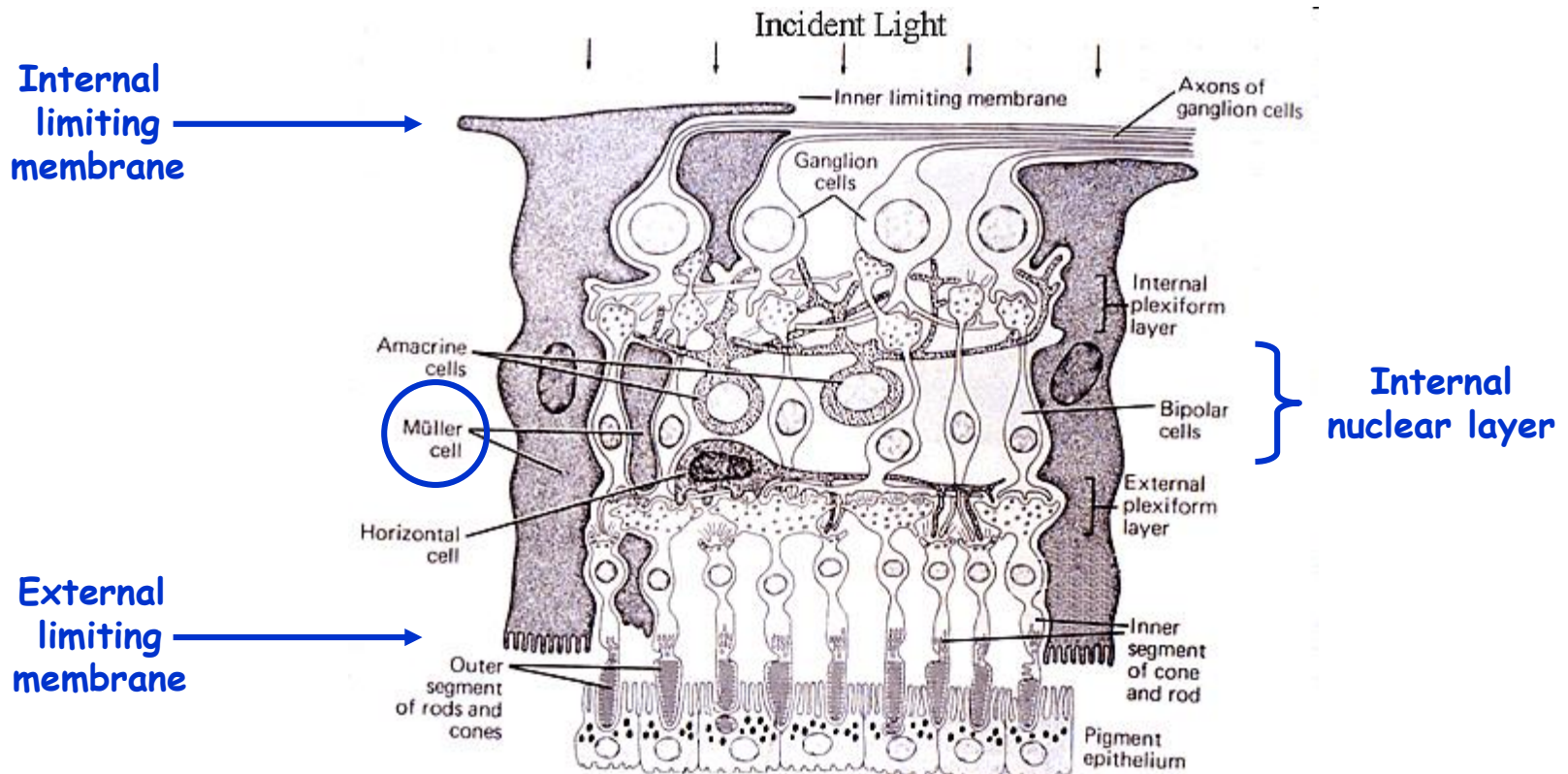
- Internal limiting membrane
- Layer of nerve fibers
- Ganglion cell layer
- Internal plexiform layer
- Internal nuclear layer
- External plexiform layer
- External nuclear layer
- External limiting membrane
- Layer of rods and cones
- Stratum pigmenti {



Supporting cells of the retina 1

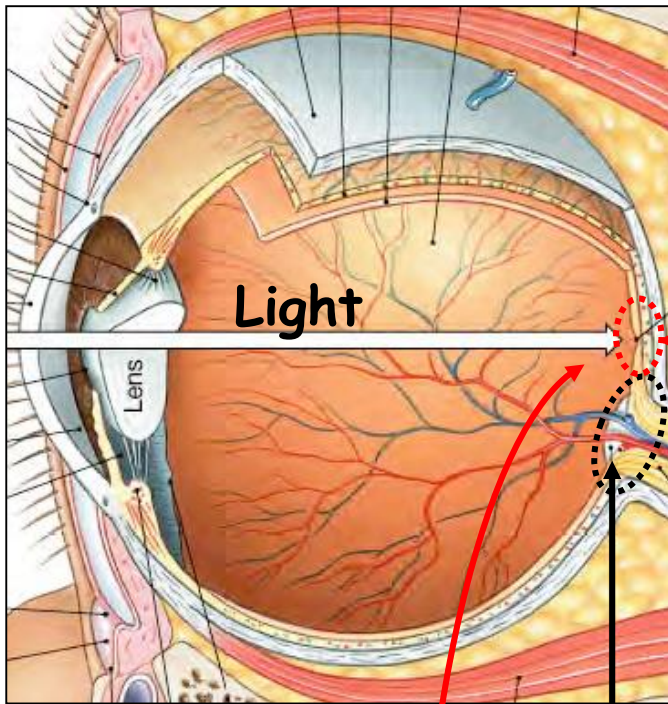
Müller cells

= modified glial cells of the CNS



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

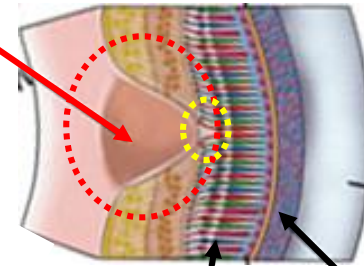
Central x Peripheral vision



Light

Lens

Macula lutea

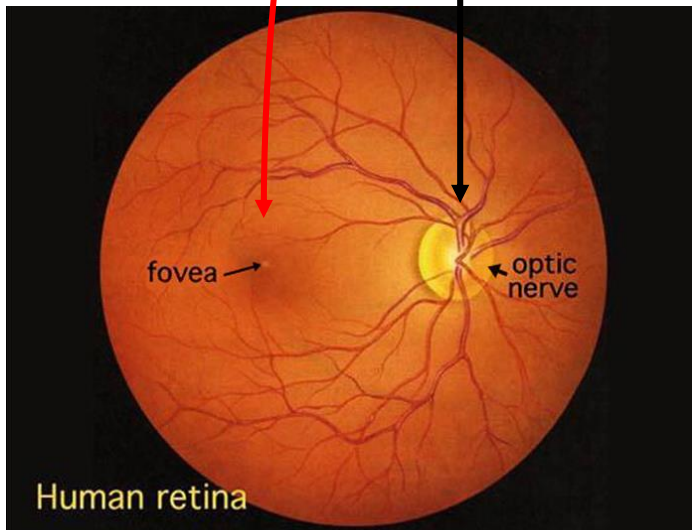


Retina

Choroid

Papilla of the optic nerve

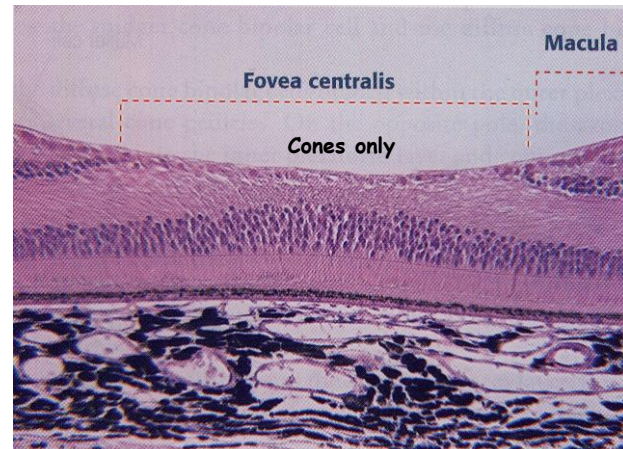
Fovea centralis of the macula lutea = the sharpest vision



