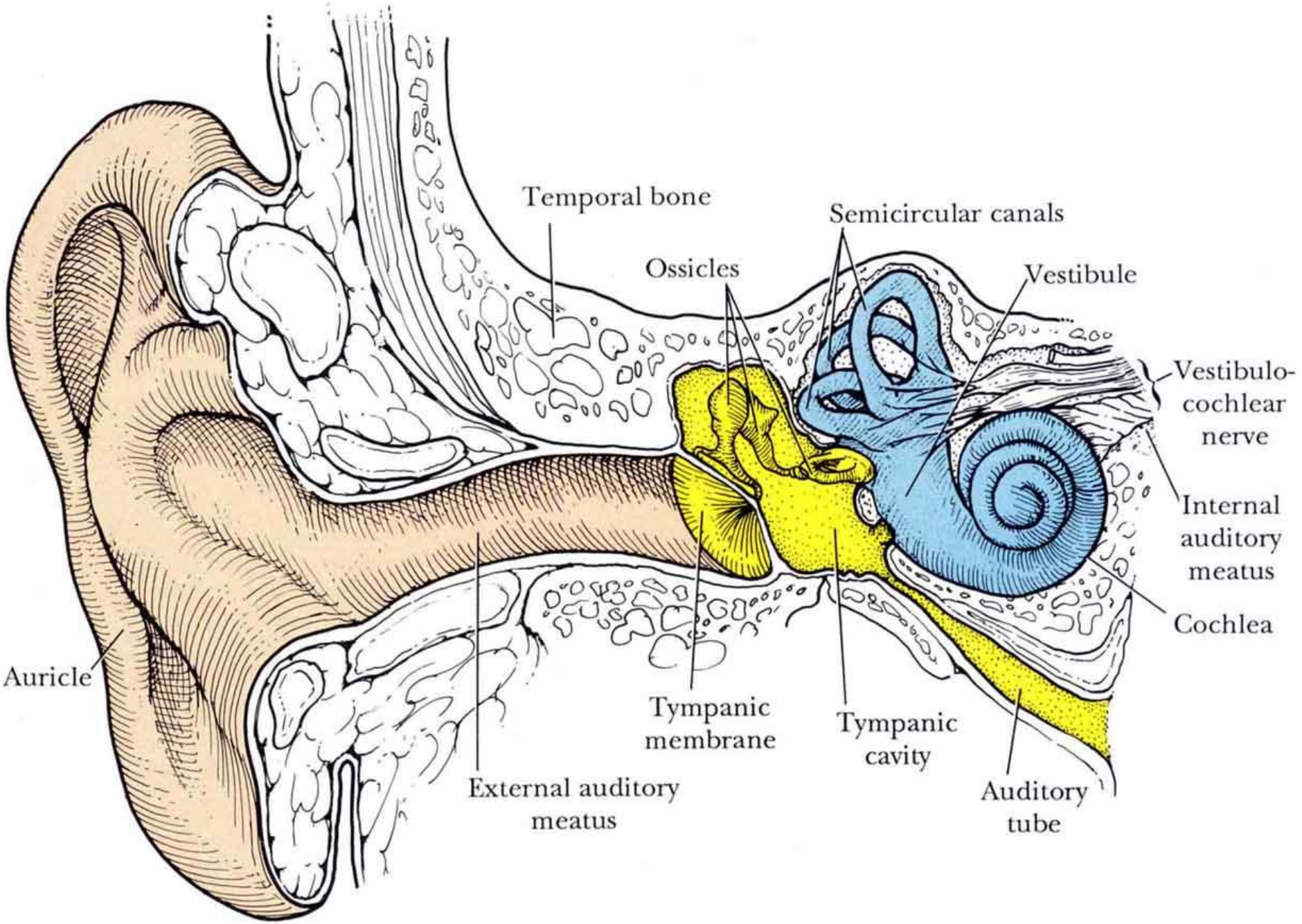
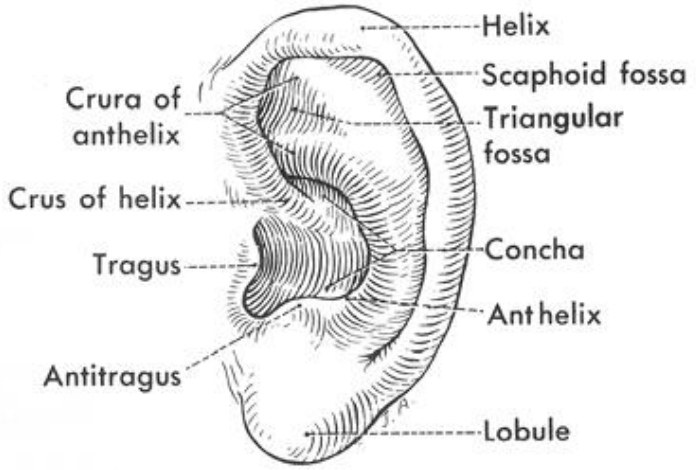
Senses II
ear, smell, taste

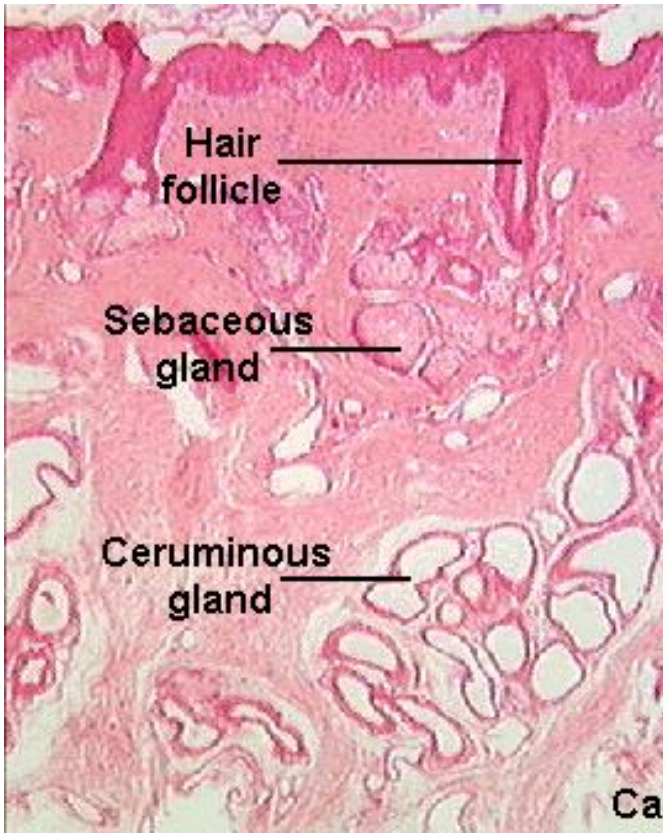
MUDr. Andrea Felšöová

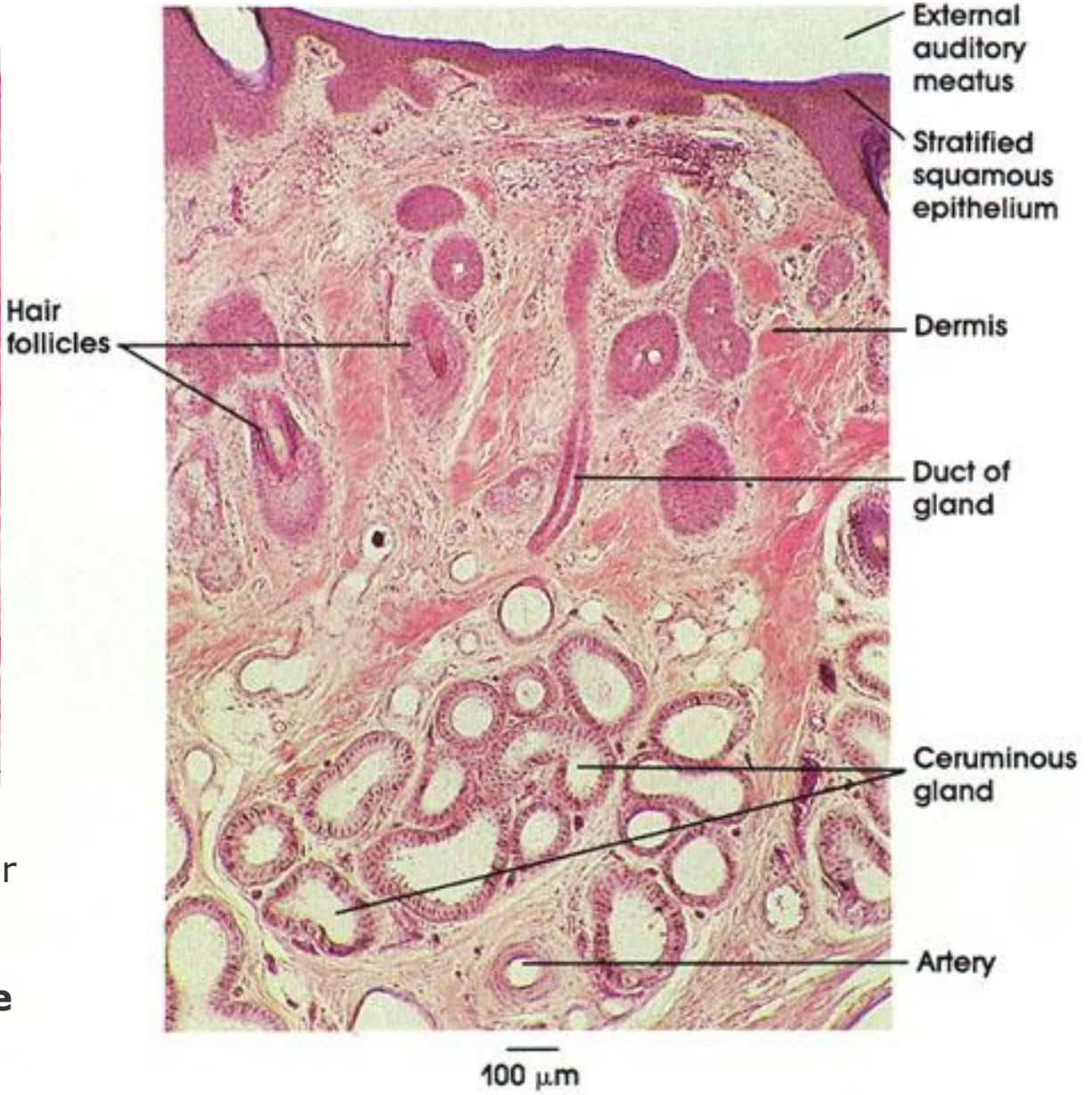

Temporal bone
Semicircular canals
Ossicles
Vestibule
Vestibulo-
cochlear
nerve
Internal
auditory
meatus
Cochlea
Auricle
Tympanic
membrane
Tympanic
cavity
External auditory
meatus
Auditory
tube



the auricle is essentially an **elastic cartilage** covered with the skin: keratinizing, stratified squamous epithelium with associated cutaneous adnexal structures in the dermis that include **hair follicles**, **sebaceous glands,** and **eccrine sweat glands**

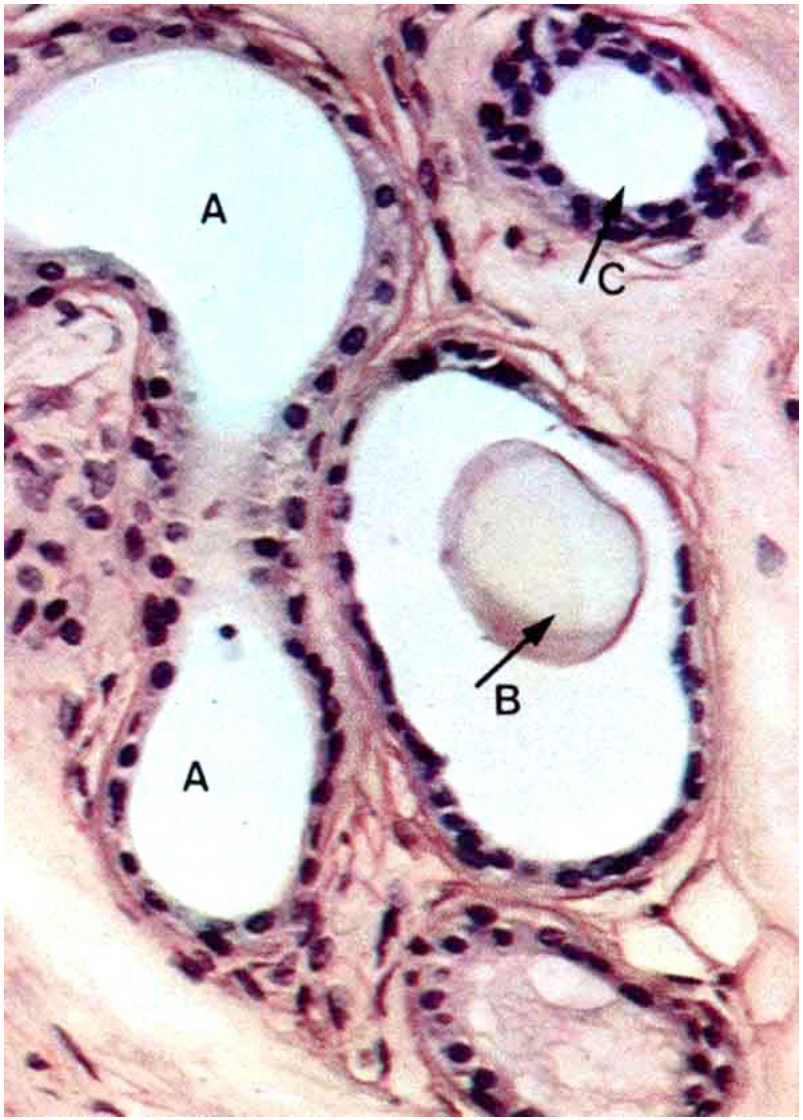
external auditory meatus

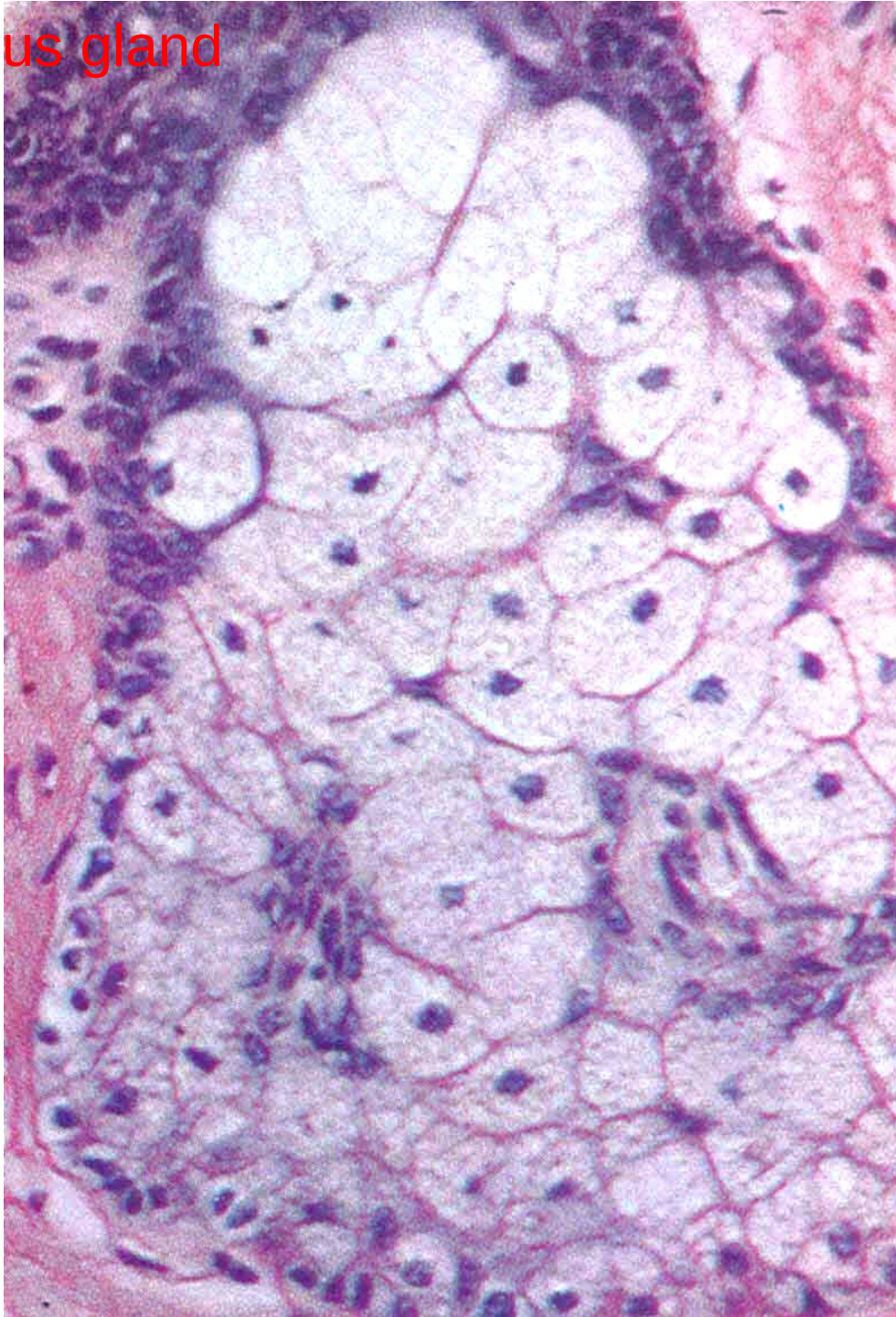


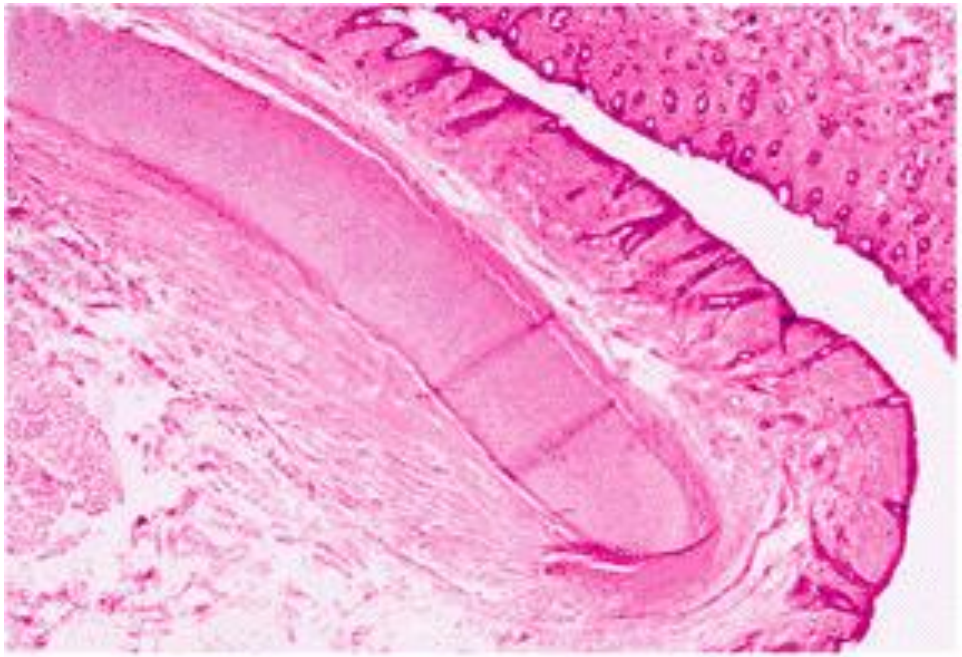


In addition to the hair follicles and sebaceous glands, the outer third of the external auditory canal is noteworthy for the presence of **modified apocrine glands called ceruminal glands**

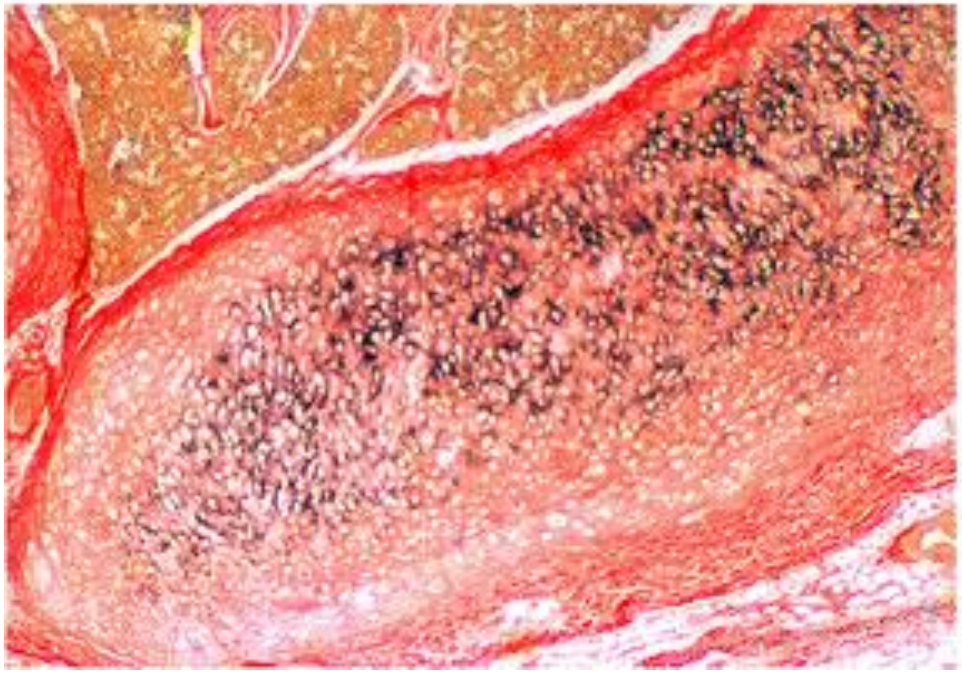
A = secretory tubule of ceruminous gland
B = cerumen
C = duct of ceruminous gland







A



B

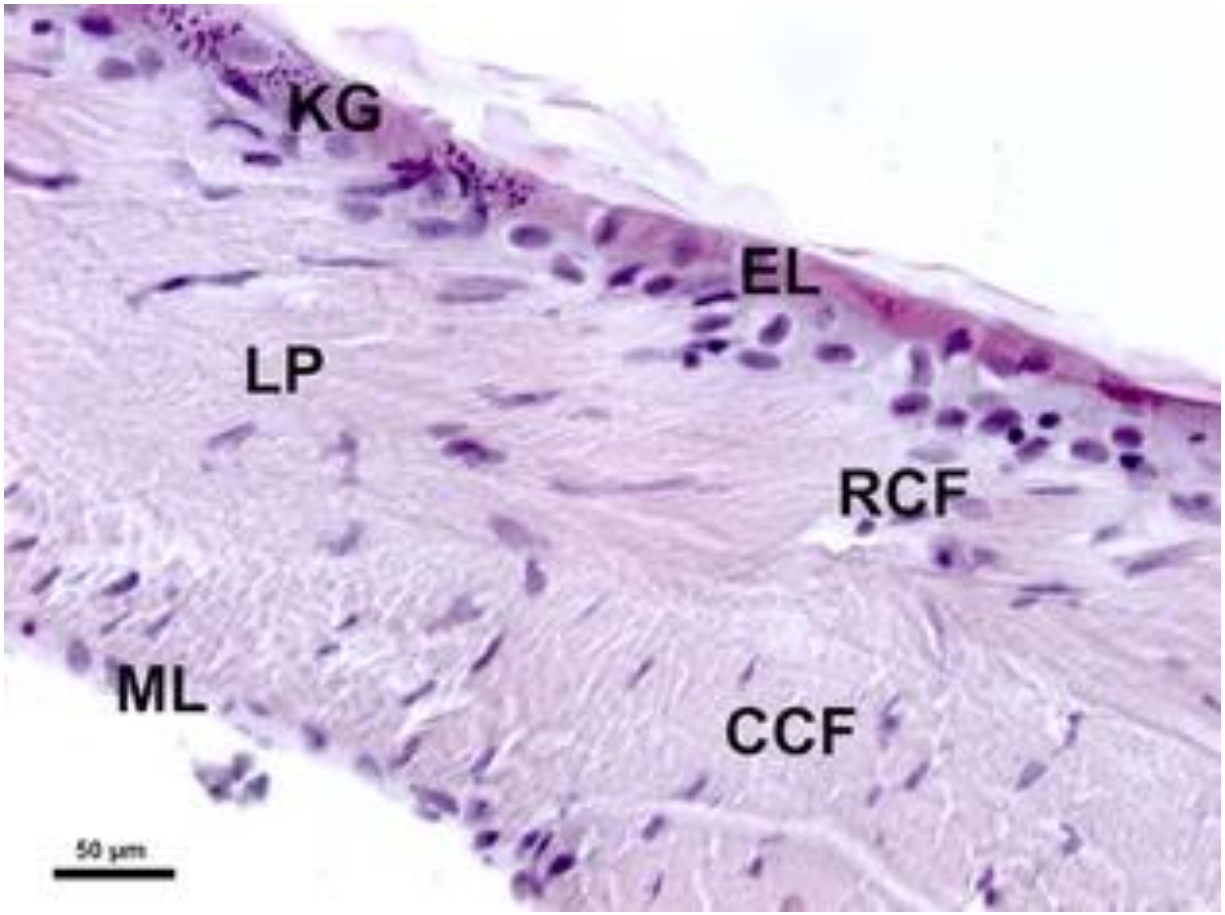
The cartilage of the external ear and external auditory canal is **elastic**

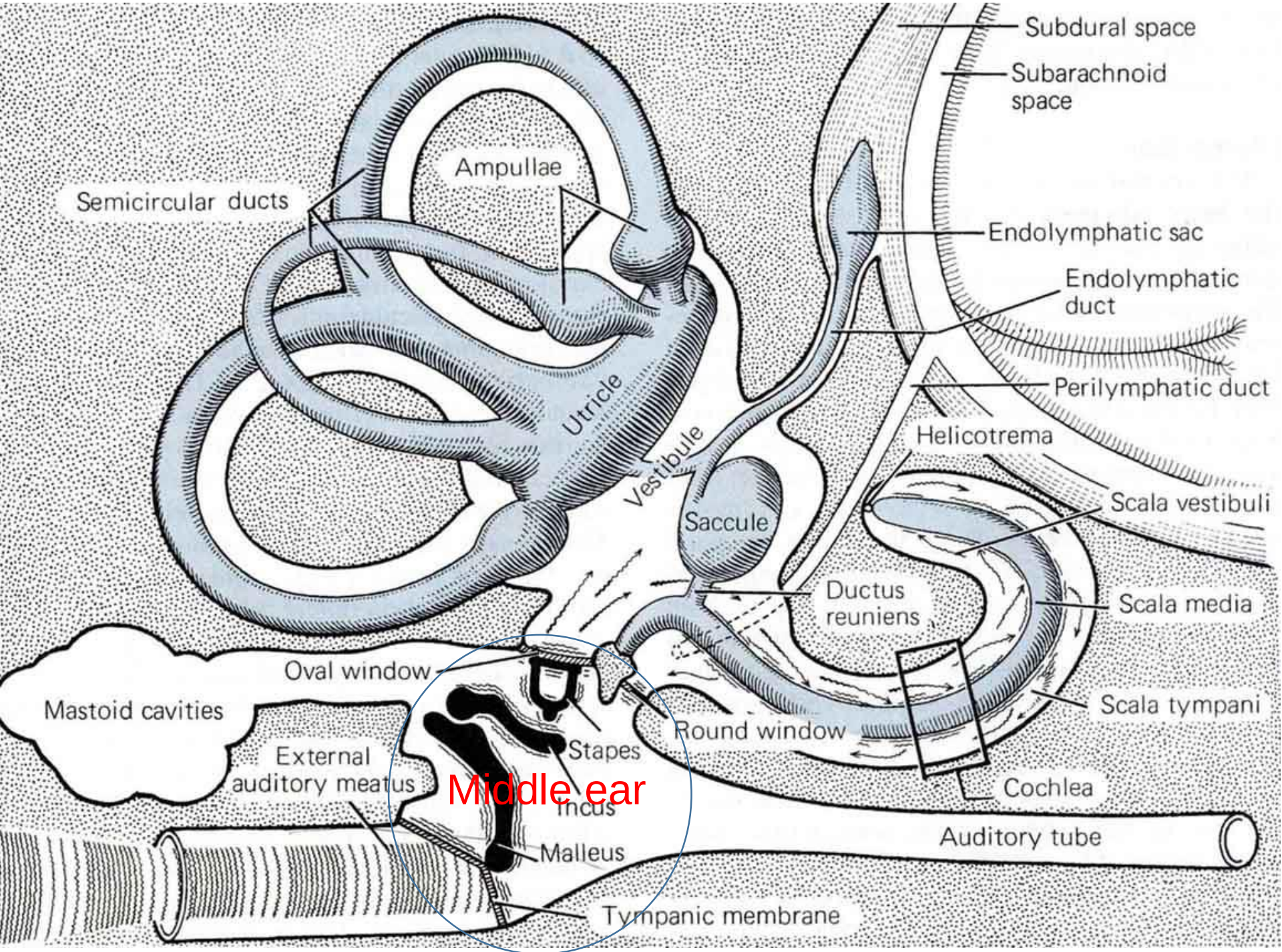
The lateral portion of external auditory canal consists of cartilage and connective tissue

The medial portion of its wall consists of bone.

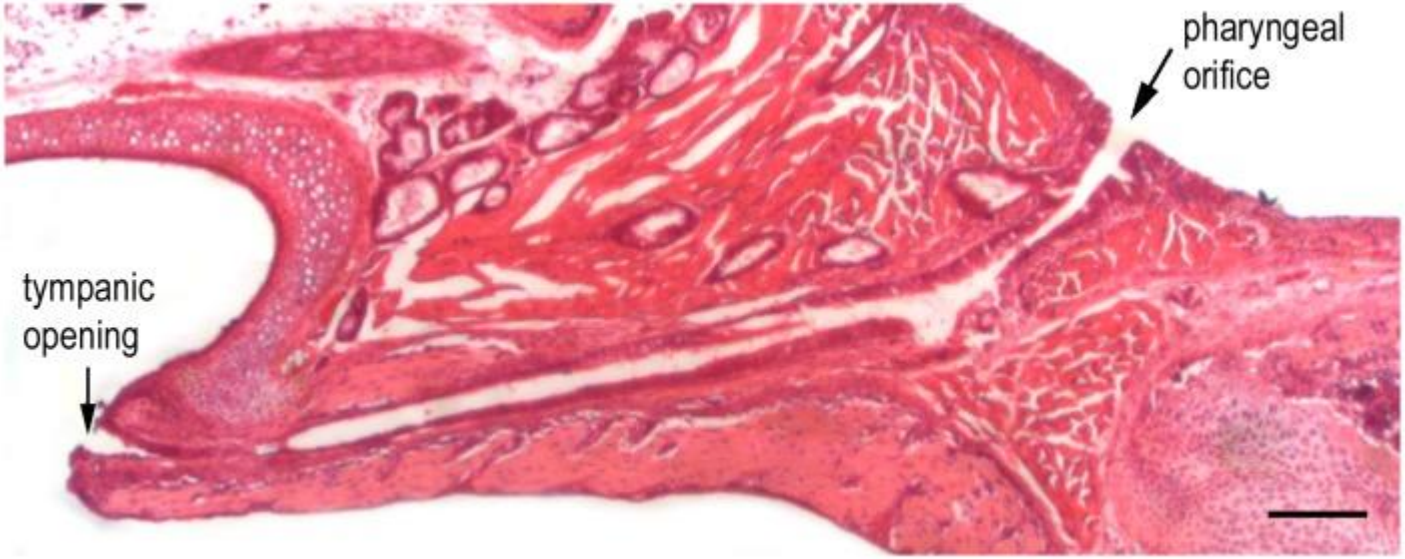
The cartilaginous part of the external auditory canal constitutes slightly less than half its total length.

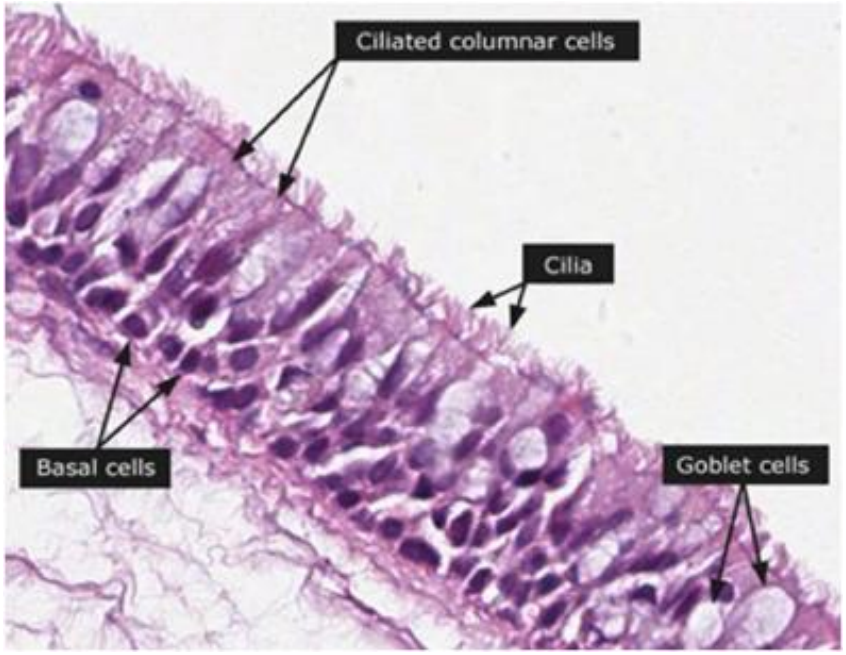
tympanic membrane
EL = epidermal layer
LP = lamina propria
ML = mucosa- simple cuboidal epithelium

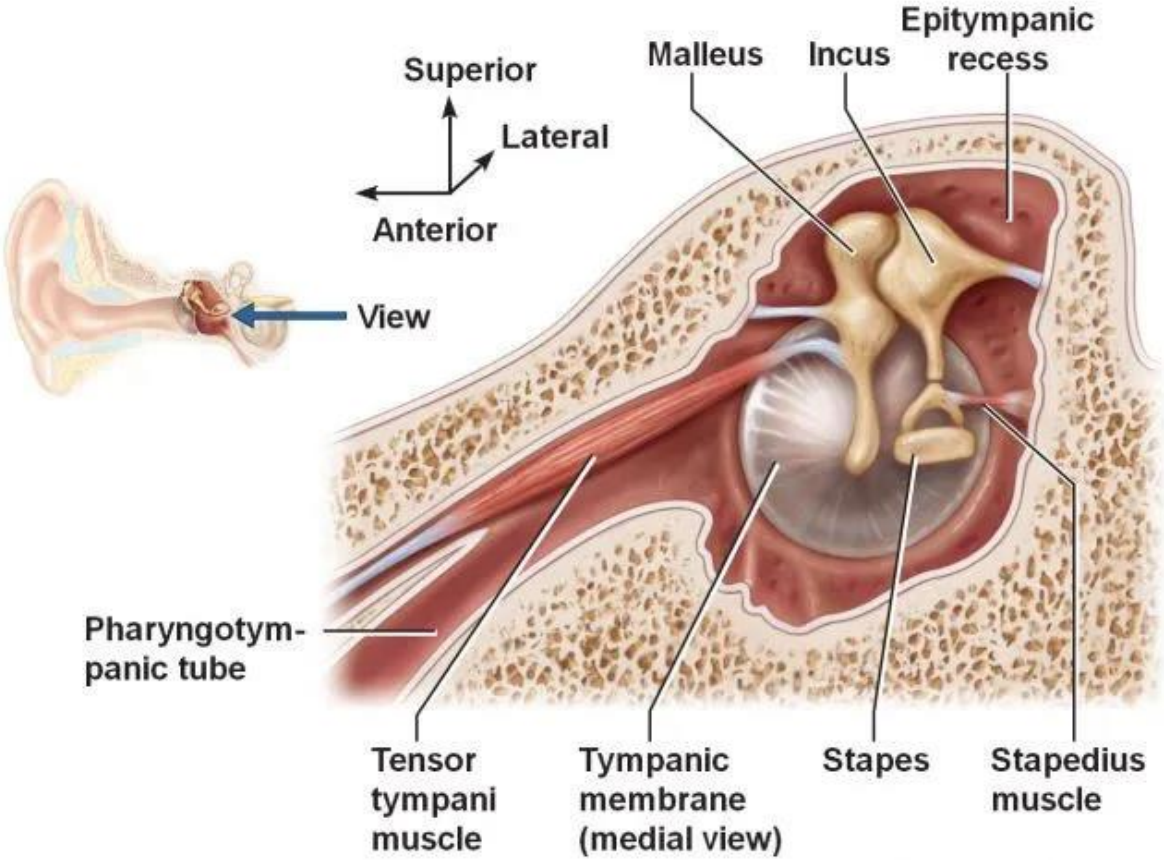



Subdural space
Subarachnoid space
Ampullae
Semicircular ducts
Endolymphatic sac
Endolymphatic duct
Perilymphatic duct
Utricle
Vestibule
Helicotrema
Saccule
Scala vestibuli
Ductus reuniens
Scala media
Oval window
Mastoid cavities
Scala tympani
Round window
Stapes
External auditory meatus
Middle ear
Cochlea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

Eustachian tube

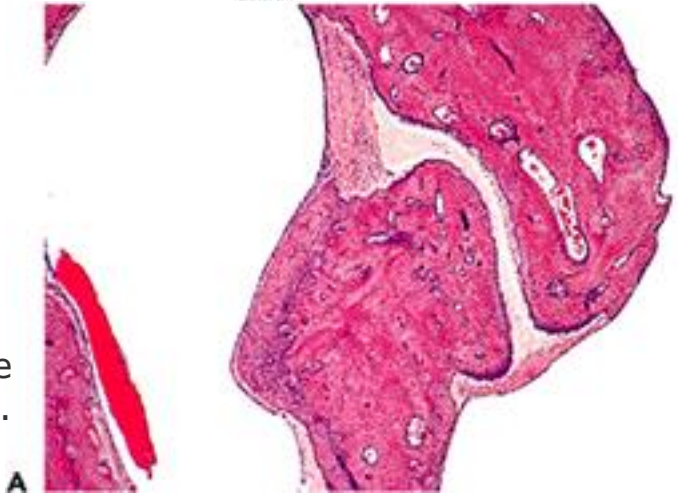






feather-shaped configuration of muscles in the middle ear

- function as insulation and protection from loud sounds

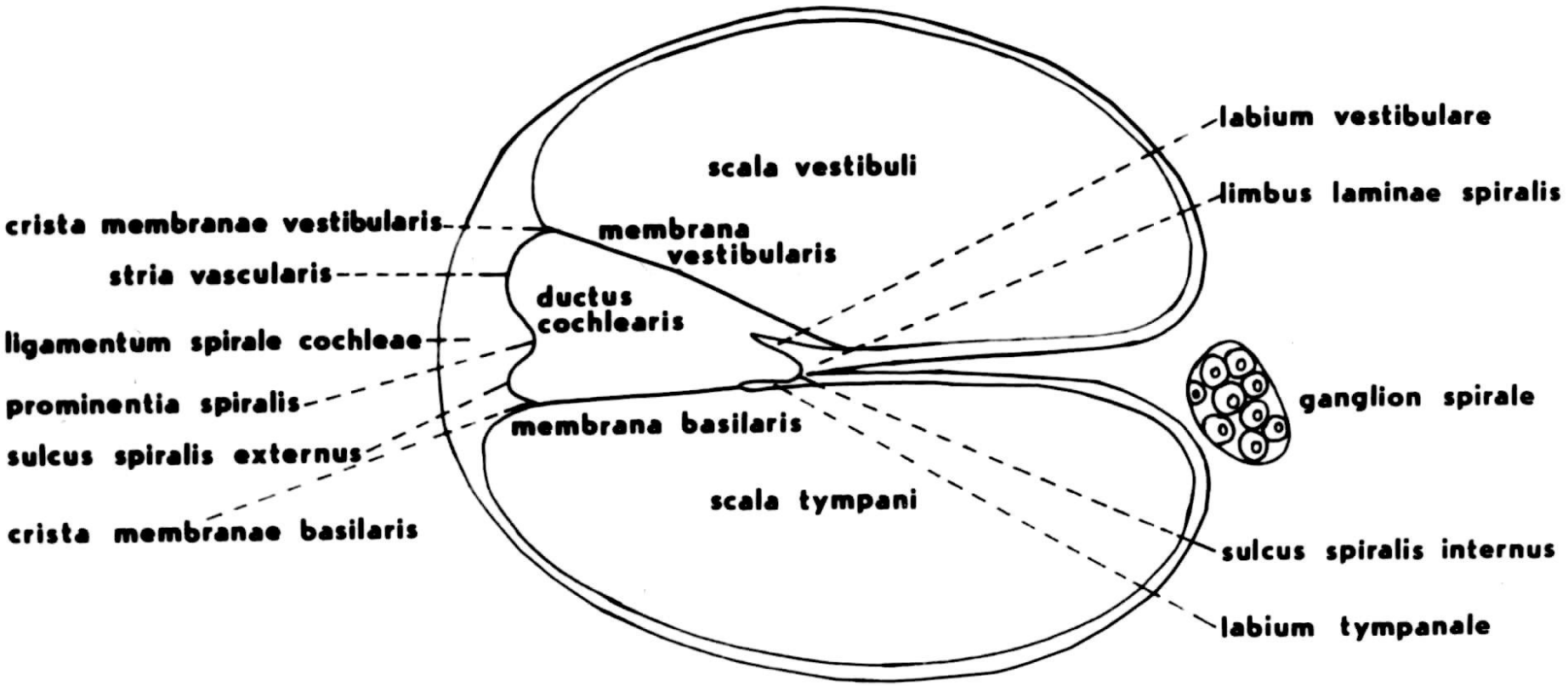


Incudomalleal joint.
The joint space is occupied by the fibrocartilage of the articular disk.

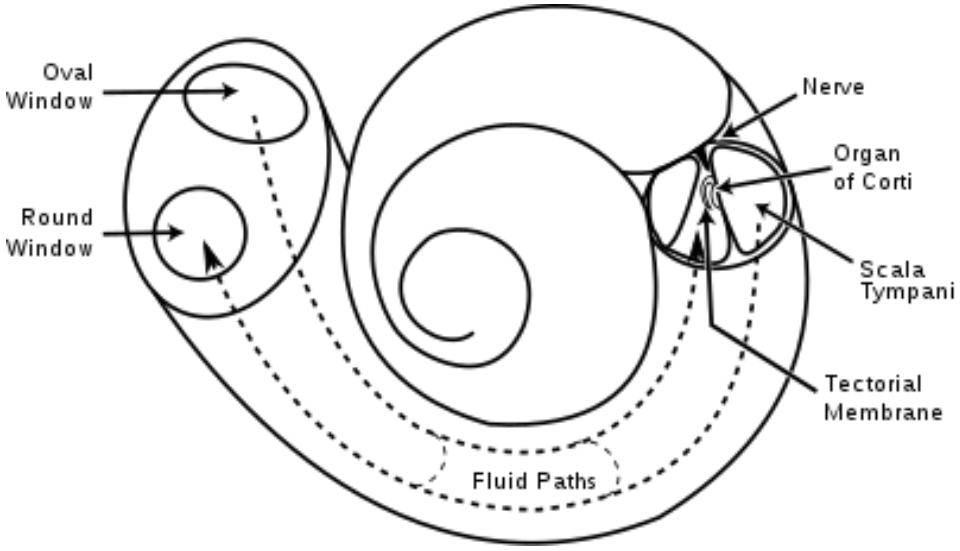
Corti organ (cochlear apparatus)

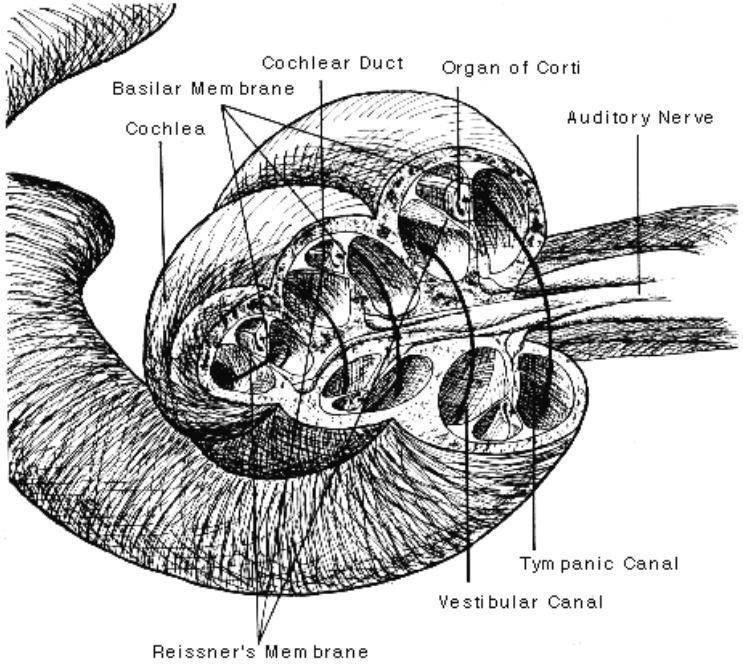
The organ of Corti

- neurotransmitting hair cells + supporting cells
- on the basilar membrane
- arranged in a spiral like the duct itself

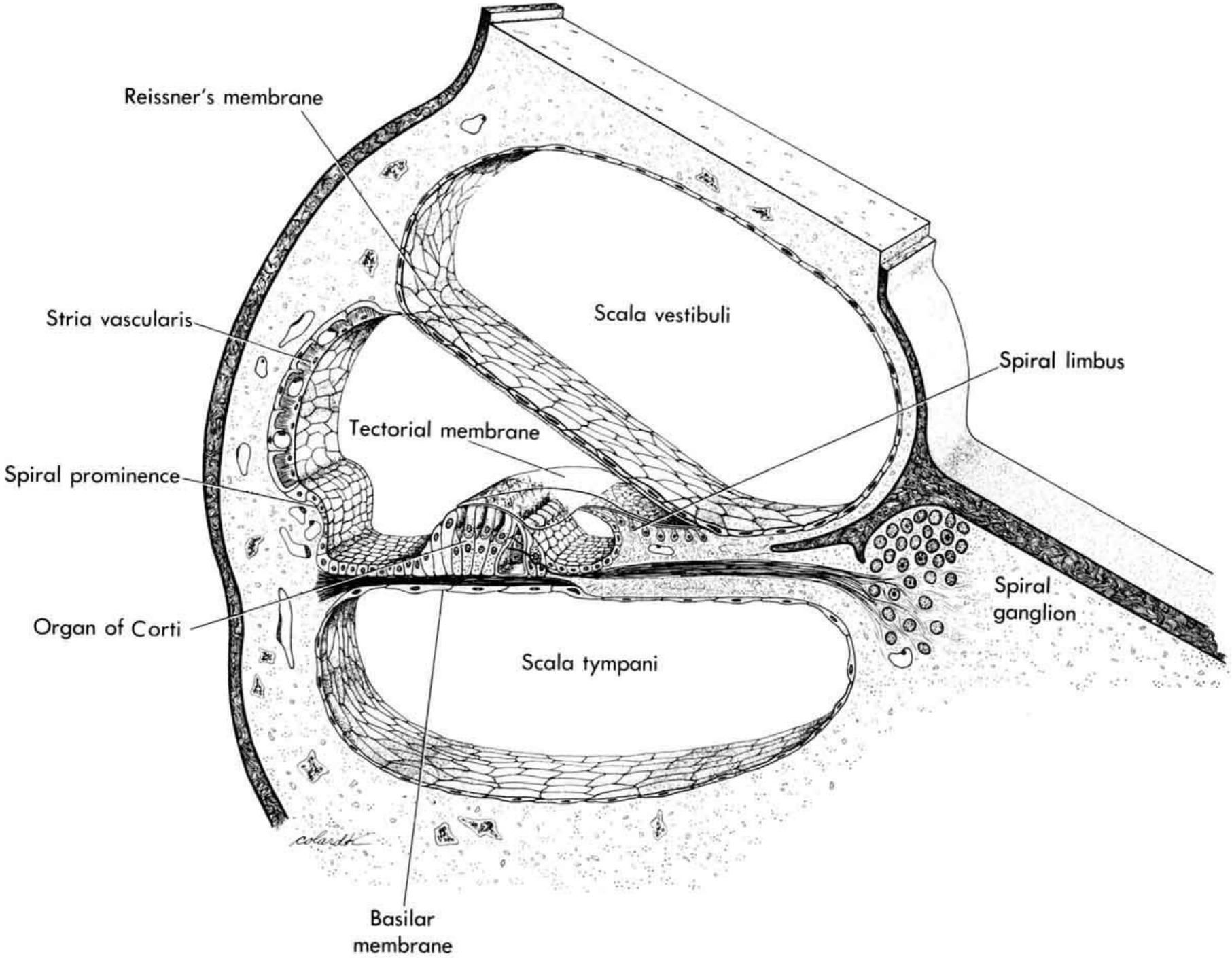


Cochlea

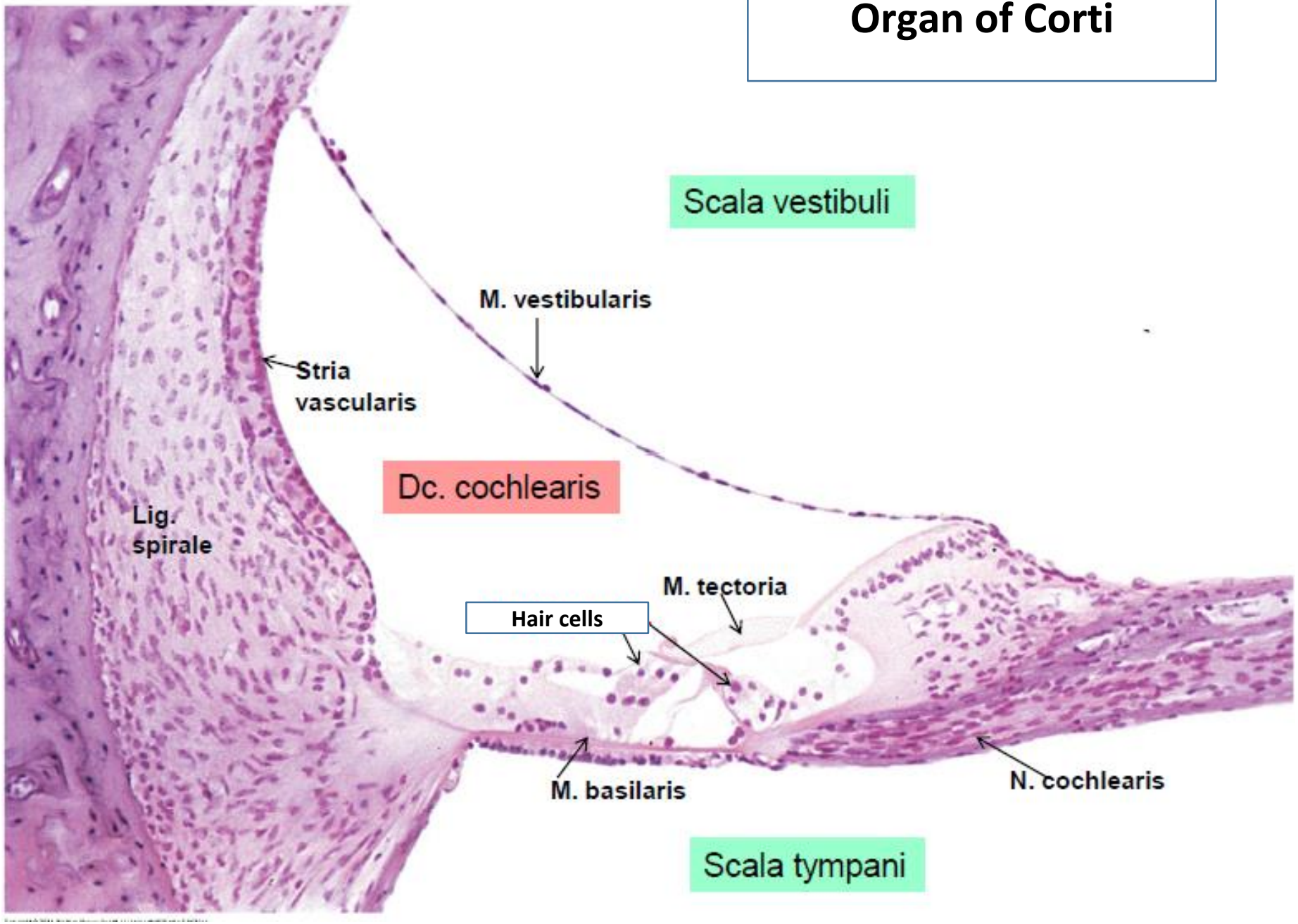

Oval Window
Round Window
Nerve
Organ of Corti
Scala Tympani
Tectorial Membrane
Fluid Paths


Cochlear Duct
Organ of Corti
Basilar Membrane
Cochlea
Auditory Nerve
Tympanic Canal
Vestibular Canal
Reissner's Membrane

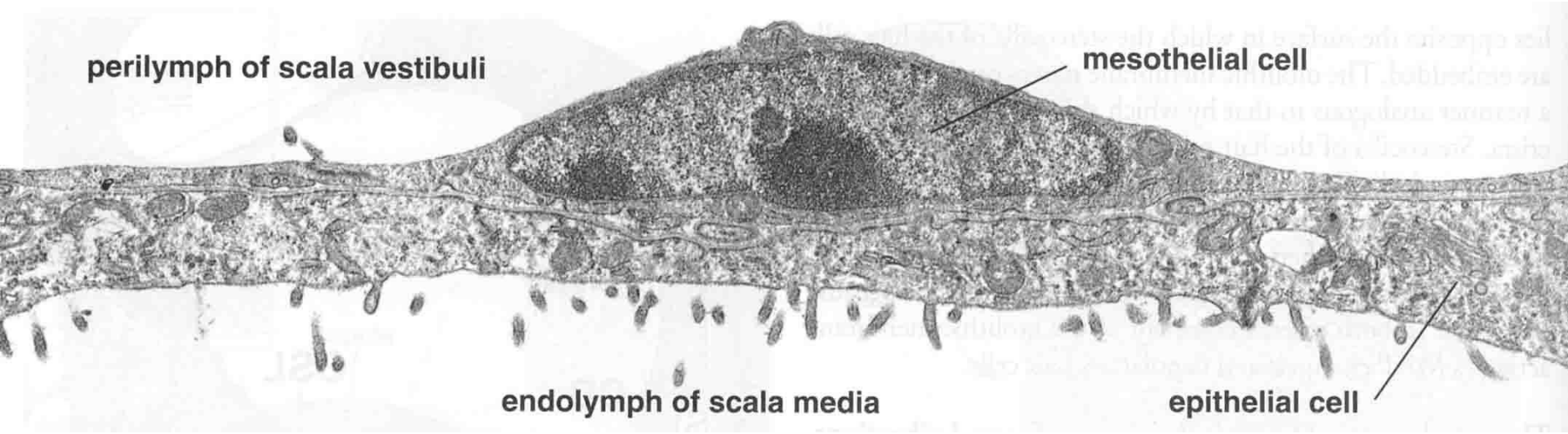

G
SV
SM
ST
G
G
SV
SM
G
ST


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

Organ of Corti



Membrana vestibularis (Reissner's membrane)



Reissner's, membrane is thin and consists of two layers of cells: an inner cell layer of ectodermal origin (consisting of epithelial-like clusters) and an outer layer of mesenchymal origin (consisting of large, flat, and elongated cells)

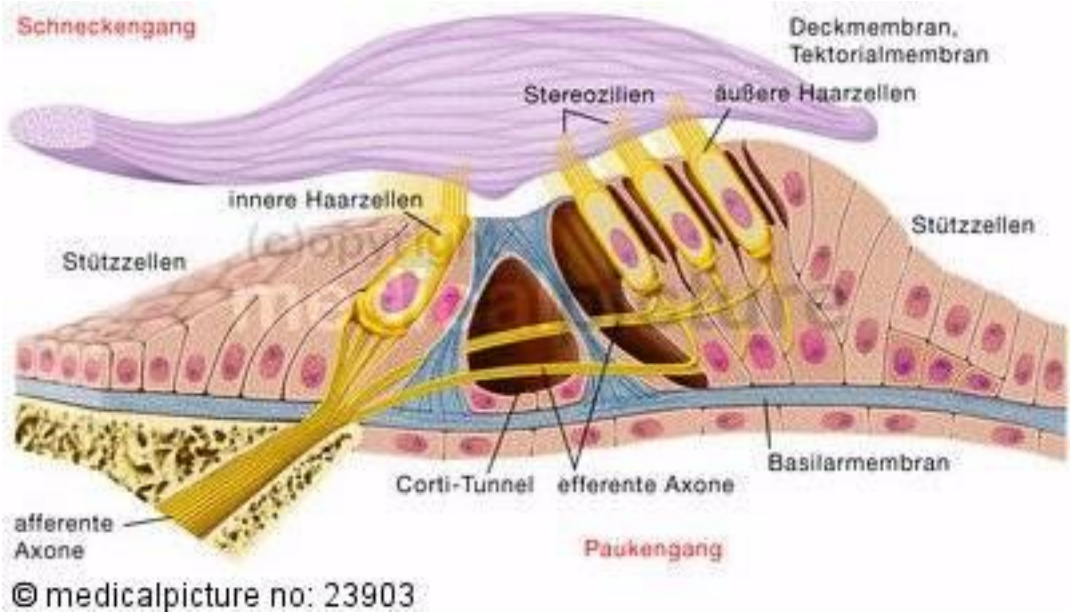
Spaces

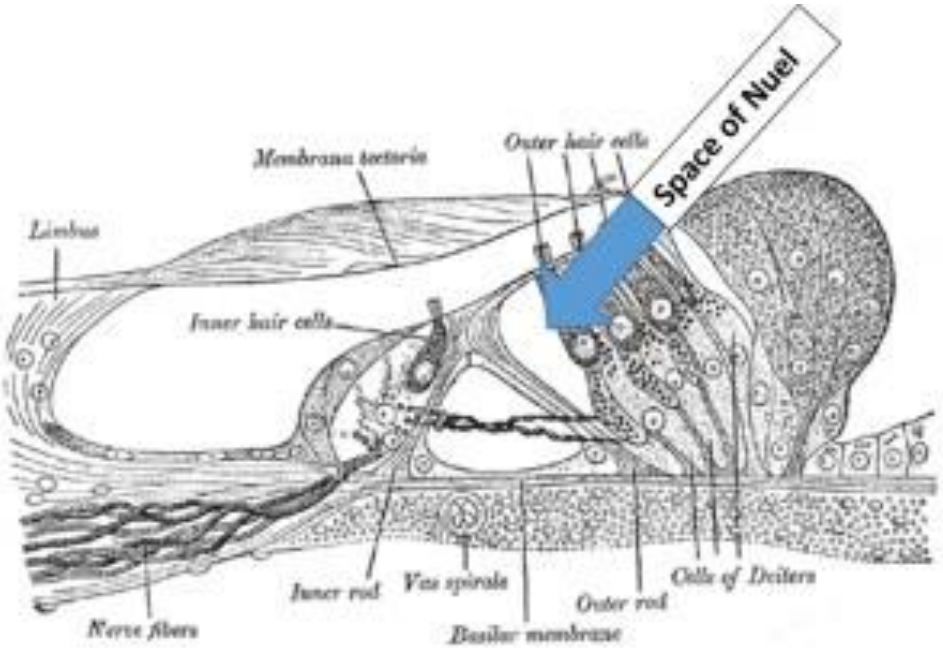
Nuel's space = the space between the outer pillar cell and the first row of phalanx cells and hair cells

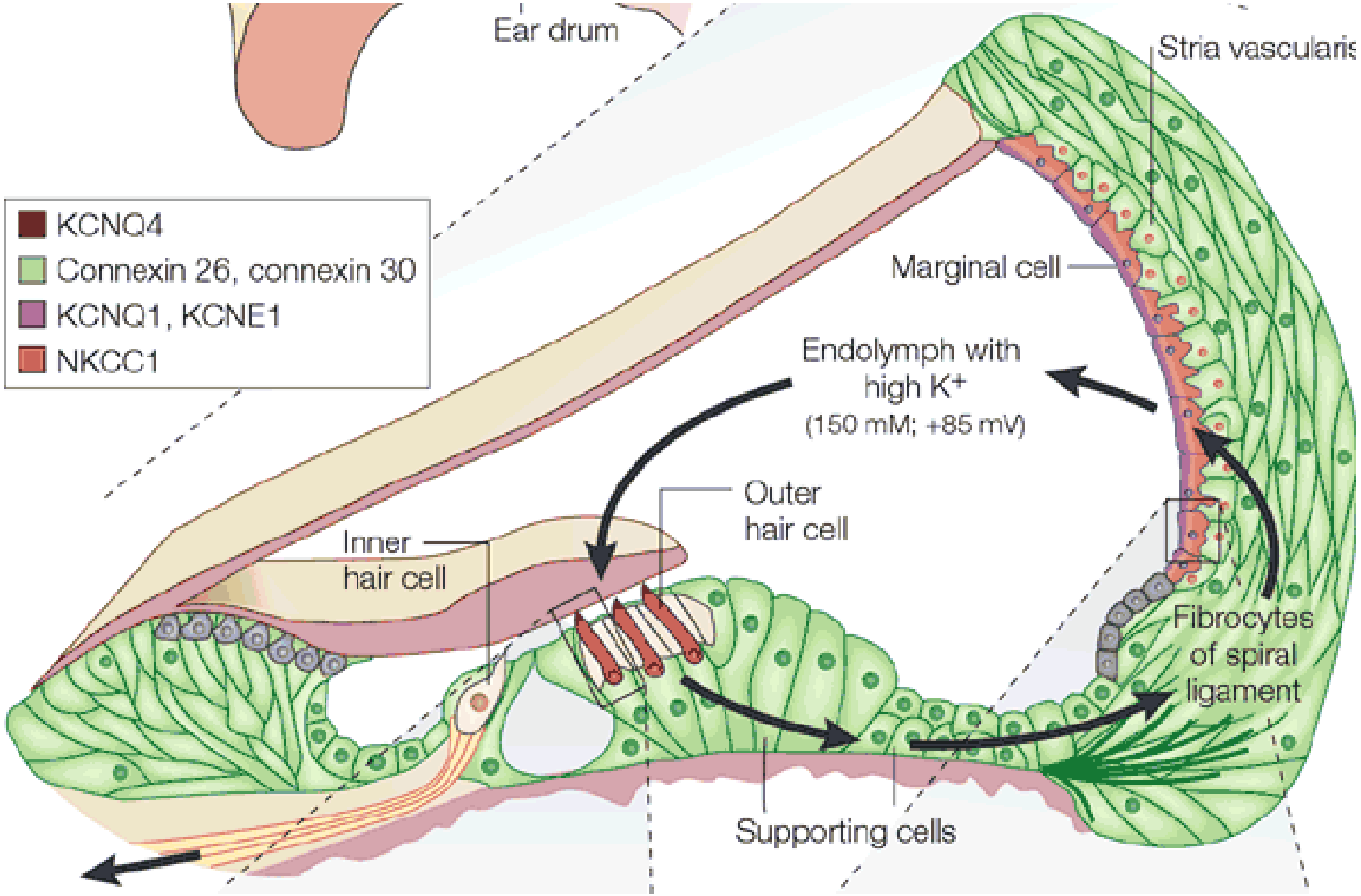
tunnel of Corti = space between pillar cells

Course of the nerve:

The fibers pass through the internal tunnel of Corti through the lamina spiralis to the spiral ganglion.






Ear drum
Stria vascularis
KCNQ4
Connexin 26, connexin 30
KCNQ1, KCNE1
NKCC1
Marginal cell
Endolymph with
high K+
(150 mM; +85 mV)
Outer
hair cell
Inner
hair cell
Fibrocytes
of spiral
ligament
Supporting cells

stria vascularis

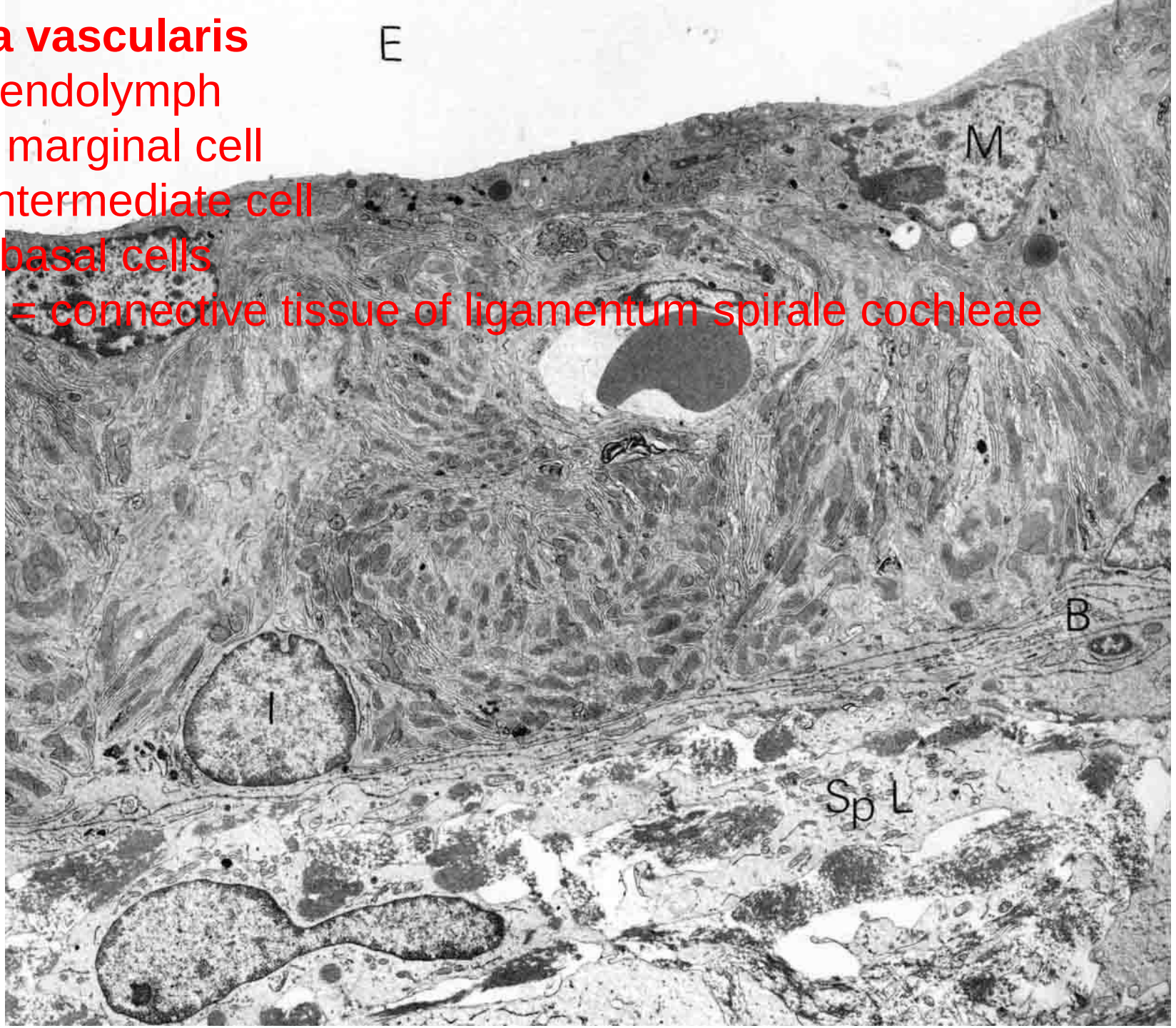
E = endolymph

M = marginal cell

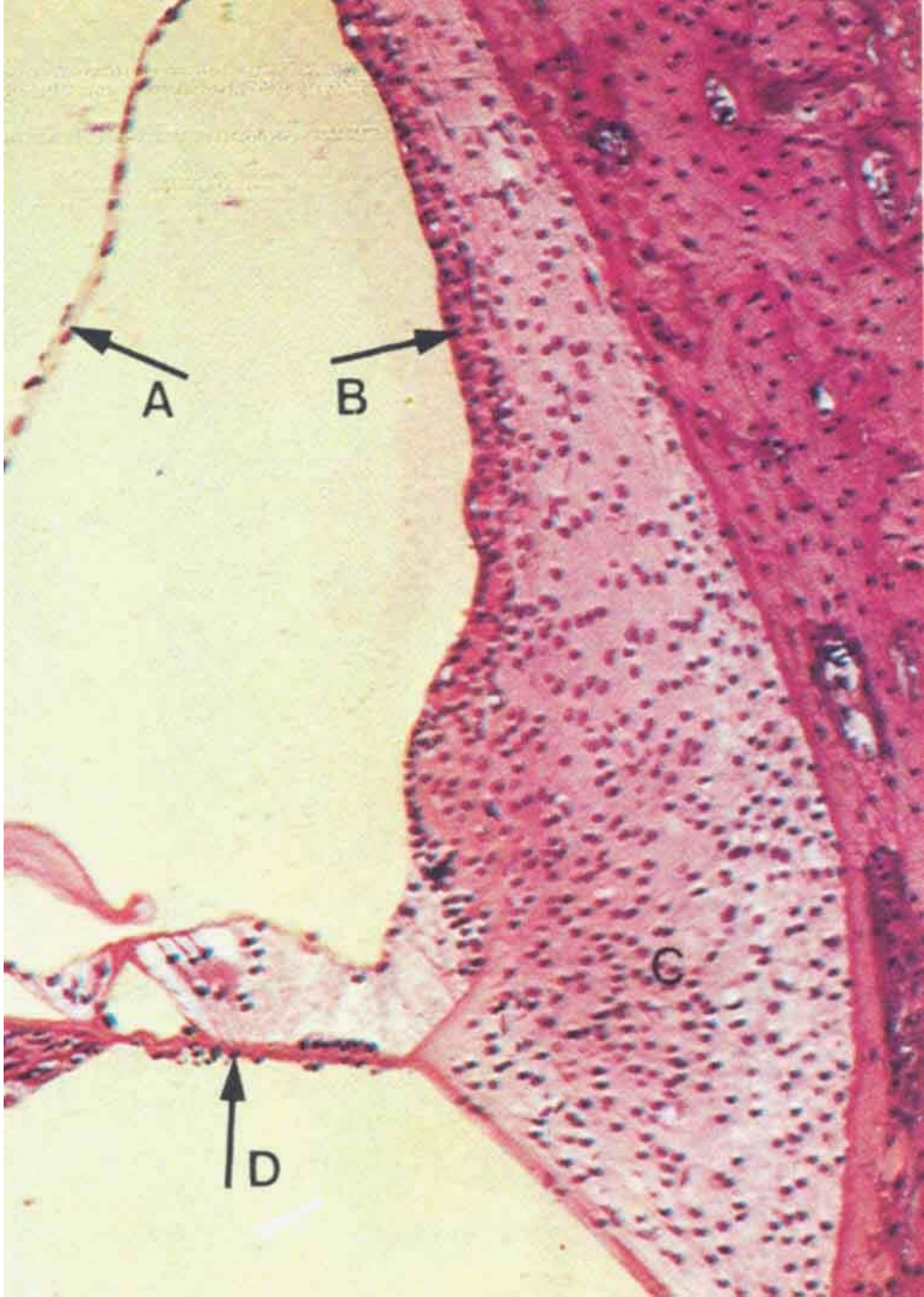
I = intermediate cell

B = basal cells

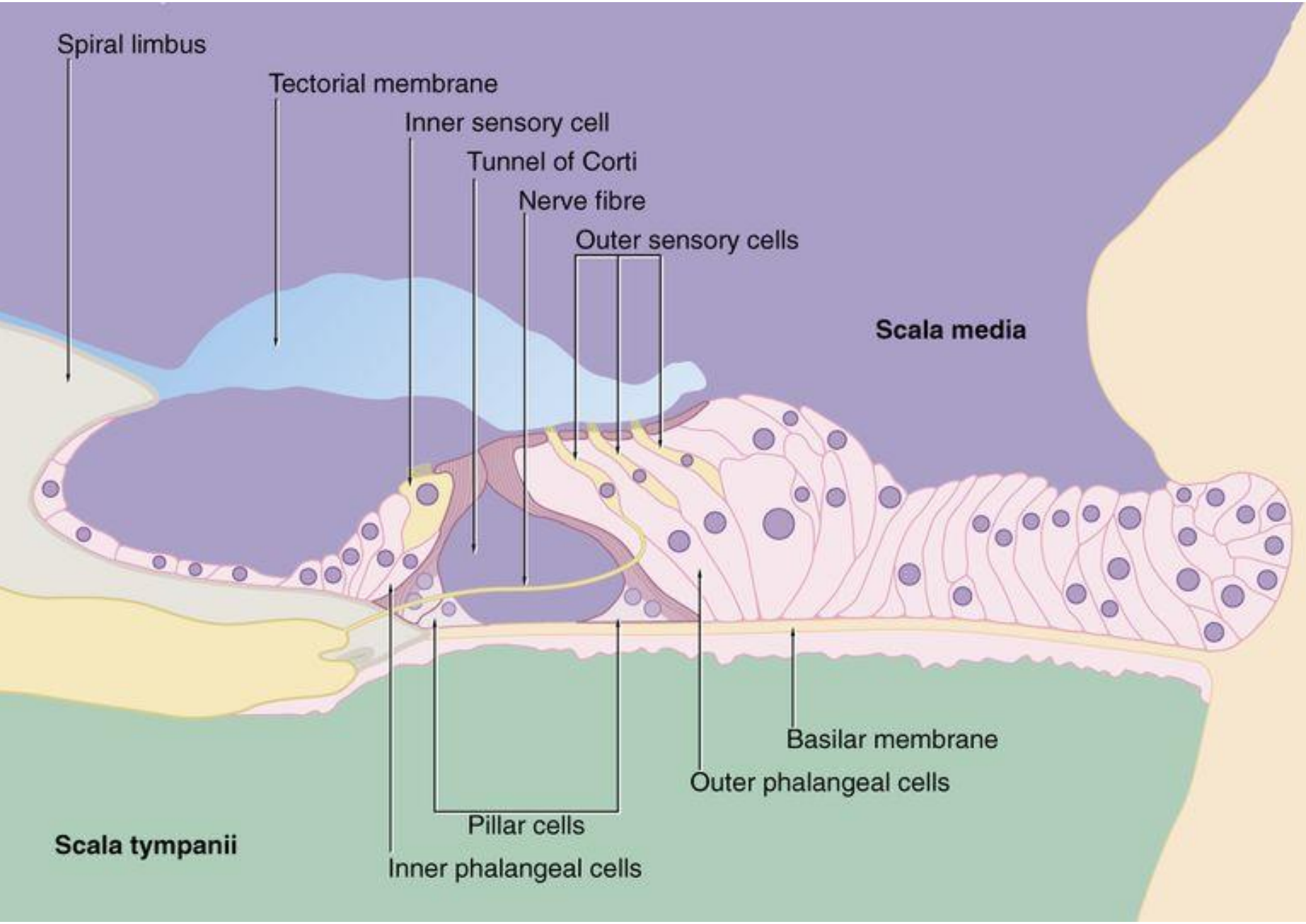
SpL = connective tissue of ligamentum spirale cochleae



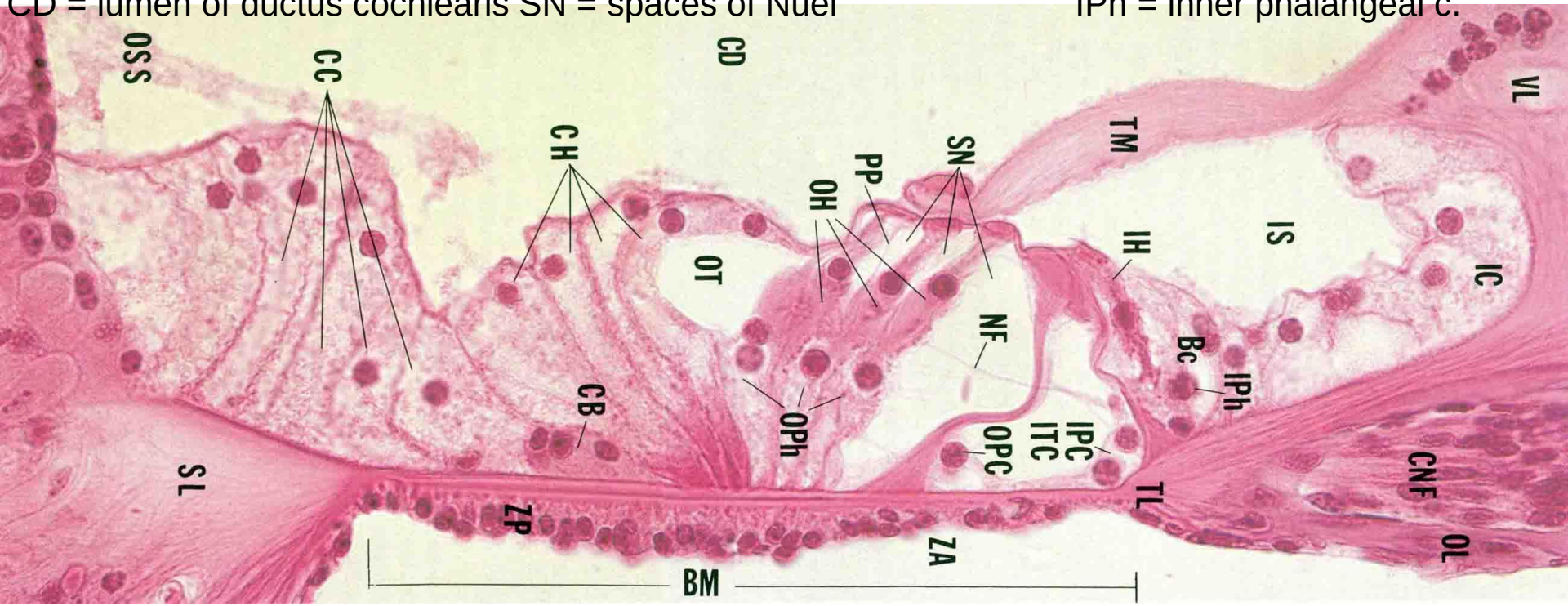
A = membrana vestibularis
B = stria vascularis
C = ligamentum spirale cochleae
D = membrana basilaris



The spiral ligament is a thickened, modified portion of periosteum of the osseous cochlea


Spiral limbus
Tectorial membrane
Inner sensory cell
Tunnel of Corti
Nerve fibre
Outer sensory cells
Scala media
Basilar membrane
Outer phalangeal cells
Pillar cells
Scala tympanii
Inner phalangeal cells

OSS = sulcus spiralis externus
CC = Claudius' cells
CH = Hensen's cells
CB = Böttcher's cells
CD = lumen of ductus cochlearis
OT = outer tunnel
OPh = outer phalangeal c. (Deiters)
OH = outer hair cells
PP = process of Deiters' cell
SN = spaces of Nuel
TM = membrana tectoria
IH = inner hair cell
IS = sulcus spiralis internus
Bc = border cells
IPh = inner phalangeal c.