fovea

optic nerve

Human retina

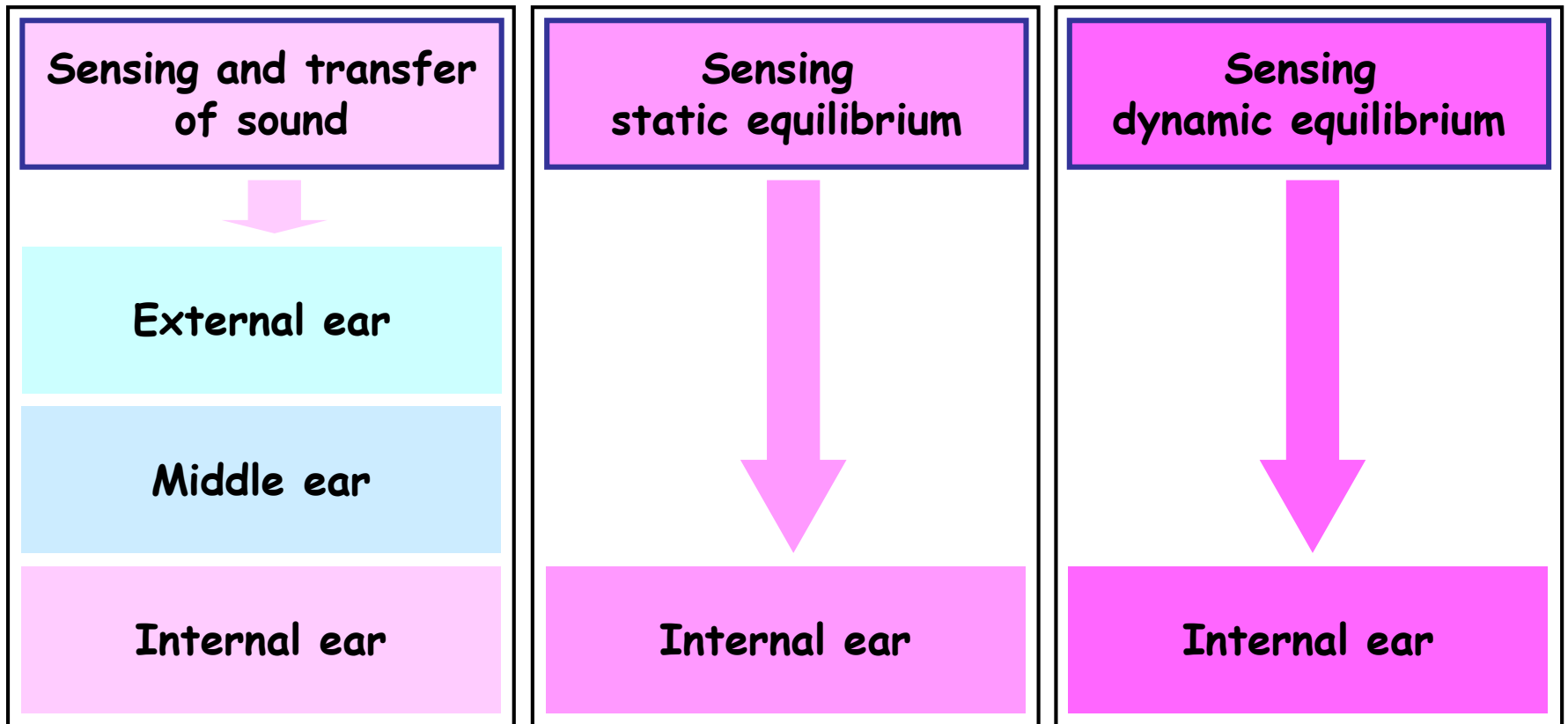


Macula

Fovea centralis

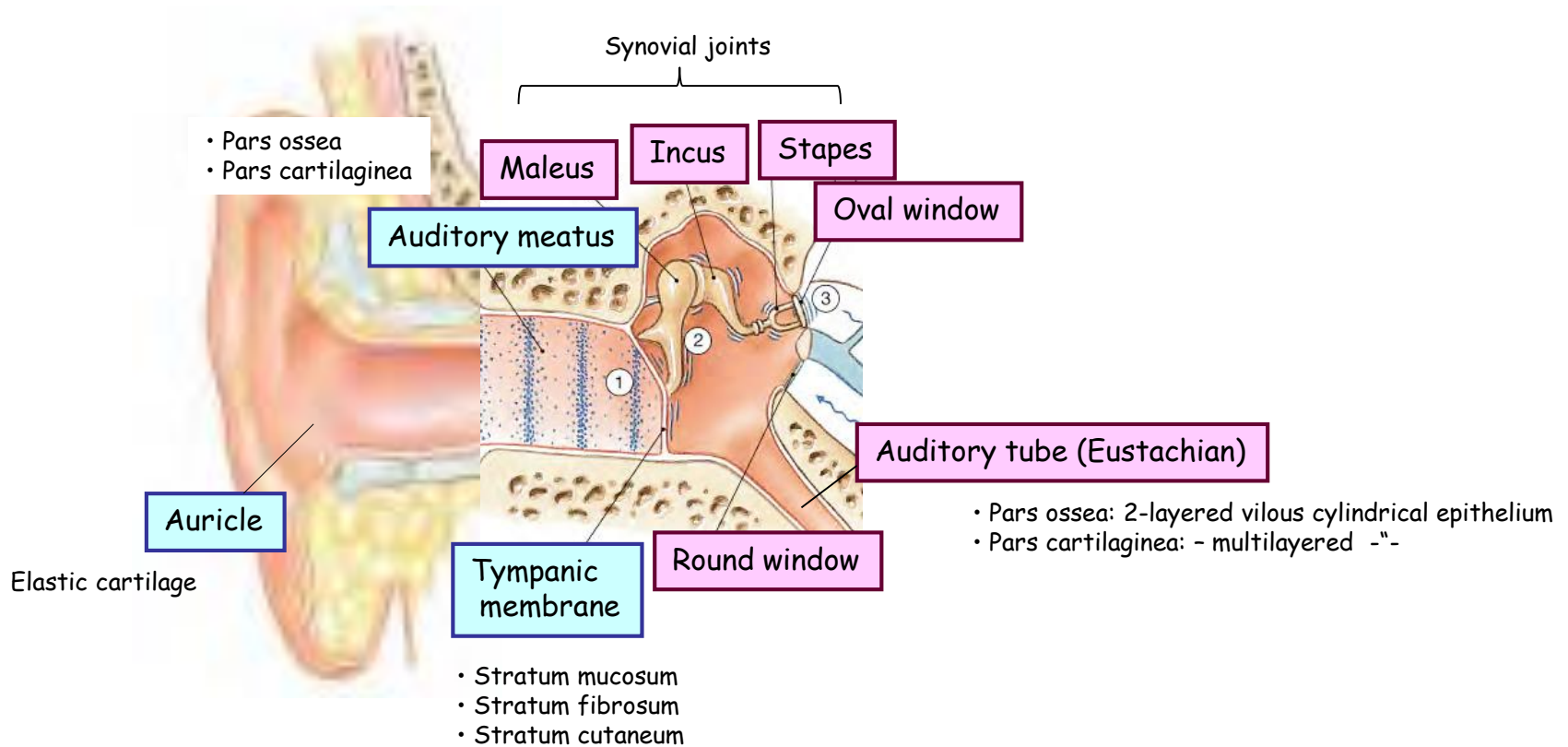
Cones only

Audioreceptor system = Vestibulocochlear apparatus

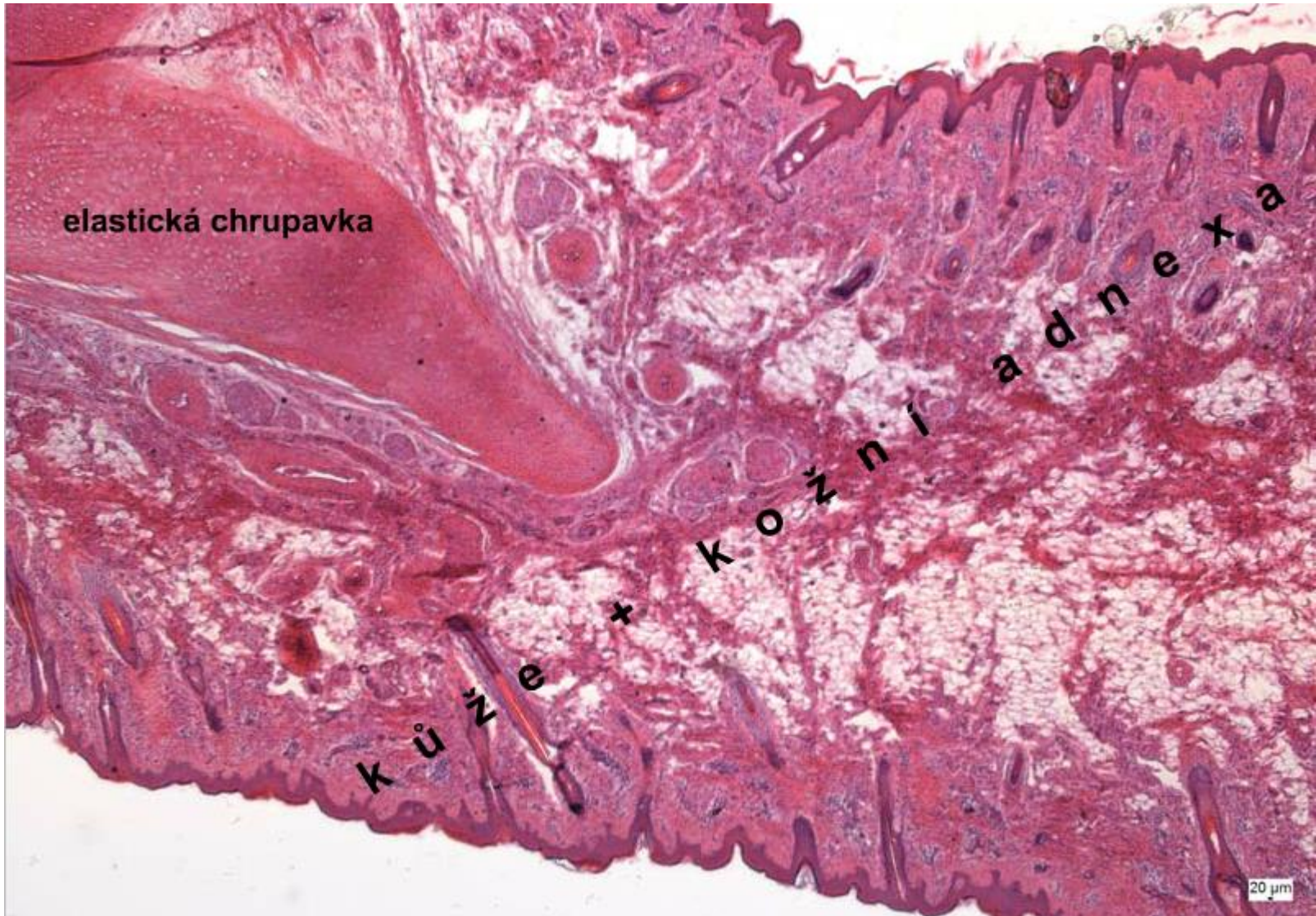


External + Middle ear - Organ of hearing

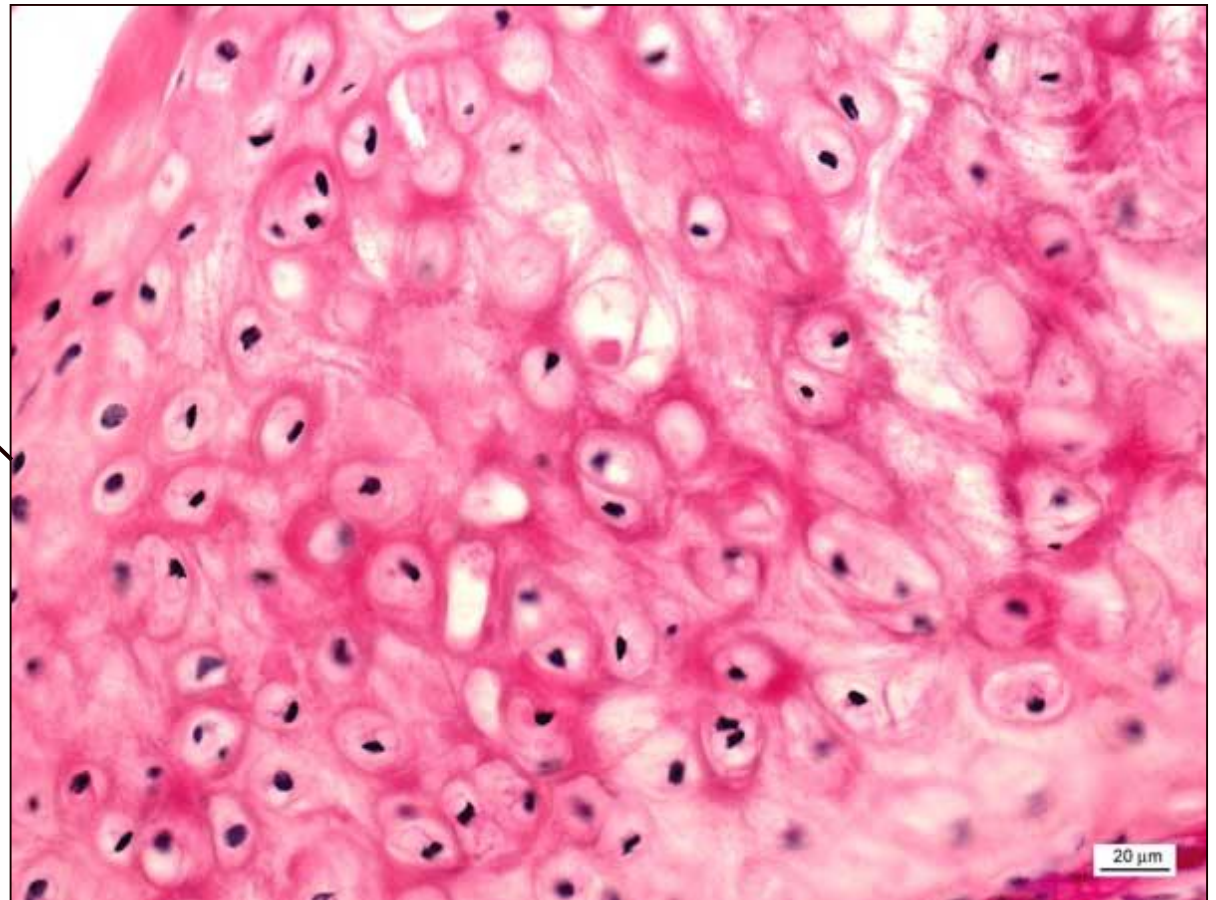
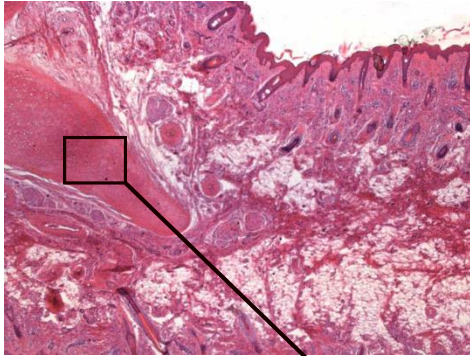
Middle ear - fitted in the cavities of **temporal bone** along with internal ear - osseous labyrinth.



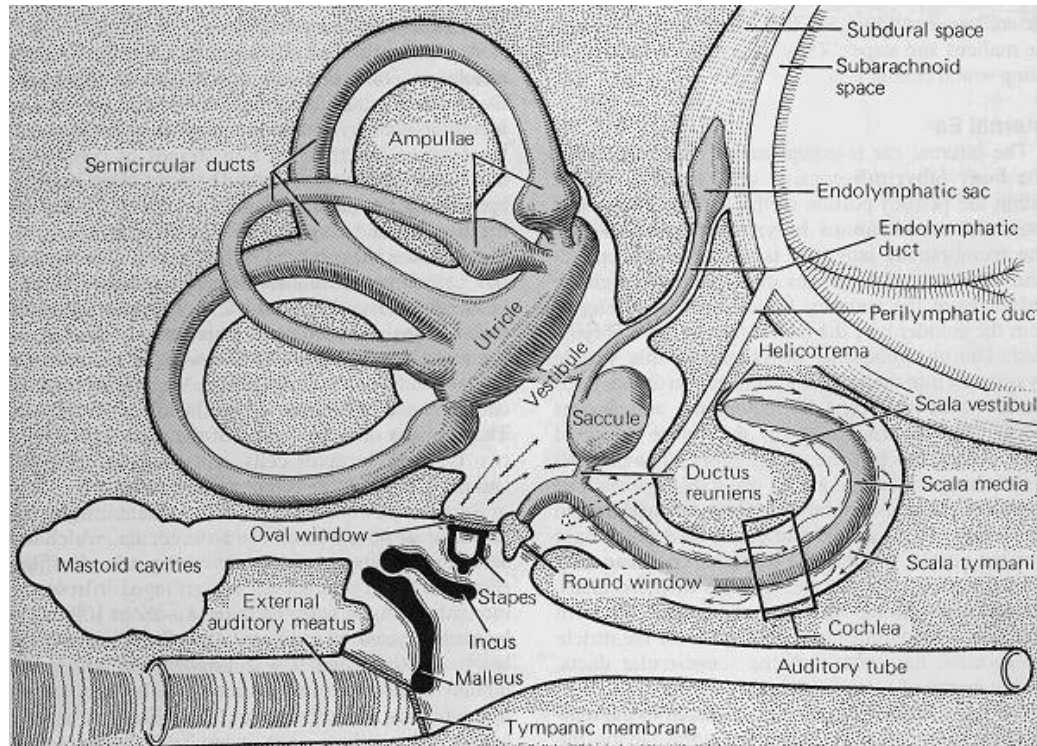
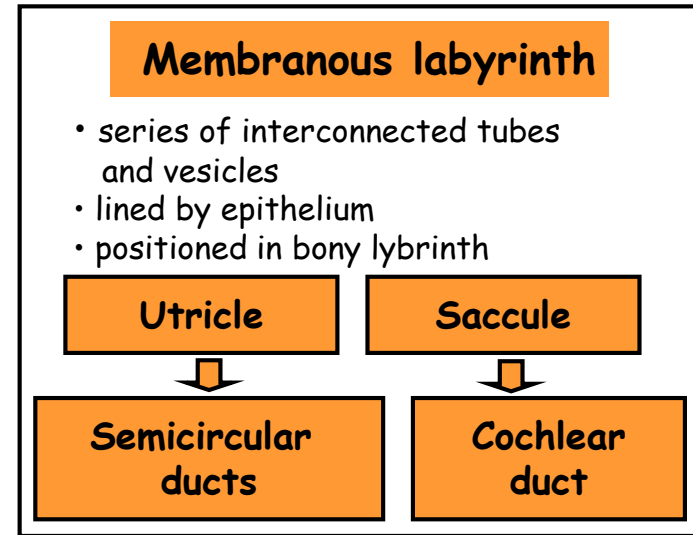
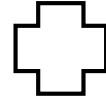
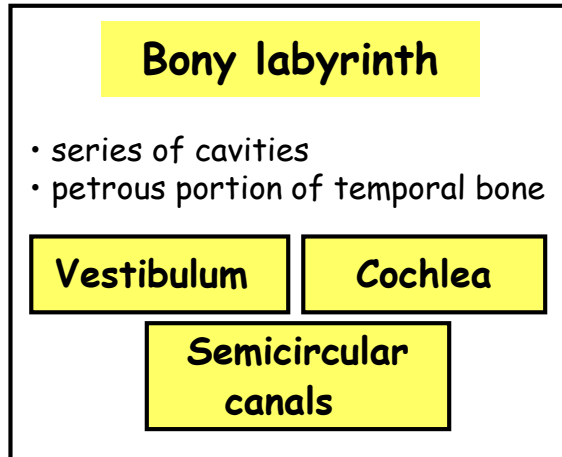
Extrenal ear - Auricle



External ear - Auricle - Elastic cartilage



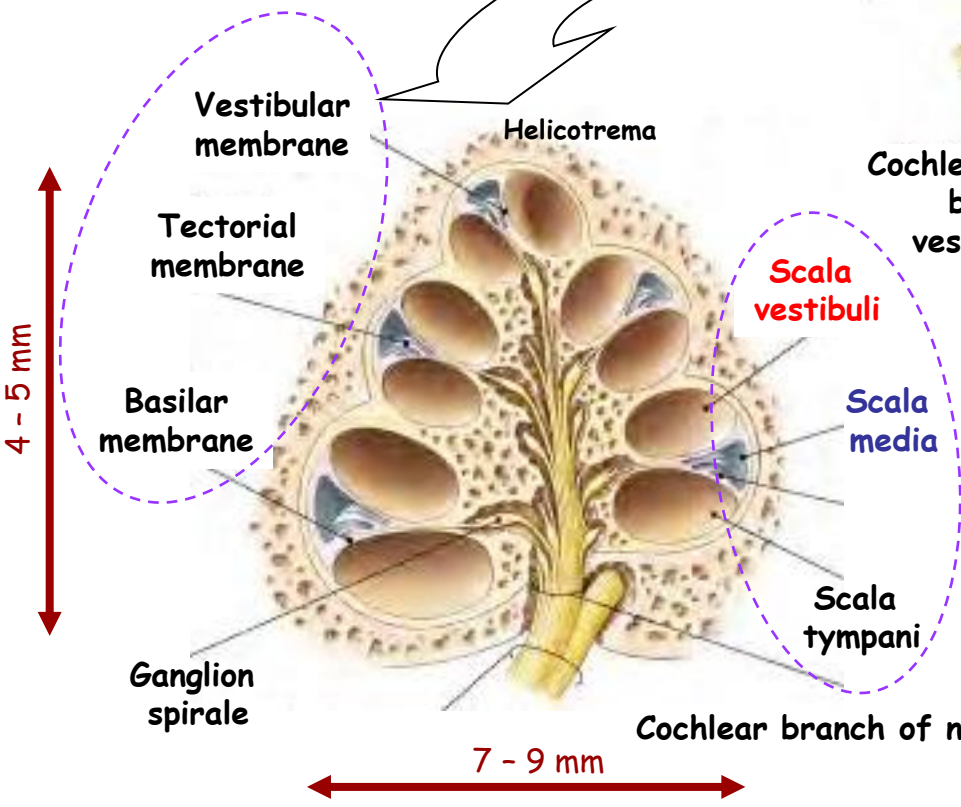
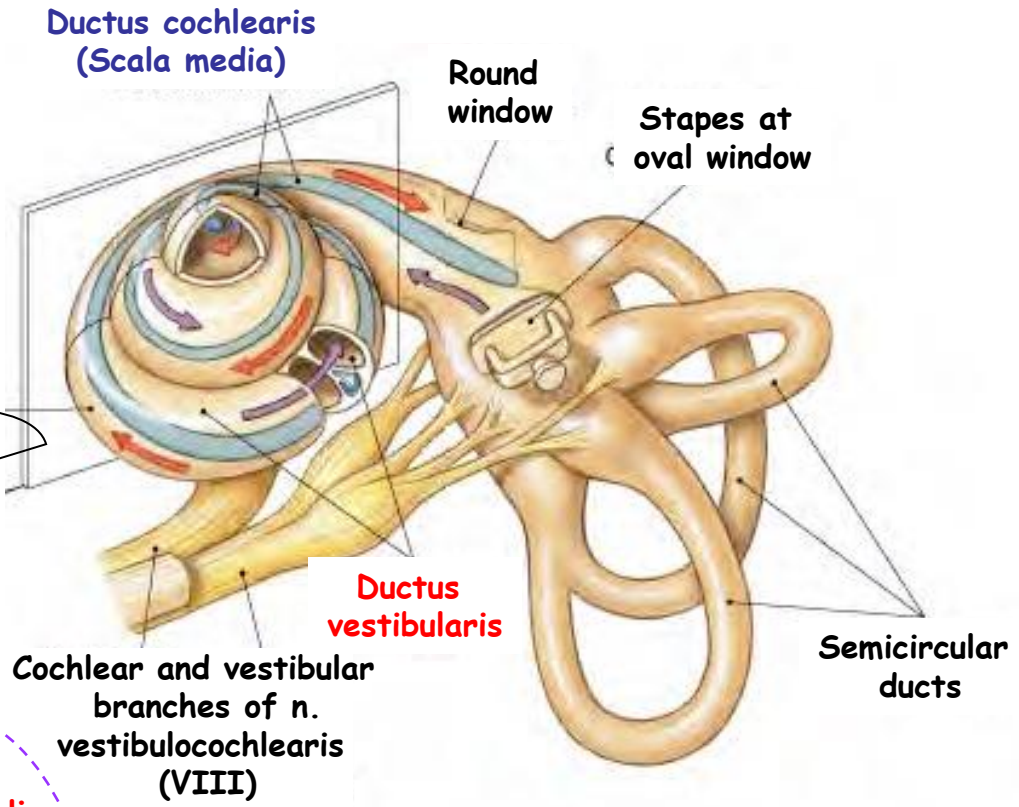
Internal ear



Internal ear - Organ of hearing

Cochlea

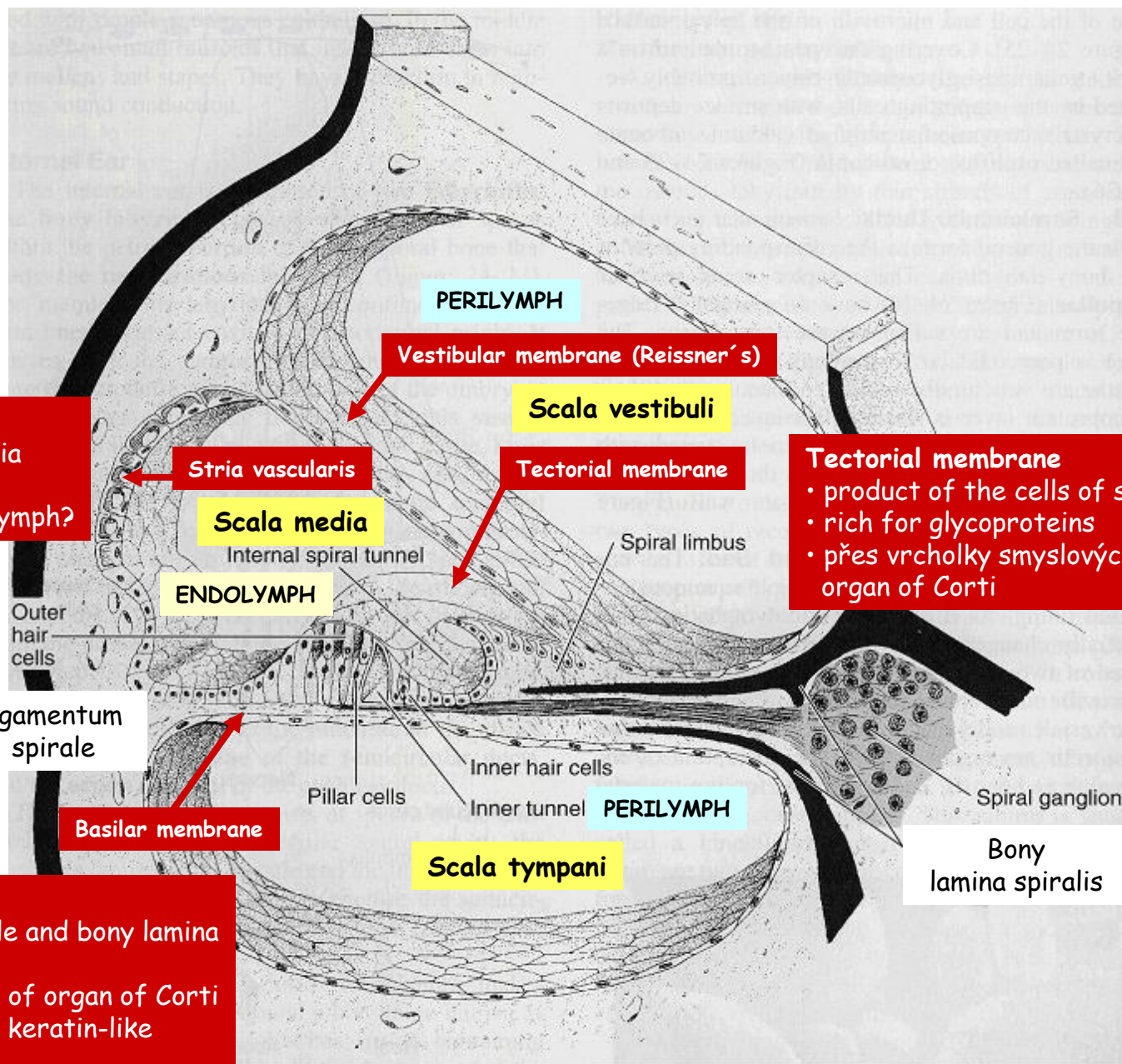
- 2,5 turns around modiolus
- total length about 35 mm



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?

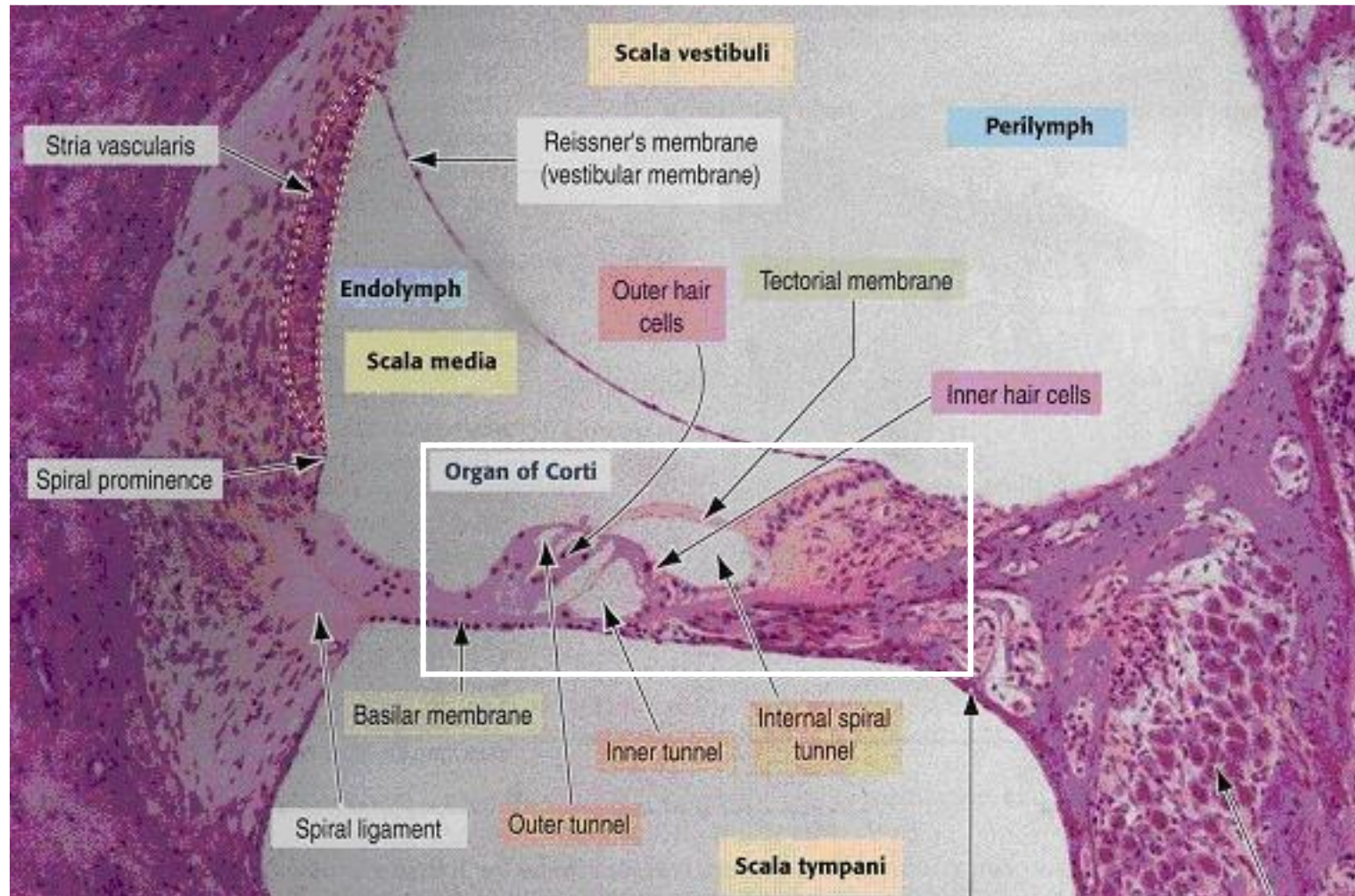
Tectorial membrane
 • product of the cells of spiral limbus
 • rich for glycoproteins
 • přes vrcholky smyslových buněk organ of Corti

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

Internal ear - Organ of Corti - 1



Ganglion spirale

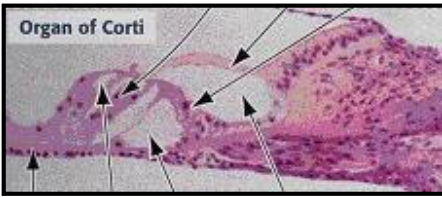


Inner hair cells

Outer hair cells

20 μ m

Internal ear - Organ of Corti - 2



Secondary receptor cells

- hearing hairs - stereocilia
- in contact with tectorial membrane
- bases wrapped 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.