SL = ligamentum spirale
BM = membrana basilaris
ZP = zona pectinata
ZA = zona arcuata
NF = nerve fibre
OPC = outer pillar cell
ITC = inner tunnel
IPC = inner pillar cell
TL = labium typanale
OL = lamina spiralis ossea
CNF = processes of neurons from g. spirale
IC = epithelium of sulcus spiralis internus
VL = labium vestibulare

inner hair cell

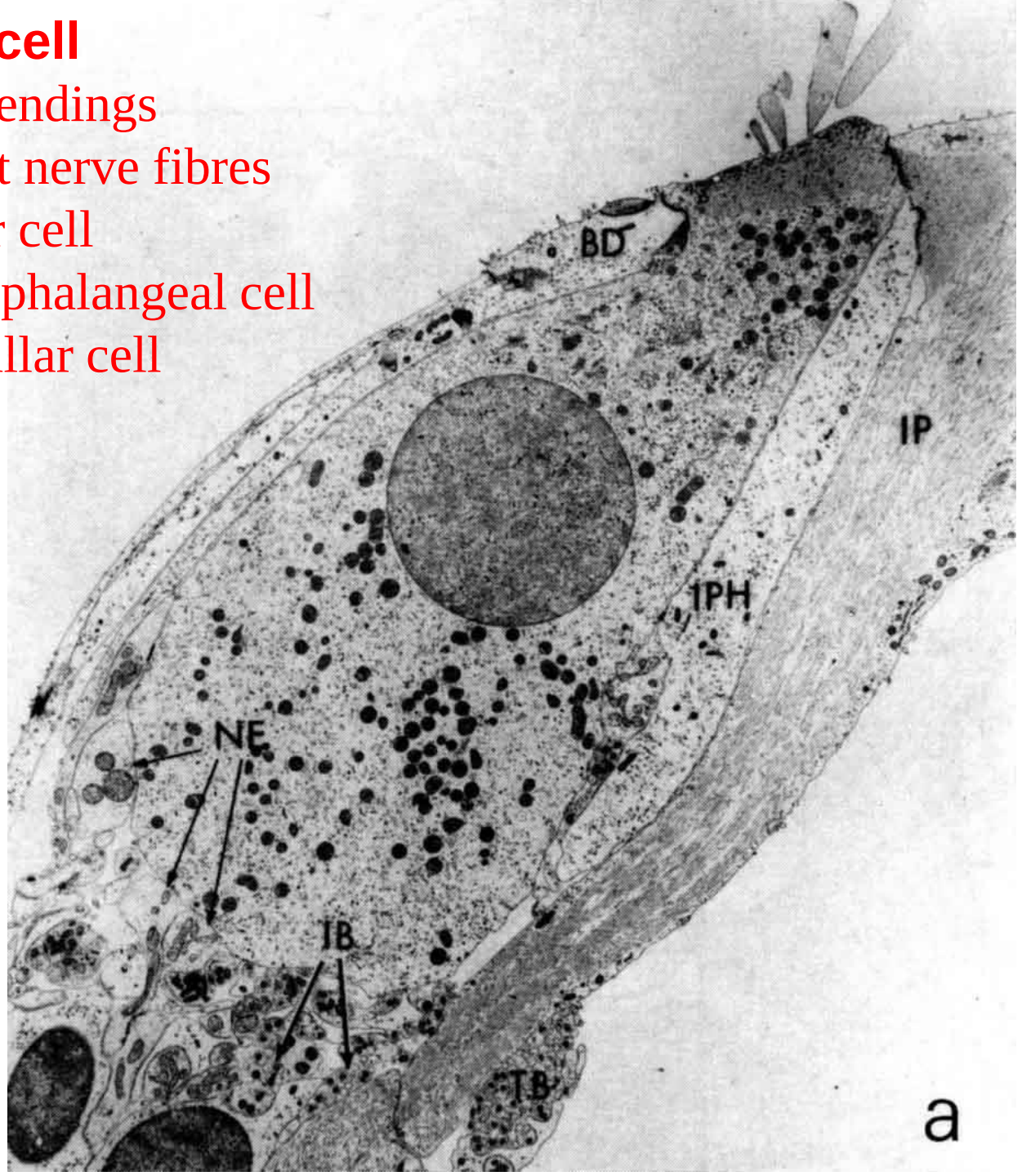
NE = nerve endings

IB = afferent nerve fibres

BD = border cell

IPH = inner phalangeal cell

IP = inner pillar cell

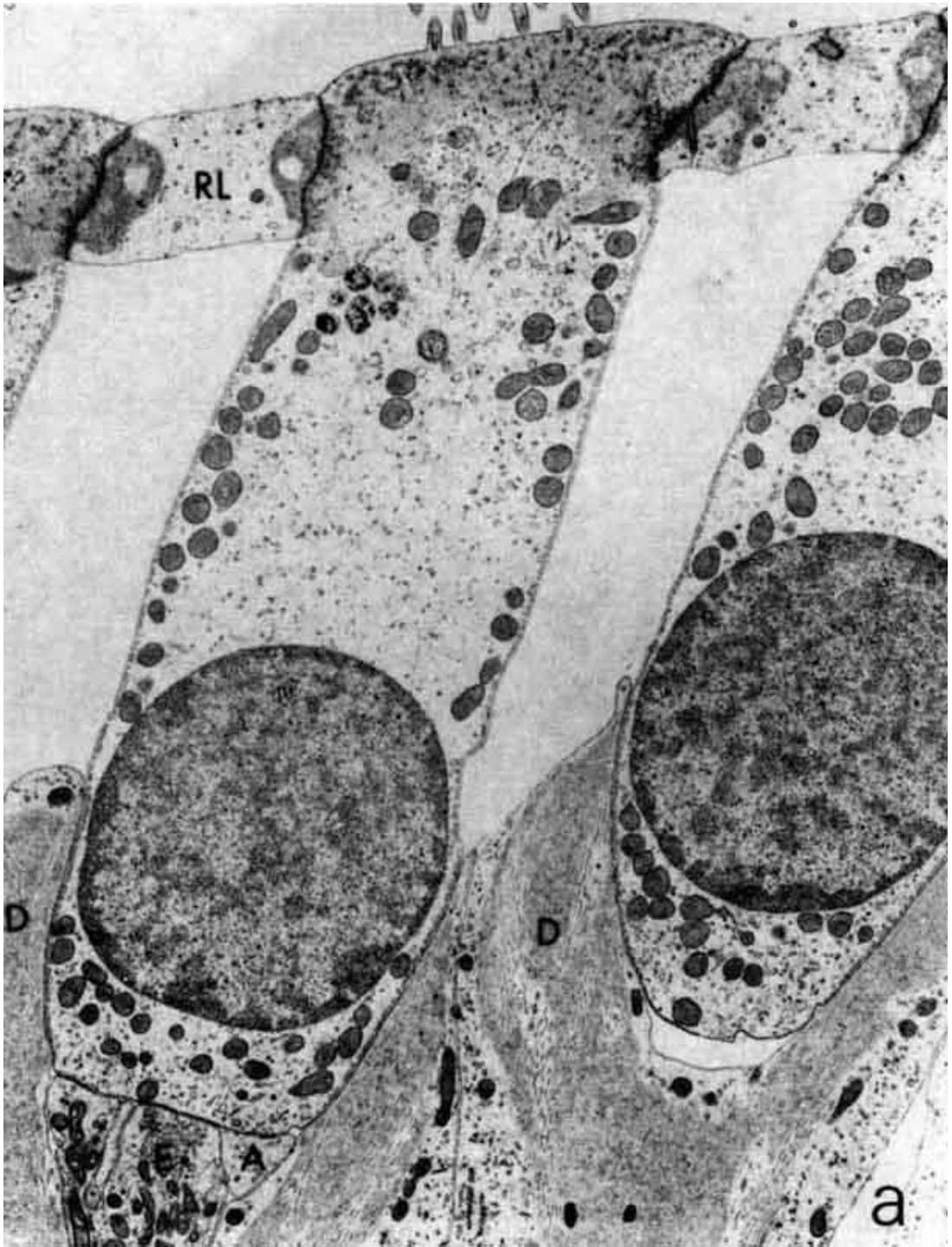


outer hair cells

E,A = nerve endings

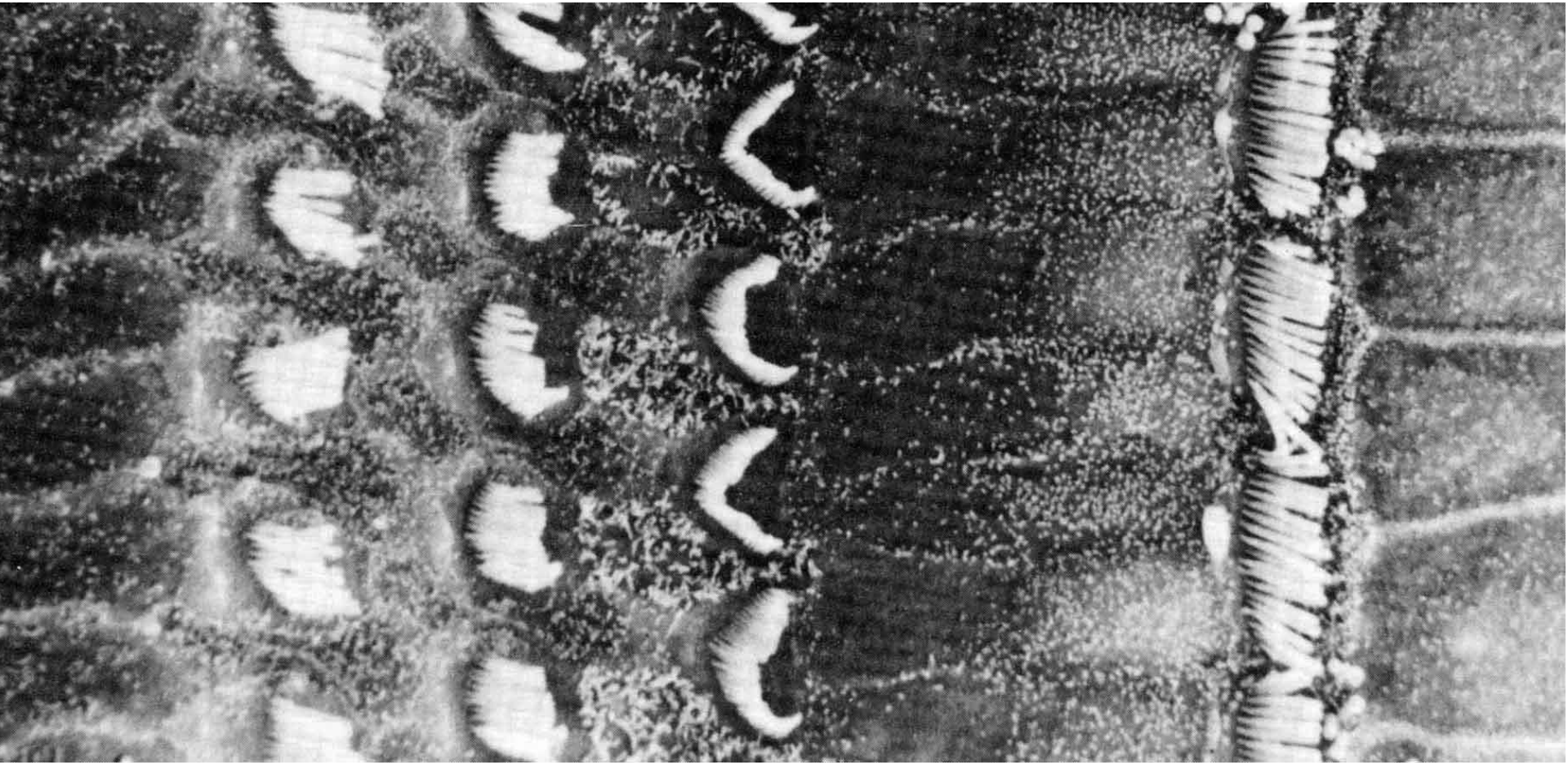
D = Deiters' cells

RL = distended end of process of Deiters' cell

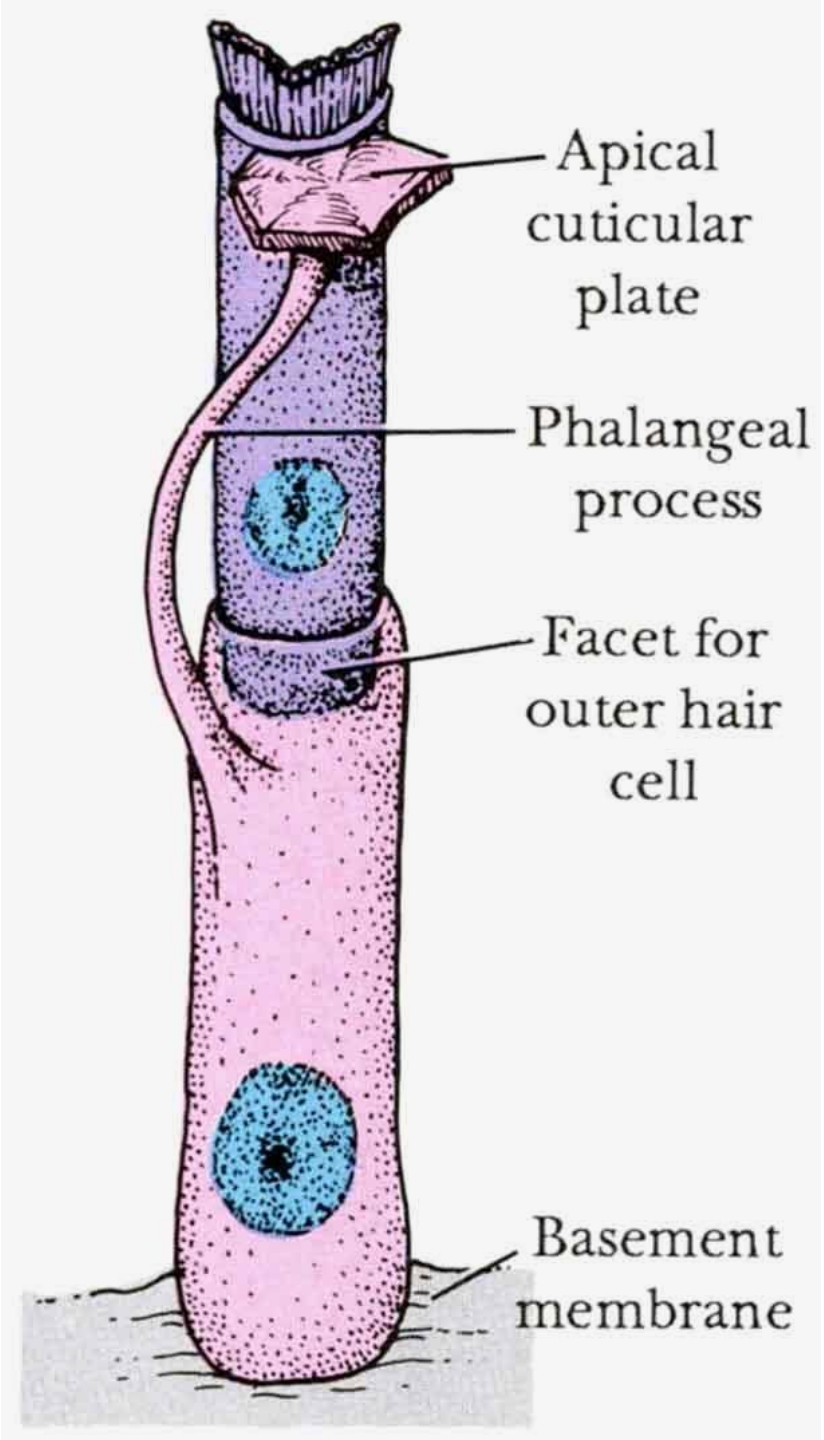


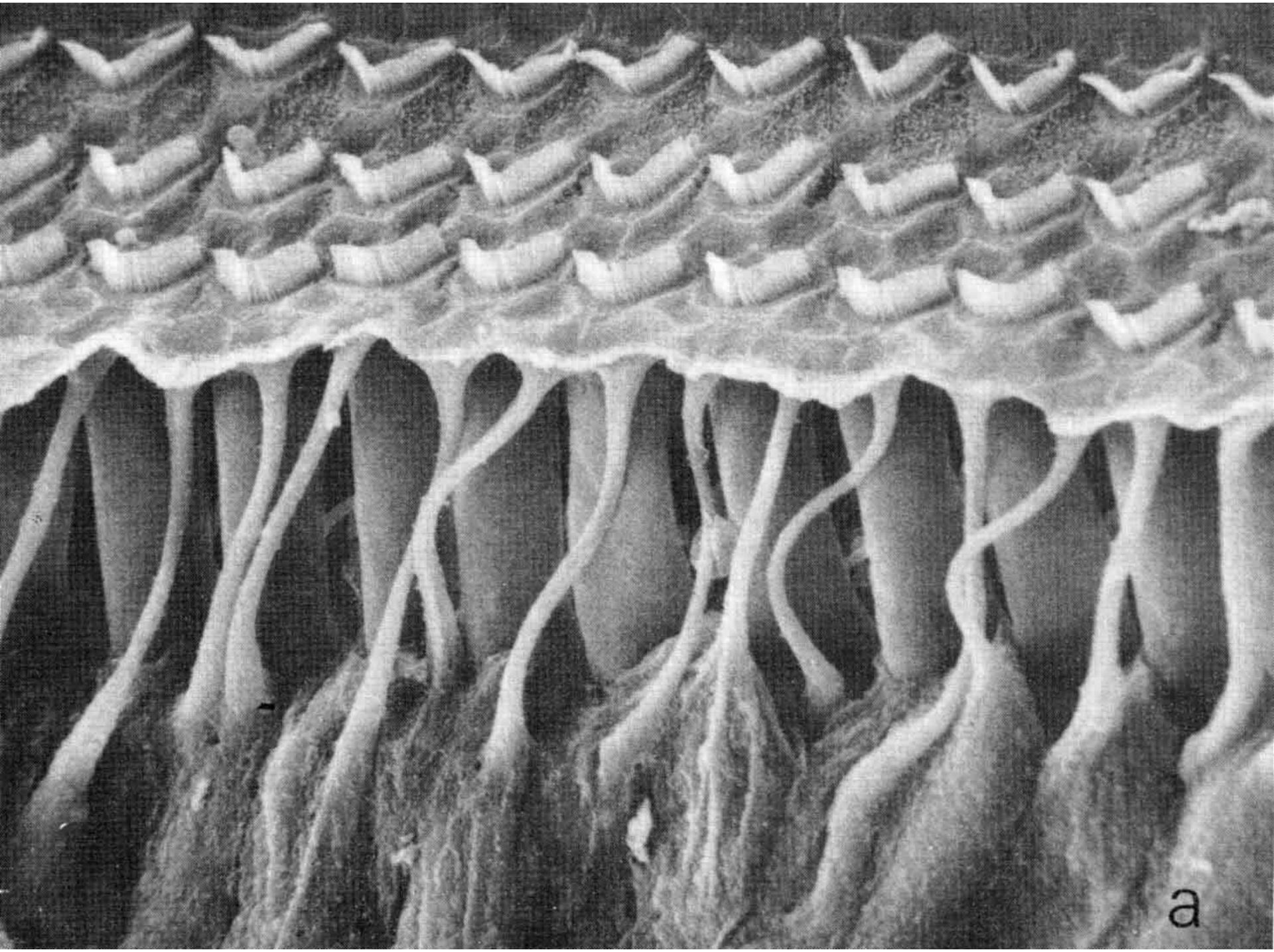
outer hair cells

inner hair cells

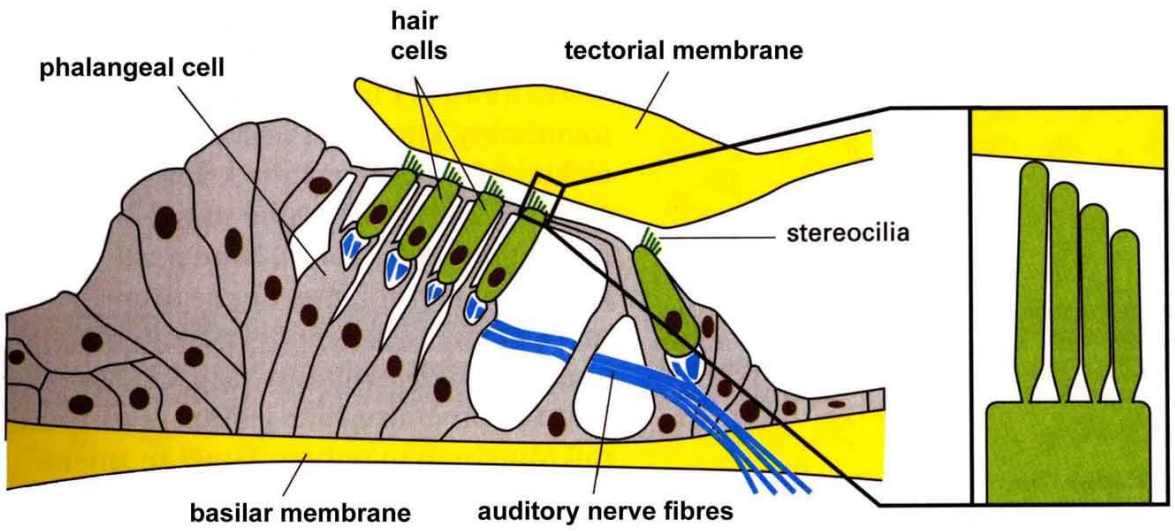


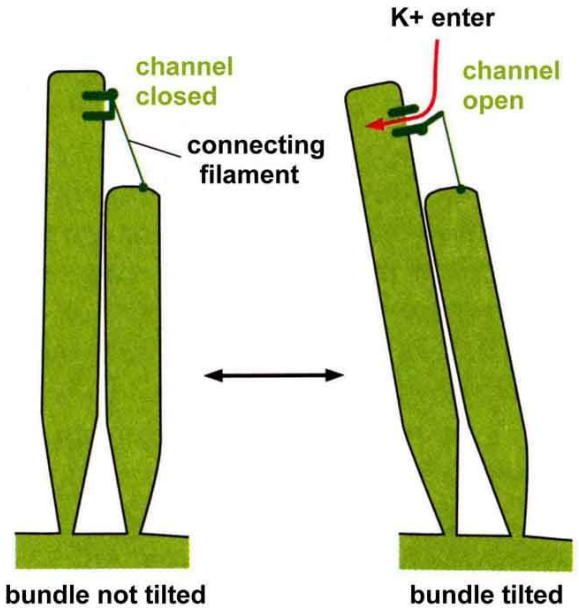
Deiters' cell

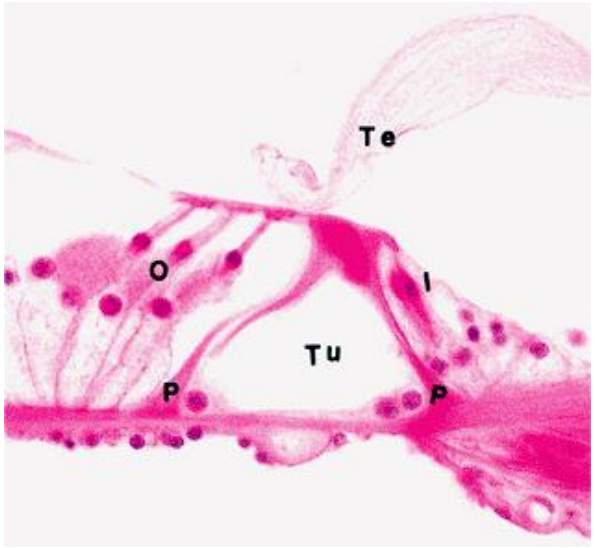



a

Mechanism of activation of hair cells







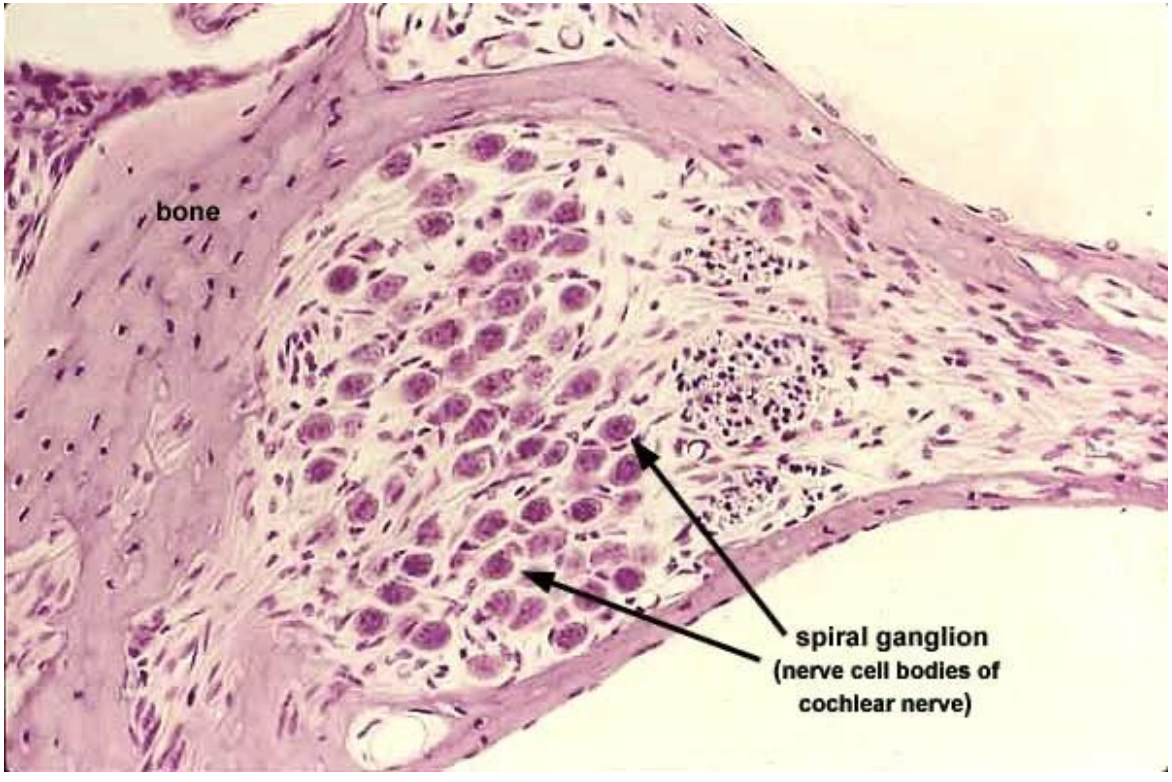
The tectorial membrane is a gelatinous structure with numerous fine fibers


stereocilium
stereocilium
connecting filament
connecting filament
stereocilium
stereocilium
100 nm

The cells of origin for the cochlear nerve form the **spiral ganglion** located in coils of the modiolus at the base of attachment of the osseous spiral lamina

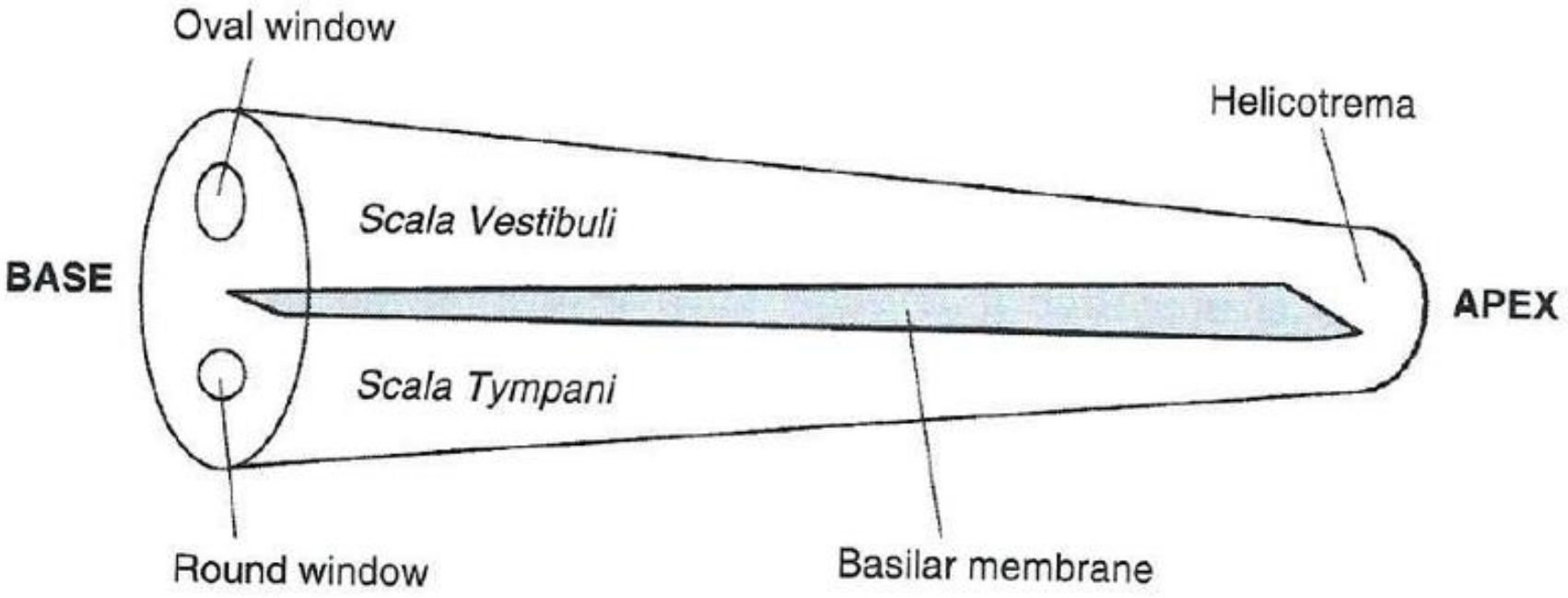
The osseous spiral lamina is a thin trabecula of bone surrounding afferent nerve fibers that run from the organ of Corti through the habenula perforata to the acoustic nerve and efferent fibers to the outer hair cells that arise from the olivocochlear system of Rasmussen.

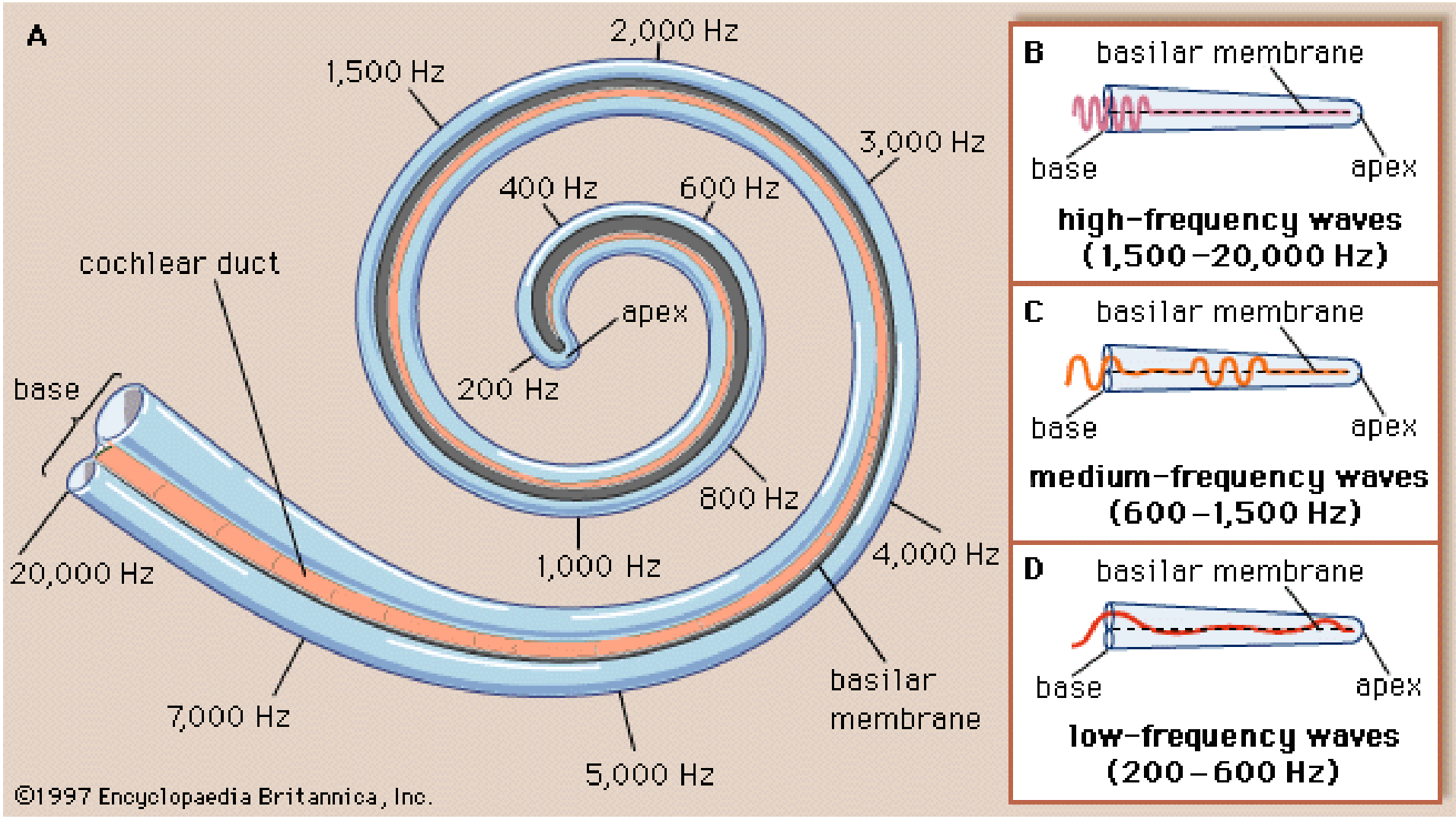
bipolar neurons



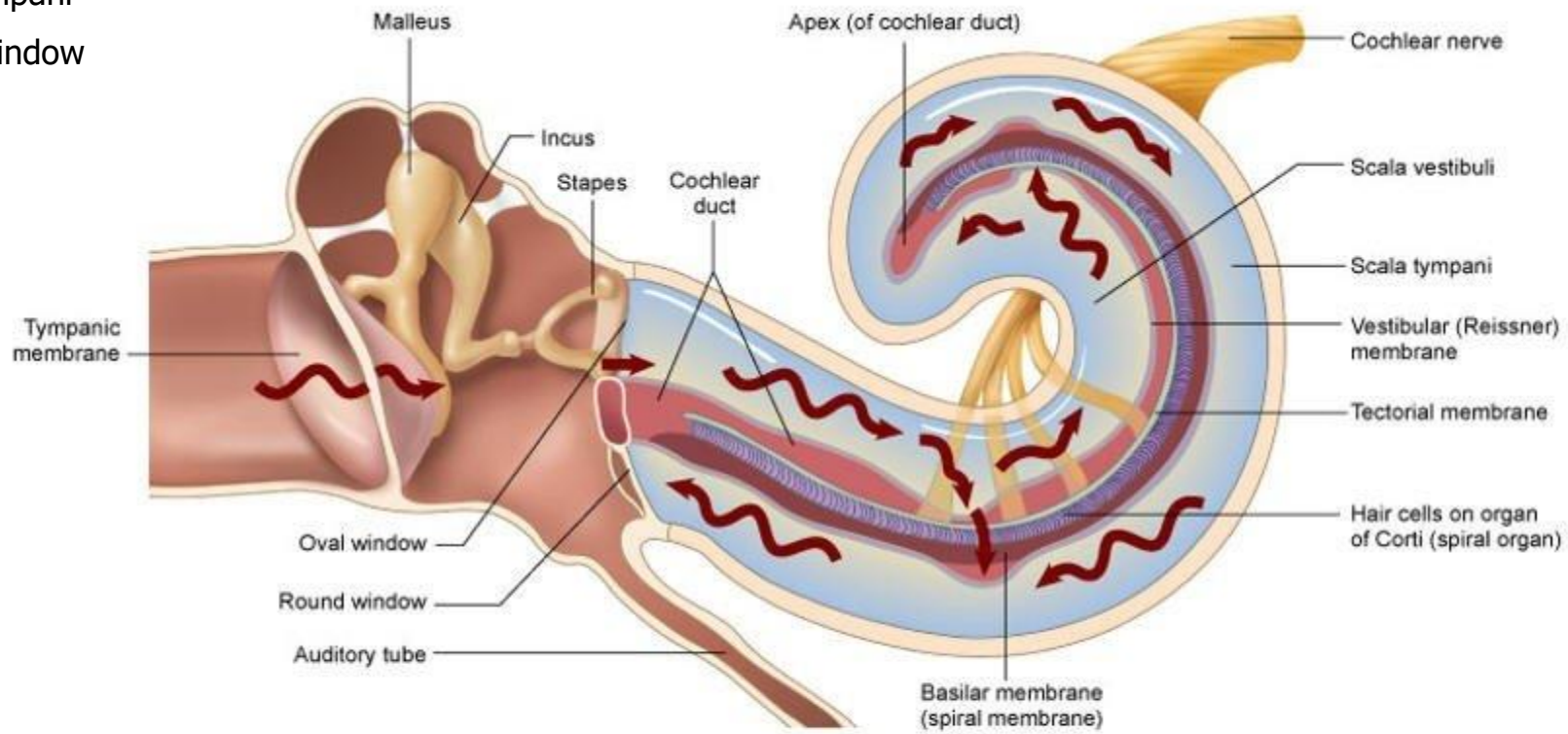
The **basilar membrane** increases in thickness from the base to the apex of the cochlea - resonator action with deformation of the membrane by sound

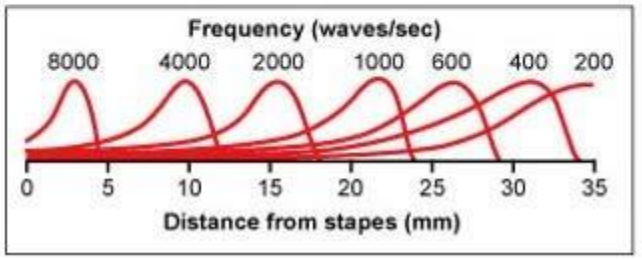
The **tectorial membrane** is a gelatinous structure with numerous fine fibers.
- increases in size from the base to the apex of the cochlea and is believed to have a vibratory effect on the hair cells.

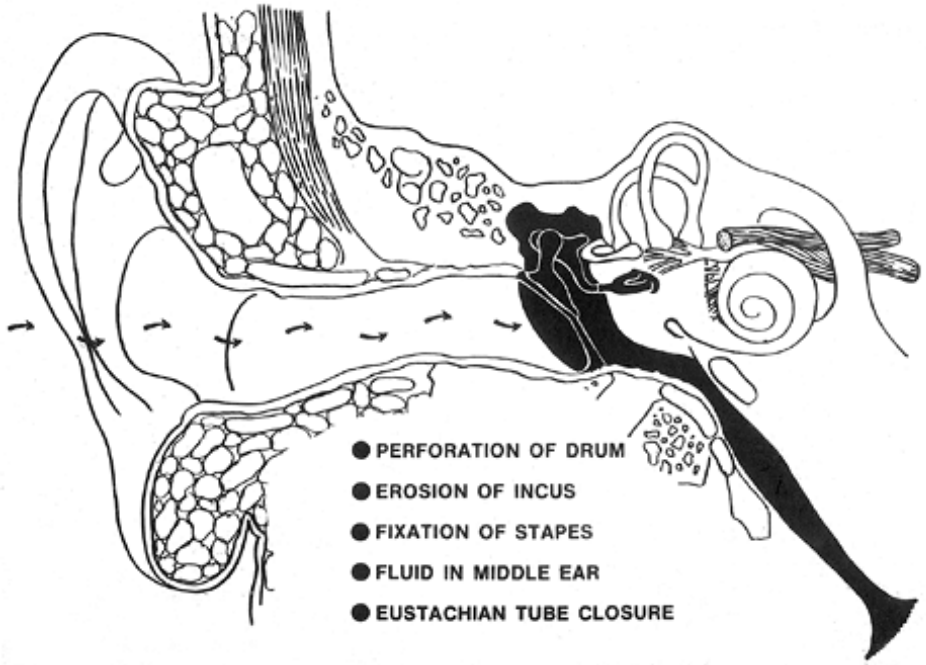



A
2,000 Hz
1,500 Hz
3,000 Hz
400 Hz
600 Hz
cochlear duct
apex
200 Hz
base
800 Hz
20,000 Hz
1,000 Hz
4,000 Hz
basilar membrane
7,000 Hz
5,000 Hz
©1997 Encyclopaedia Britannica, Inc.
B
basilar membrane
base
apex
high-frequency waves (1,500–20,000 Hz)
C
basilar membrane
base
apex
medium-frequency waves (600–1,500 Hz)
D
basilar membrane
base
apex
low-frequency waves (200–600 Hz)

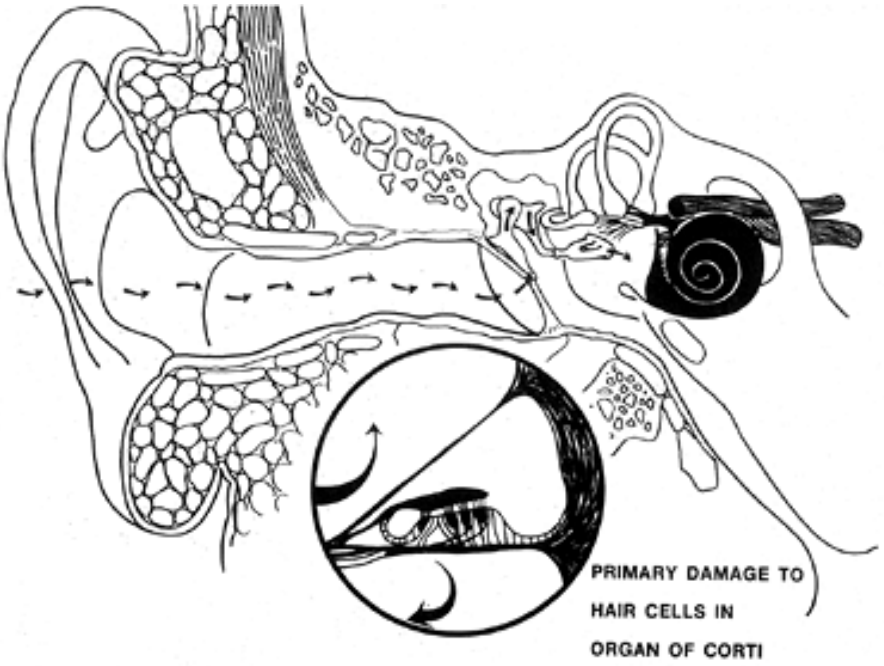
- Tympanic membrane
- ossicles
- Oval window
- Scala vestibuli
- Helicotrema
- Scala tympani
- Round window







Causes of conductive hearing loss.



Cause of sensorineural hearing loss.

Semicircular ducts

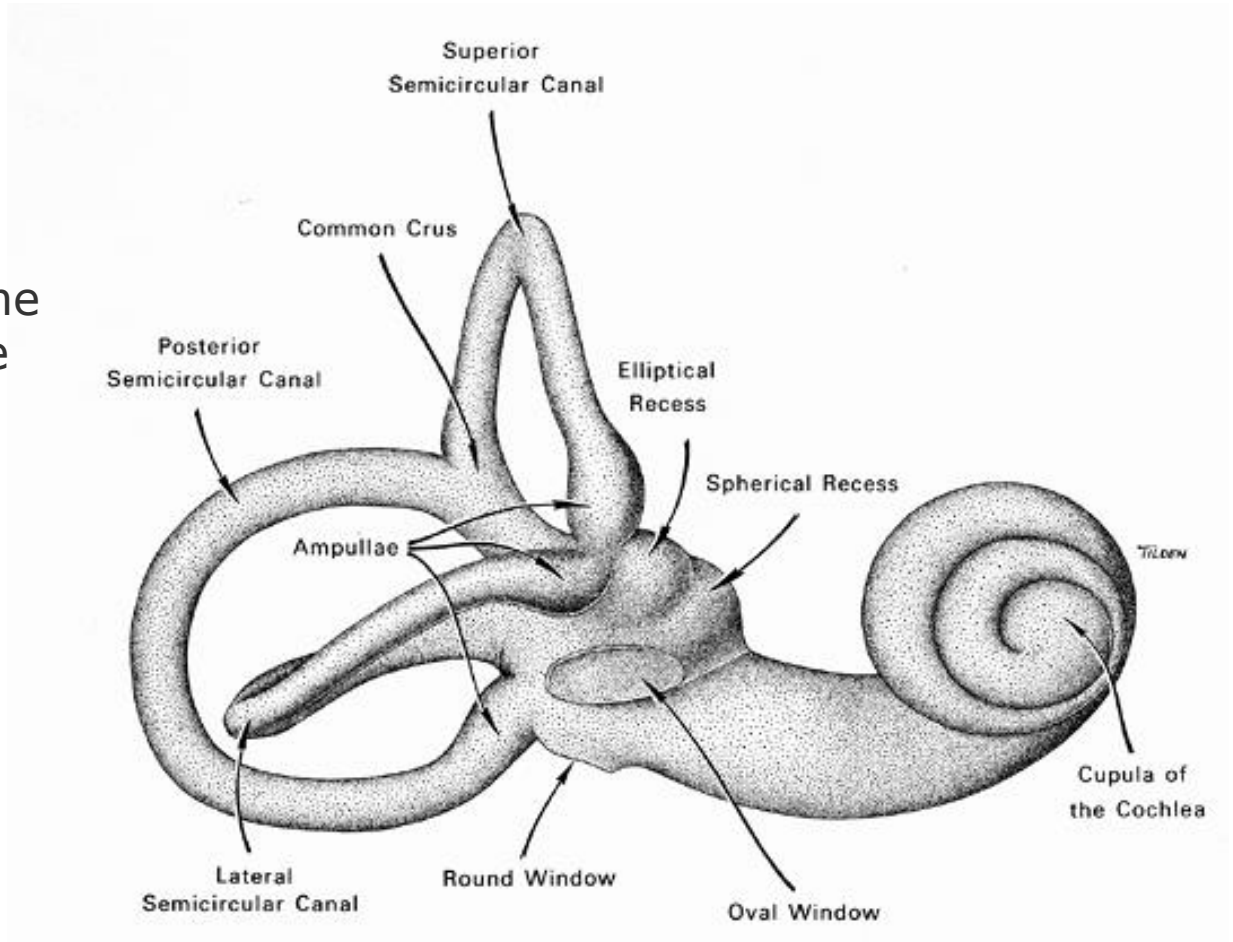
The semicircular ducts include the anterior or **superior** duct, the **posterior** duct, and the **lateral** ducts.