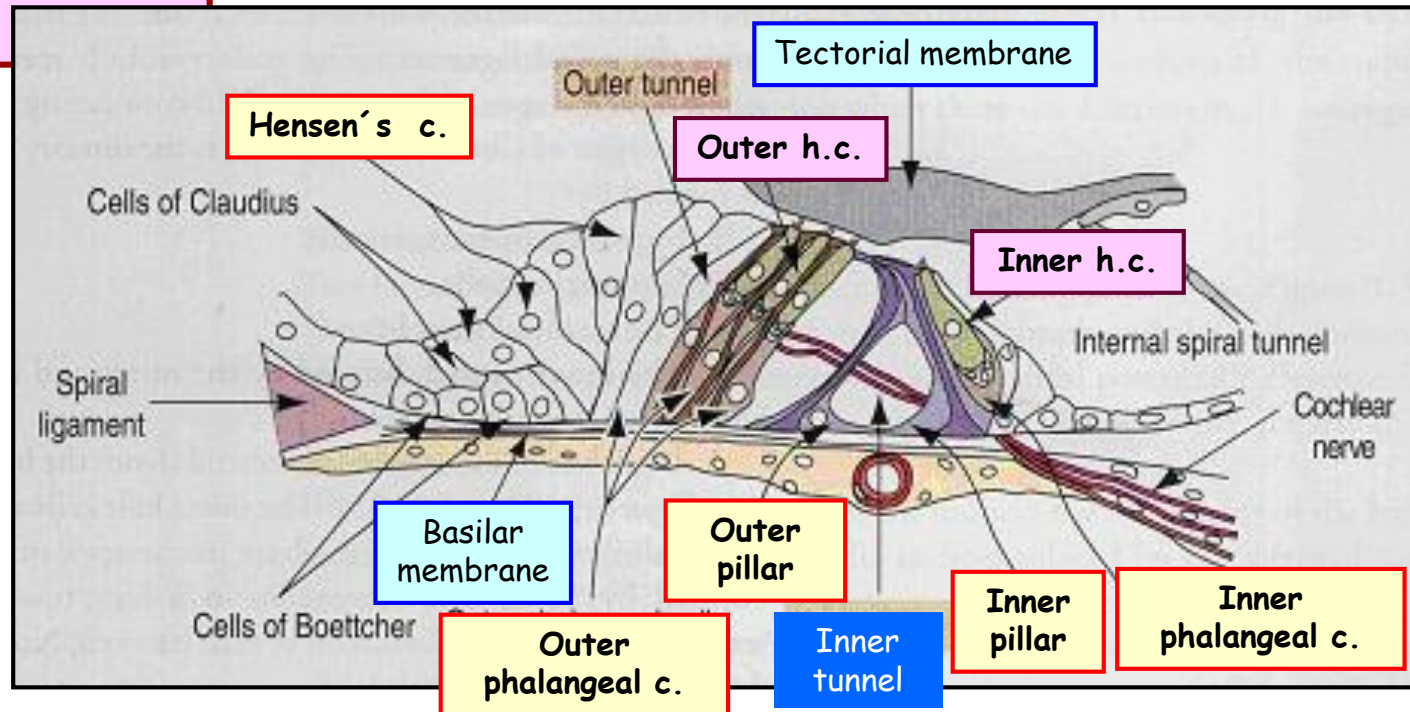
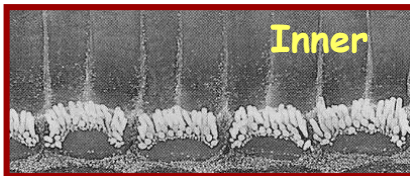
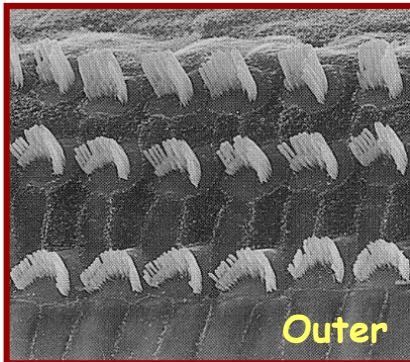
Outer pillar of Corti

Outer pillar of Corti

Inner phalangeal cells

- same as inner ph. cells

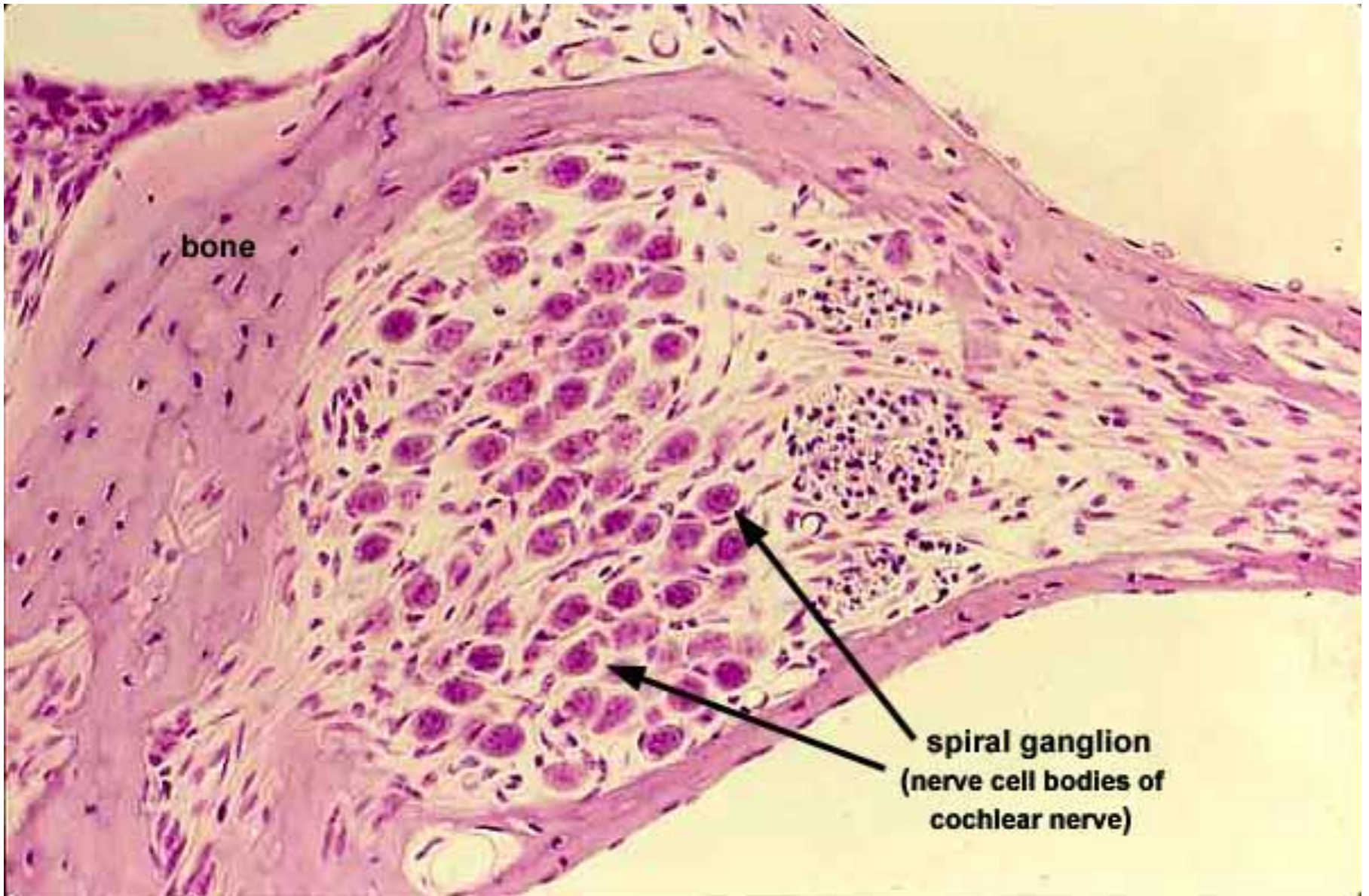
Border cells



Hair and phalangeal cells



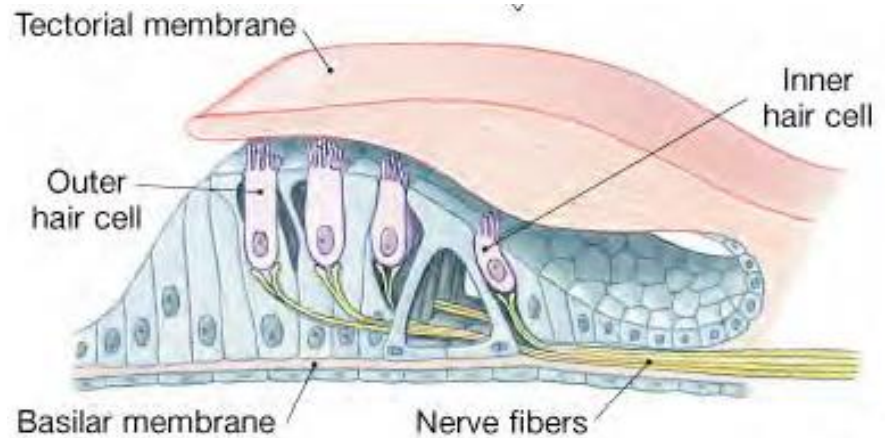
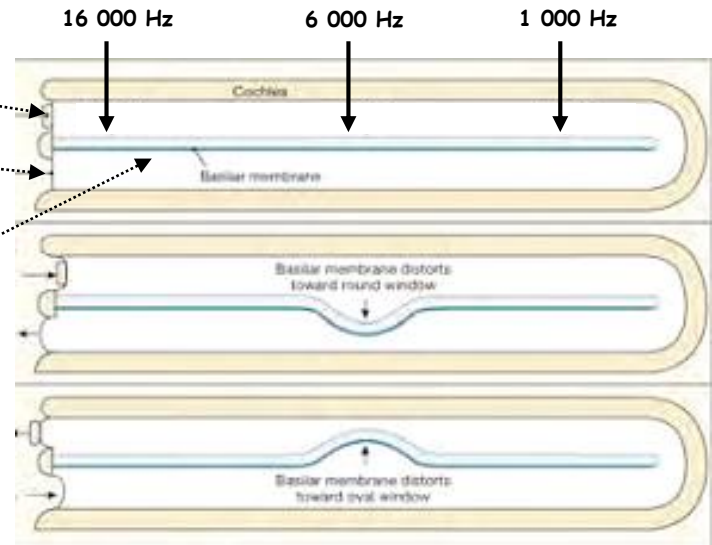
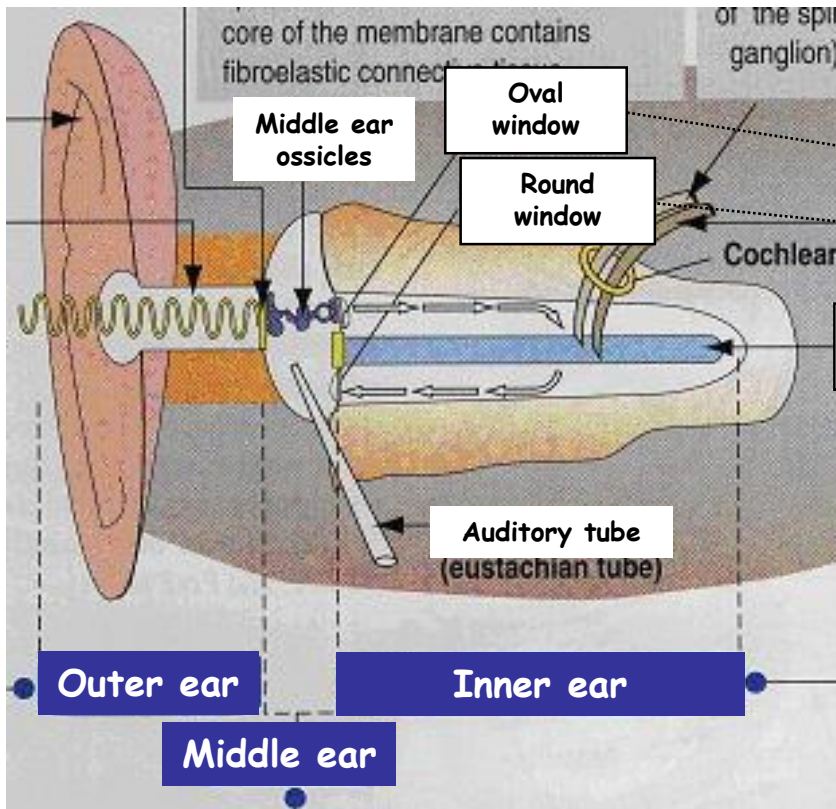
Spiral ganglion