The end of each semicircular duct is expanded to form an **ampulla**.

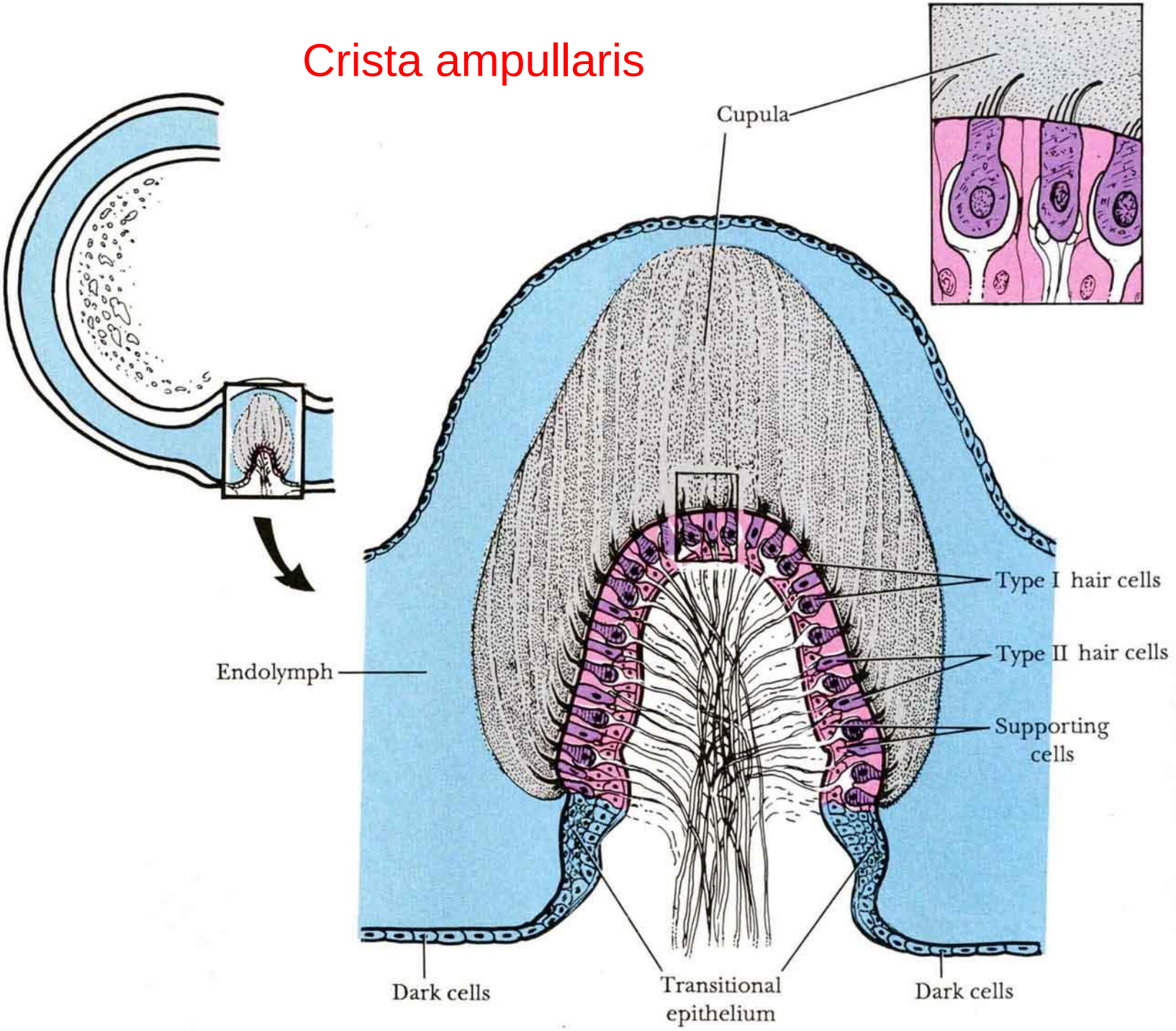
The sensory endings in the ampullae of the ducts are the **cristae**.

Each crista consists of thickened epithelium

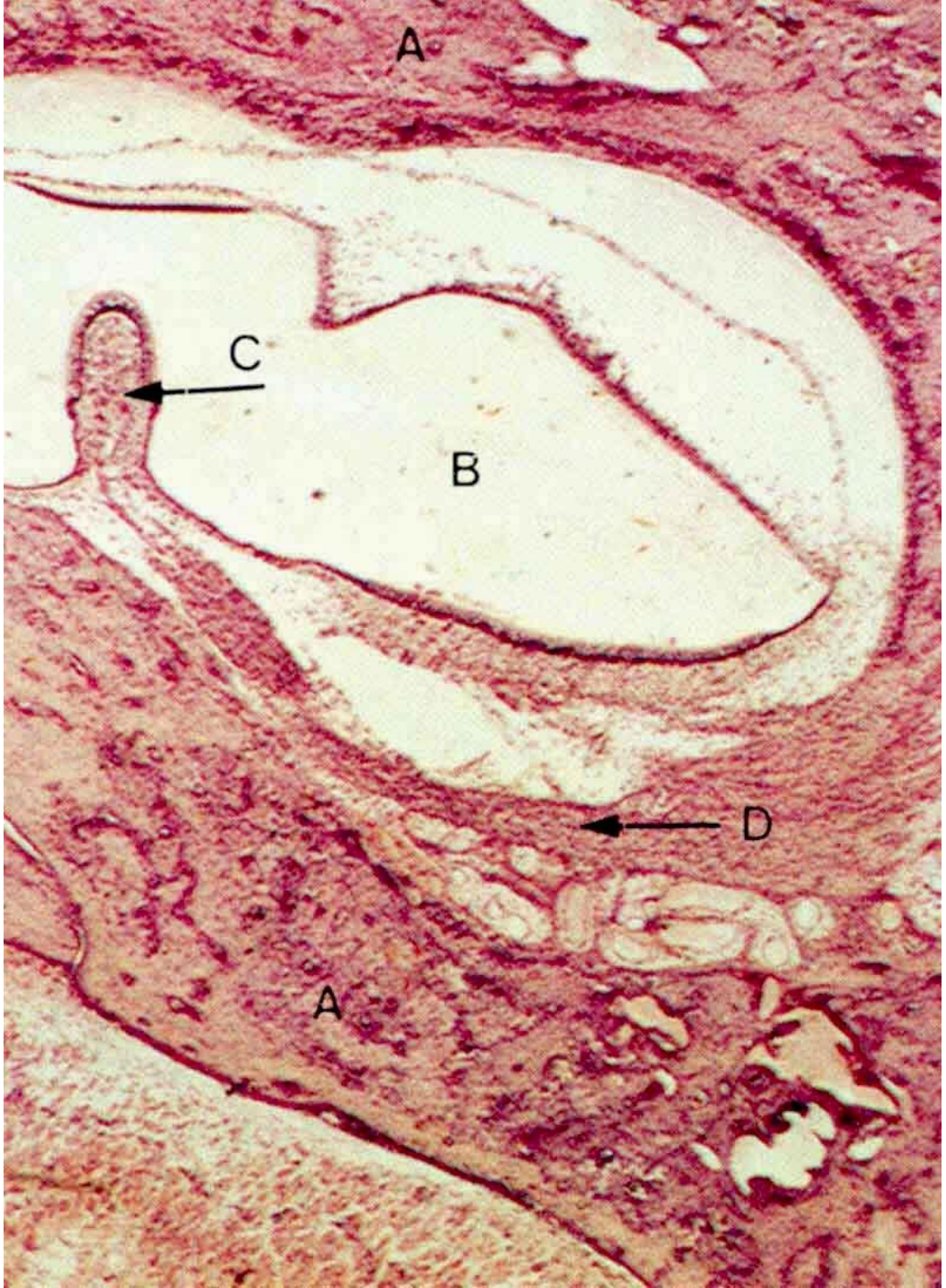
above each crista rests a gelatinous formation of viscous protein polysaccharide called the **cupula**



Crista ampullaris



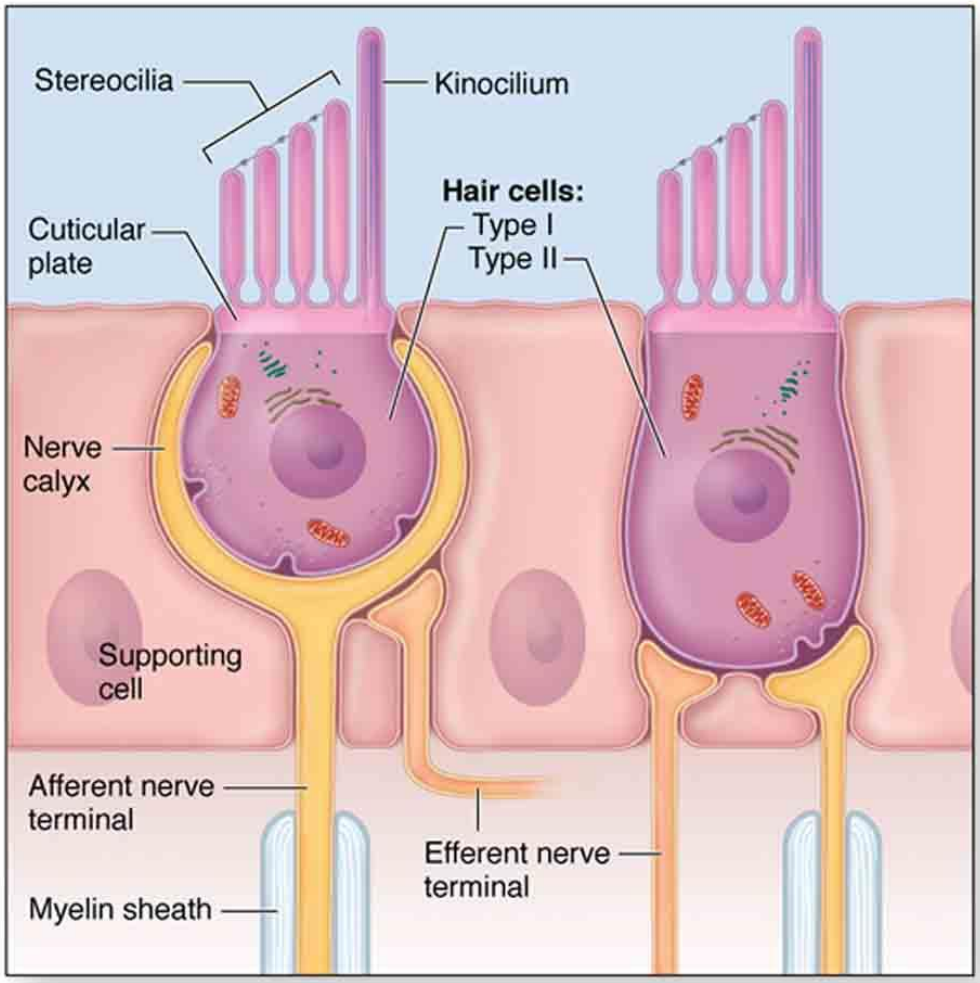
A = wall of bony semicircular canal
B = lumen of membranous semicircular duct
C = crista ampullaris
D = branch of vestibular nerve



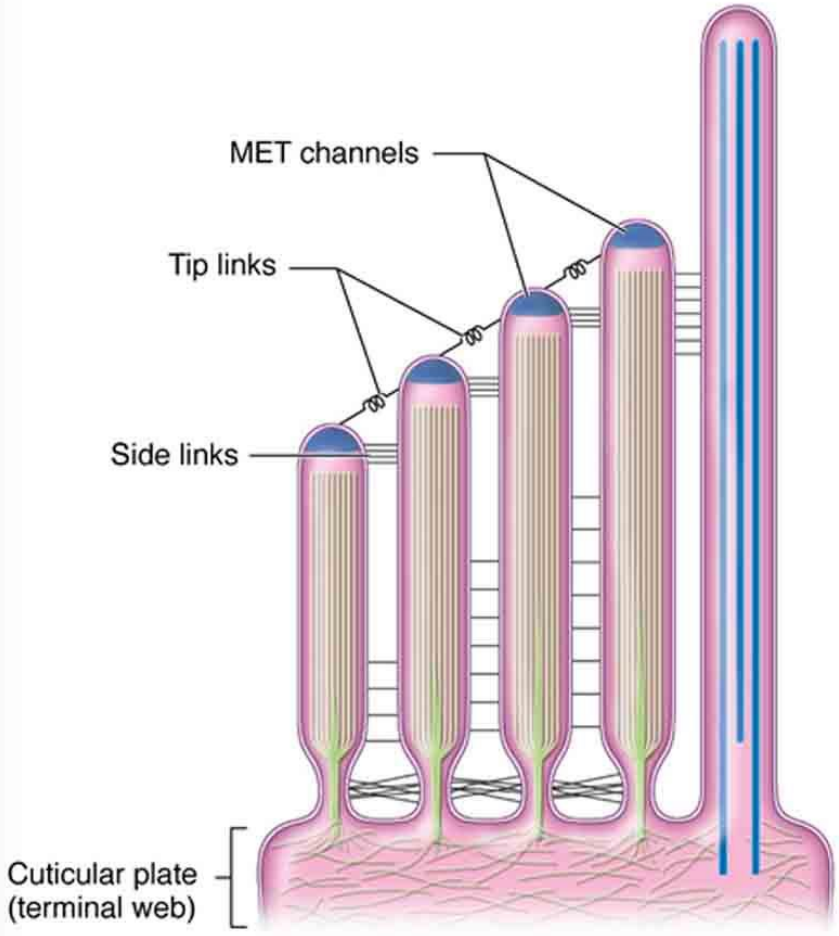
crista

The hairs of the epithelial hair cells project into the base of the cupula.
As a result of the gelatinous nature of the cupula, it may be bent by the pressure of the endolymph, which apparently stimulates the hair cells and, therefore, the nerve endings of the cristae.

Types of hair cells (same in maculae and cristae)

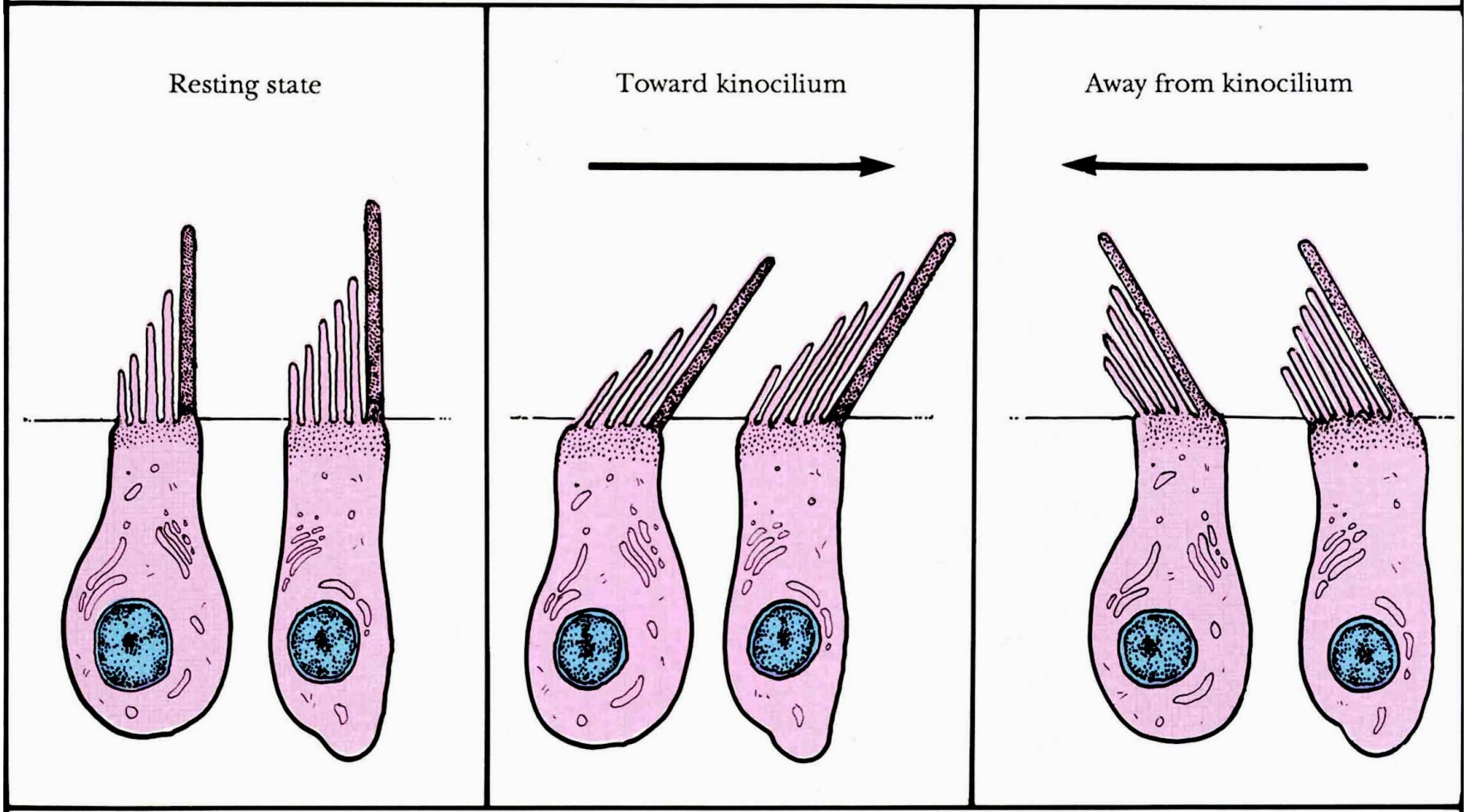


a



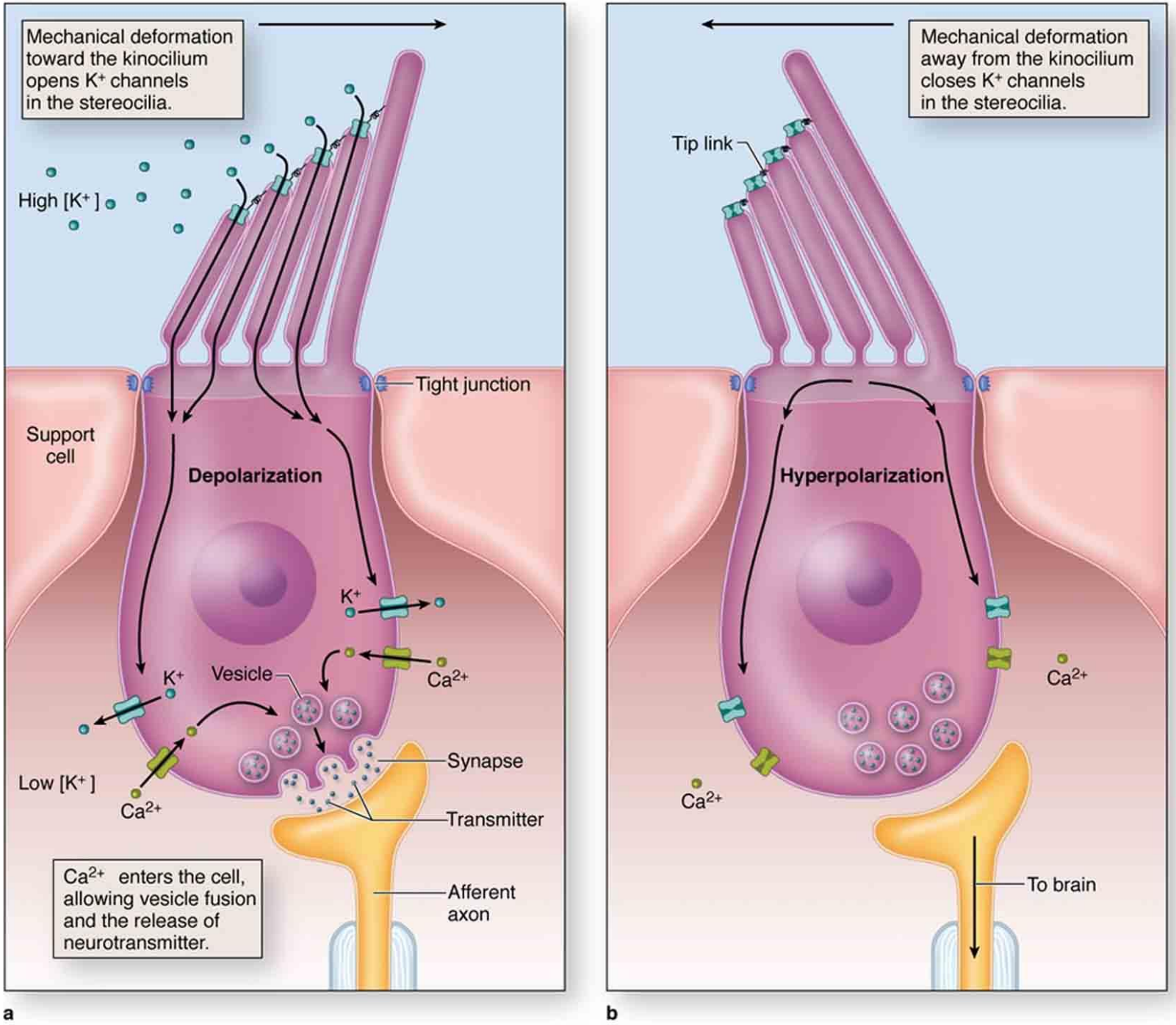
b

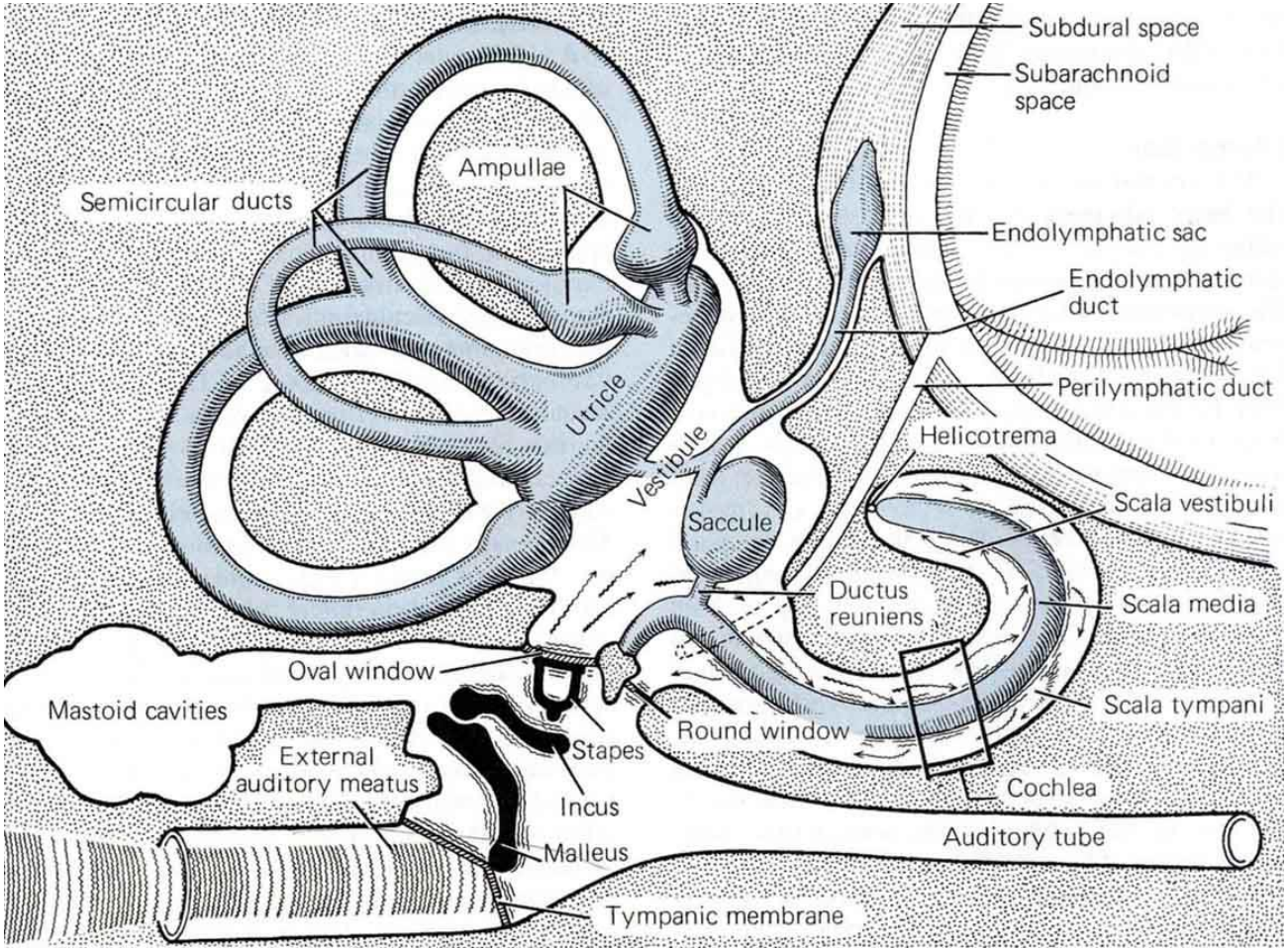
Displacement of Vestibular Sensory Hairs



Discharge rate of vestibular nerve

Resting activity	Stimulation (depolarization)	Inhibition (hyperpolarization)

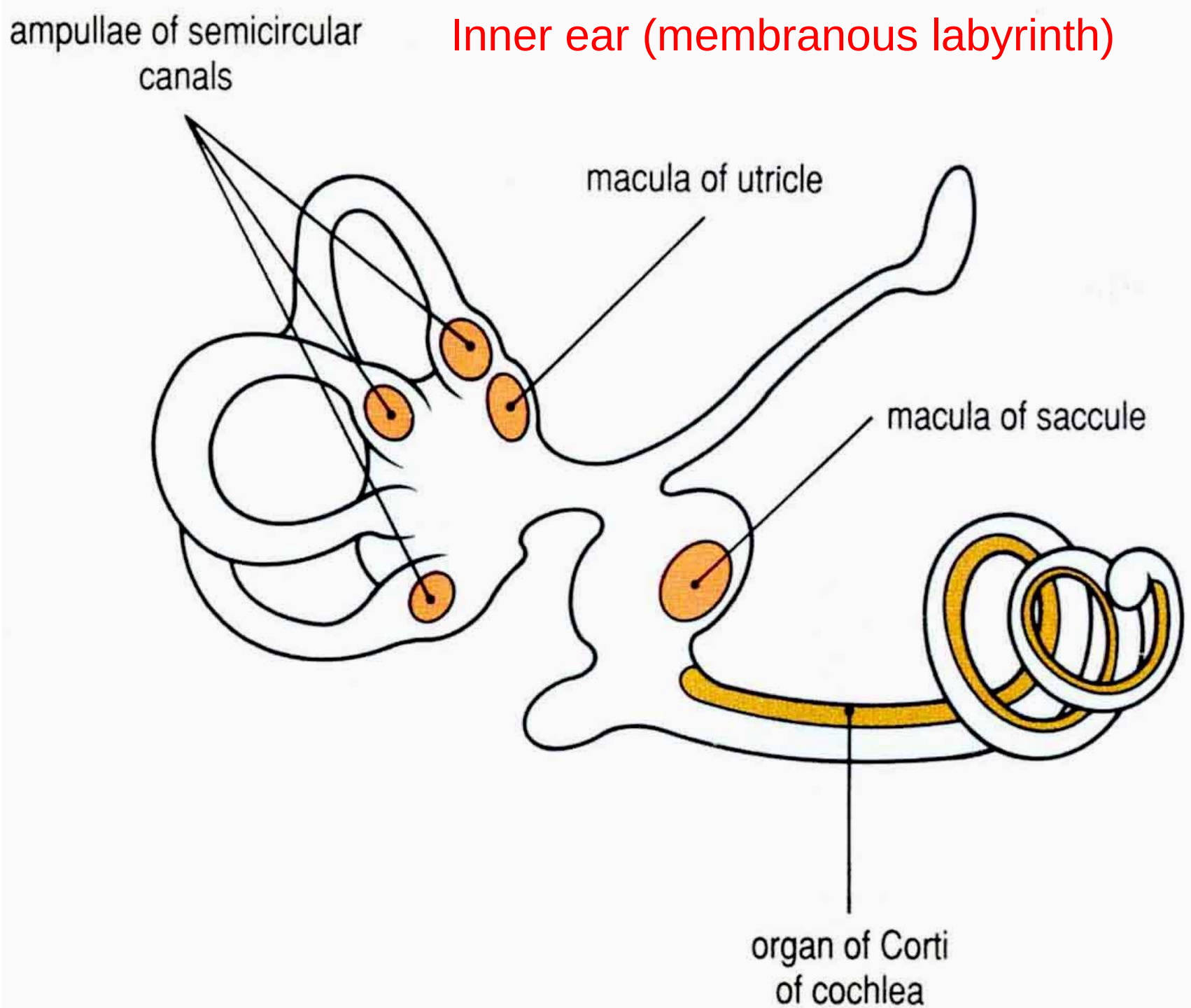

Mechanical deformation toward the kinocilium opens K+ channels in the stereocilia.
High [K+]
Tight junction
Support cell
Depolarization
K+
K+
Vesicle
Ca2+
Low [K+]
Ca2+
Synapse
Transmitter
Afferent axon
Ca2+ enters the cell, allowing vesicle fusion and the release of neurotransmitter.
a
Mechanical deformation away from the kinocilium closes K+ channels in the stereocilia.
Tip link
Hyperpolarization
Ca2+
Ca2+
To brain
b



The **utricle** and **saccule**, representing the two main membranous structures of the vestibule, are lined by a sensory epithelium known as the **macula**

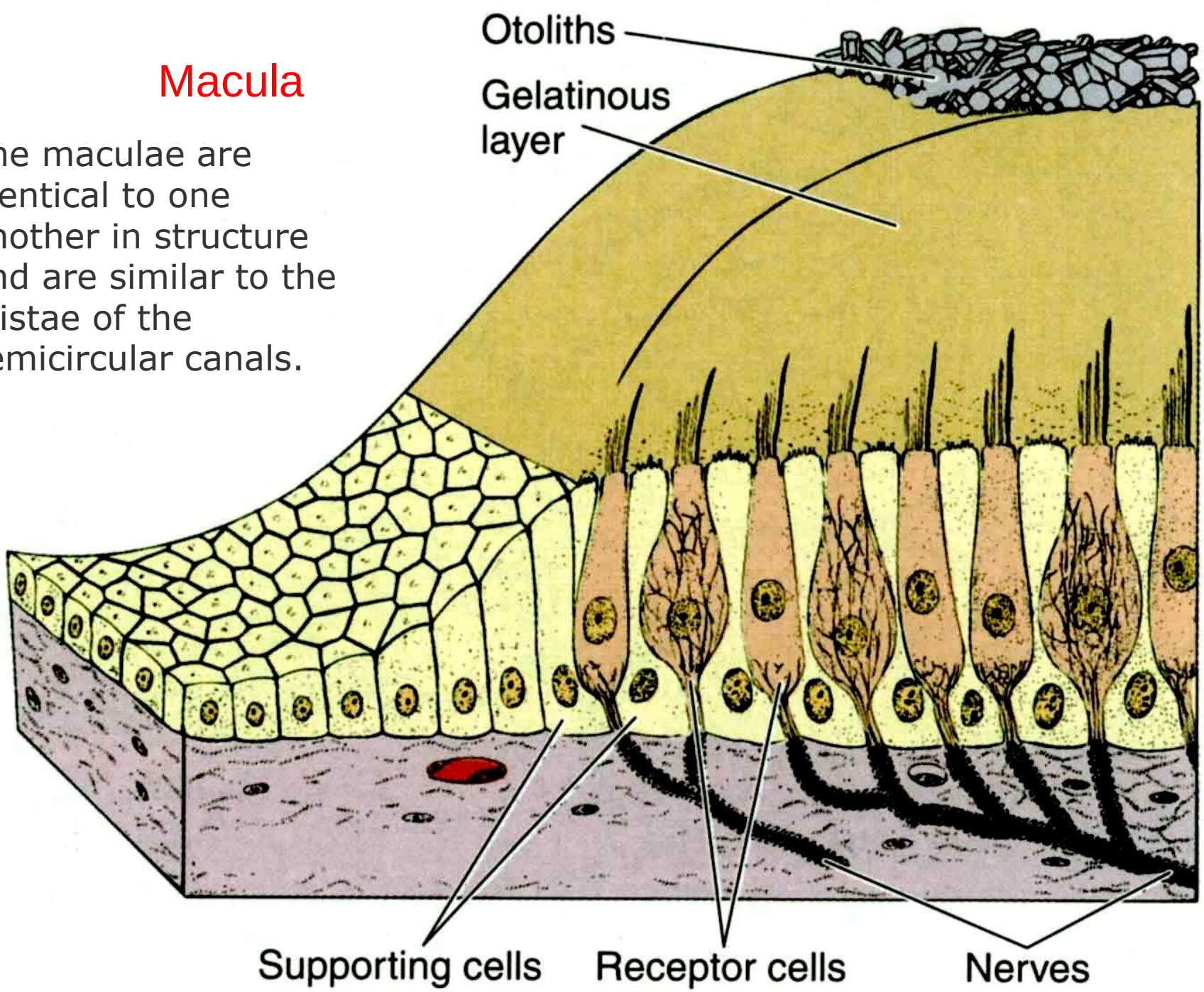
The saccule and utricle are continuous via the **utriculosaccular duct** and with the cochlear duct by the ductus reuniens

Inner ear (membranous labyrinth)

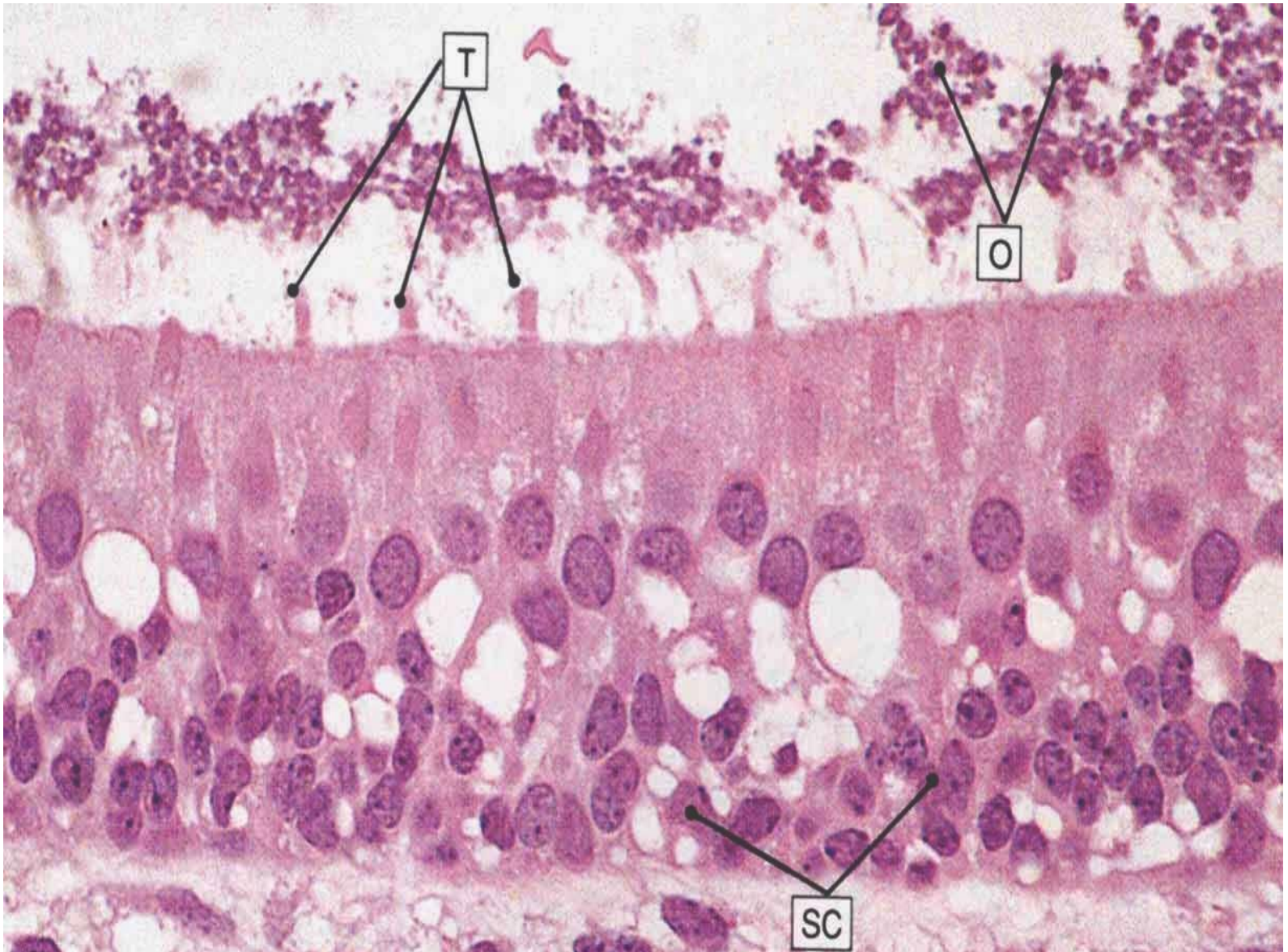


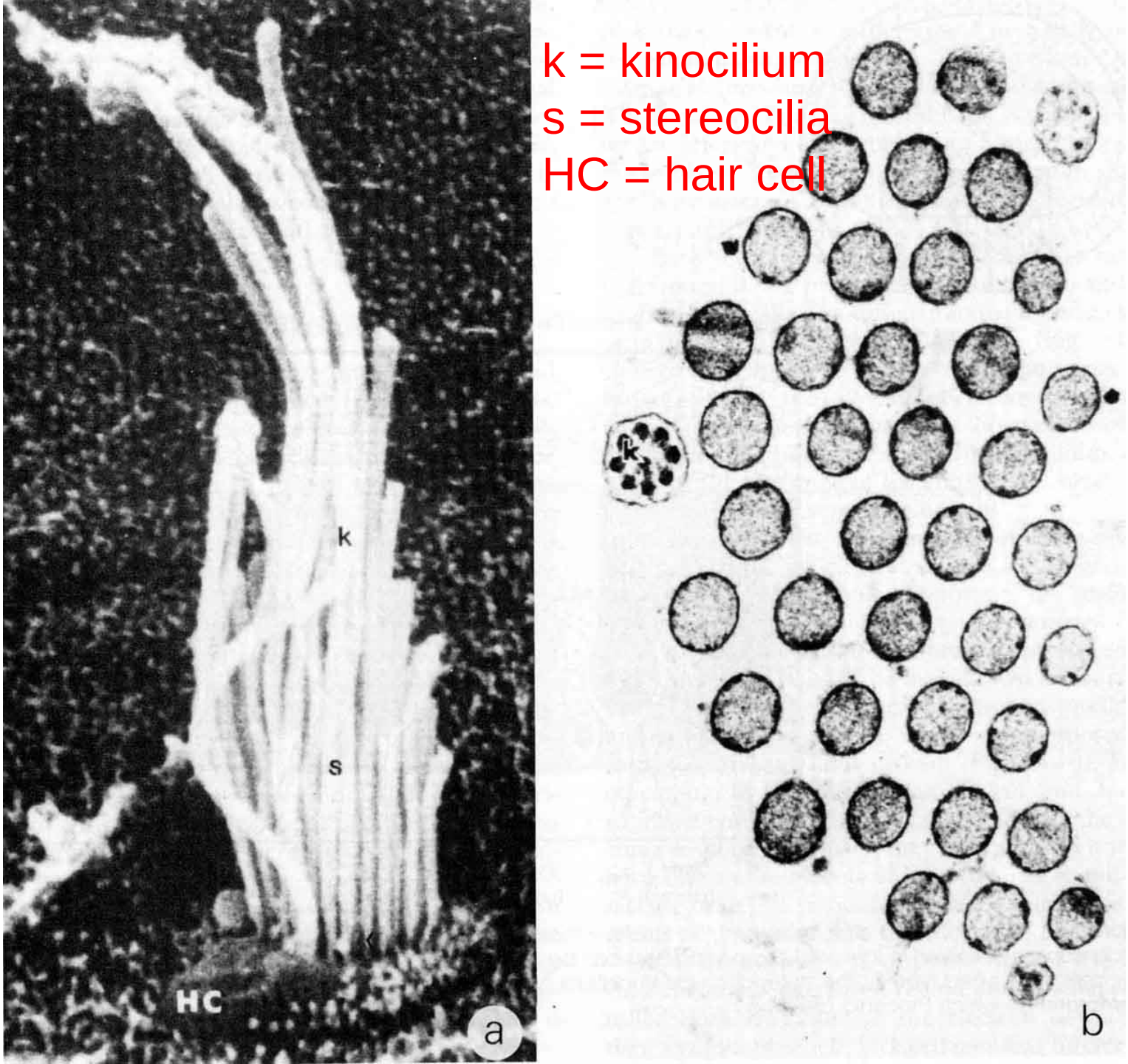
Macula

The maculae are identical to one another in structure and are similar to the cristae of the semicircular canals.



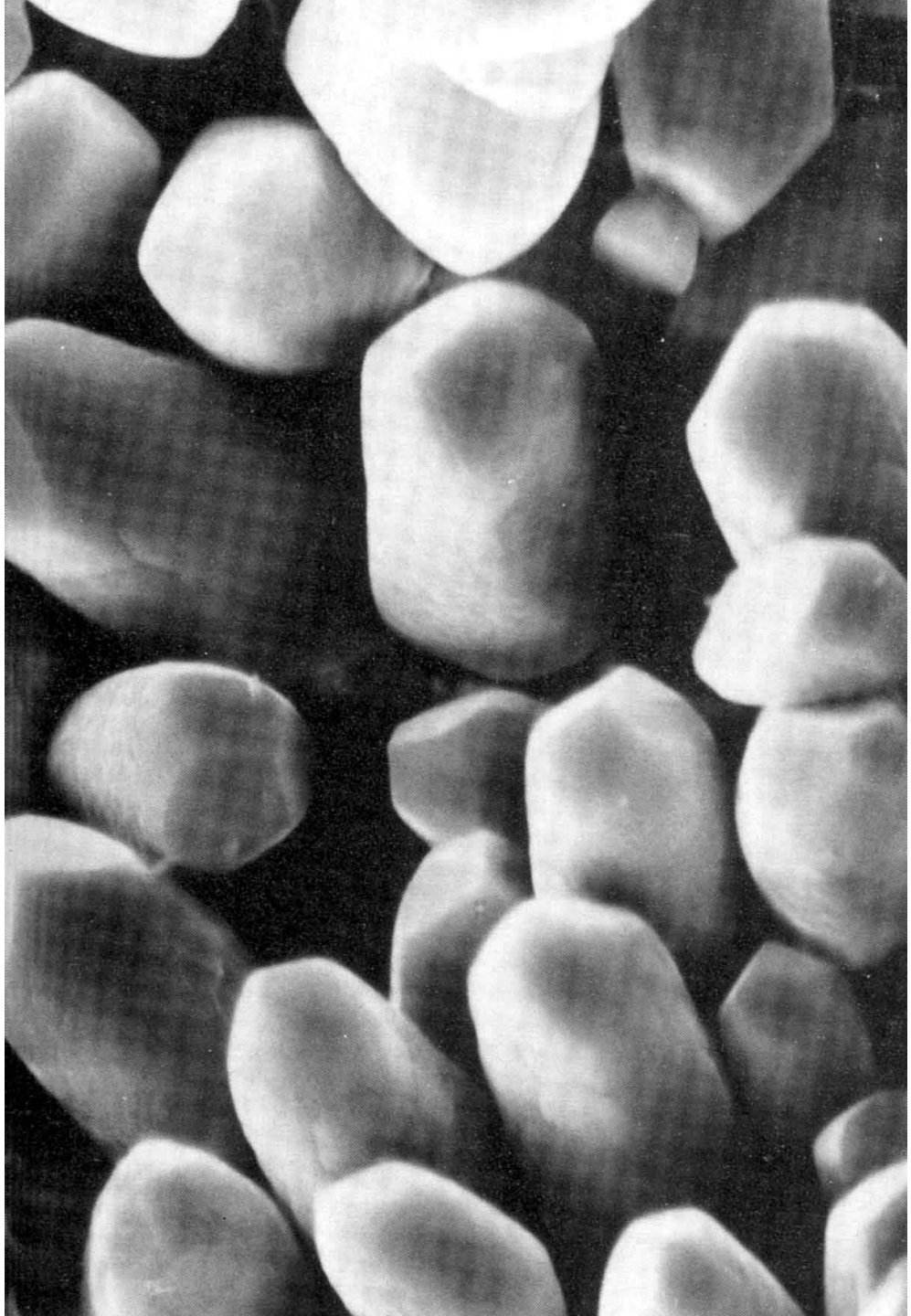
T = processes of receptor cells
SC = nuclei of supporting cells
O = otoliths




k = kinocilium
s = stereocilia
HC = hair cell
k
s
HC
a
b

otoliths

contain calcium carbonate and proteins

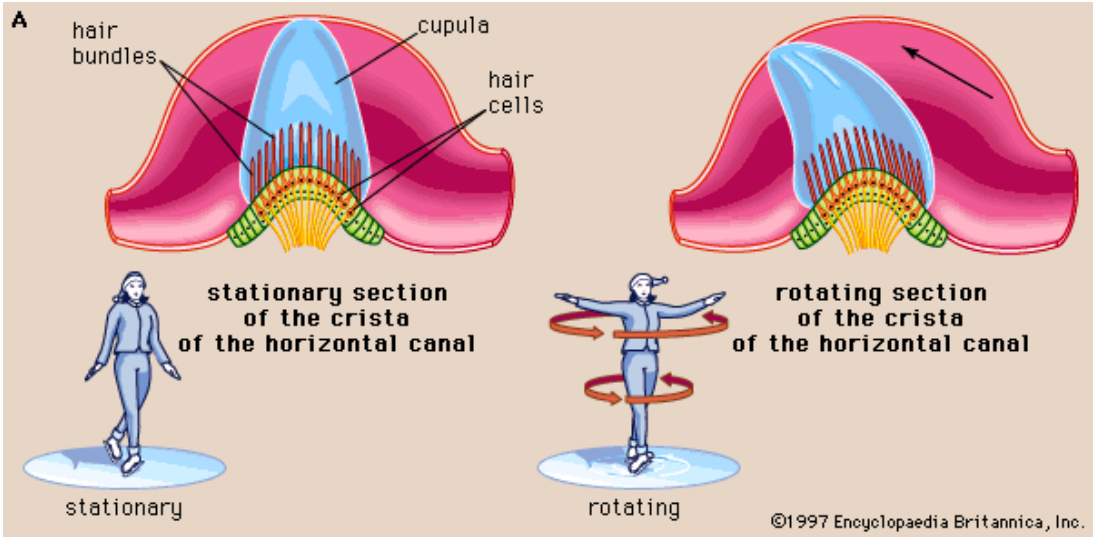


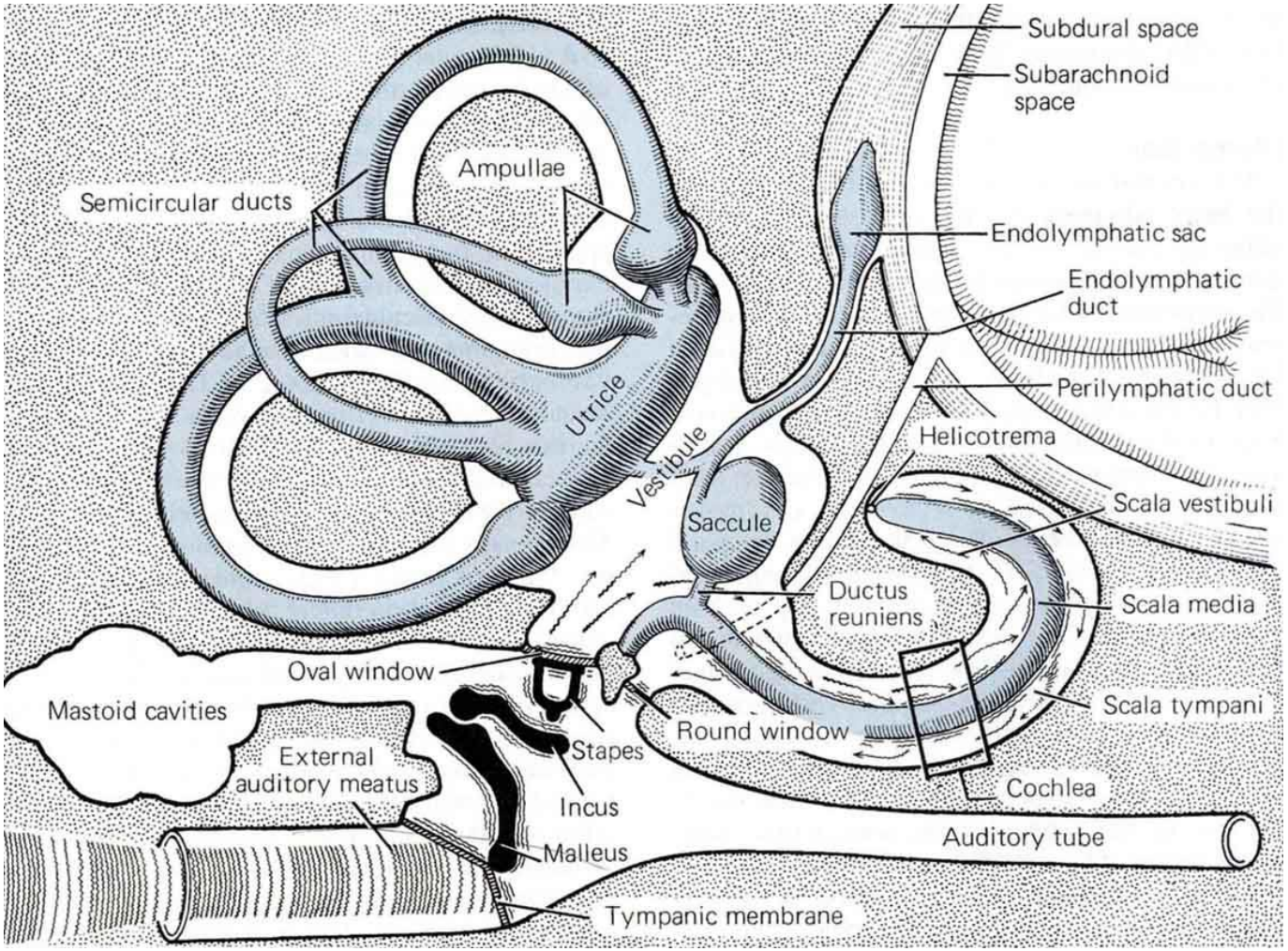
Perilymph - filtration of cerebrospinal fluid (CSF) + filtration from blood vessels of the ear

- similar chemical composition as CSF, resembling extracellular fluid
- low potassium and high sodium concentrations.
- the cochlear aqueduct (perilymphatic duct) opens into both the subarachnoid and perilymphatic spaces.
- an increase in CSF pressure results in flow into the labyrinth.

Endolymph

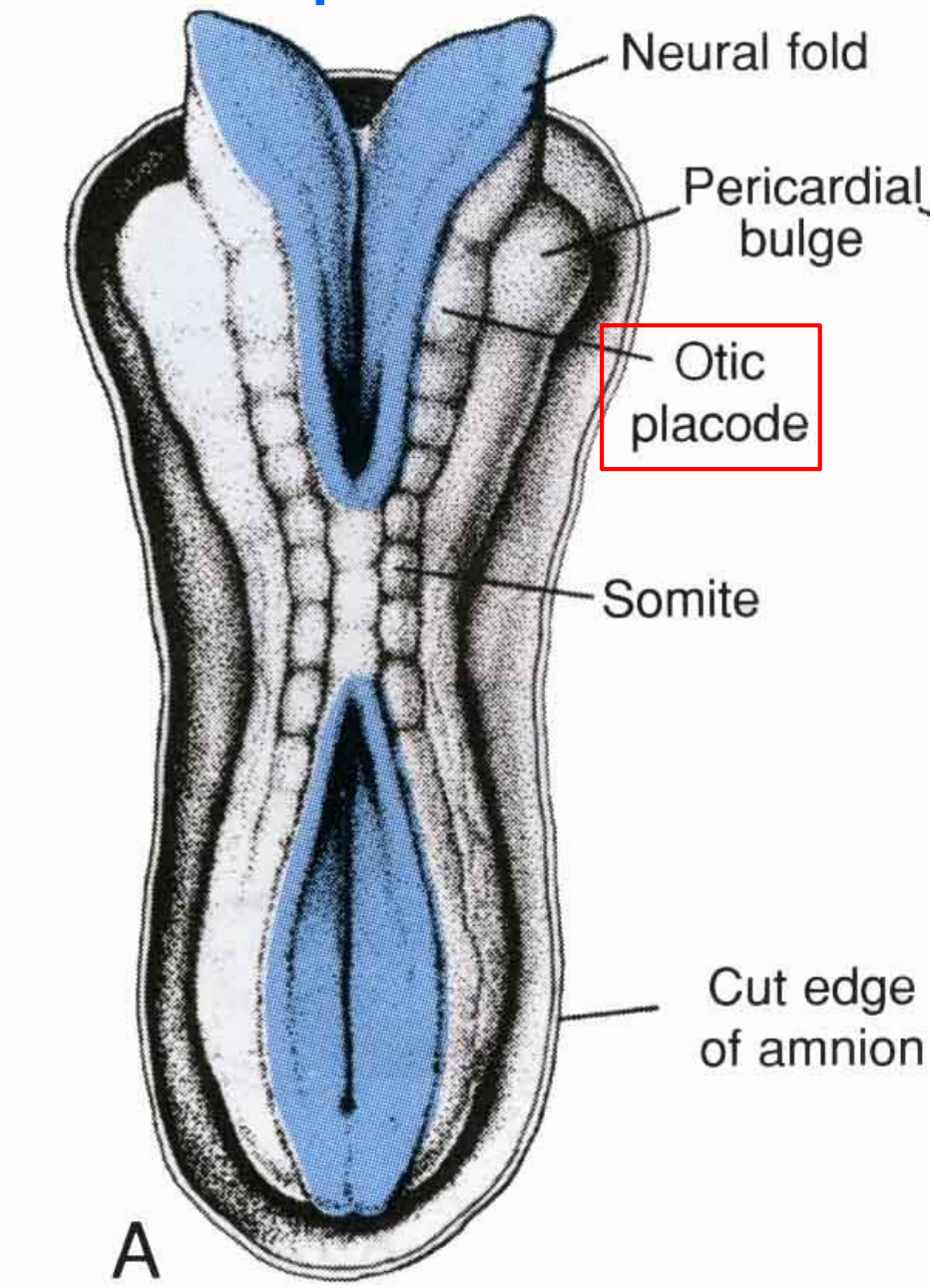
- intracellular-like fluid containing high potassium and low sodium concentrations.
- low protein content; its protein is entirely globulin instead of an admixture of globulin and albumin
- It has a viscosity similar to the vitreous of the eye because of its high mucopolysaccharide content.
- The electrolyte concentration of the endolymph is critical for normal functioning of the sensory organs.
- main sources of endolymph are the stria vascularis, the epithelium of the ampullae of the semicircular ducts, and the epithelium of the maculae of the utricle and saccule.

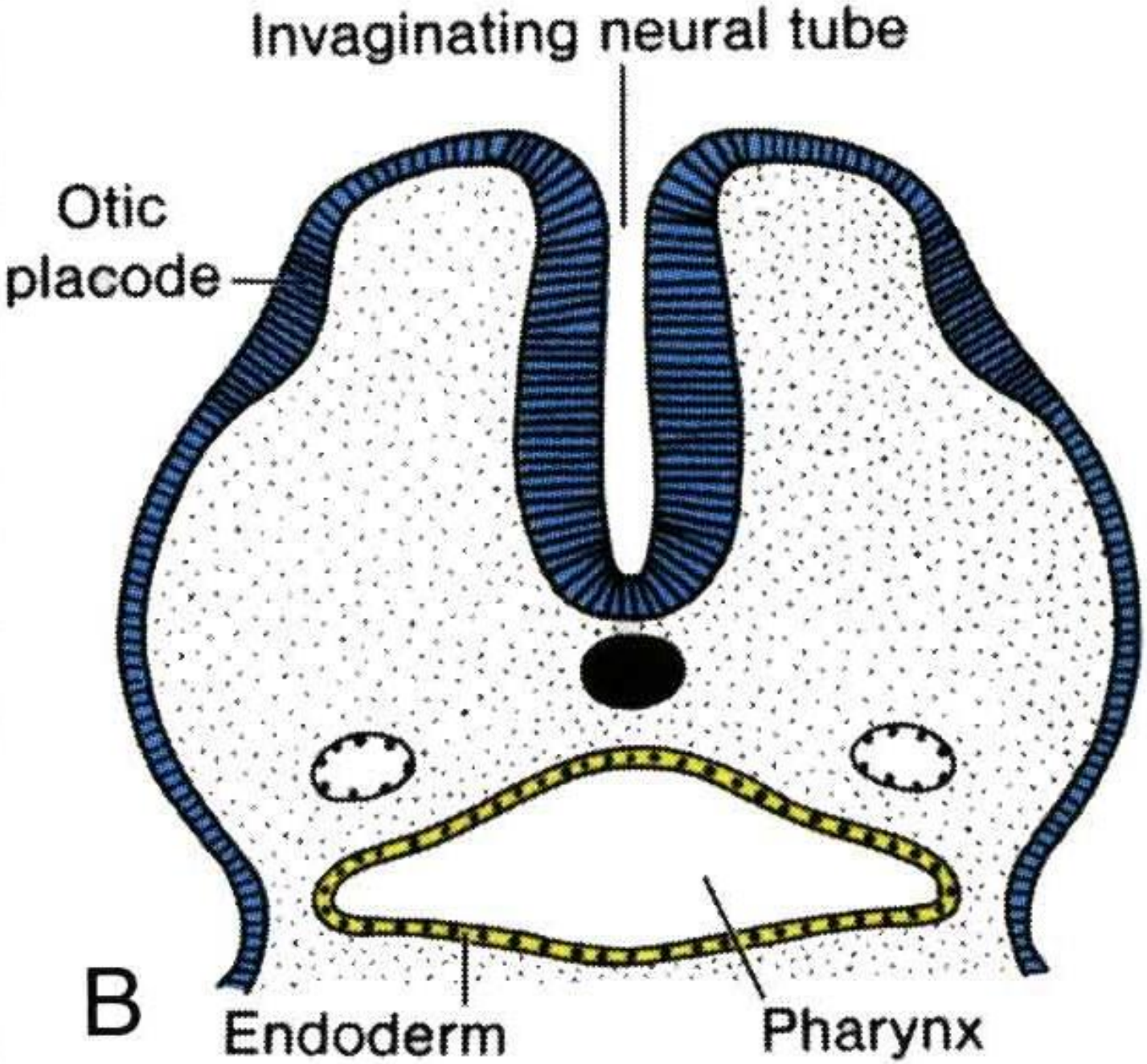


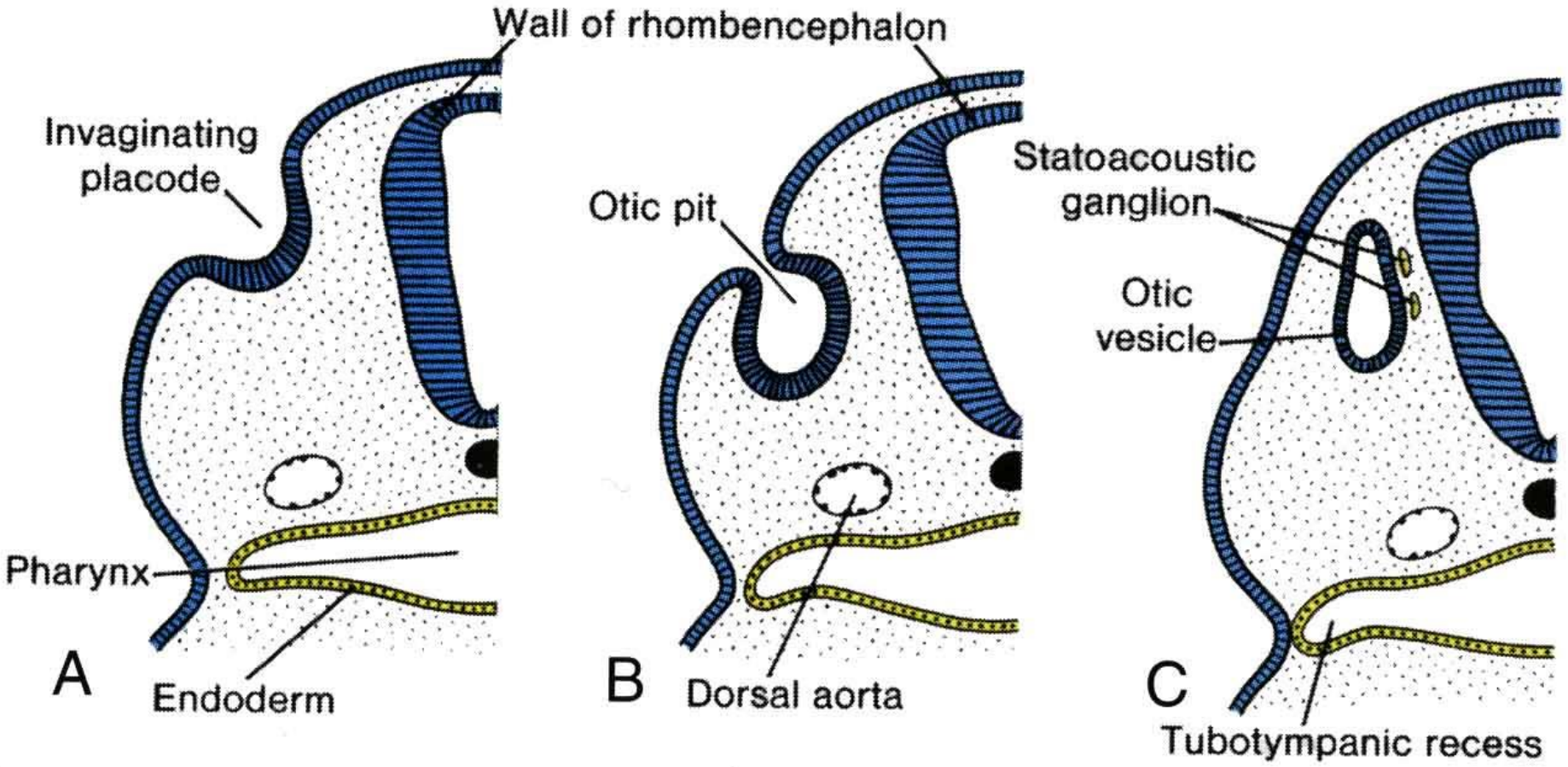


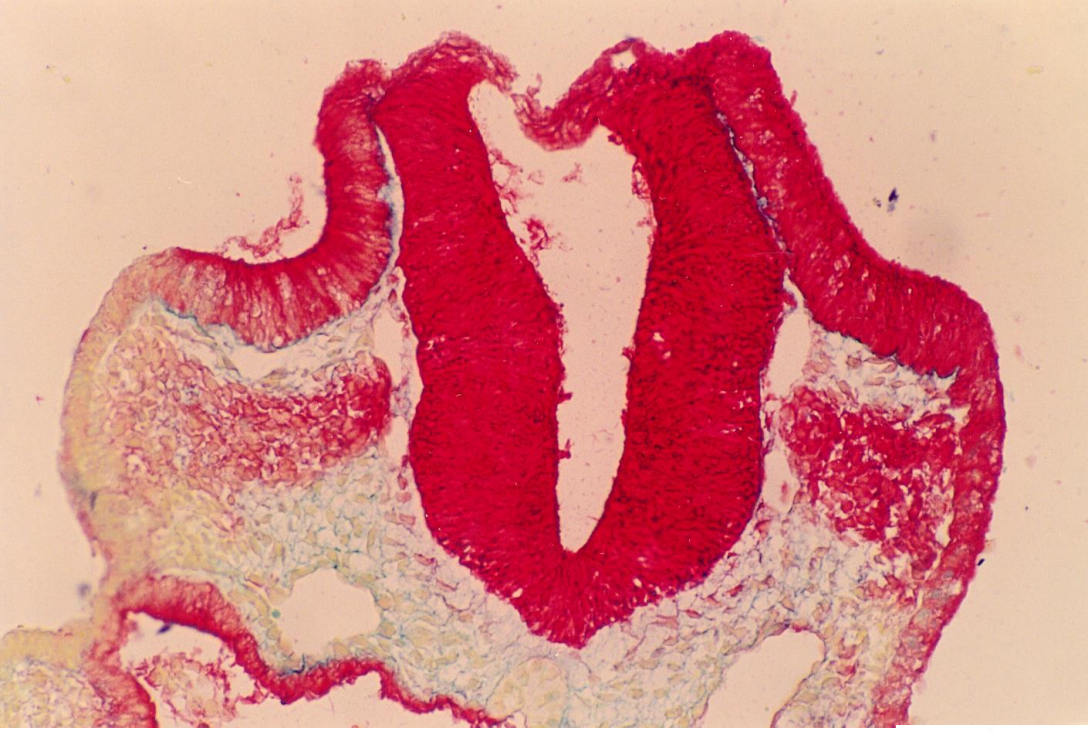
cochlear duct (scala media) -> base of the cochlea-> ductus reuniens -> saccule -> endolymphatic sac and duct, where it is reabsorbed.
ampullae-> utricle -> endolymphatic sac and duct
The cochlear duct communicates with the vestibular endolymph-containing sacs through two canals

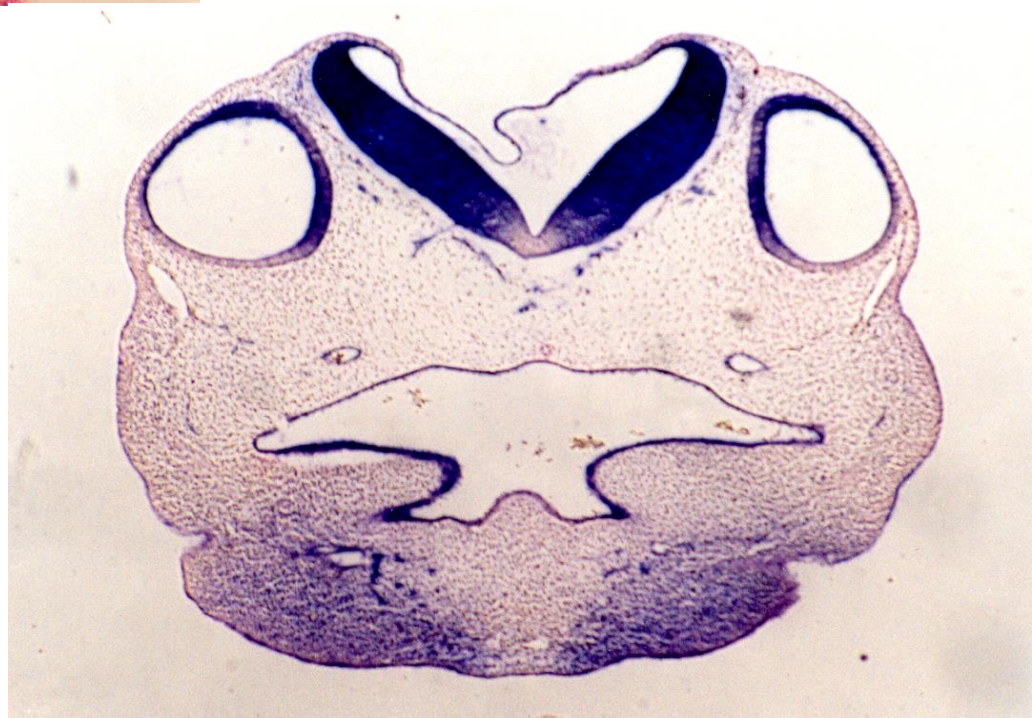
Development of ear

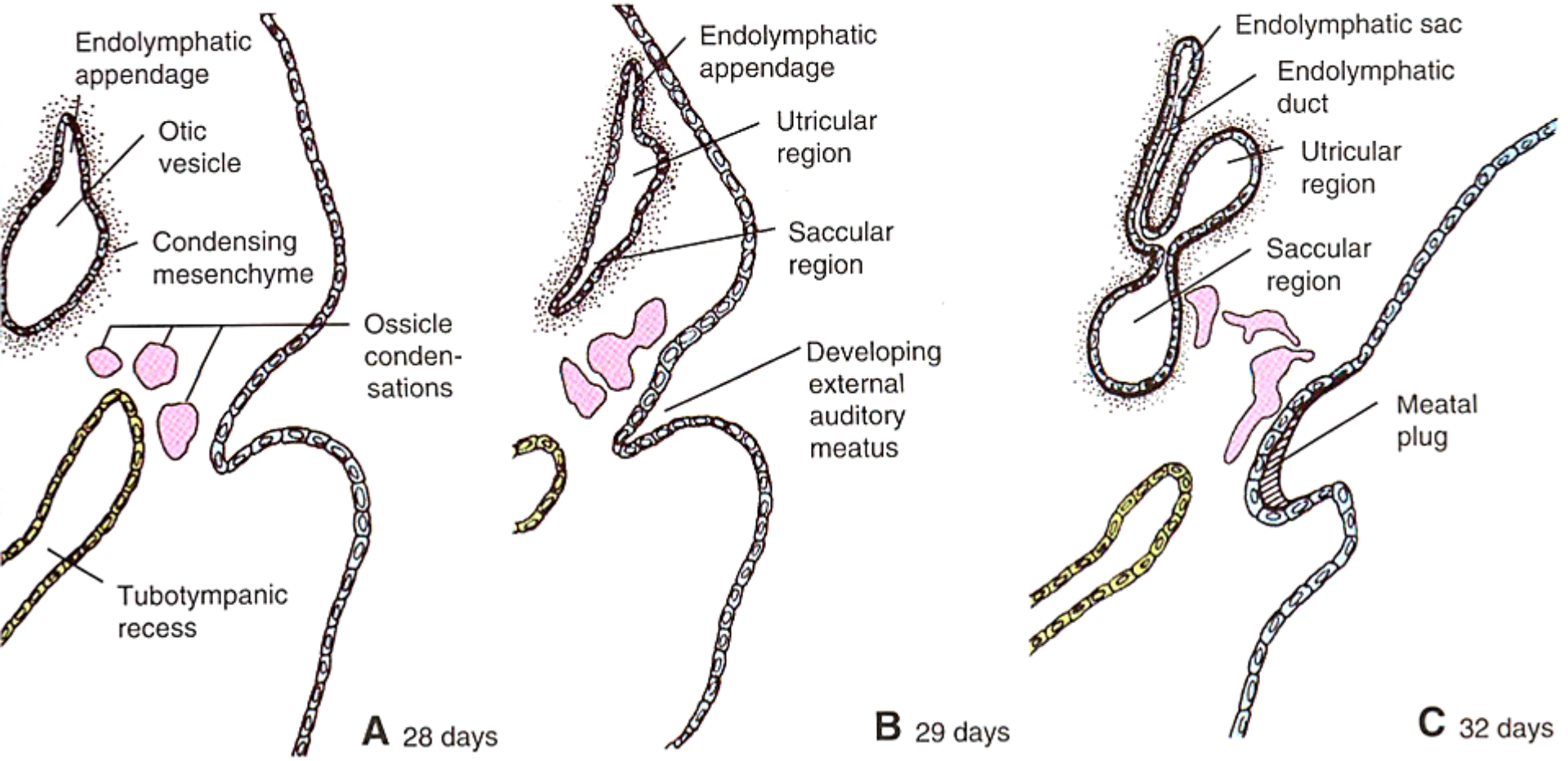


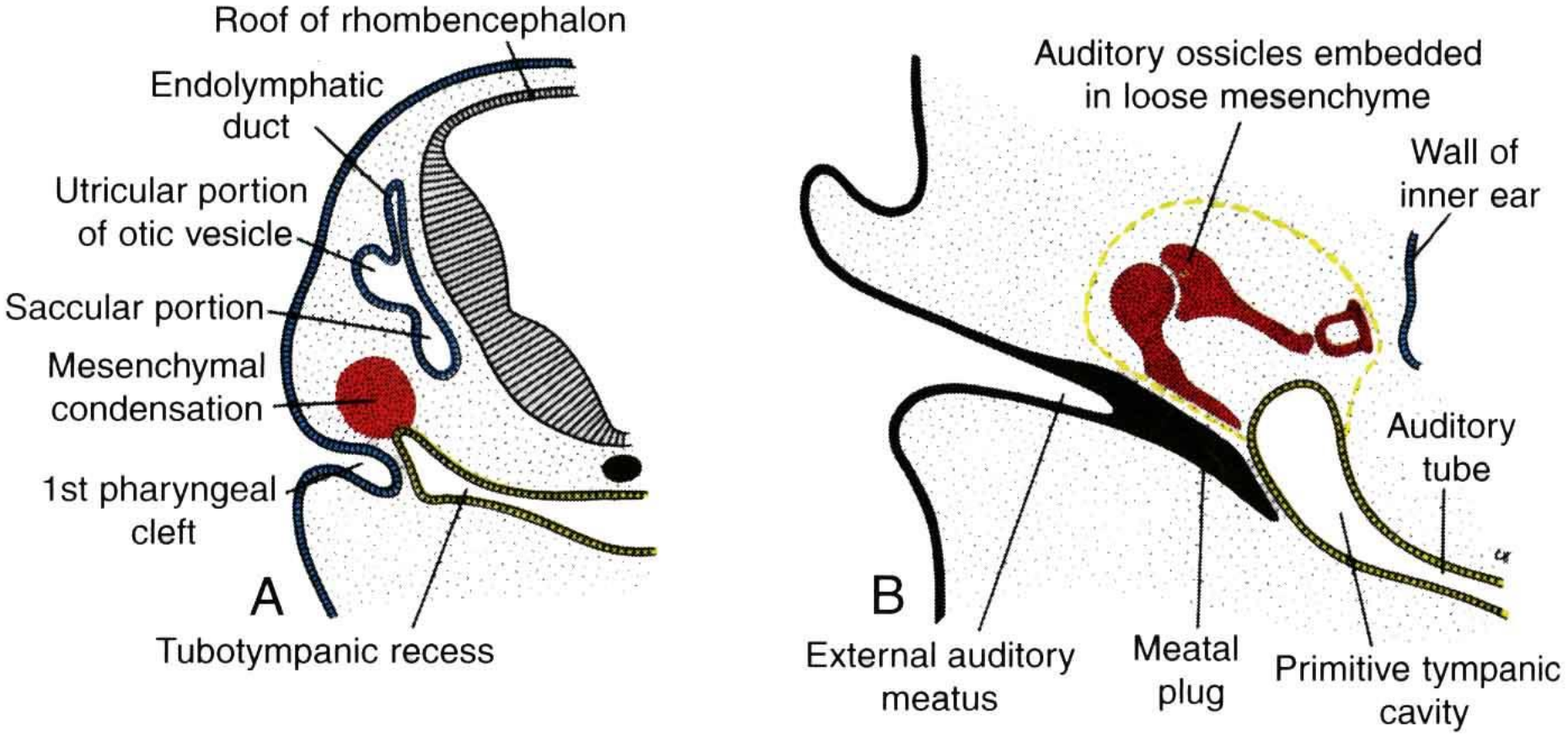

Invaginating neural tube
Otic placode
B
Endoderm
Pharynx

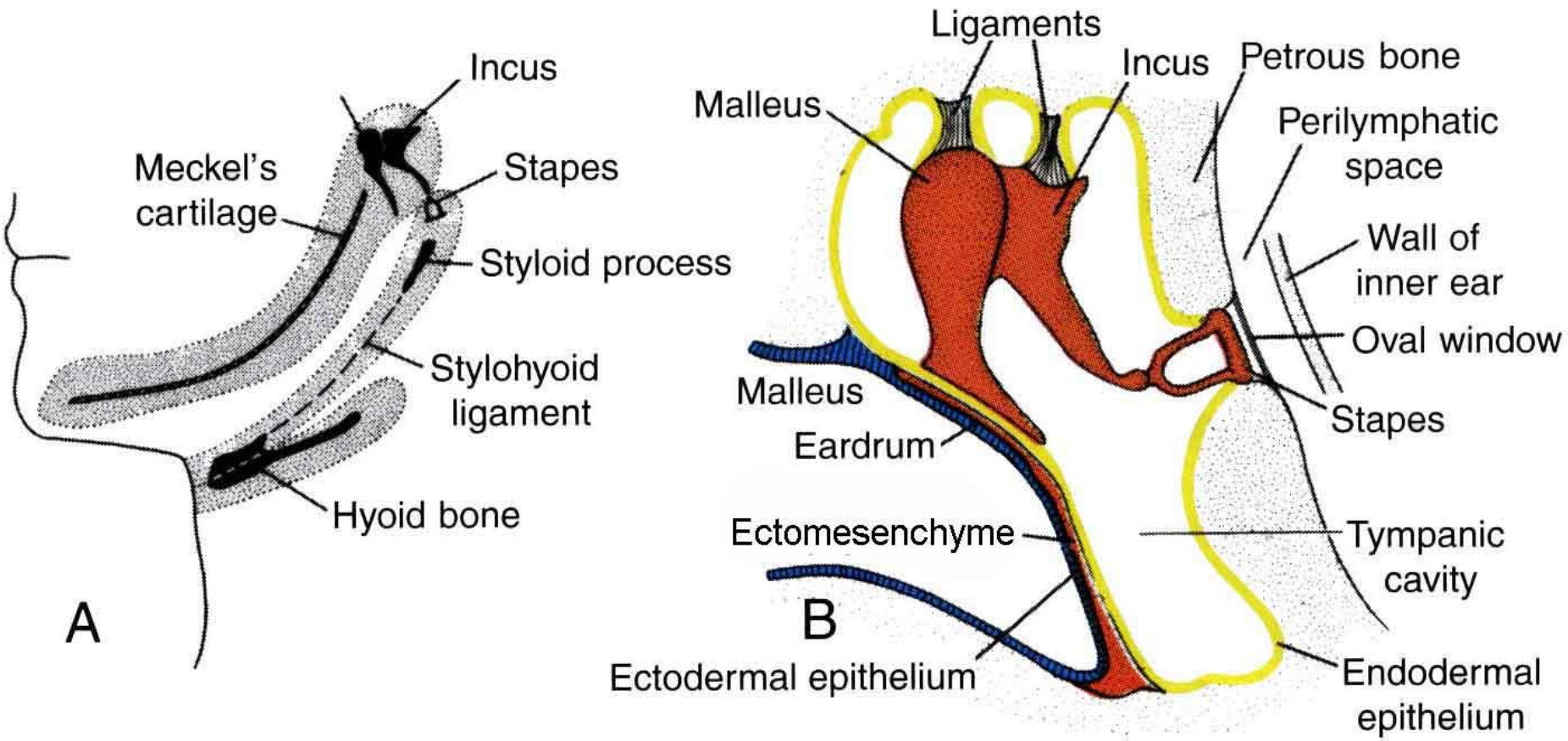

Wall of rhombencephalon
Invaginating placode
Pharynx
A
Endoderm
Otic pit
B
Dorsal aorta
Statoacoustic ganglion
Otic vesicle
C
Tubotympanic recess