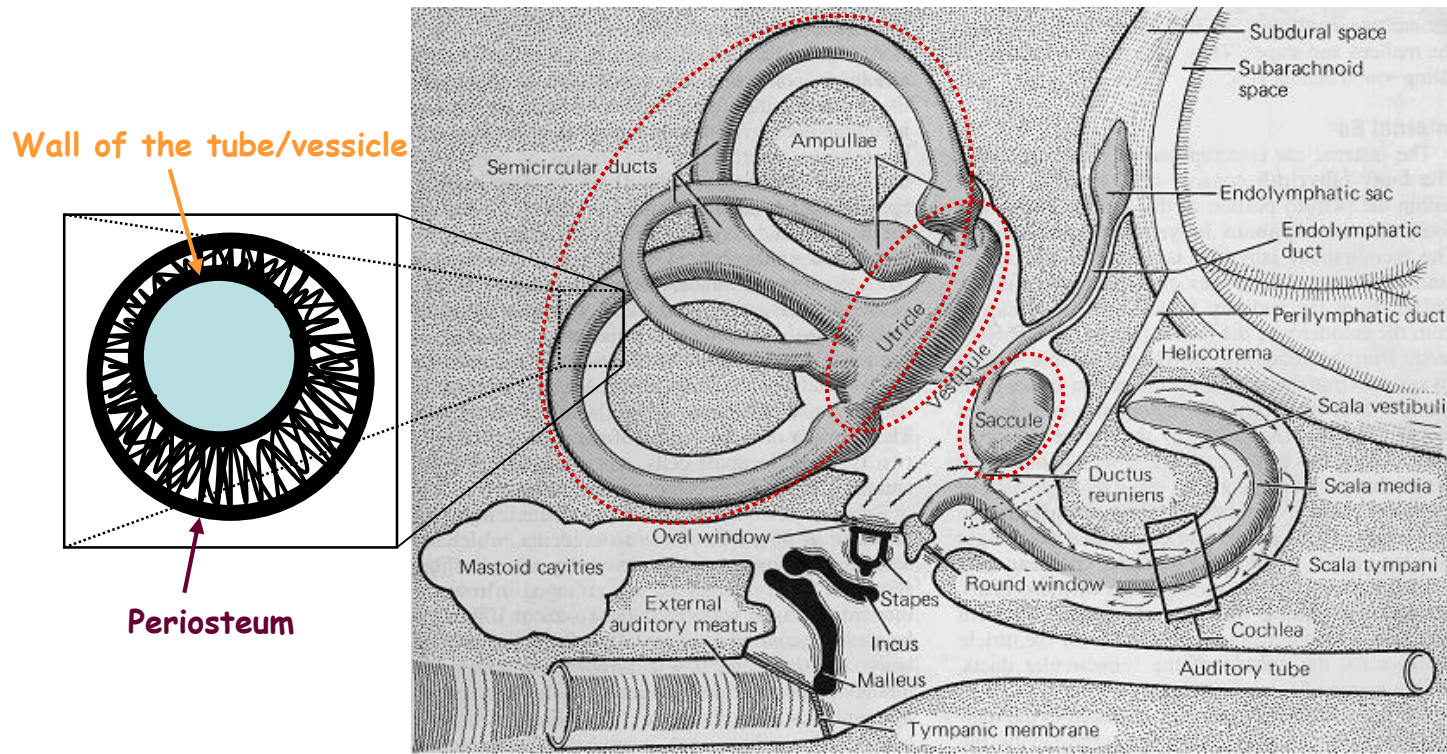
bone

spiral ganglion
(nerve cell bodies of
cochlear nerve)

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 innervated by branches of n. vestibularis.

Inner ear - Statokinetic / Vestibular organ - 2

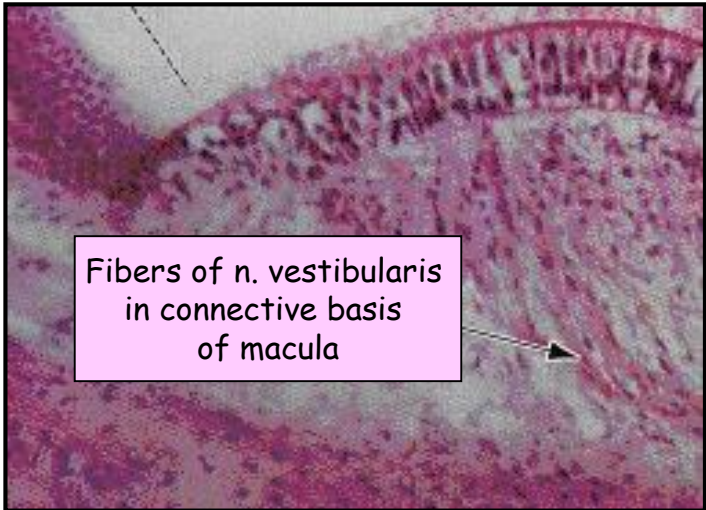
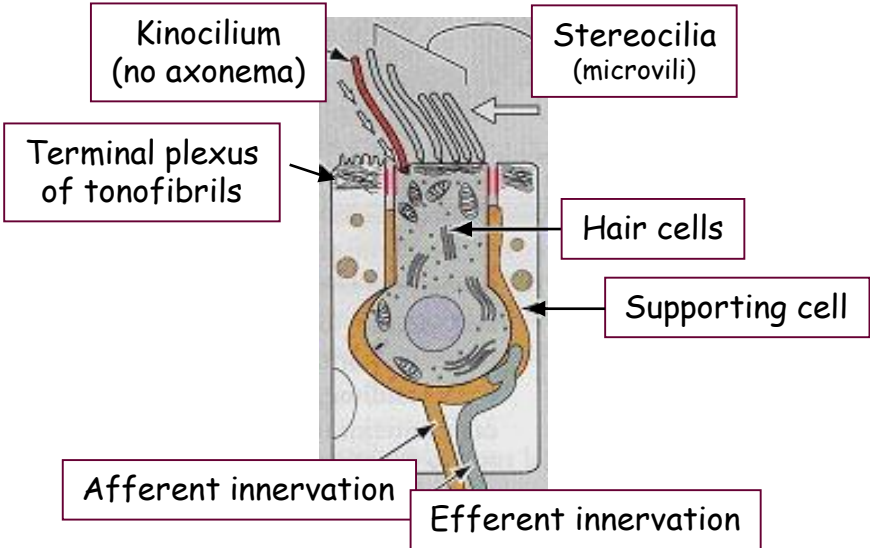
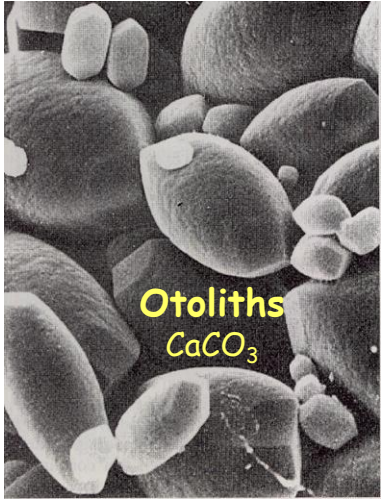
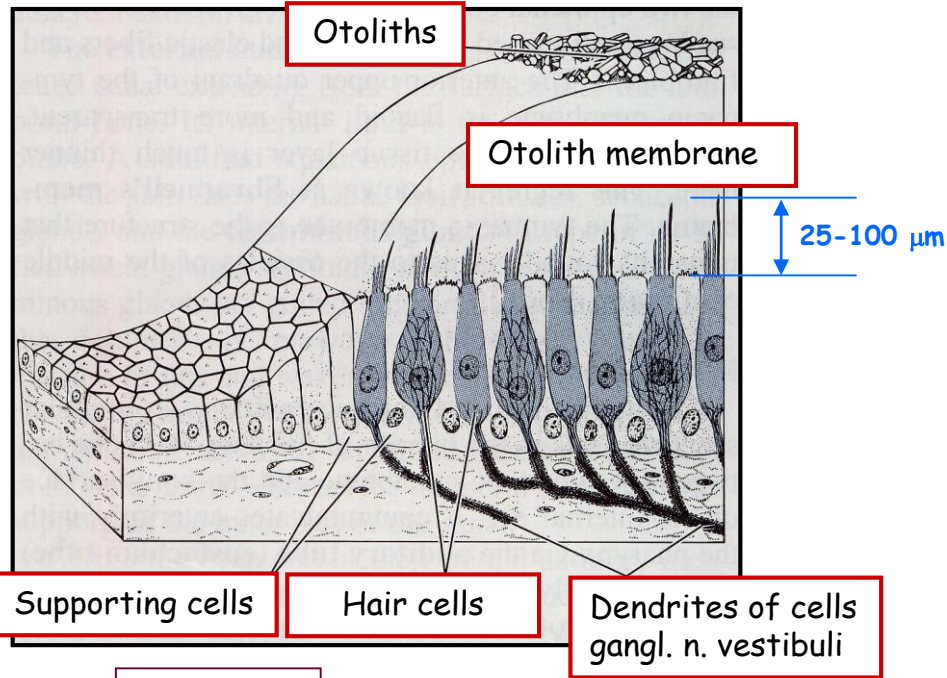
Sensing of static equilibrium (maculae = static spots)

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

Position of maculae

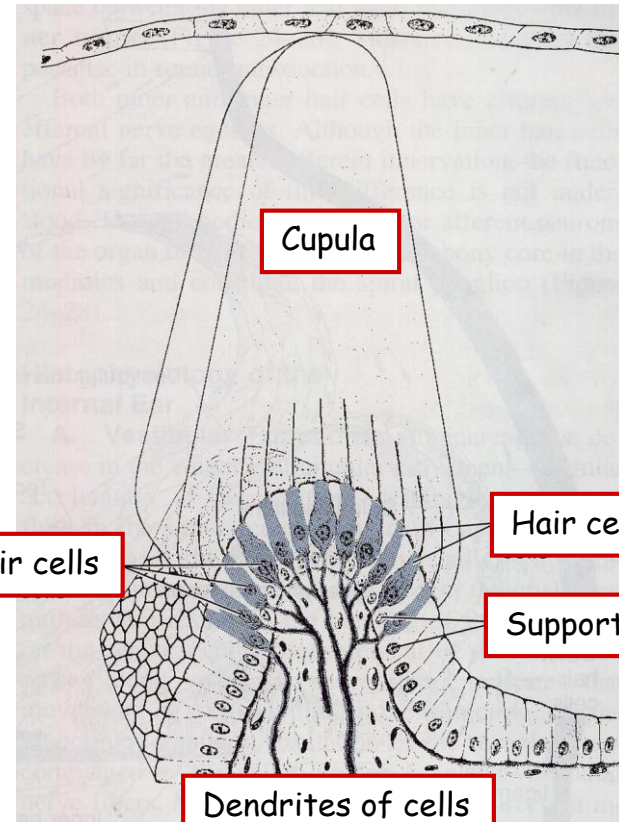
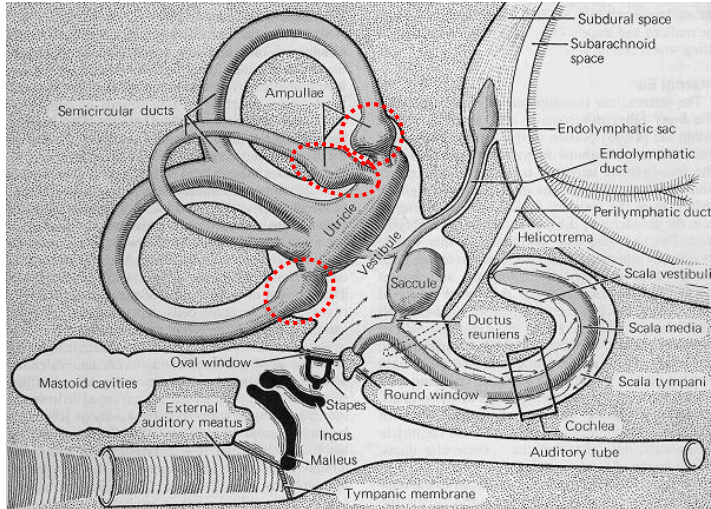
Saccul
bottom

Utricl
lateral wall

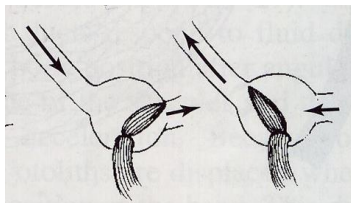


Inner ear - Statokinetic / Vestibular organ - 3

Sensing of dynamic equilibrium (cristae ampulares)



Reaction on acceleration/deceleration
(movement of endolymph)



Position of cristae ampullares

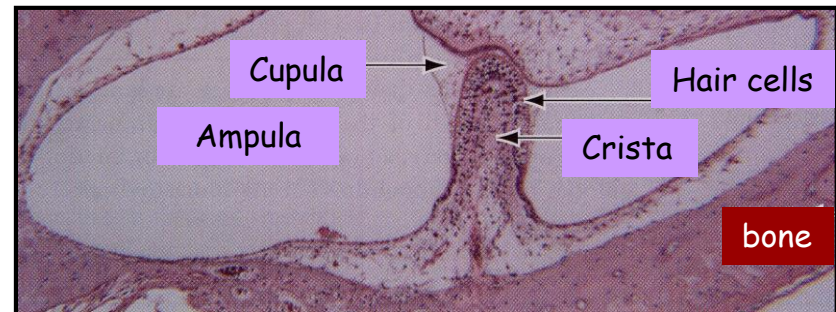
- in ampules of semicircular ducts
- ridges perpendicular to axis of SDs