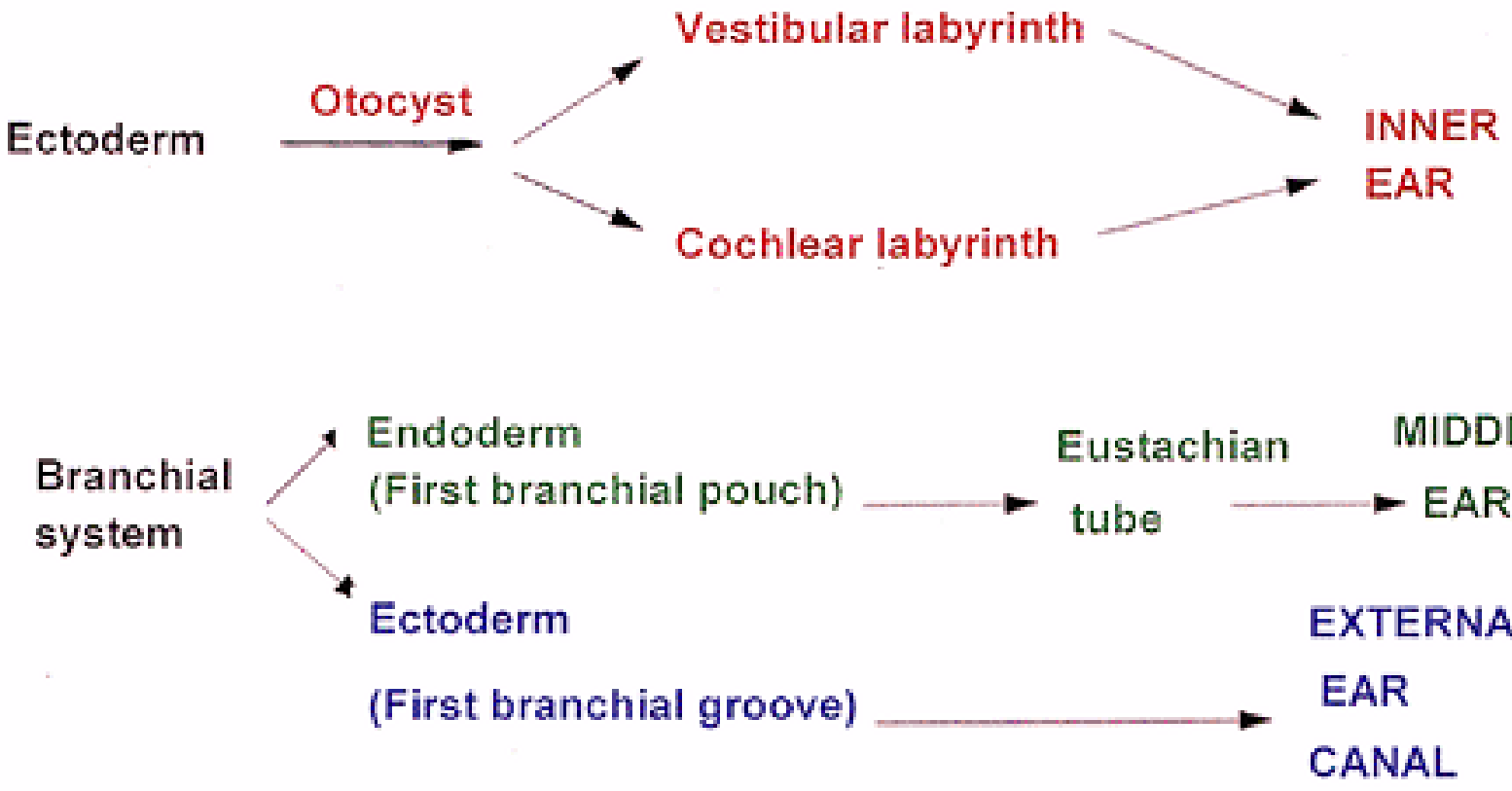


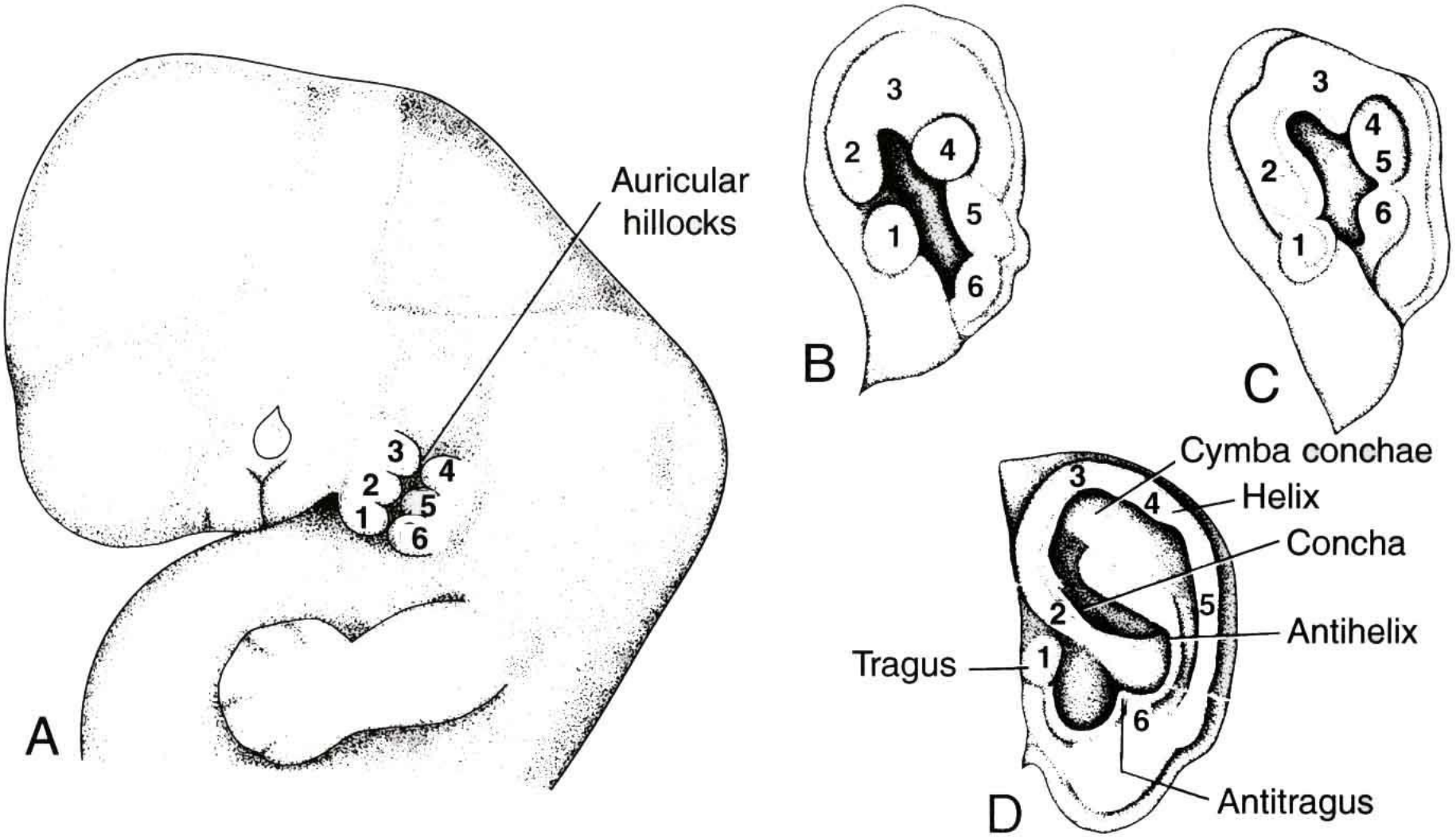

Endolymphatic appendage
Otic vesicle
Condensing mesenchyme
Ossicle condensations
Tubotympanic recess
A 28 days
Endolymphatic appendage
Utricular region
Saccular region
Developing external auditory meatus
B 29 days
Endolymphatic sac
Endolymphatic duct
Utricular region
Saccular region
Meatal plug
C 32 days


Roof of rhombencephalon
Endolymphatic duct
Utricular portion of otic vesicle
Saccular portion
Mesenchymal condensation
1st pharyngeal cleft
A
Tubotympanic recess
Auditory ossicles embedded in loose mesenchyme
Wall of inner ear
Auditory tube
B
External auditory meatus
Meatal plug
Primitive tympanic cavity


Incus
Meckel's cartilage
Stapes
Styloid process
Stylohyoid ligament
Hyoid bone
A
Ligaments
Incus
Petrous bone
Malleus
Perilymphatic space
Wall of inner ear
Oval window
Malleus
Stapes
Eardrum
Ectomesenchyme
Tympanic cavity
B
Ectodermal epithelium
Endodermal epithelium

DEVELOPMENT OF THE EPITHELIAL SYSTEMS OF THE EAR




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

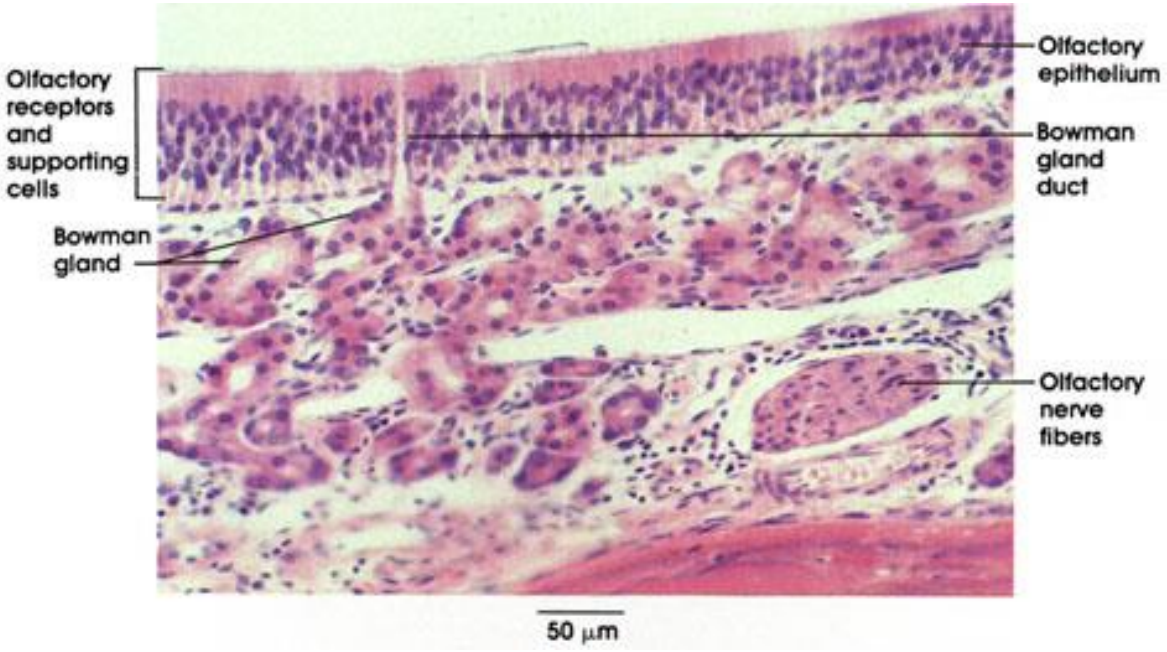
Smell

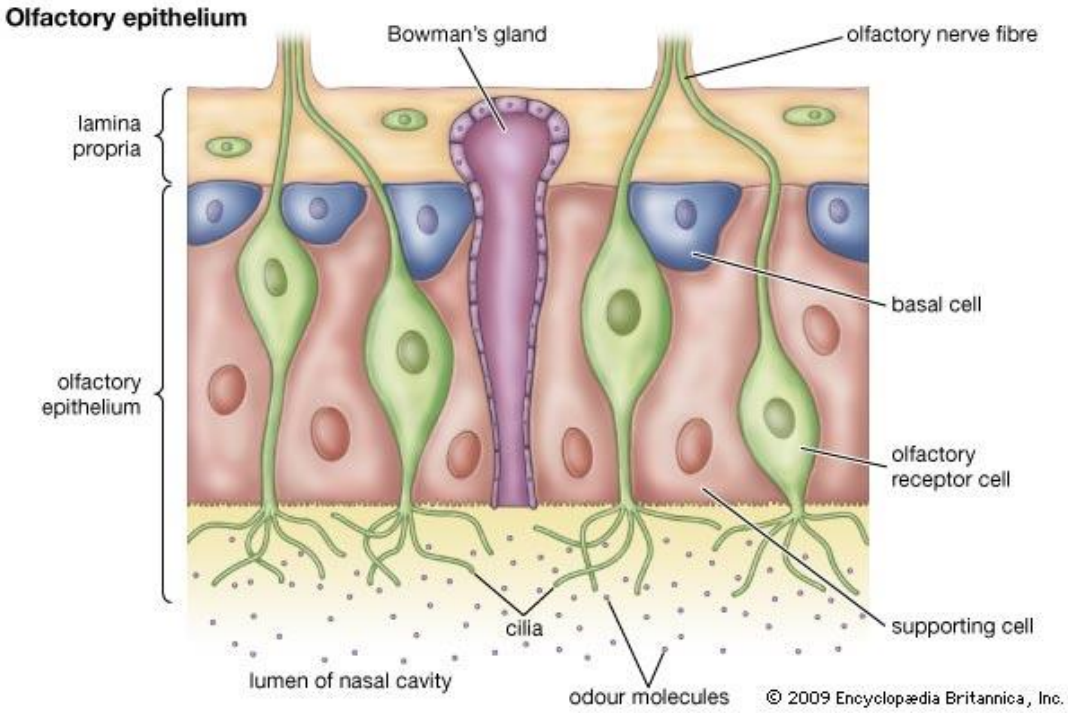
Olfactory epithelium 4 cm^2 = regio olfactoria.

- Specialized pseudostratified columnar epithelium
- 3 types of cells:

1) Basal cells
2) Sustentacular cells
3) Olfactory receptor cells

- Tuboalveolar glands in lamina propria (Bowman´s)
- lamina propria
- axons - fila olfactoria - lamina cribrosa



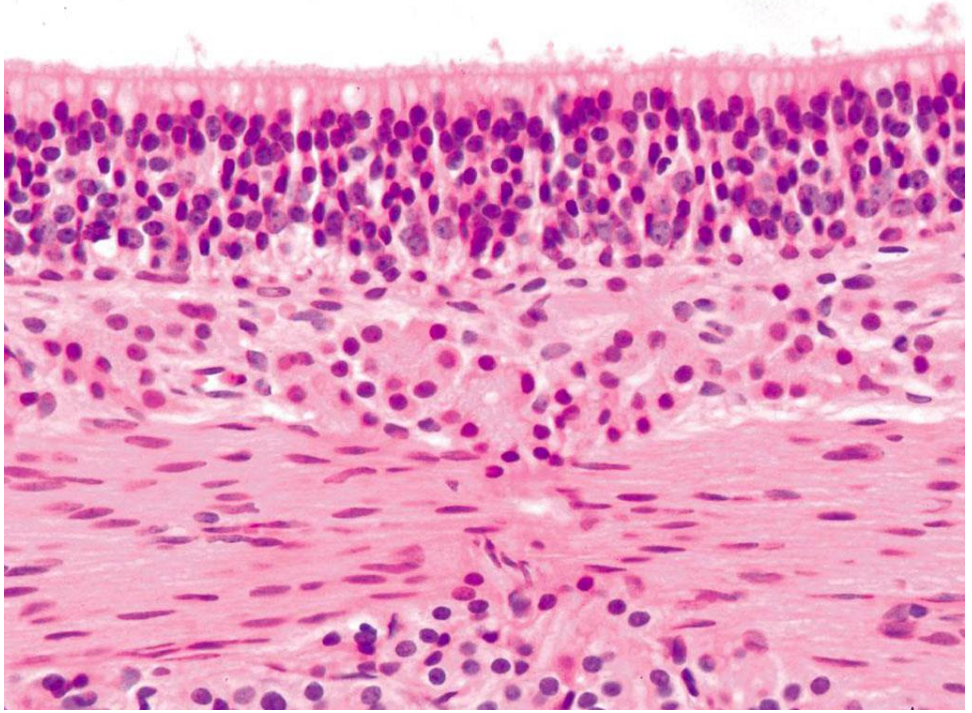


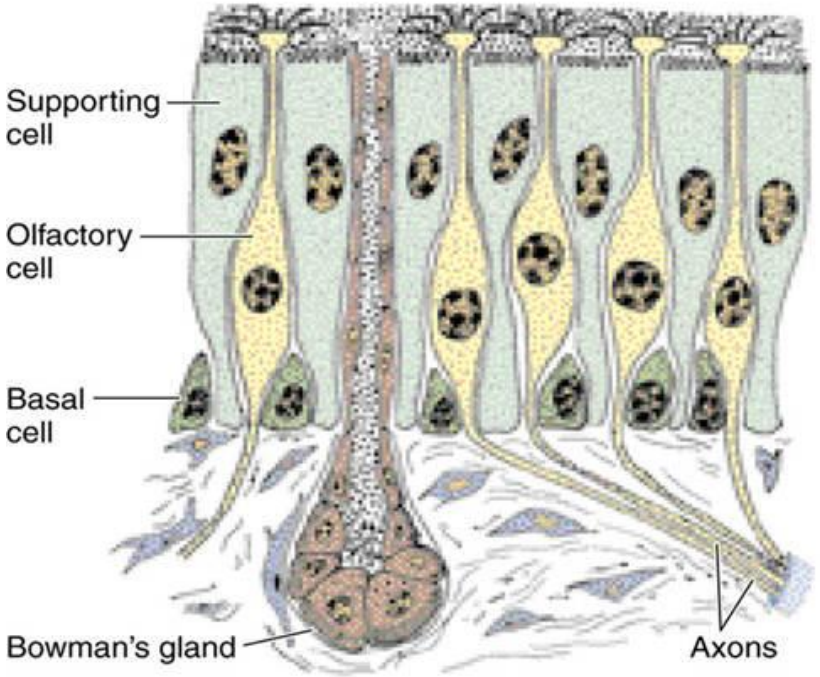
Olfactory cells

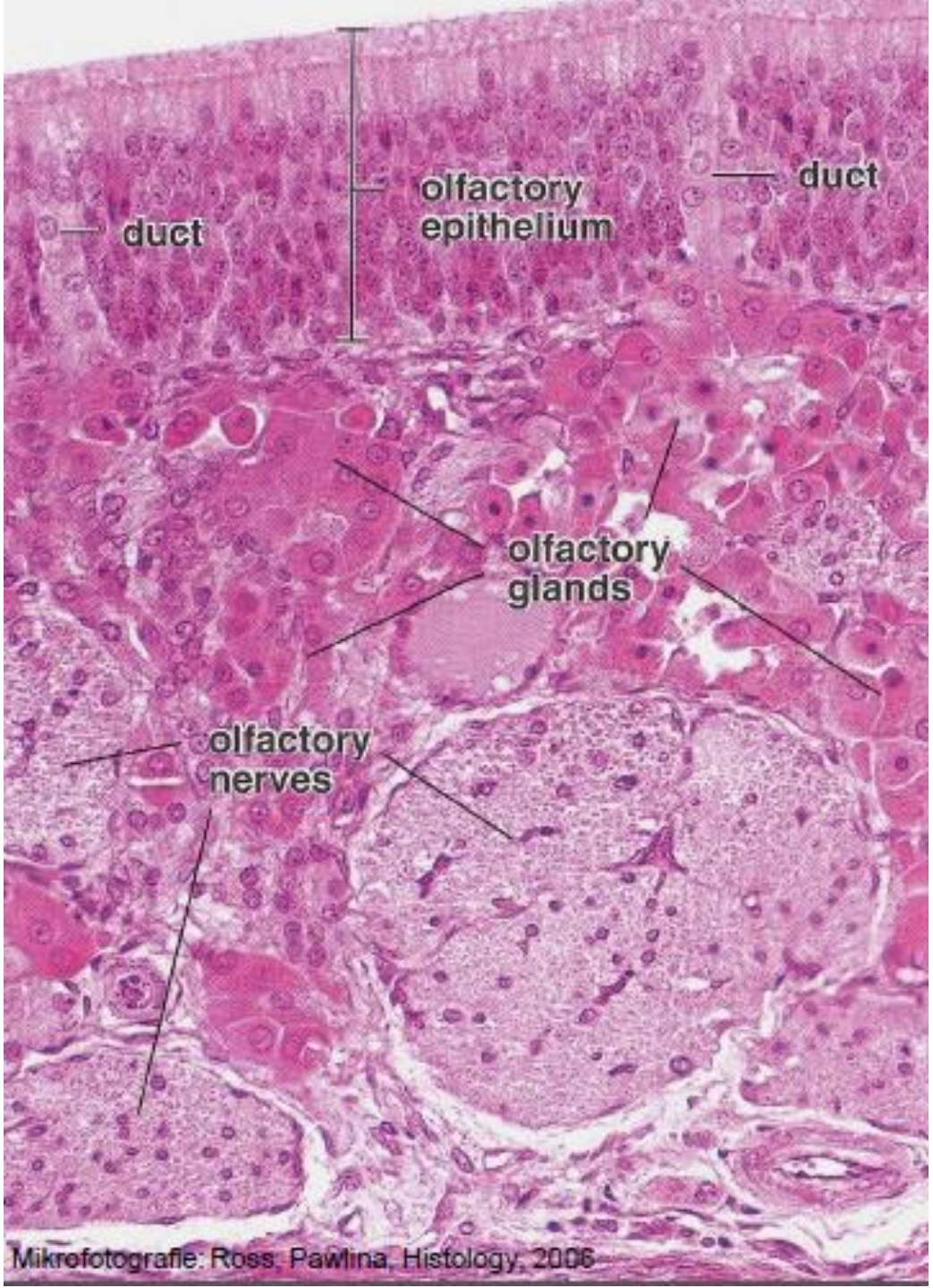
- Bipolar neurons,
- chemoreceptors
- Dendrite with cilia + unmyelinated axon
- => fila olfactoria

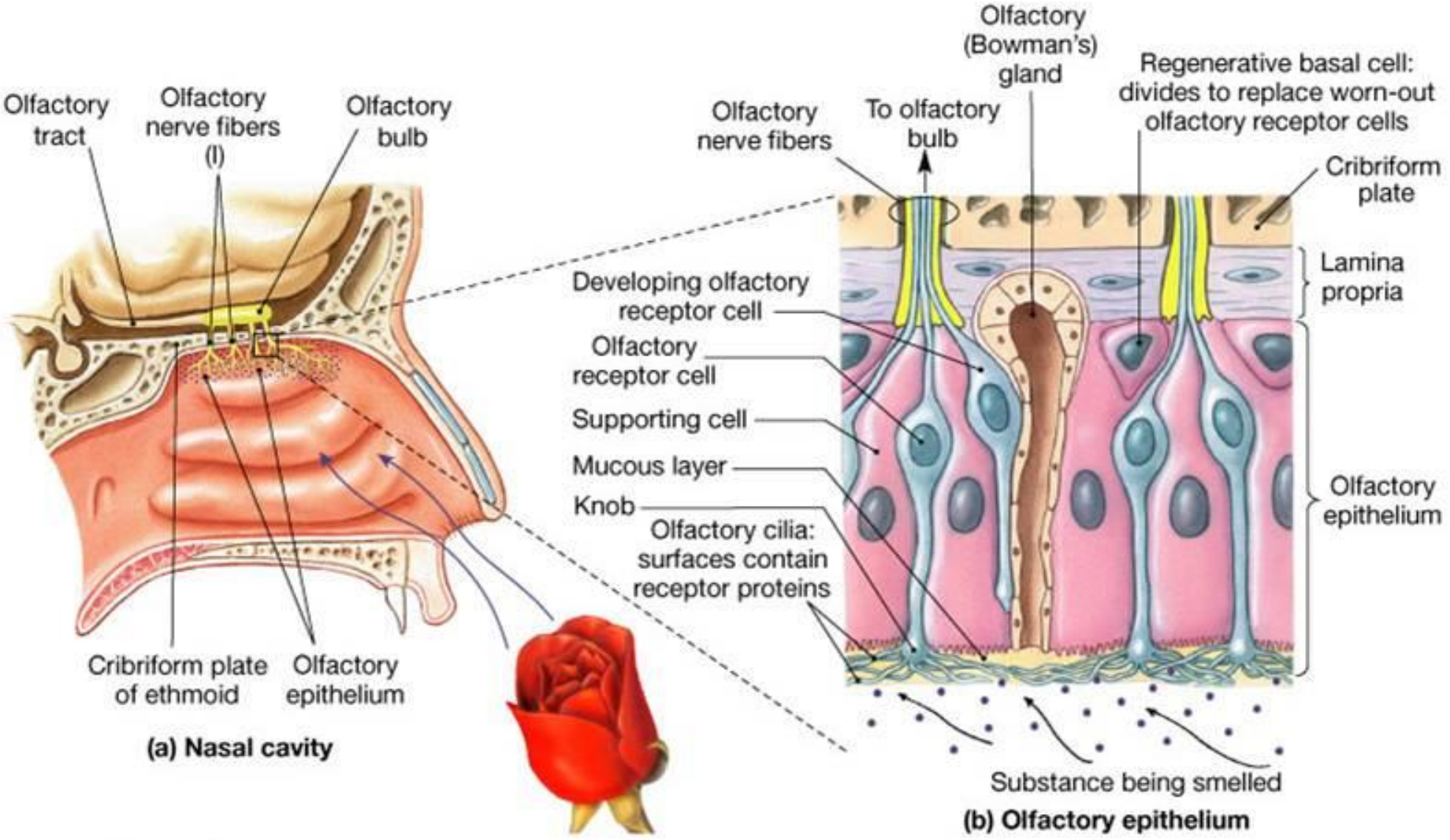
Supporting cells (sustentacular cells)

- Thin base, wide apex
- microvilli
- lipofuchsin






duct
olfactory epithelium
duct
olfactory glands
olfactory nerves
Mikrofotografie: Ross, Pawlina, Histology, 2006


Olfactory tract
Olfactory nerve fibers (I)
Olfactory bulb
Cribriform plate of ethmoid
Olfactory epithelium
(a) Nasal cavity
Olfactory (Bowman's) gland
Regenerative basal cell: divides to replace worn-out olfactory receptor cells
Olfactory nerve fibers
To olfactory bulb
Cribriform plate
Lamina propria
Developing olfactory receptor cell
Olfactory receptor cell
Supporting cell
Mucous layer
Knob
Olfactory cilia: surfaces contain receptor proteins
Olfactory epithelium
Substance being smelled
(b) Olfactory epithelium

pars olfactoria mucosae nasi

1 – olfactory epithelium

2 – basal cells

3 – olfactory cells

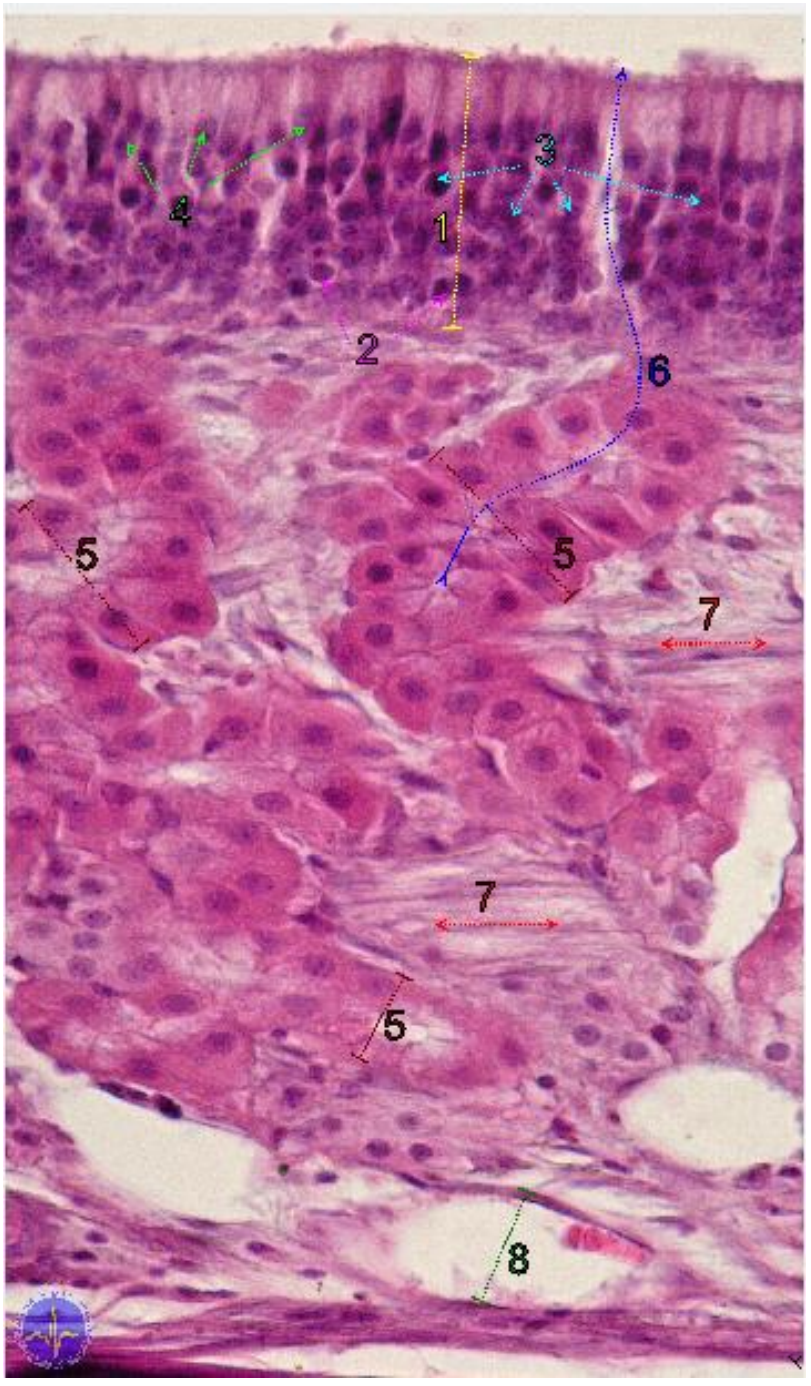
4 – supporting

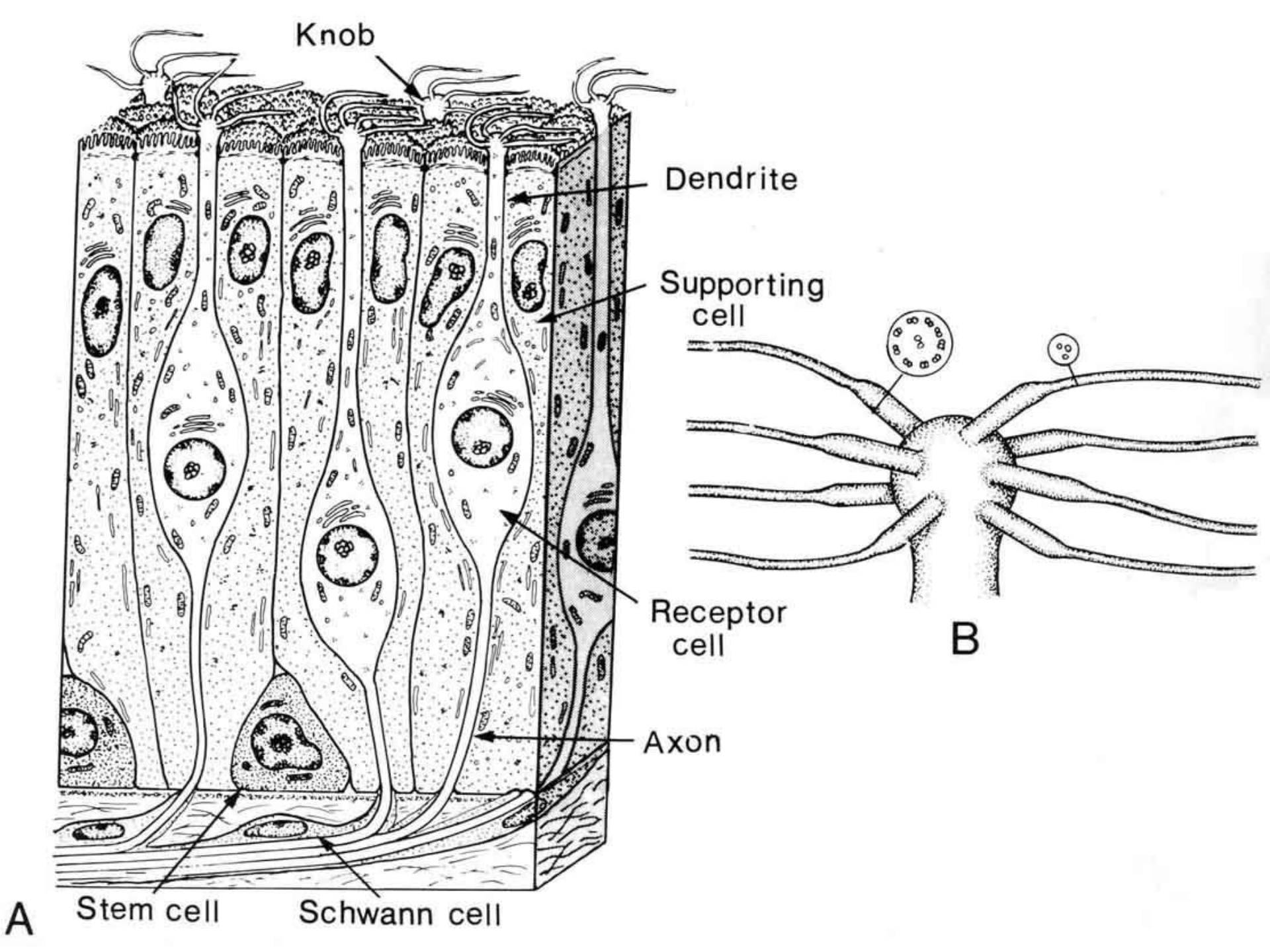
5 – Bowman´s glands

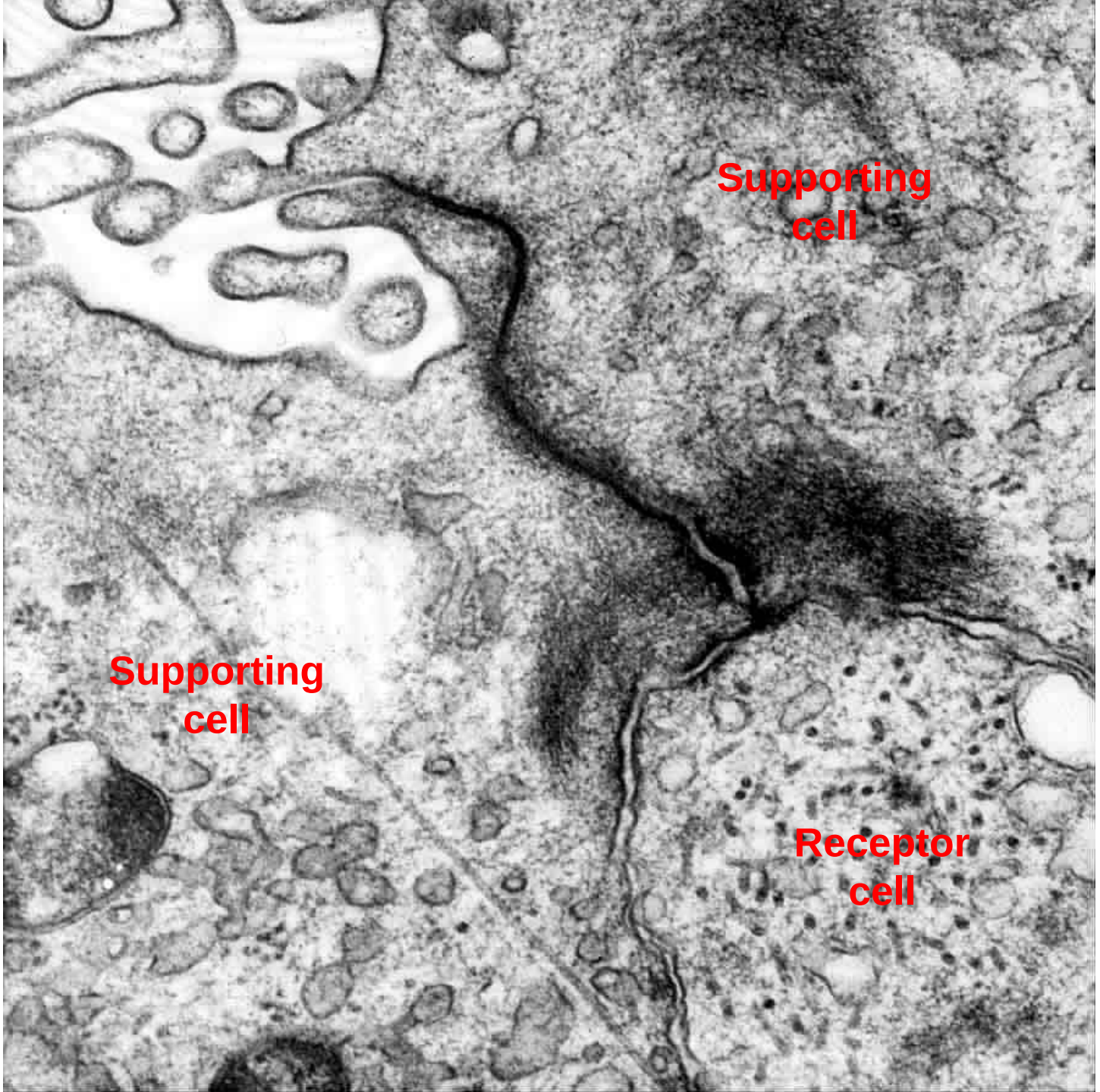
6 – duct

7 – nerves = fila olfactoria

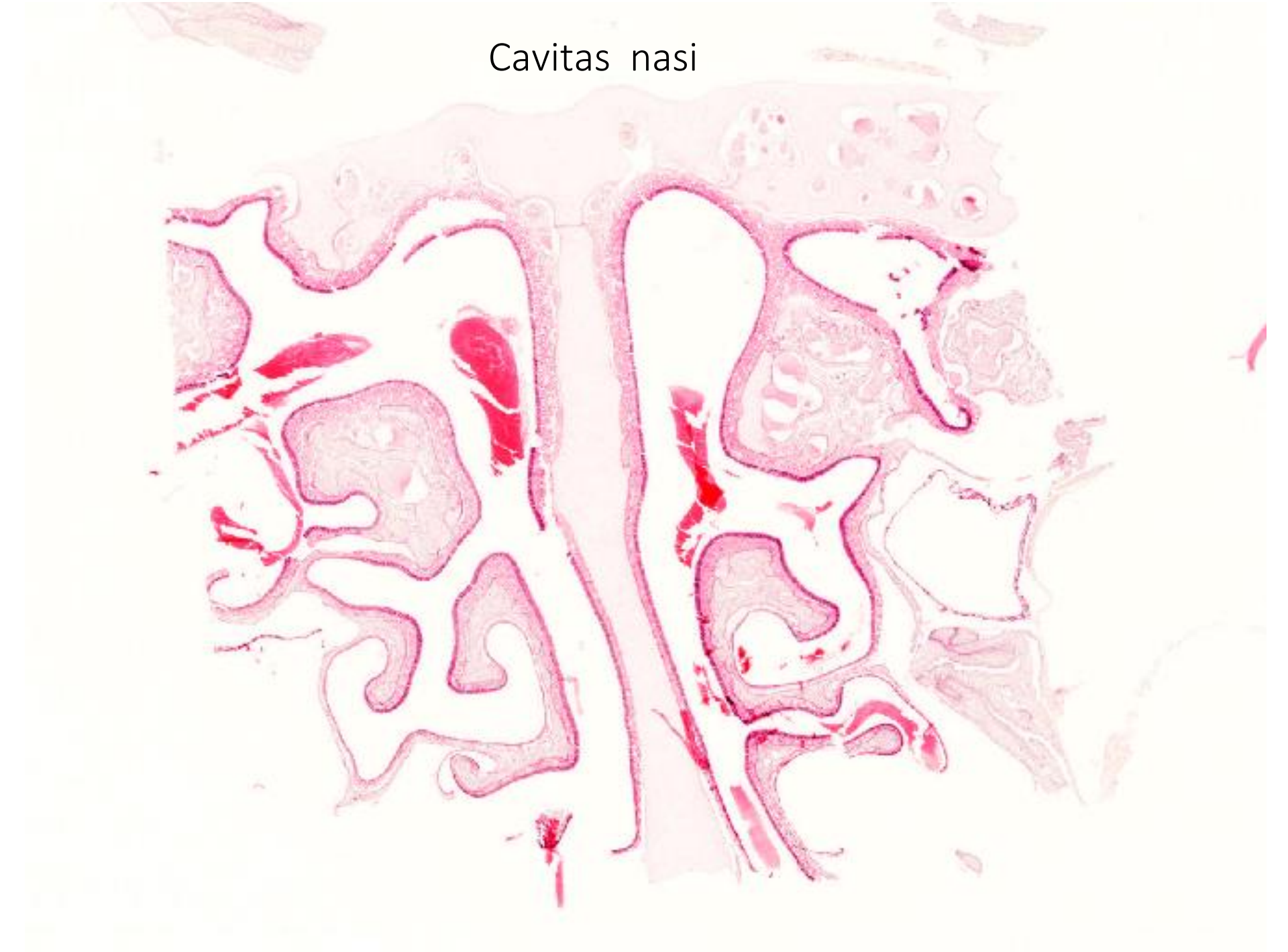
8 – vessel

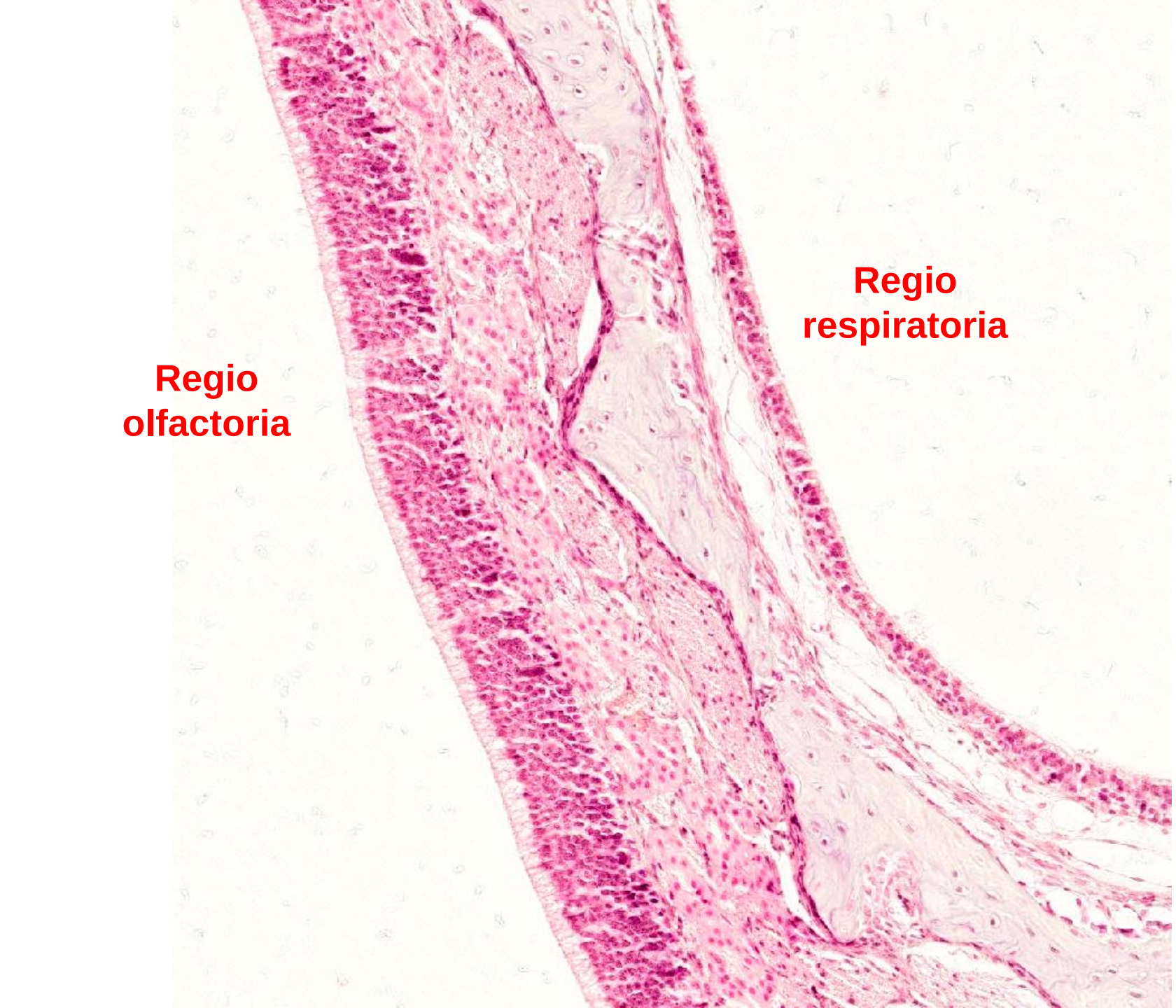


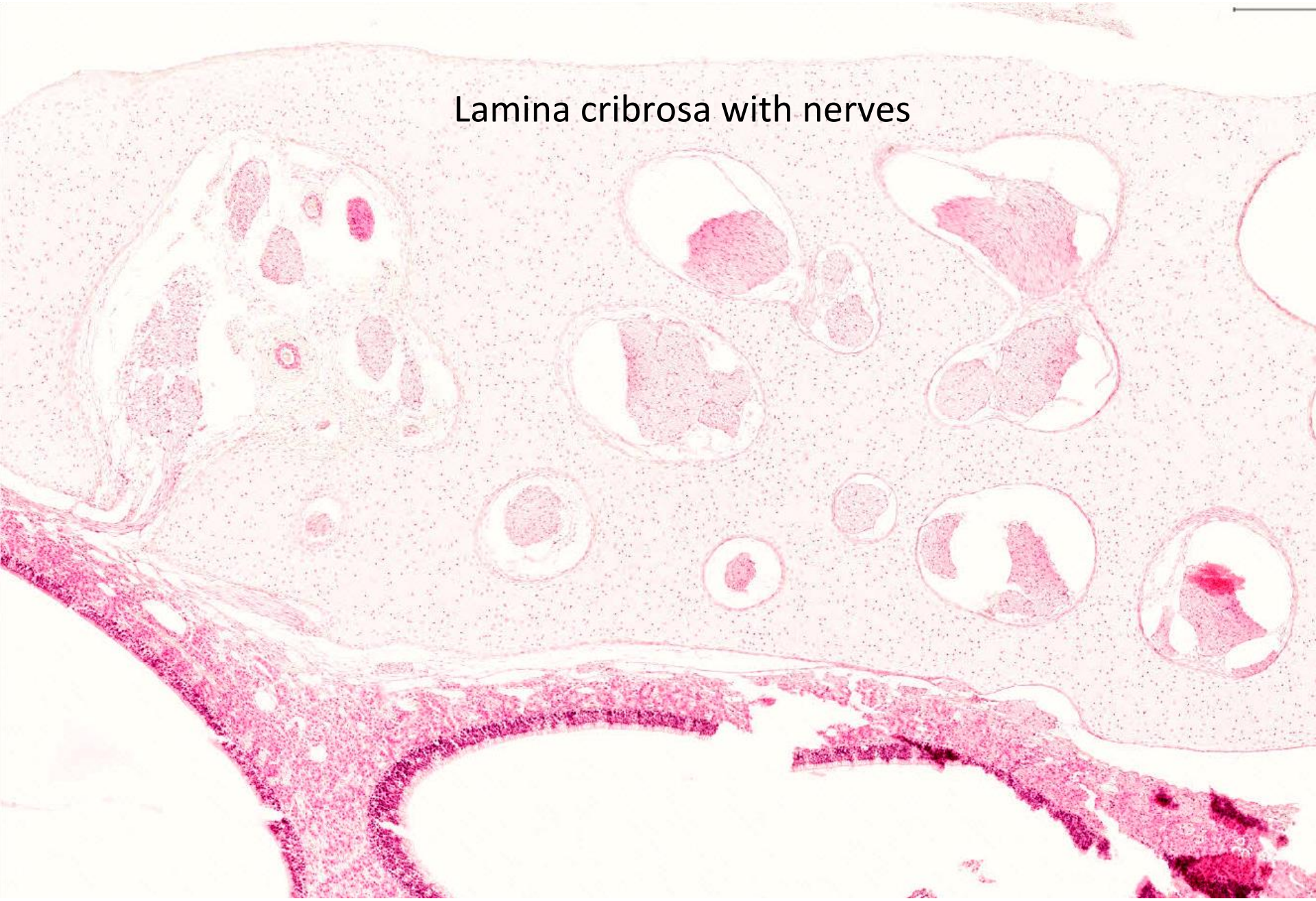

Knob
Dendrite
Supporting cell
Receptor cell
Axon
Stem cell
Schwann cell
A
B


Supporting cell
Supporting cell
Receptor cell

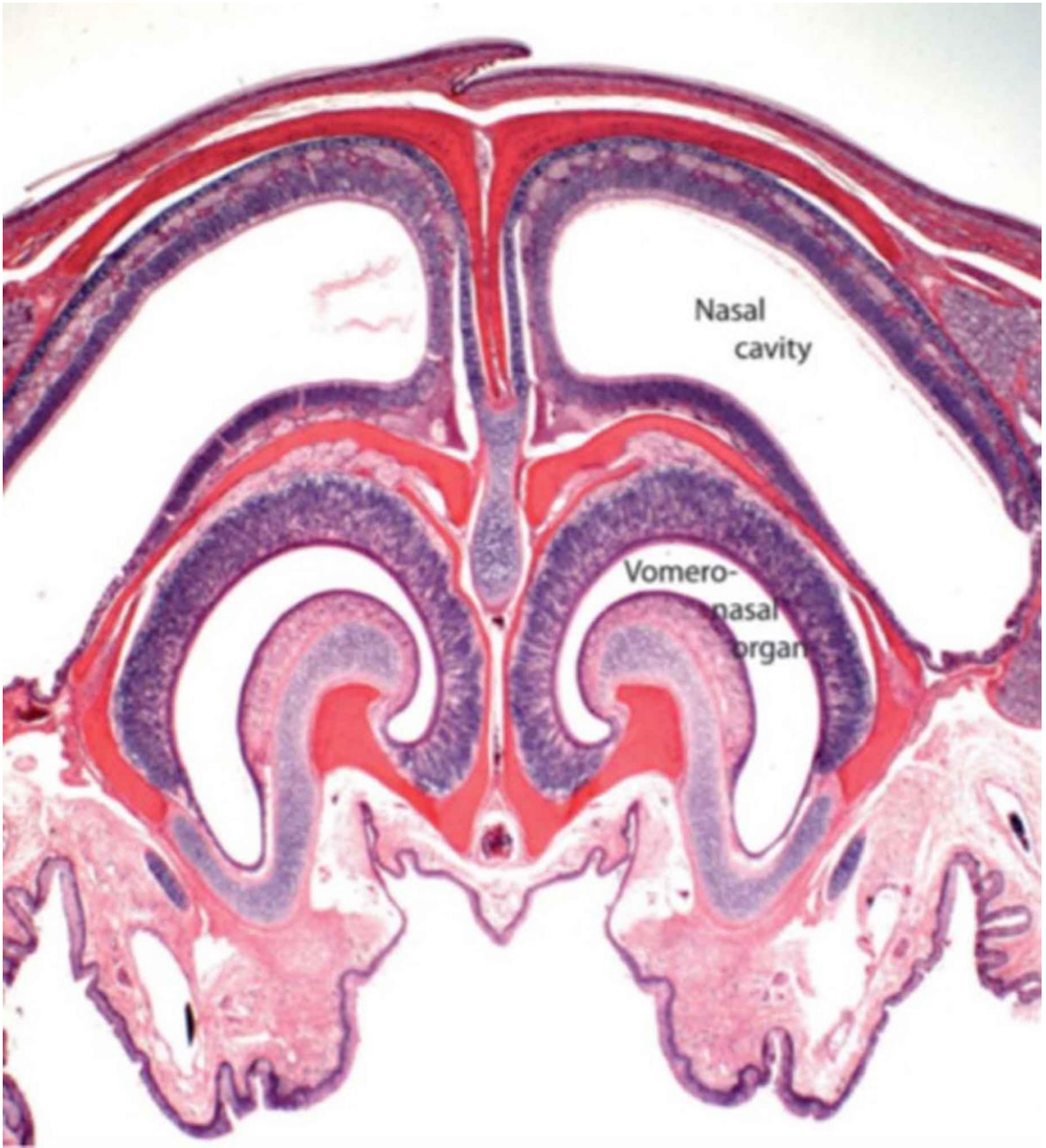
Cavitas nasi

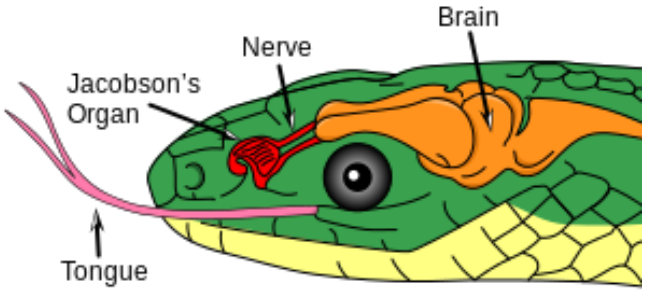



Regio respiratoria
Regio olfactoria


Lamina cribrosa with nerves

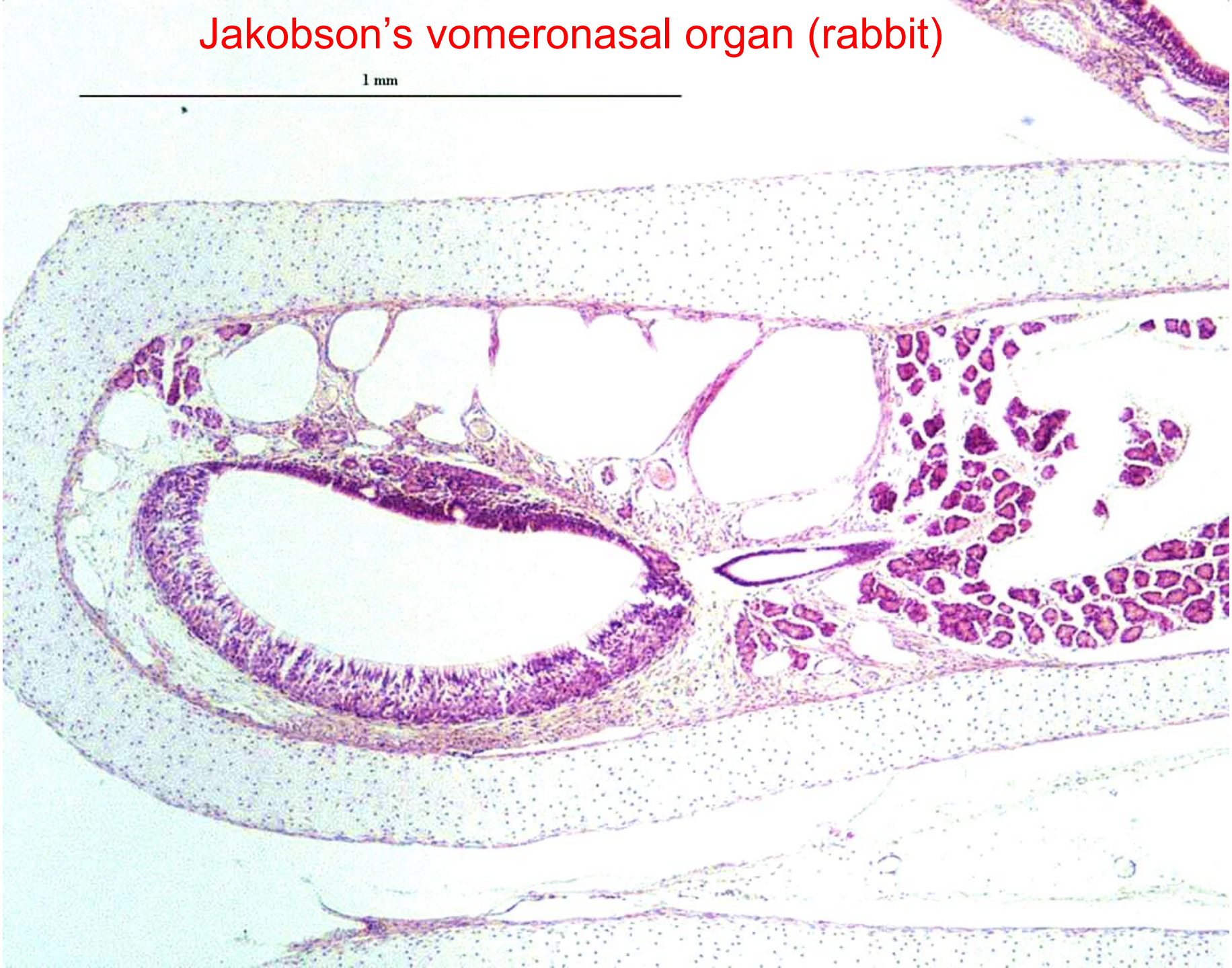
Jakobson's vomeronasal organ



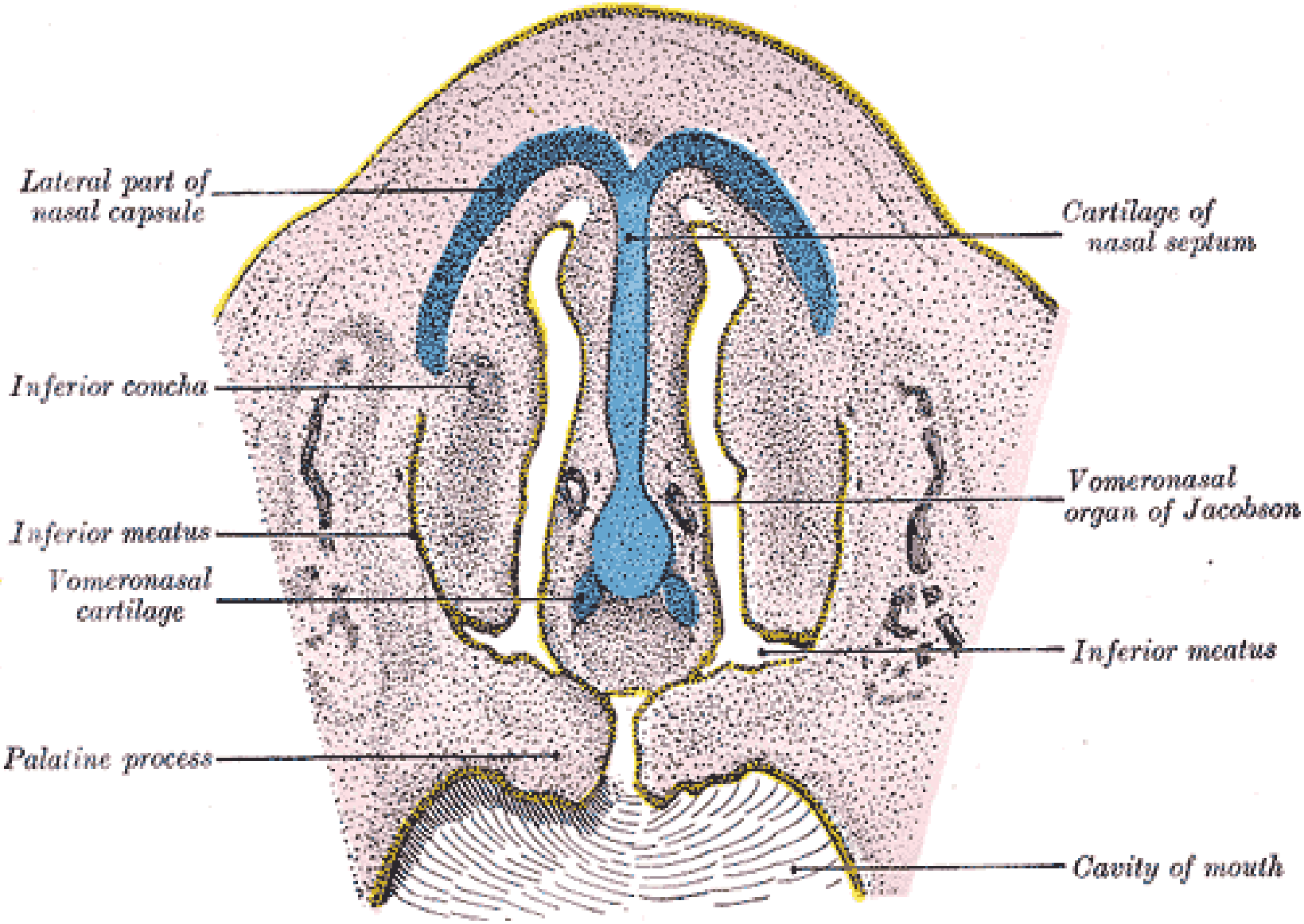


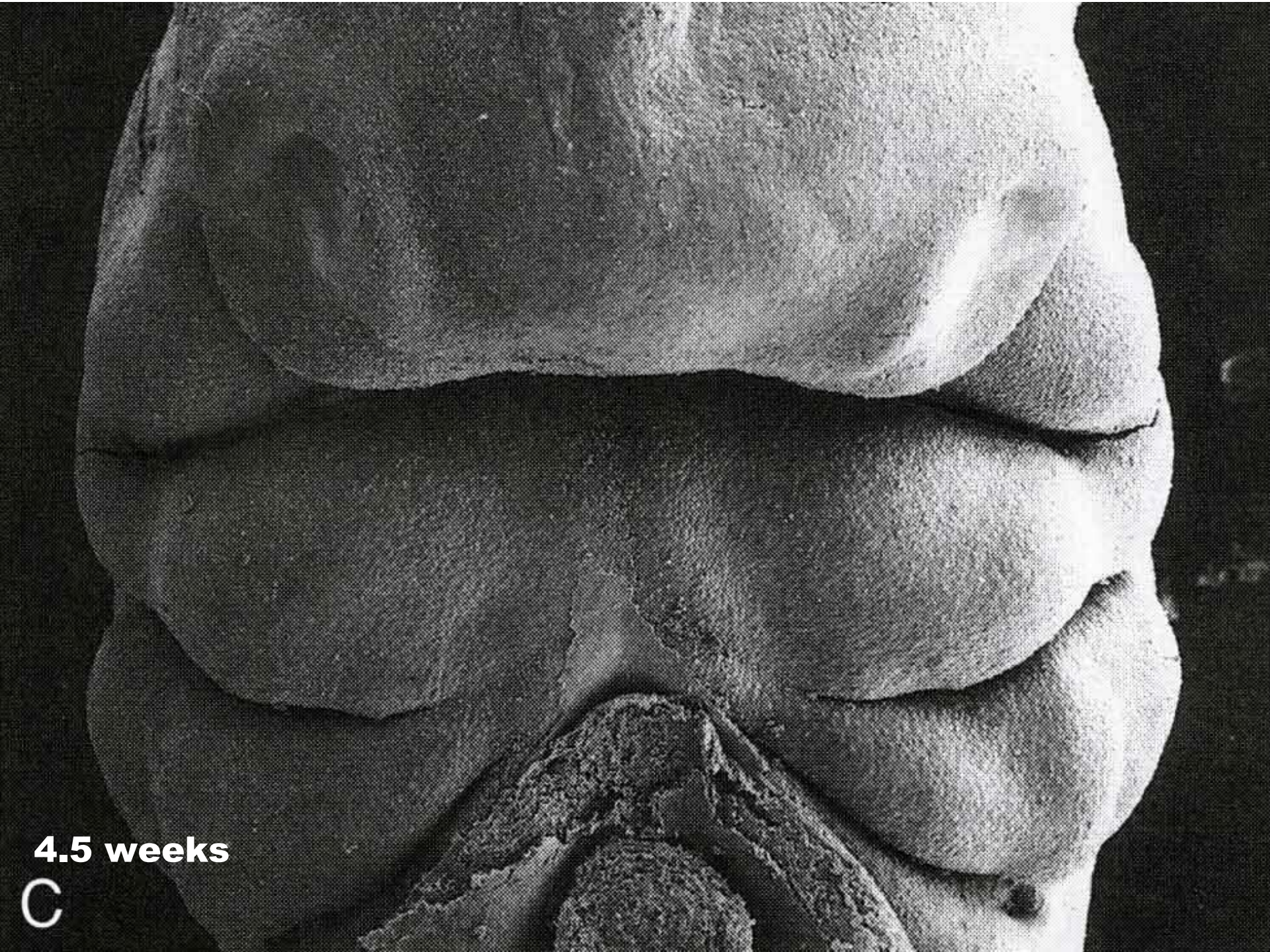
present in all vertebrates, which is essential for intra-specific chemical (Pheromone) communication

Jakobson’s vomeronasal organ (rabbit)

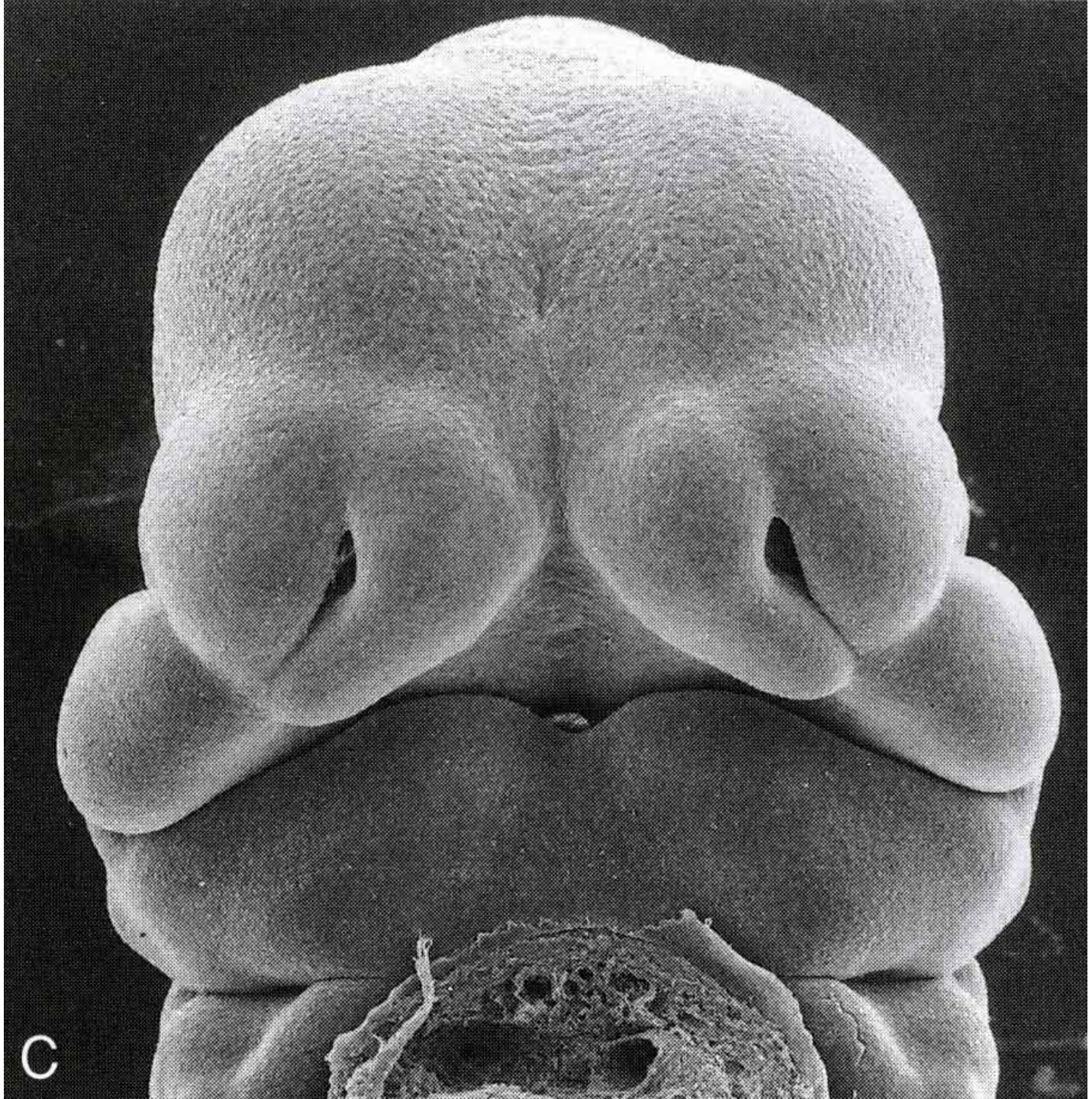


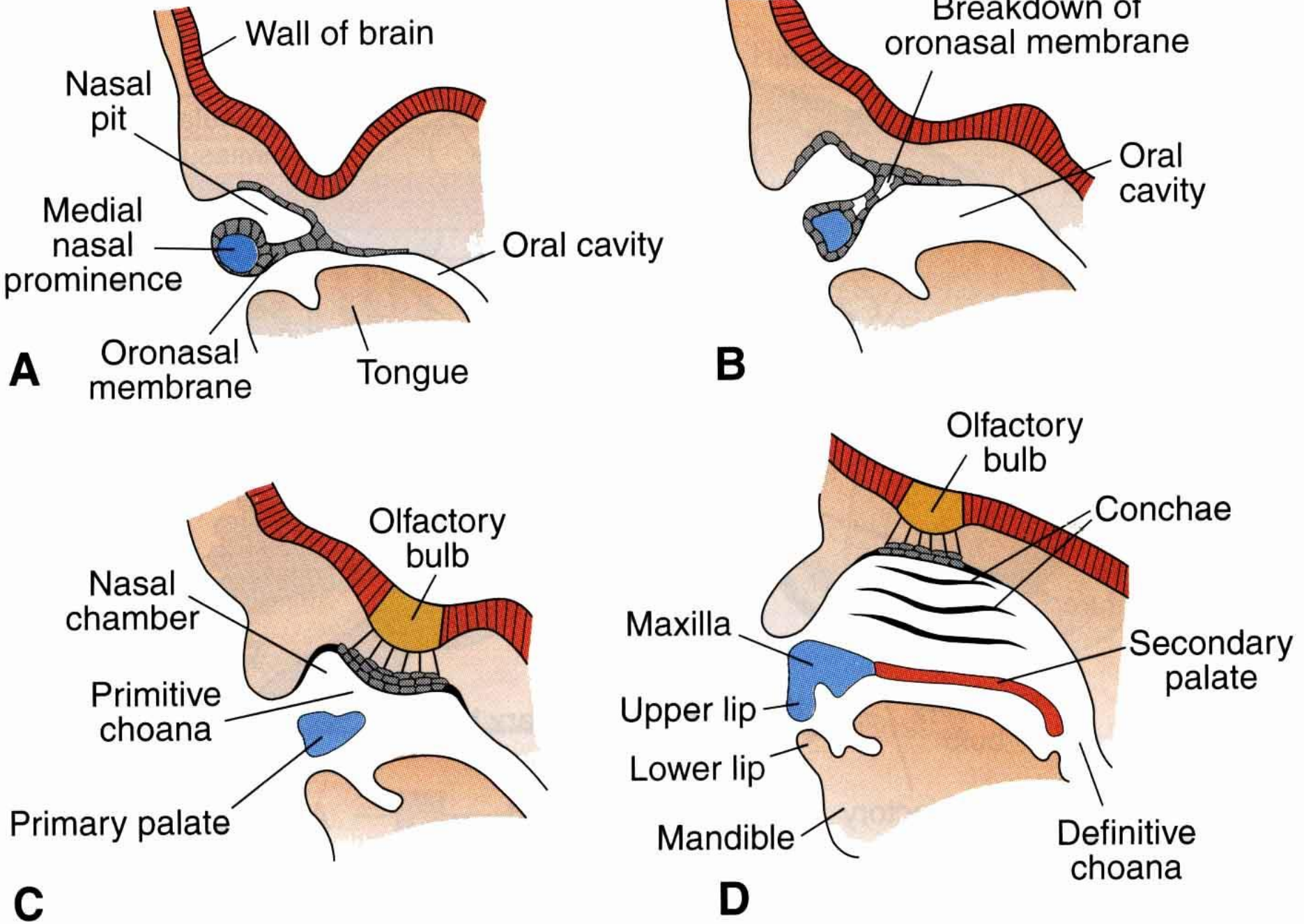
Jakobson's vomeronasal organ (human embryo)




4.5 weeks
C

6 weeks




Wall of brain
Nasal pit
Medial nasal prominence
Oral cavity
Oronasal membrane
Tongue
A
Breakdown of oronasal membrane
Oral cavity
B
Olfactory bulb
Nasal chamber
Primitive choana
Primary palate
C
Olfactory bulb
Conchae
Maxilla
Secondary palate
Upper lip
Lower lip
Mandible
Definitive choana
D

Taste

Taste buds on tongue papillae, soft pallate, epiglottis and glossopallatine arches

Taste buds

-5 000 – 10 000

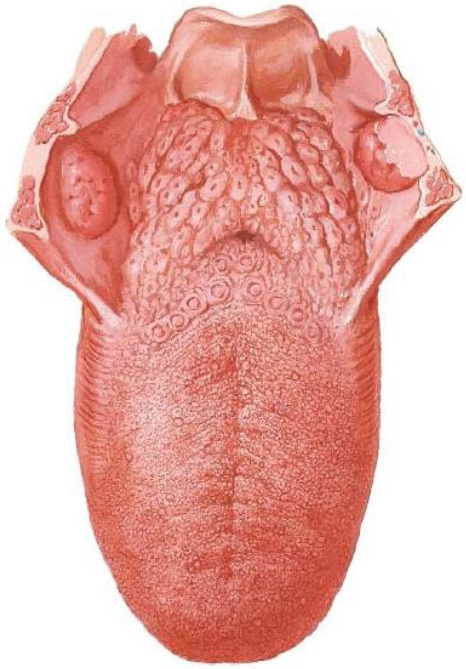
-pore

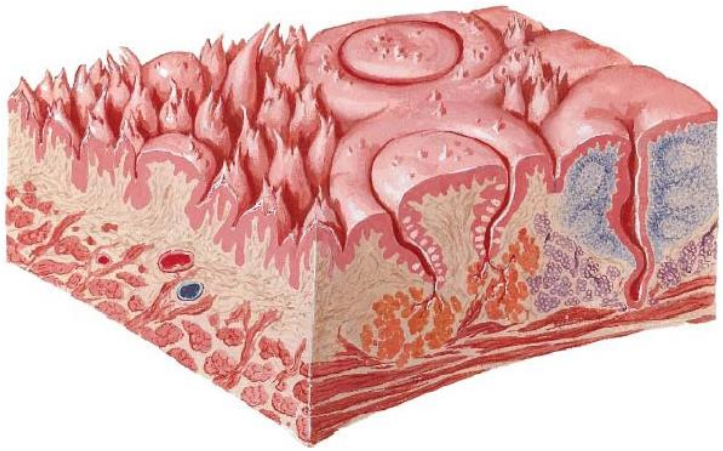
-3 types of cells

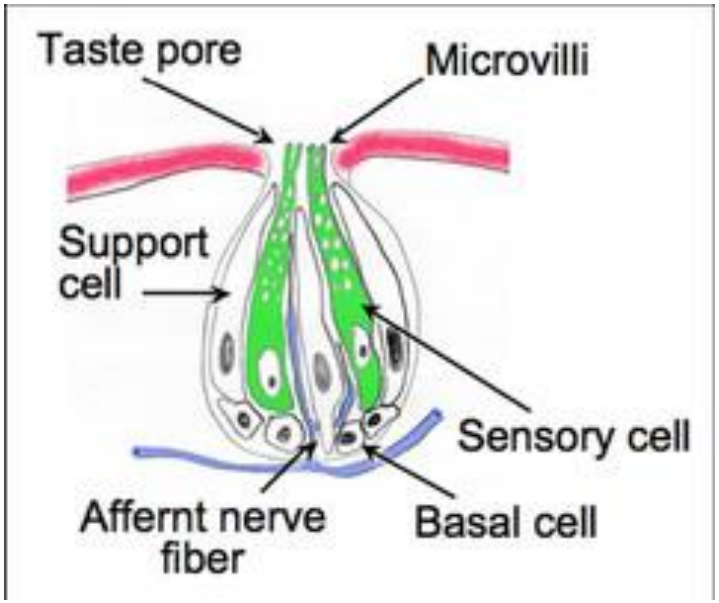
1)Sensory cells

2)Supporting cells

3)Basal cells

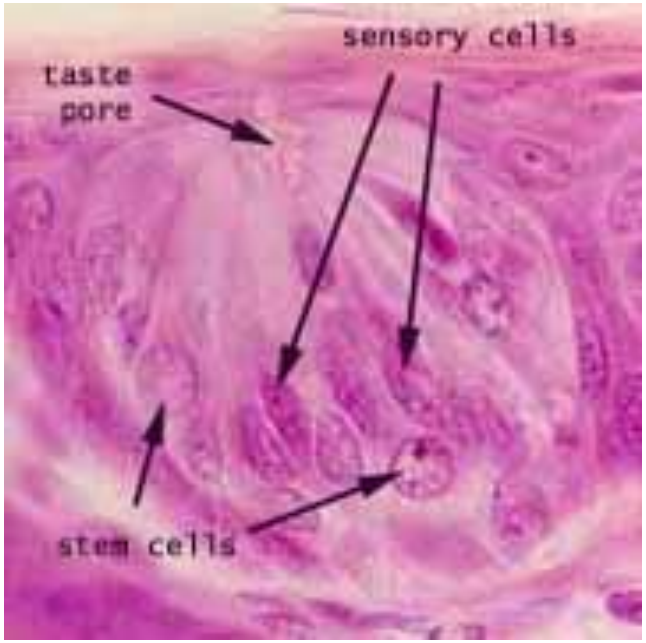


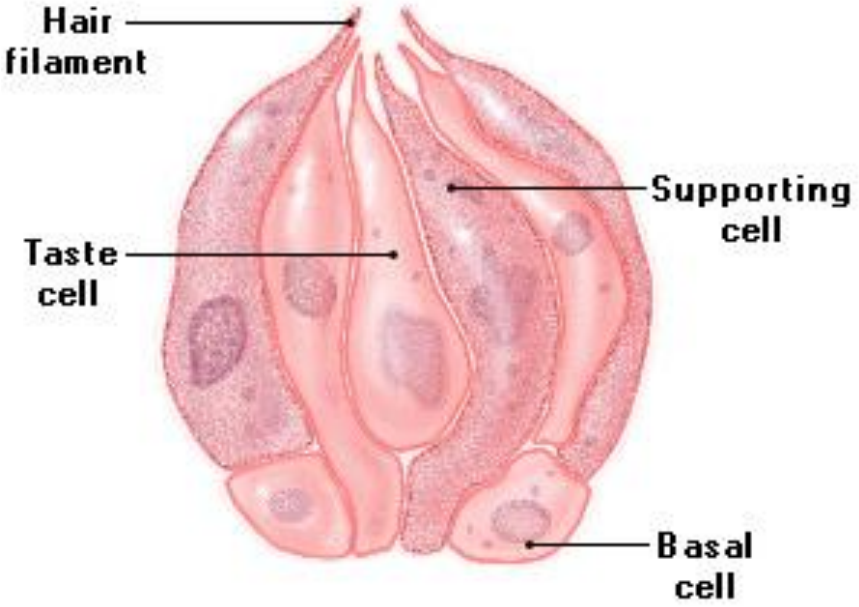




Sensory cells

- chemoreceptors
- secondary
- microvilli
- Dendrites at the base (afferent nerve fibers (n. VII, IX, X) with synapses to sensory cells)





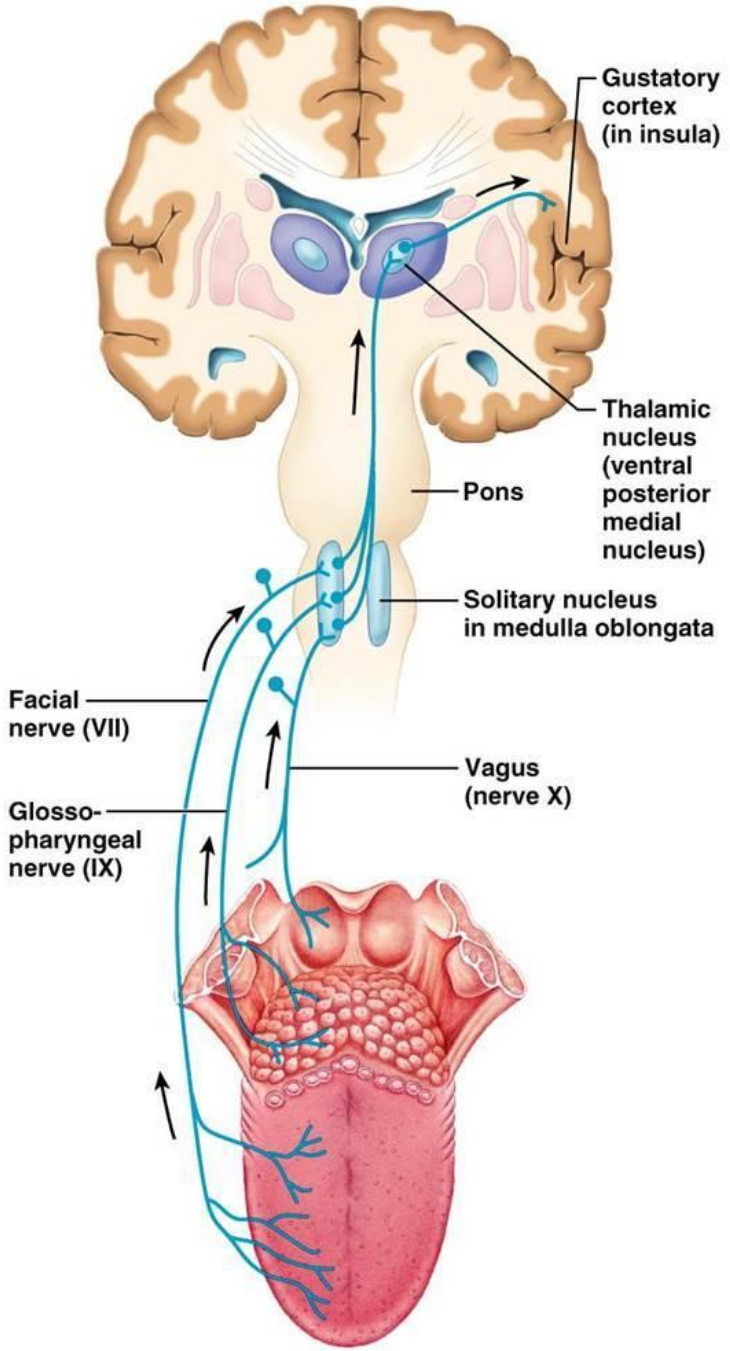
Types:

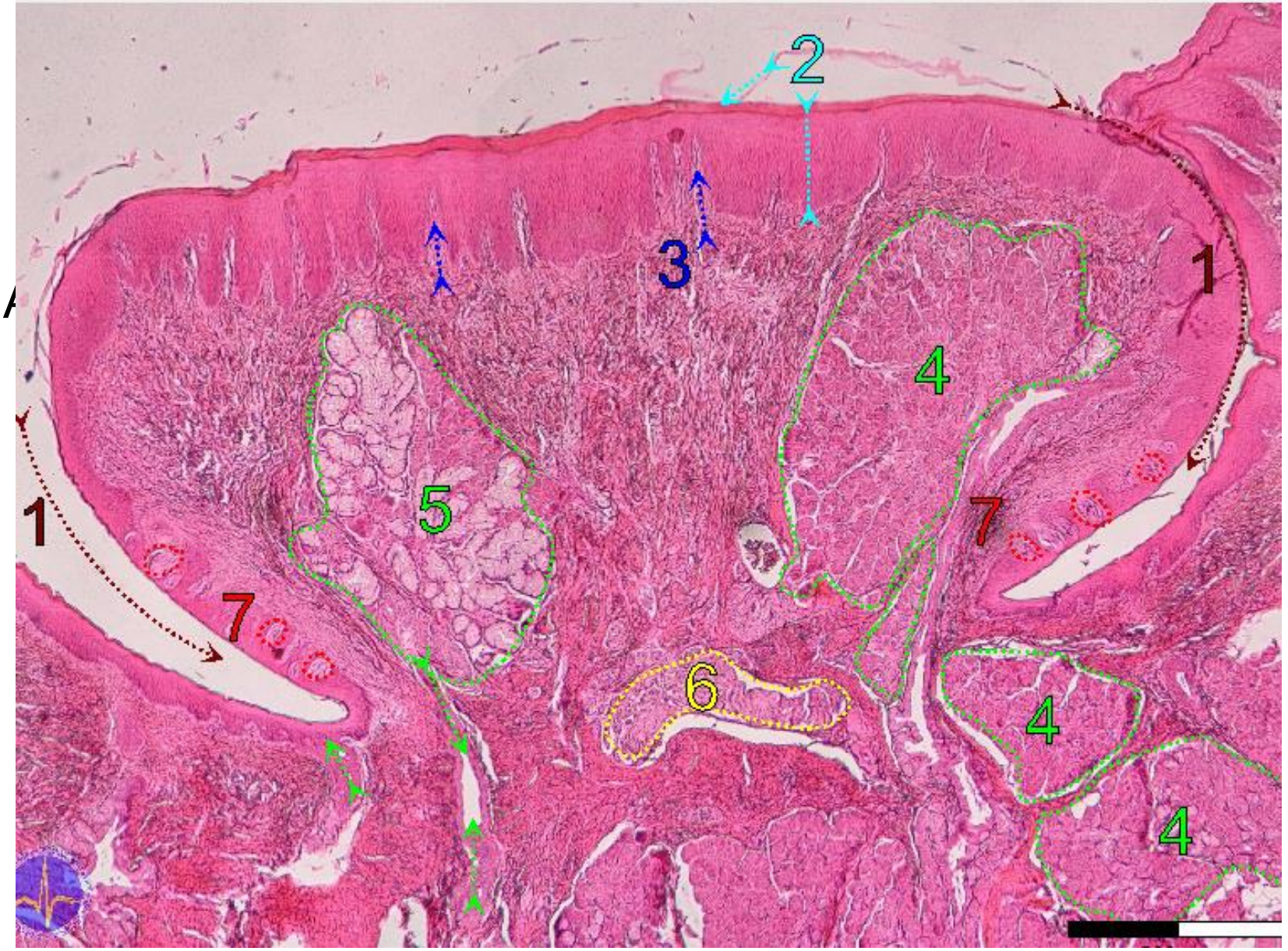
-bitter, sweet, sour, salty, umami (meaty, savory)