Cupula

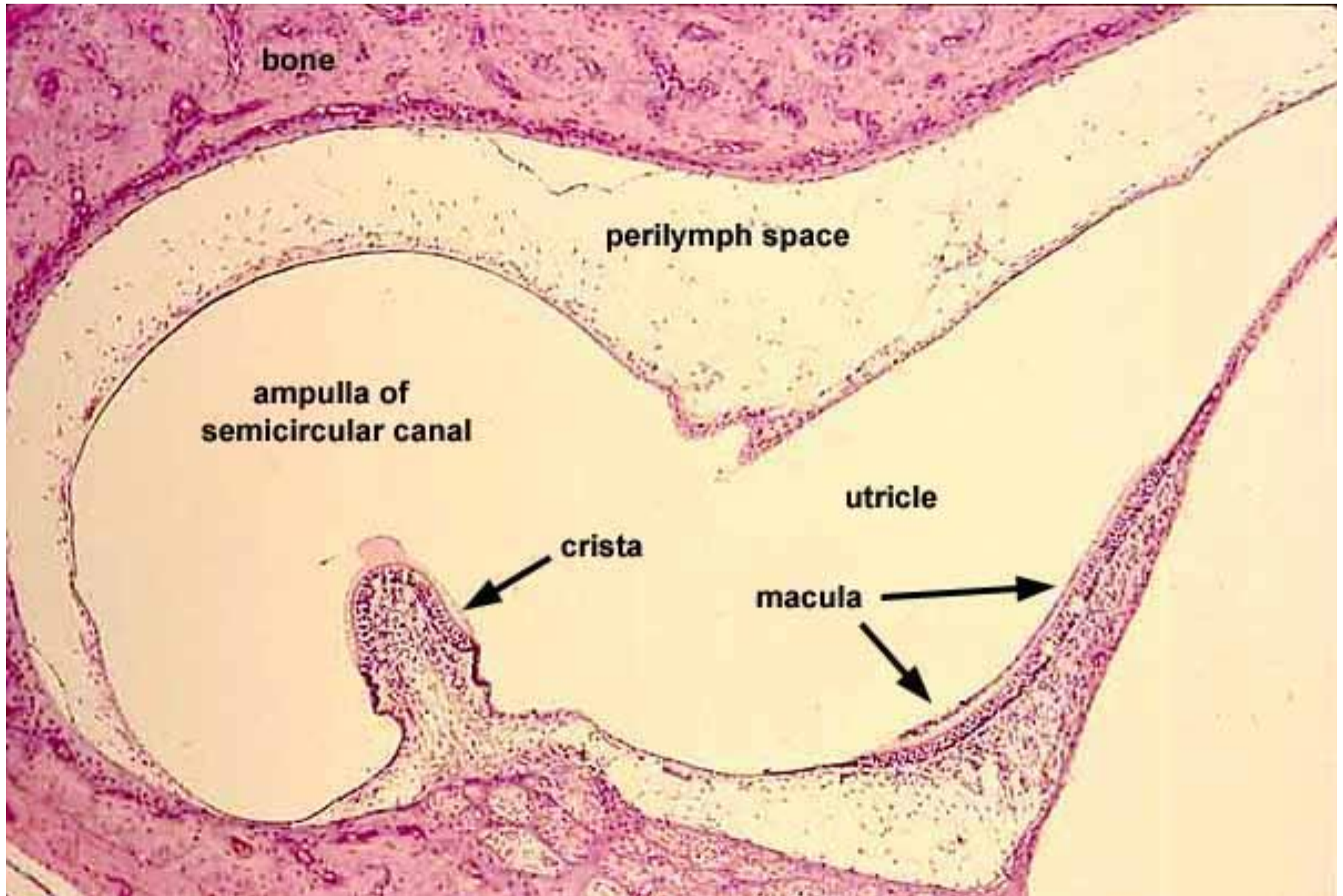
Hair cells

Supporting cells

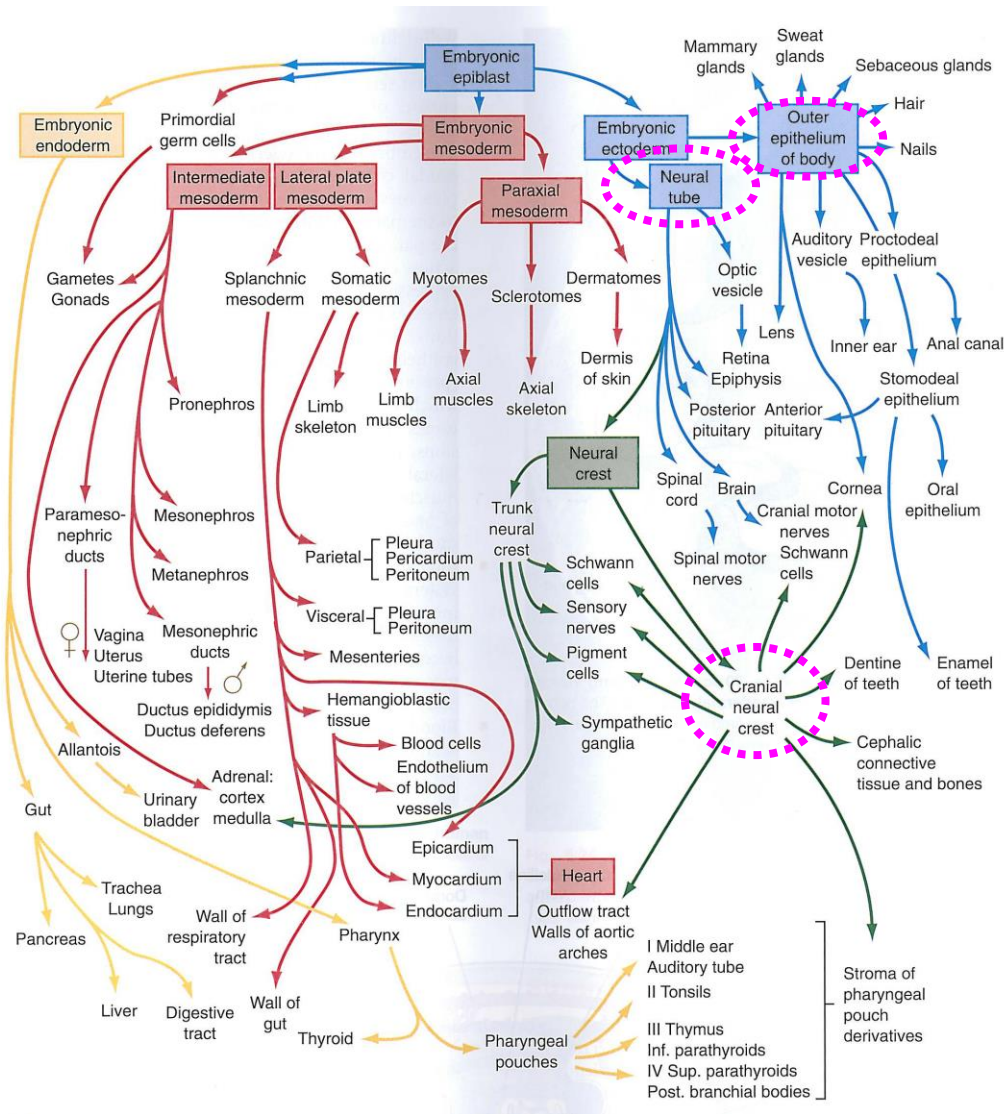
Dendrites of cells
gangl. n. vestibuli



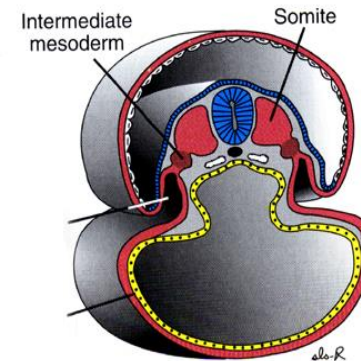
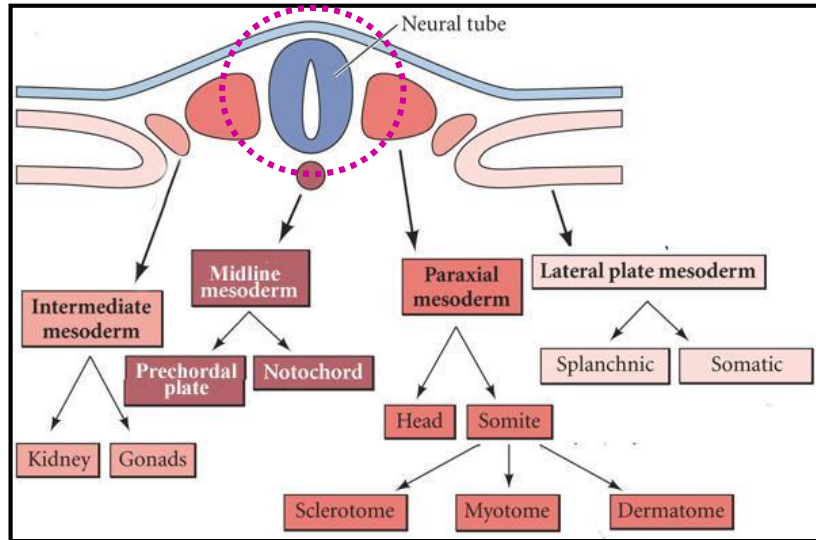
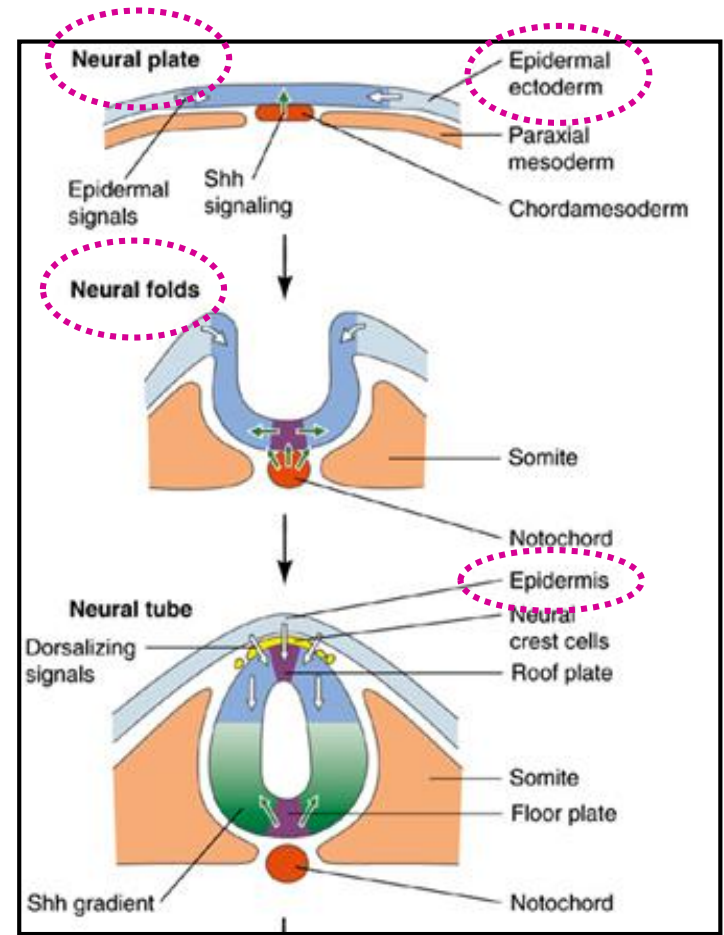
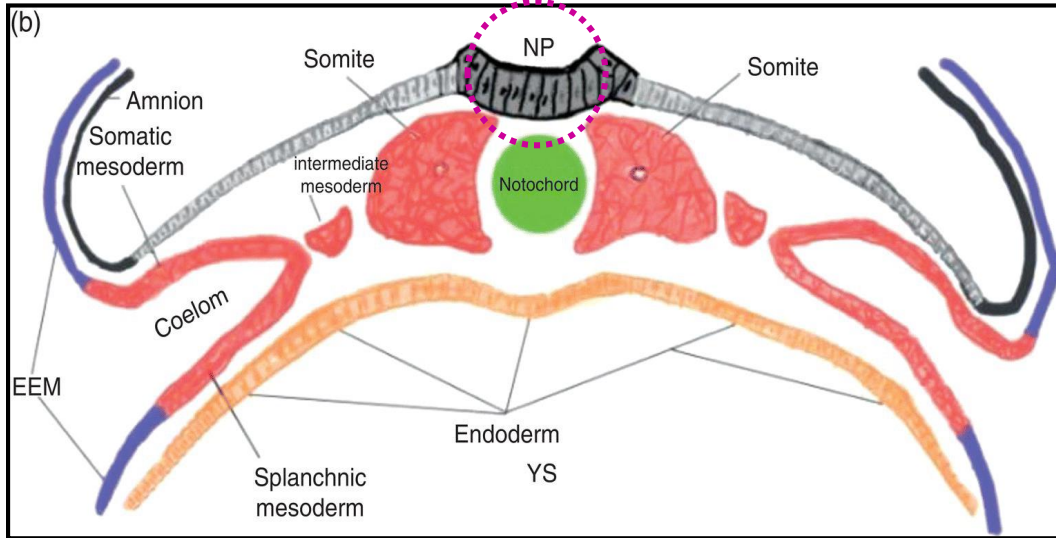
Membranous labyrinth



Development of sense organs - Overall picture

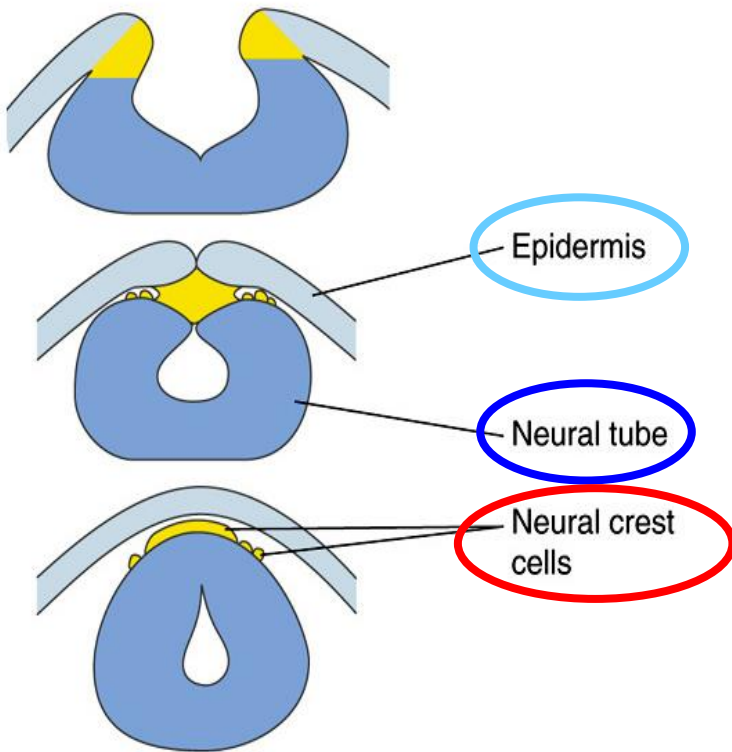


Sense organs - Reminder - Neural tube

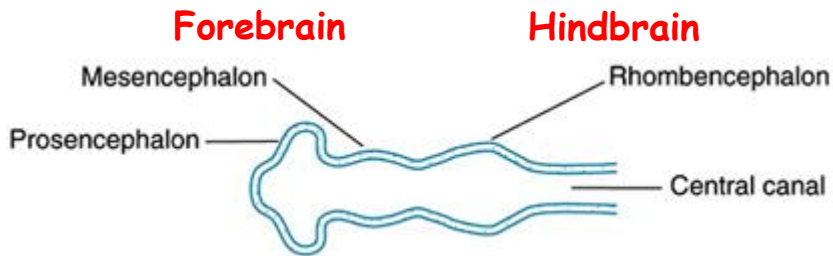


Sense organs - Reminder - Neural crest

Arise from both
dorsal epidermis and neural plate



Sense organs - Cranial neural tube + Placodes

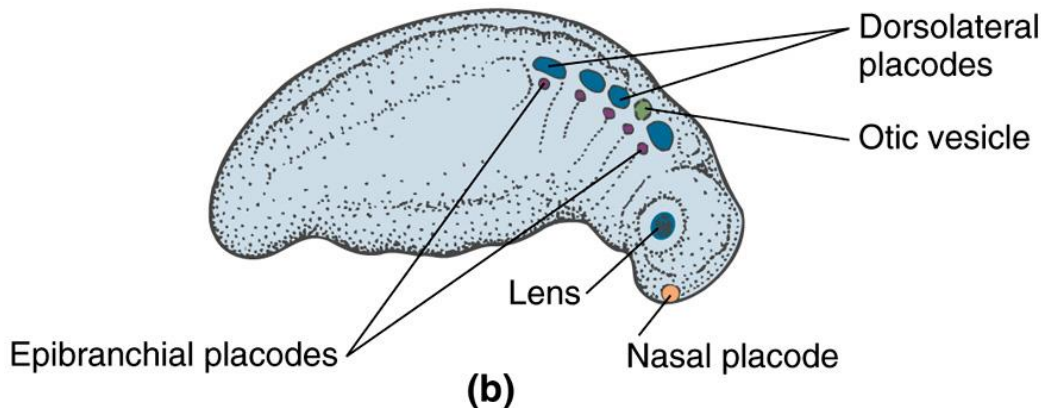


Brain after 4 weeks of development

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



Placode
(a)



Dorsolateral placodes

Contribute to:

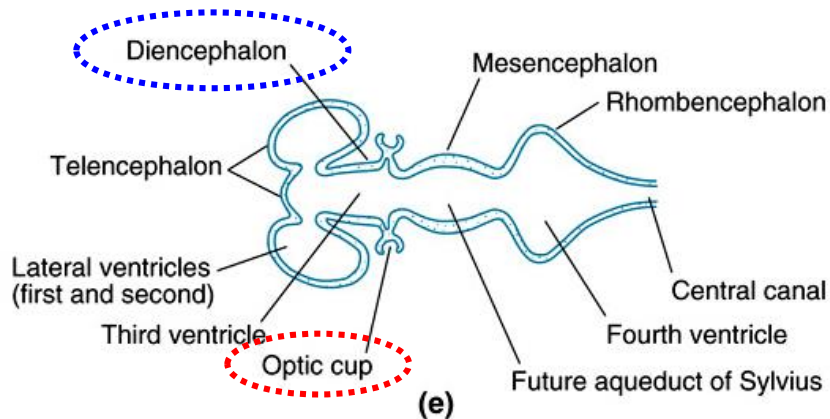
- eye - lens placode
- ear - otic placode
- nose - nasal placode
- sensory ganglia

Epibranchial placodes

Develop into:

- sensory ganglia of cranial nerves (V, VII, IX, X)

Sense organs - Eye development 1



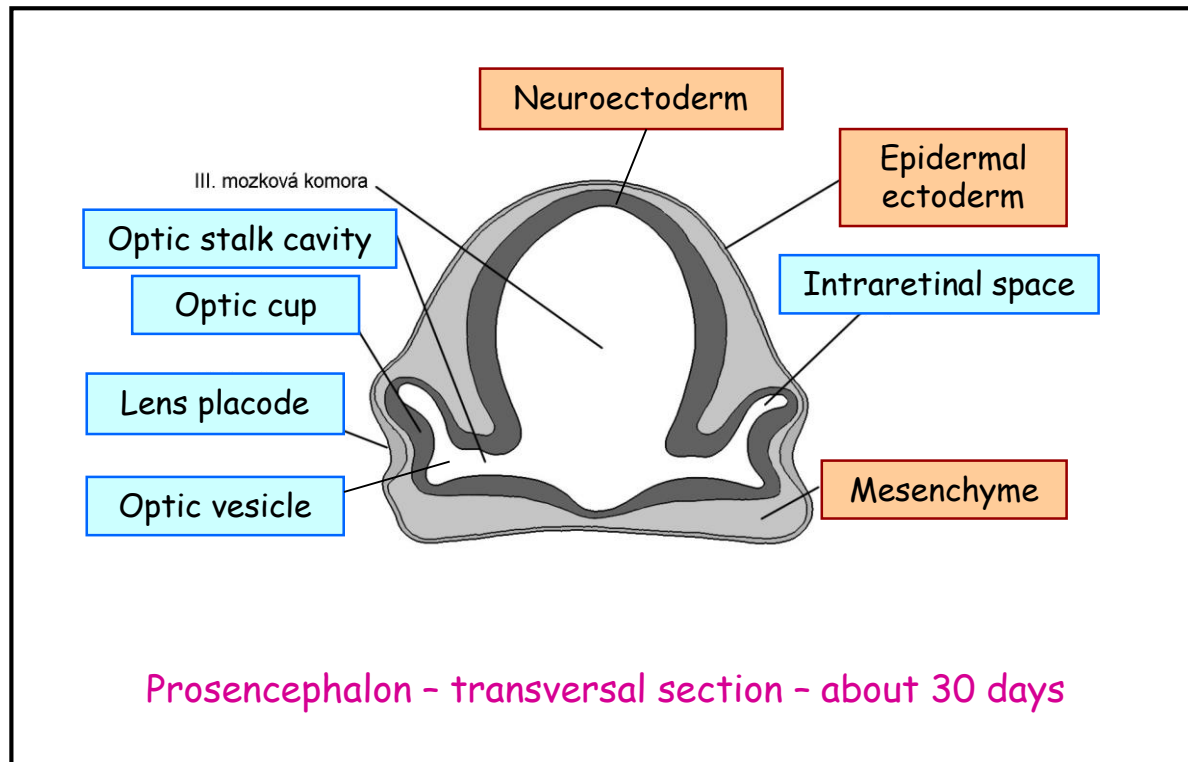
Brain after 5 weeks of development

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



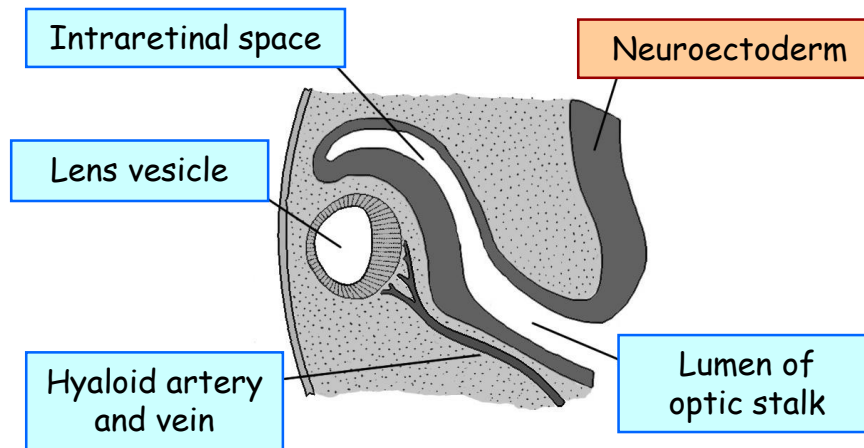
Lens placode: the ectoderm invaginates in response to signals from the optic cup underneath. It then pinches off as a lens vesicle. Cells elongate to fill the vesicle and start to synthesize crystallins.

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.

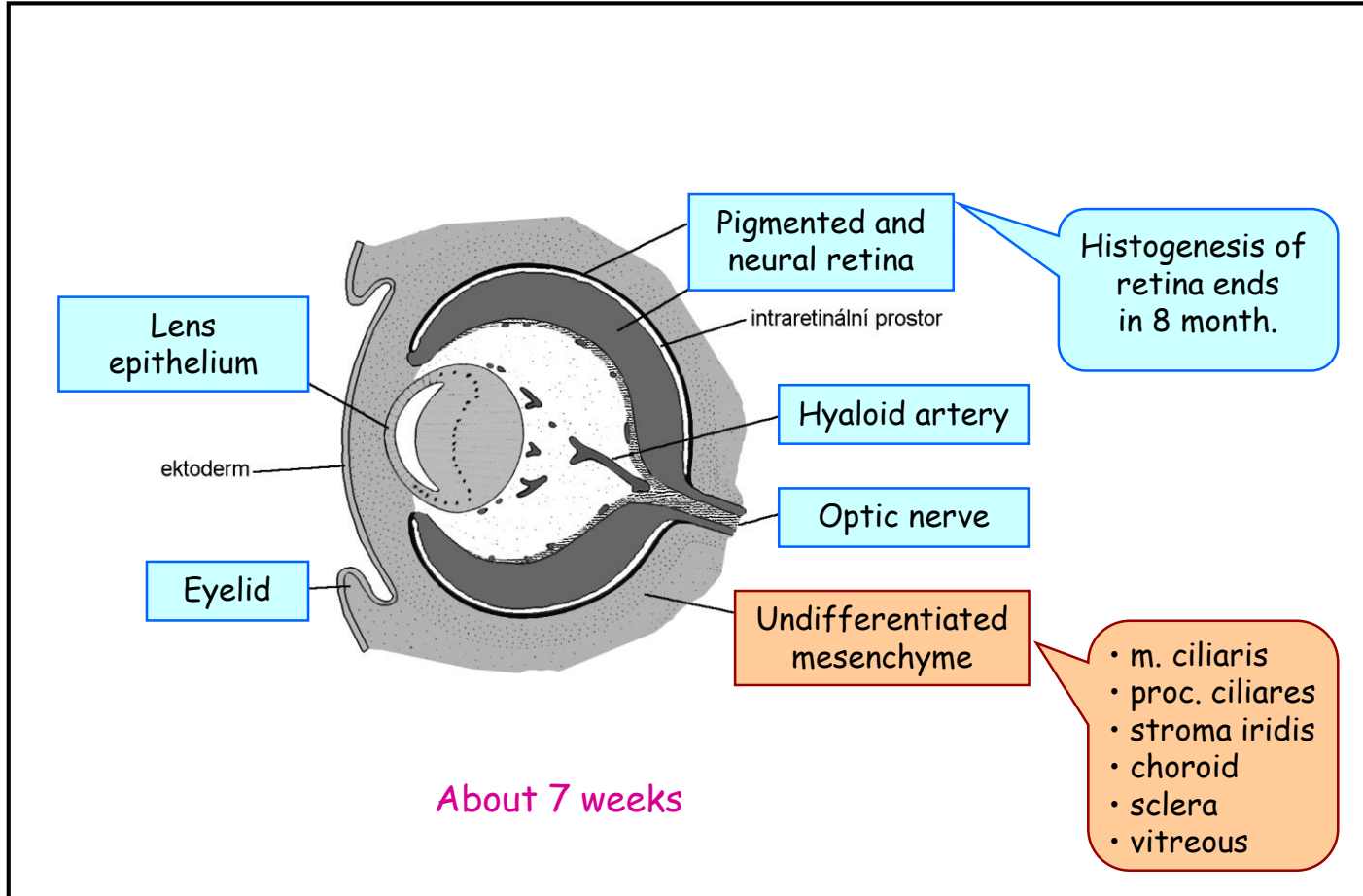
Reciprocal interaction: the lens induces the formation of the optic cup and the cup regulates formation of the lens.

Sense organs - Eye development 3

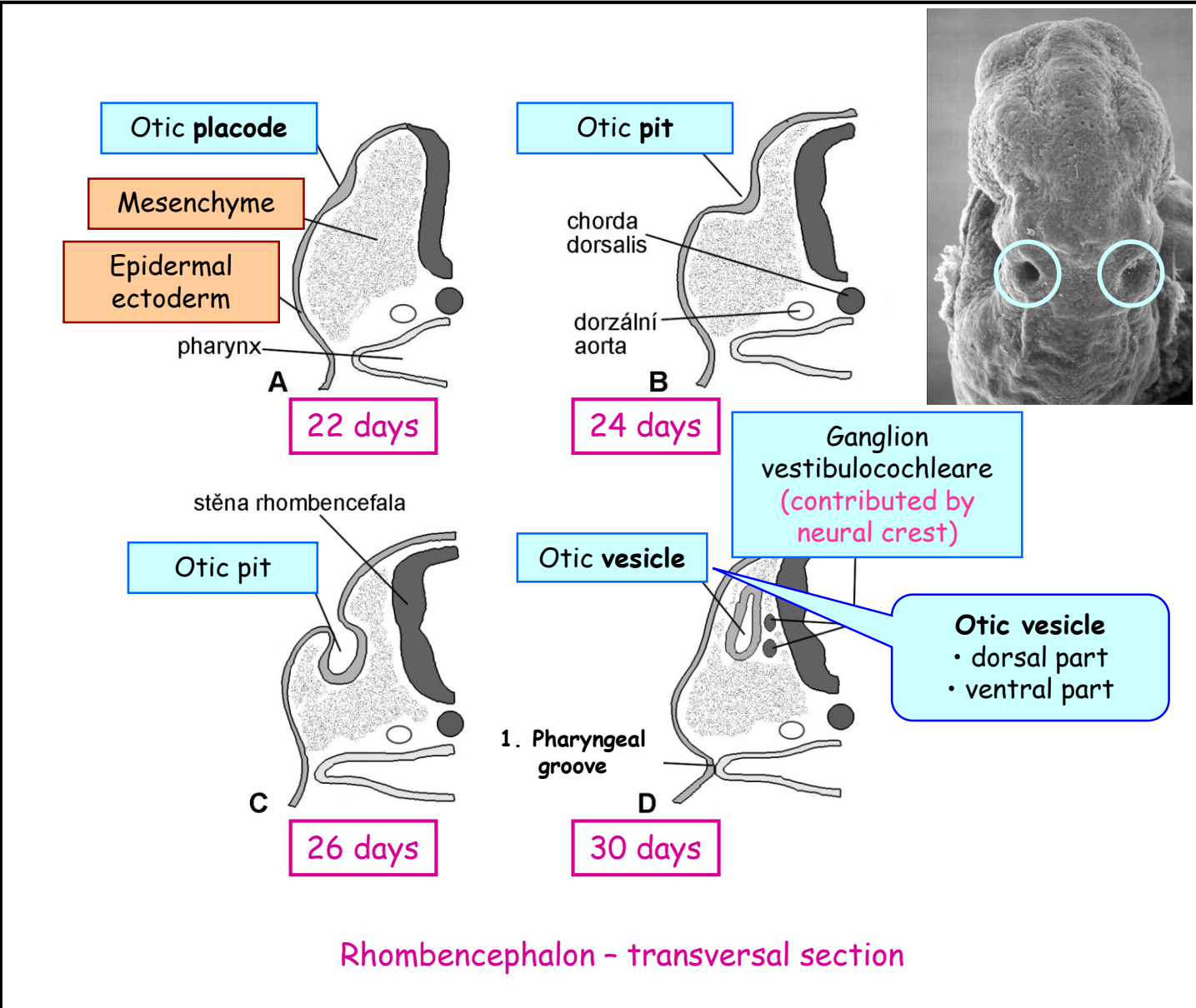


Diencephalon - transversal section - 6 weeks

Sense organs - Eye development 4

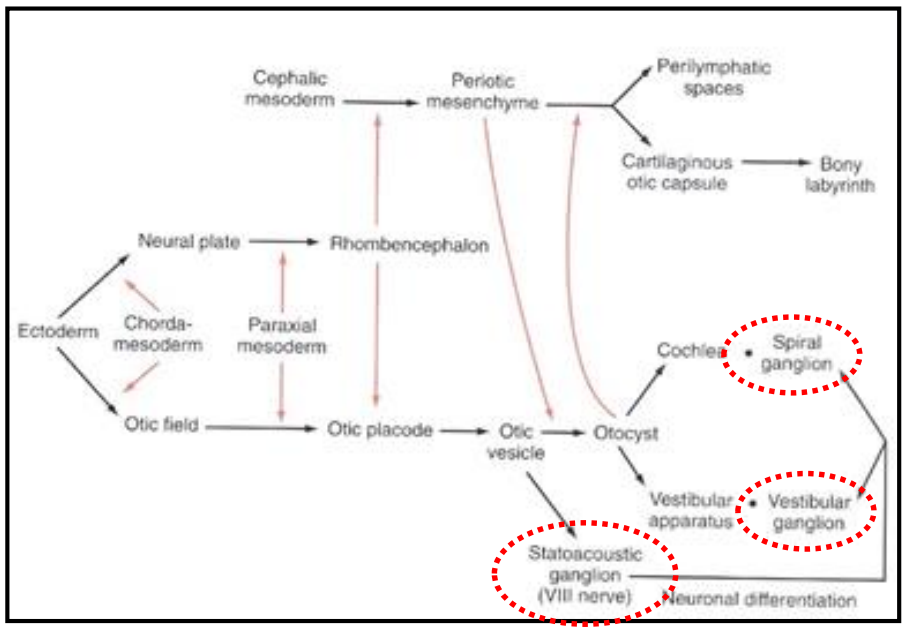
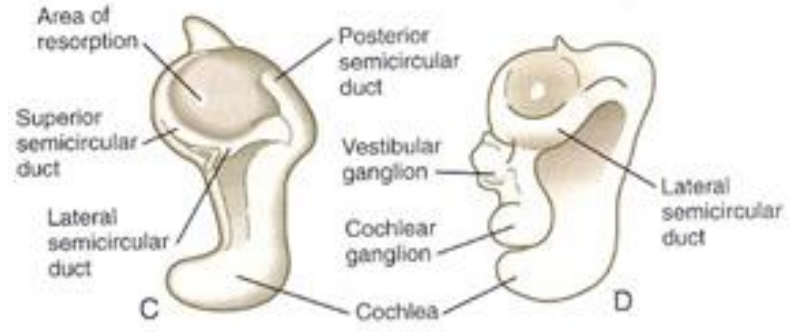


Ear development - Inner ear 1

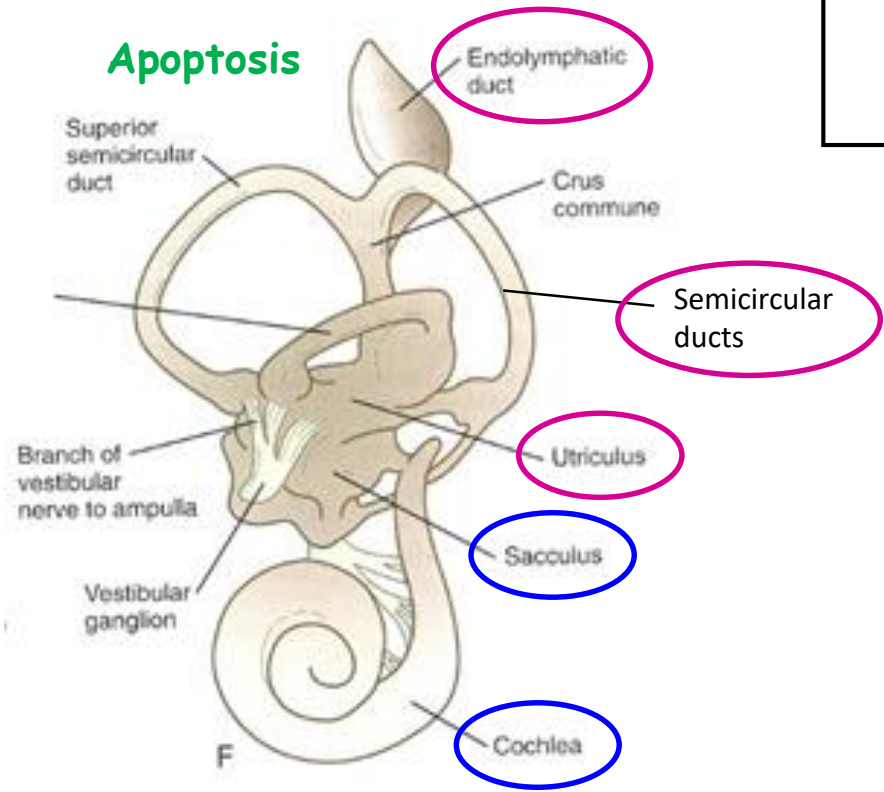


Ear development - Inner ear 2

Elongation

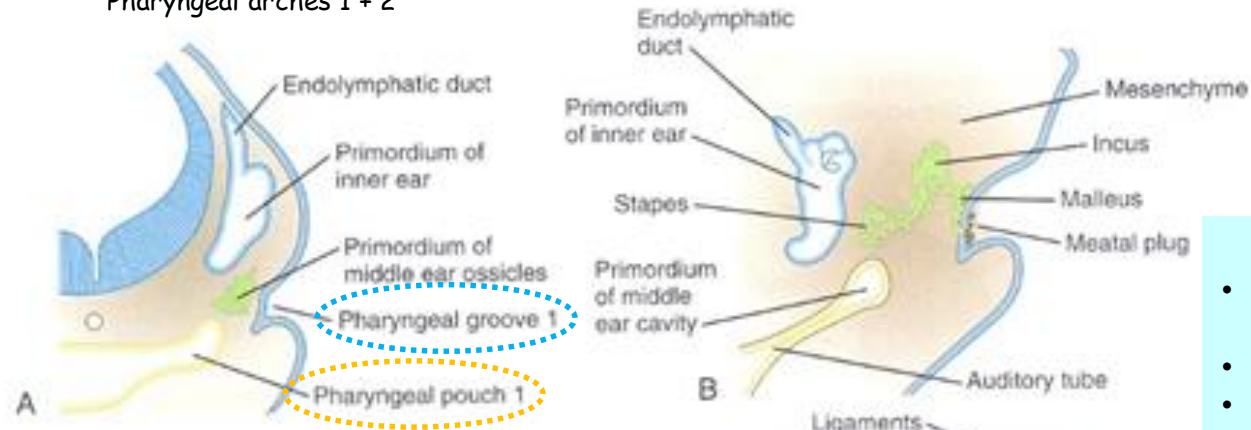


Apoptosis



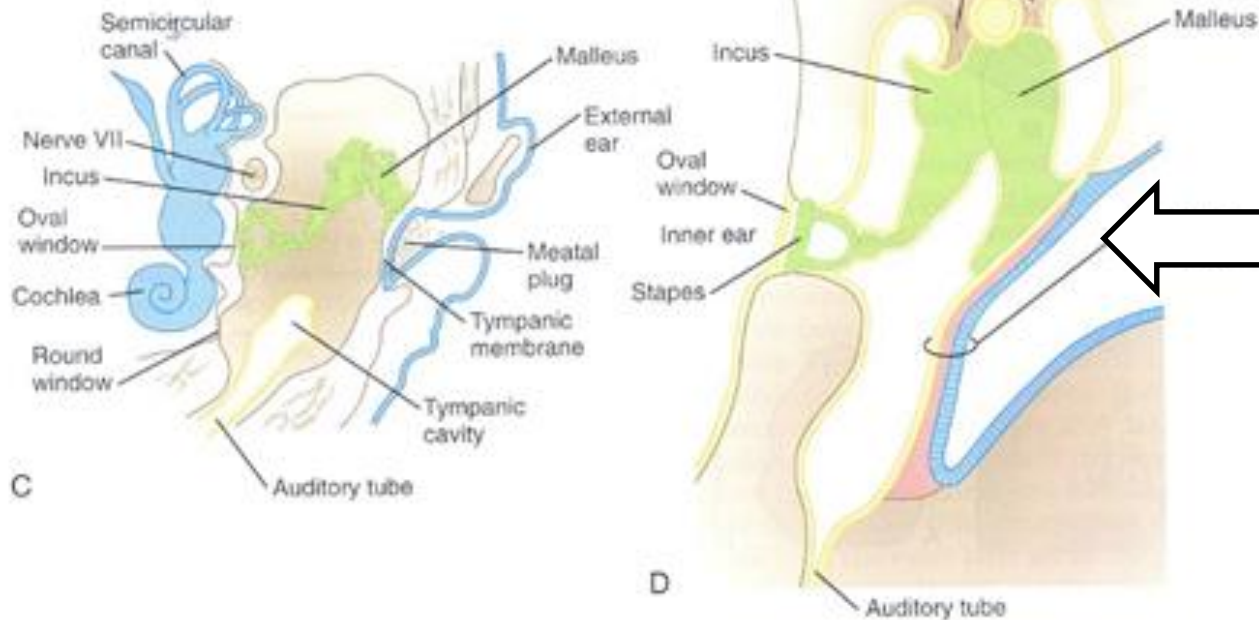
Ear development - Middle ear

Pharyngeal arches 1 + 2



Ossicles

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

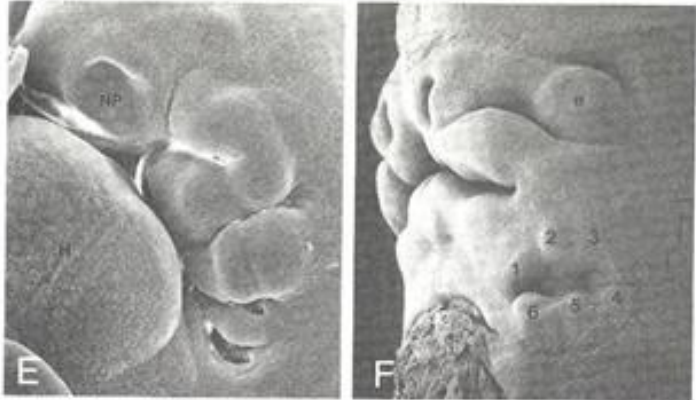
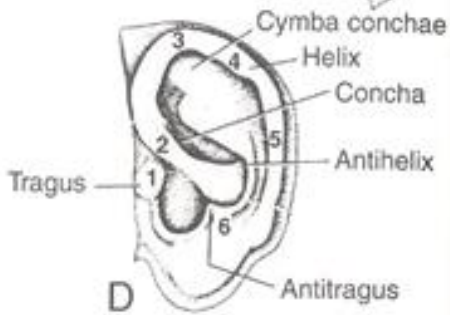
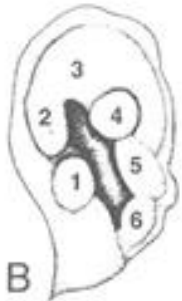
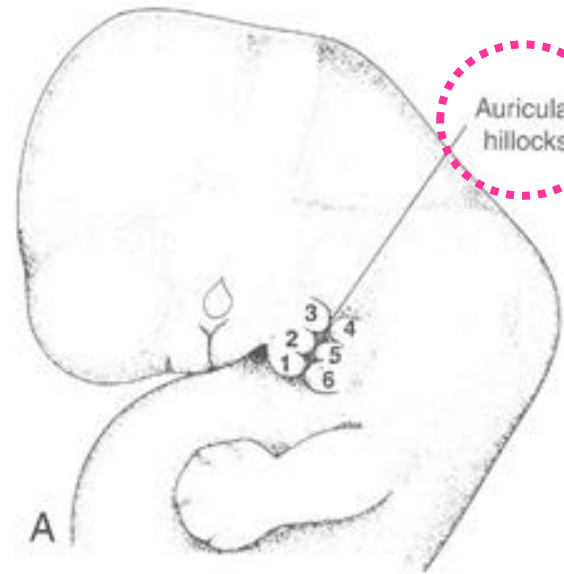


Tympanic membrane

Endoderm
Mesoderm
Ectoderm

Ear development - External ear

Mesenchyme



External auditory meatus - ectoderm

Thank you for your attention !