-Inervation:

1)VII (n. facialis) – anterior 2/3

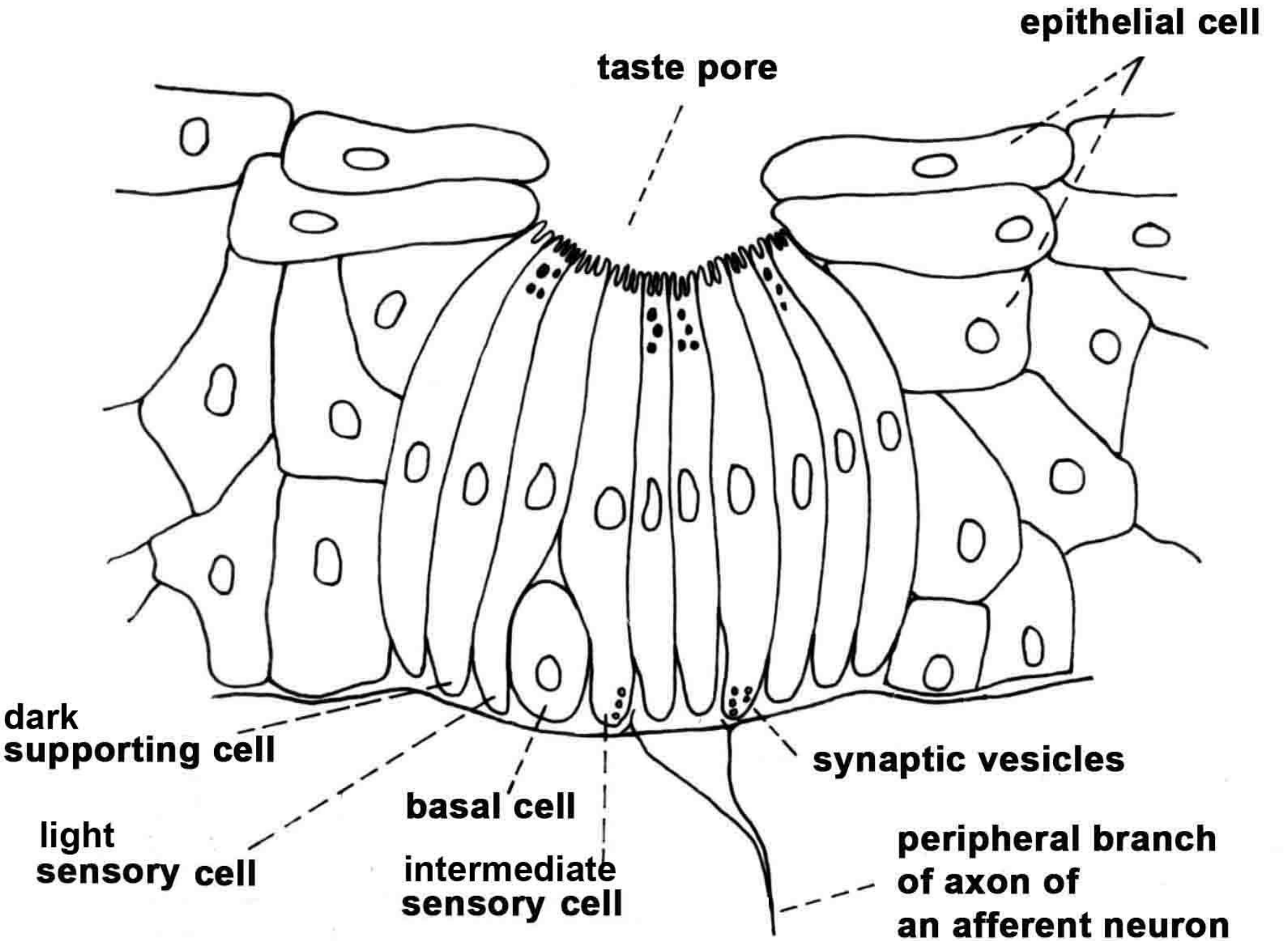
2)IX (n. glossopharyngeus) – posterior 1/3 and pharynx



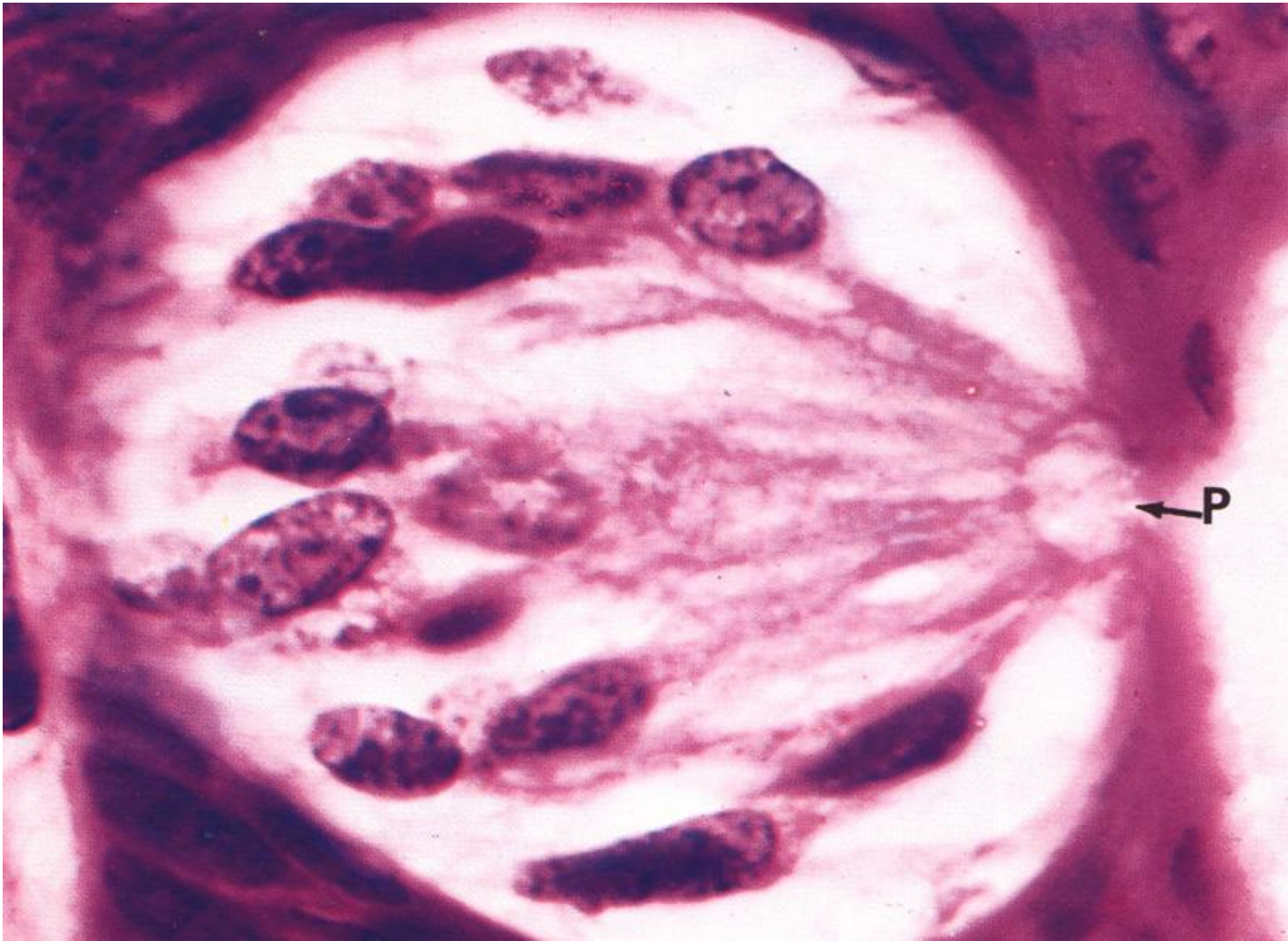


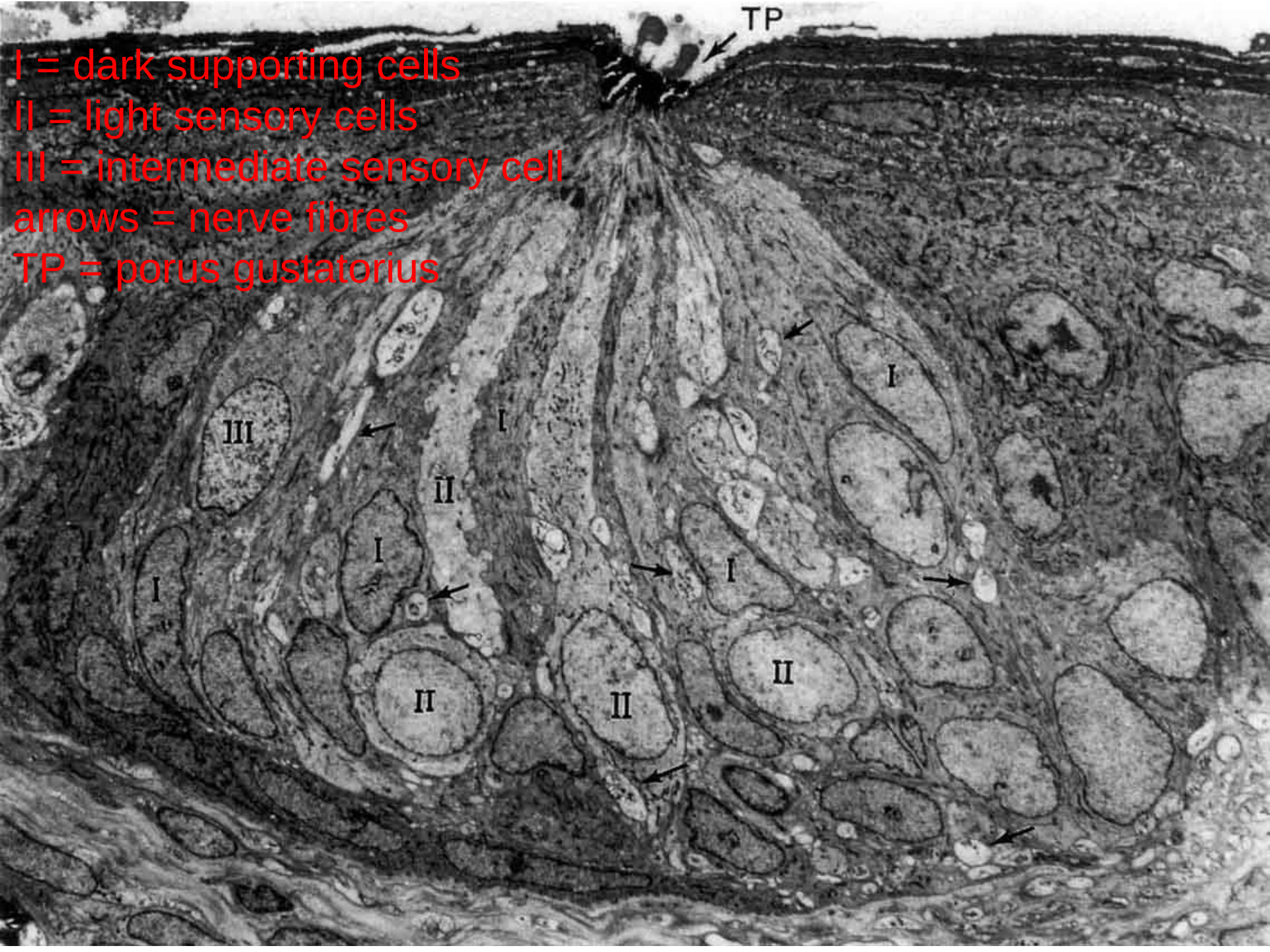
1 – sulcus
2 – epitelhelium
3 – secondary papilly
4 – von Ebner´s serous glands
5 – seromucous glands
6 - nerves
7 – taste buds

TASTE BUD


epithelial cell
taste pore
dark
supporting cell
light
sensory cell
basal cell
intermediate
sensory cell
synaptic vesicles
peripheral branch
of axon of
an afferent neuron


T

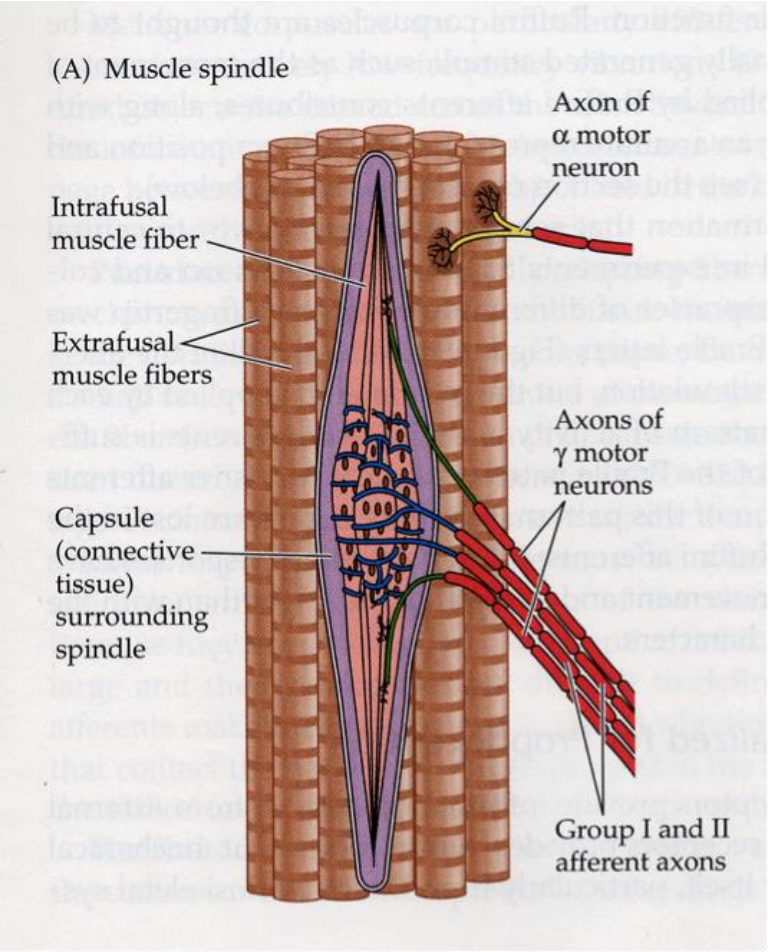

P

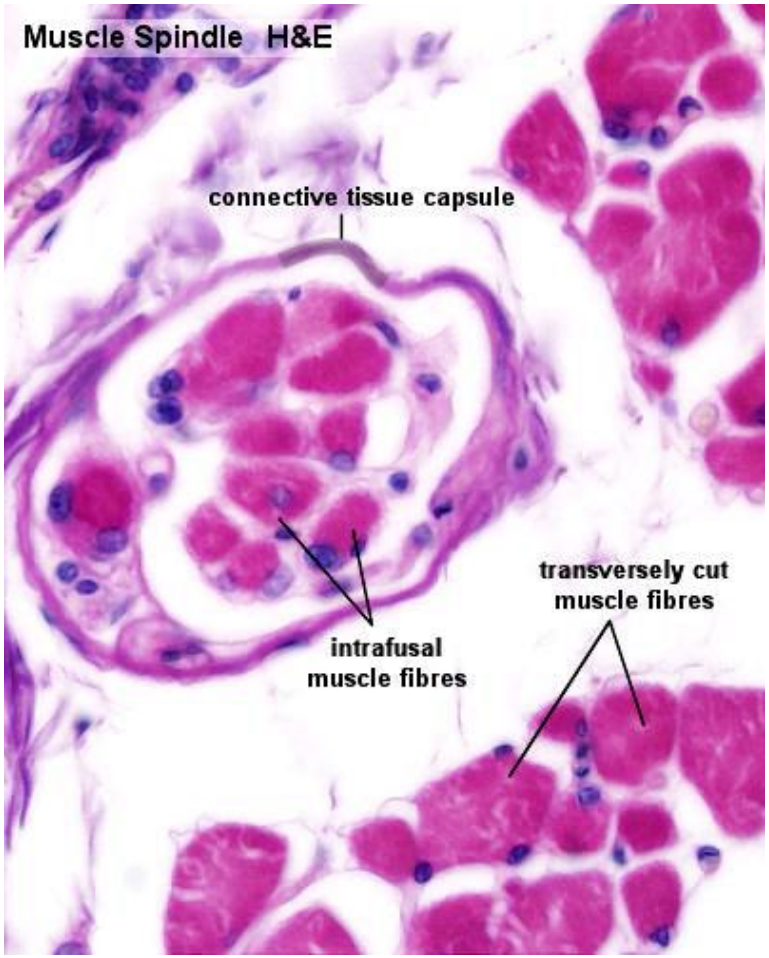

I = dark supporting cells
II = light sensory cells
III = intermediate sensory cell
arrows = nerve fibres
TP = porus gustatorius
TP
III
I
II
I
I
I
I
II
II
II

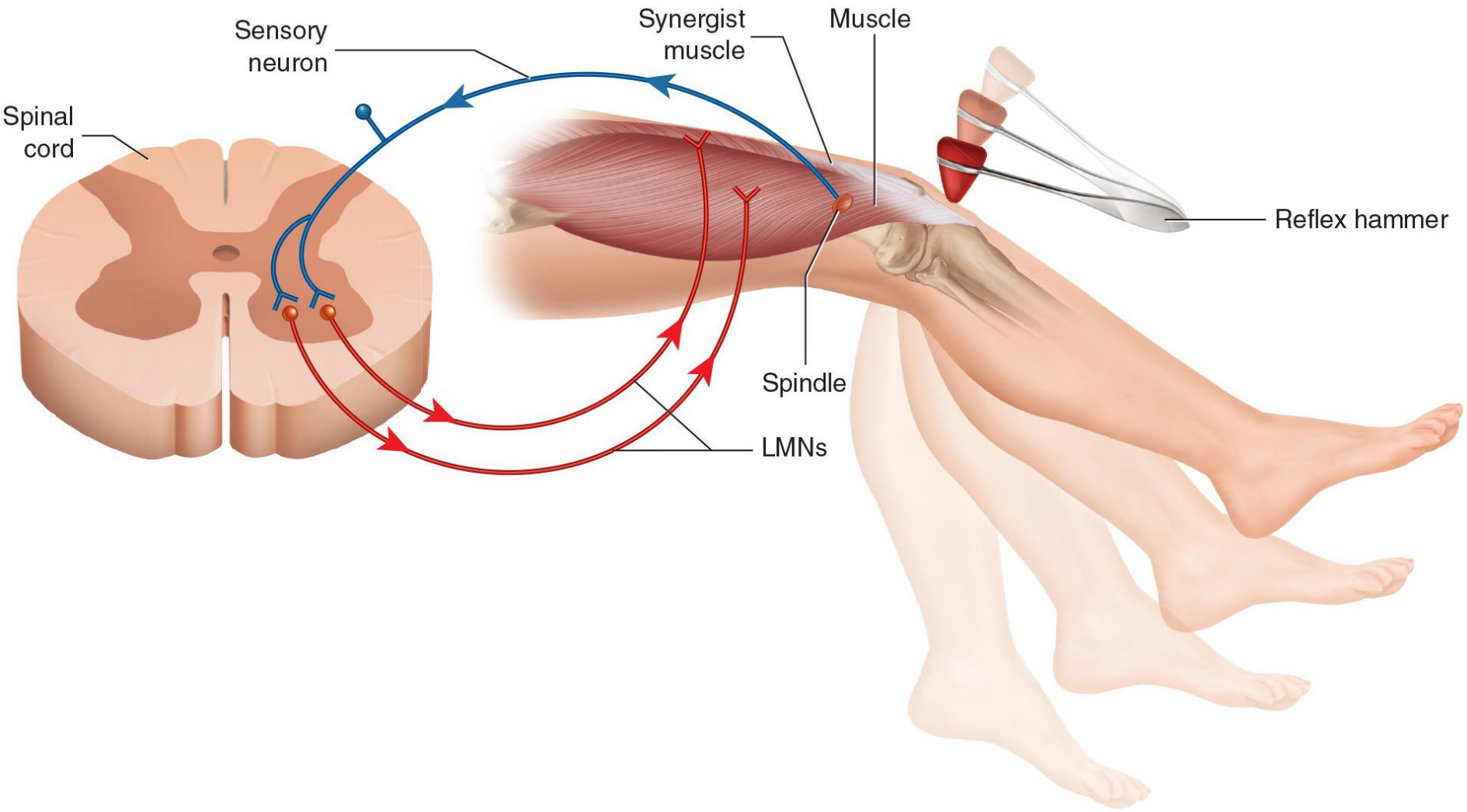
Muscle spindle, Golgi tendon organ (peripheral proprioceptors)

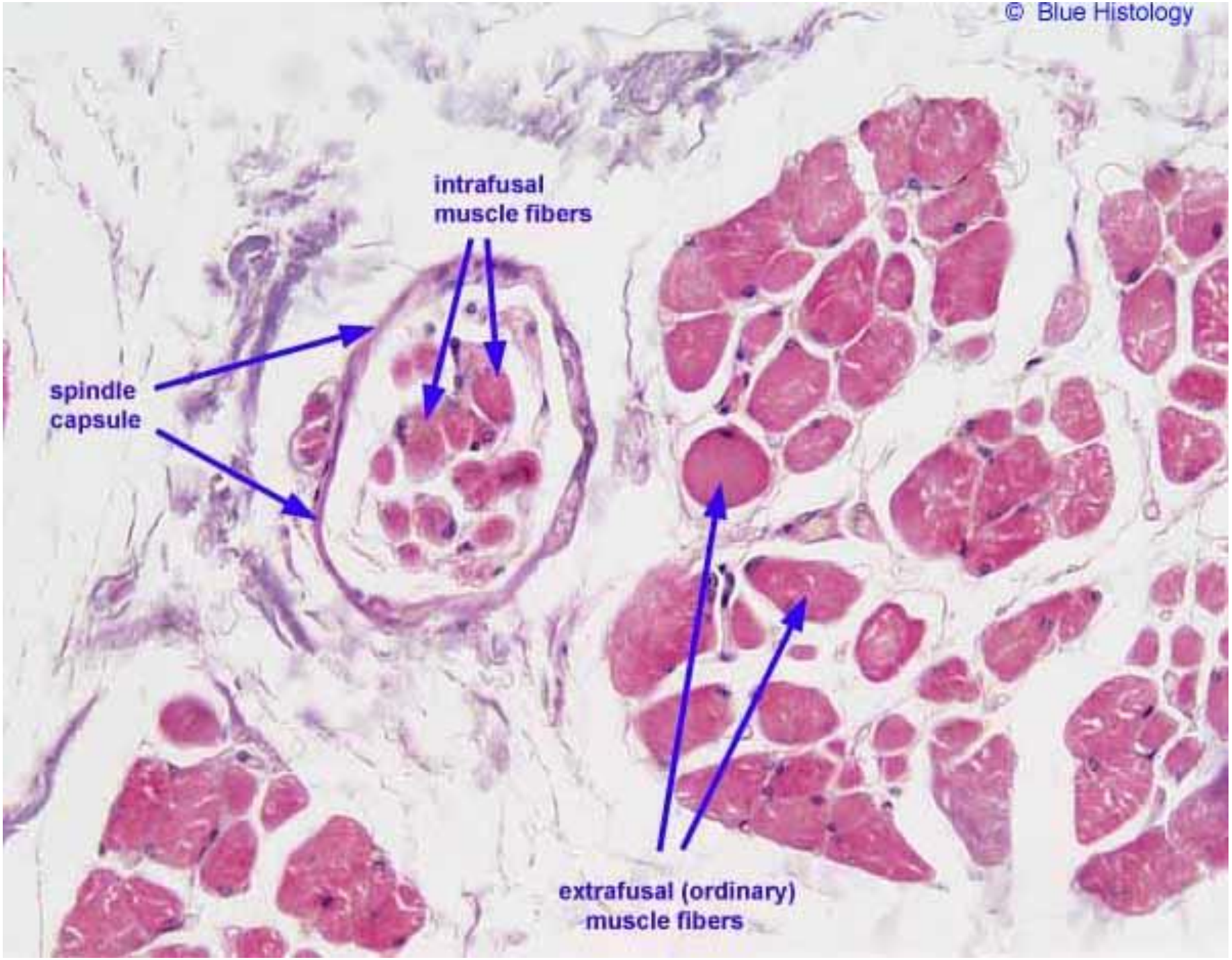
Muscle spindle

functions to alert the brain that nearby joints and soft tissues are in danger of being stretched too far.



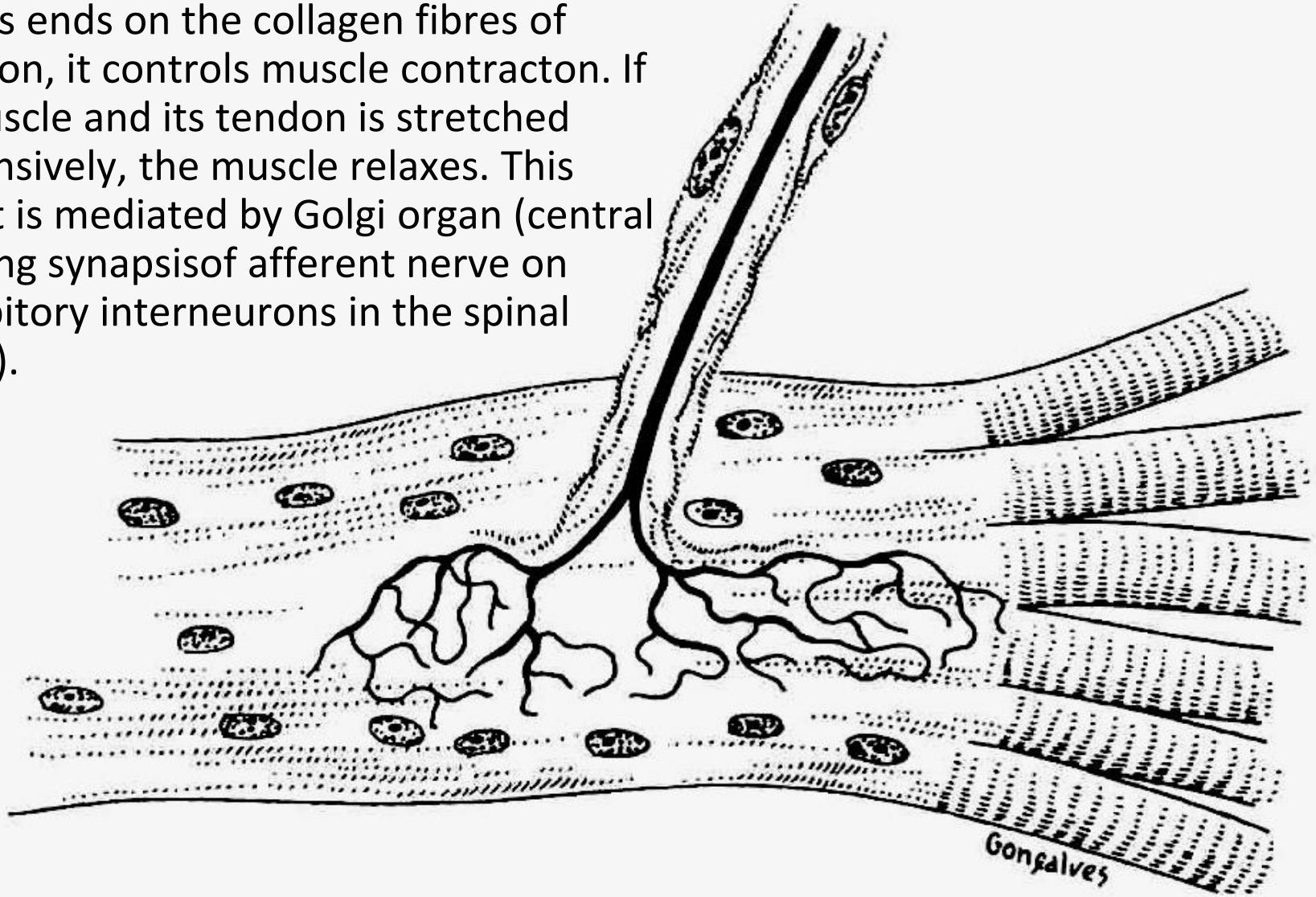





© Blue Histology
intrafusal
muscle fibers
spindle
capsule
extrafusal (ordinary)
muscle fibers

Golgi tendon organs

Similar to muscle spindle but nerve fibres ends on the collagen fibres of tendon, it controls muscle contracton. If a muscle and its tendon is stretched extensively, the muscle relaxes. This efect is mediated by Golgi organ (central ending synapsisof afferent nerve on inhibitory interneurons in the spinal cord).

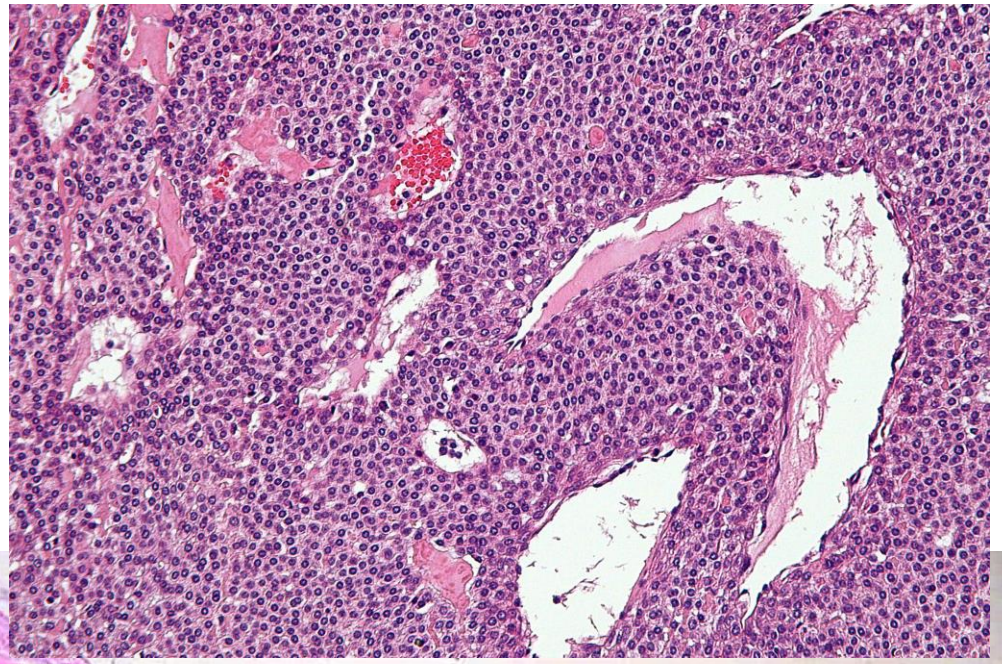


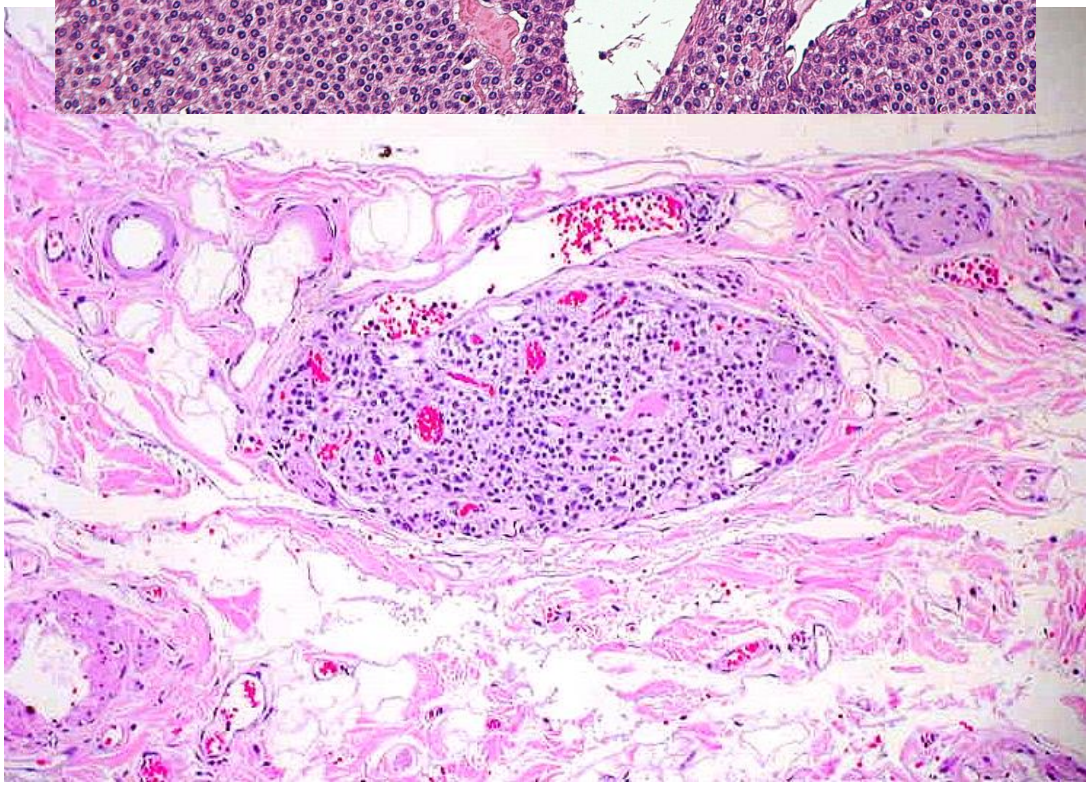
Golgi tendon organ

Receptors of deep sensation

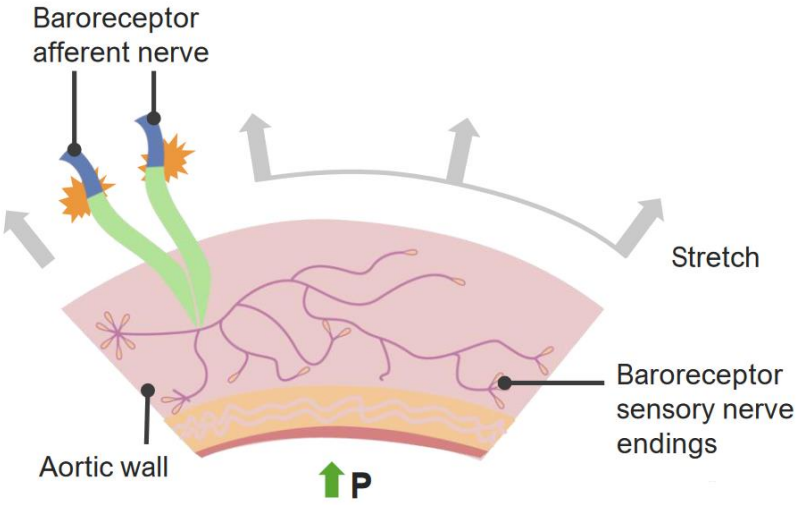
Paraganglia are clusters of **endocrine cells** (similar to adrenal medulla cells) that are scattered in the connective tissue around large vessels, autonomic nerves, and near sympathetic ganglia. They originate from the neuroectoderm (neural crest). Paraganglia belong to the sympathetic nervous system producing catecholamines (adrenaline, noradrenaline, dopamine).

Glomus caroticum is a body located in the division of the common carotid artery in the internal and external carotid arteries – vascular supply is provided by branches from the external carotid artery
- fulfills the function a **chemoreceptor** that detects the concentration of CO2 and O2 in the blood (in contrast to the high-pressure baroreceptor, which is located in the carotid sinus)






Sinus caroticus
(mechanoreceptor,
baroreceptor)



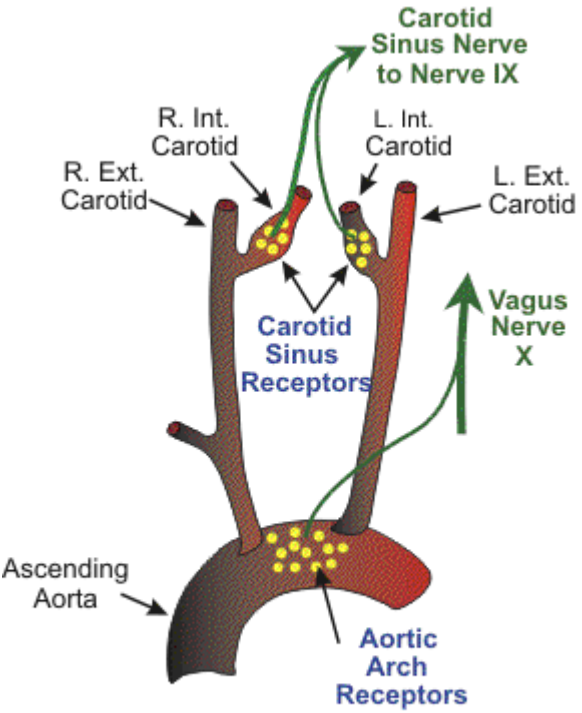
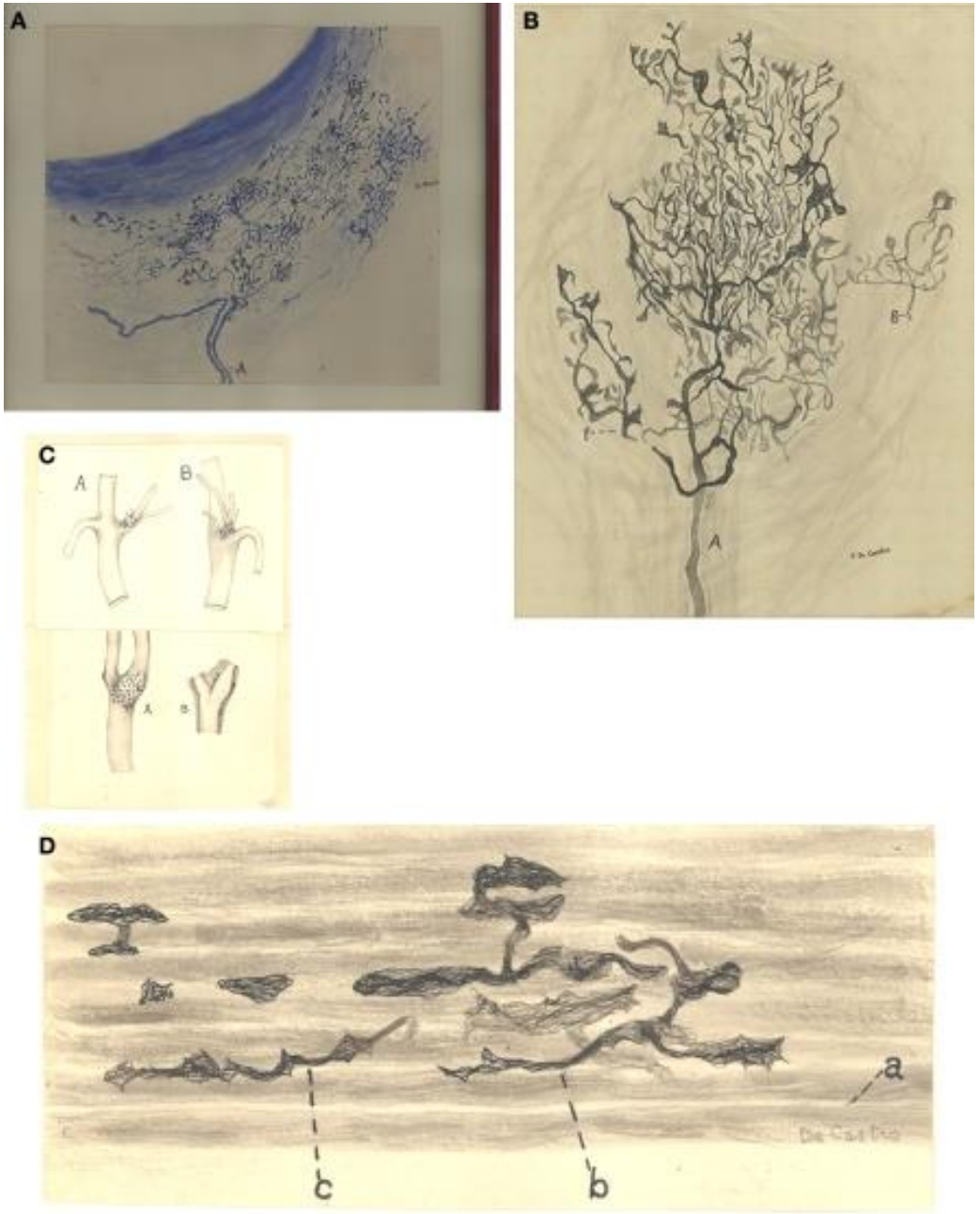
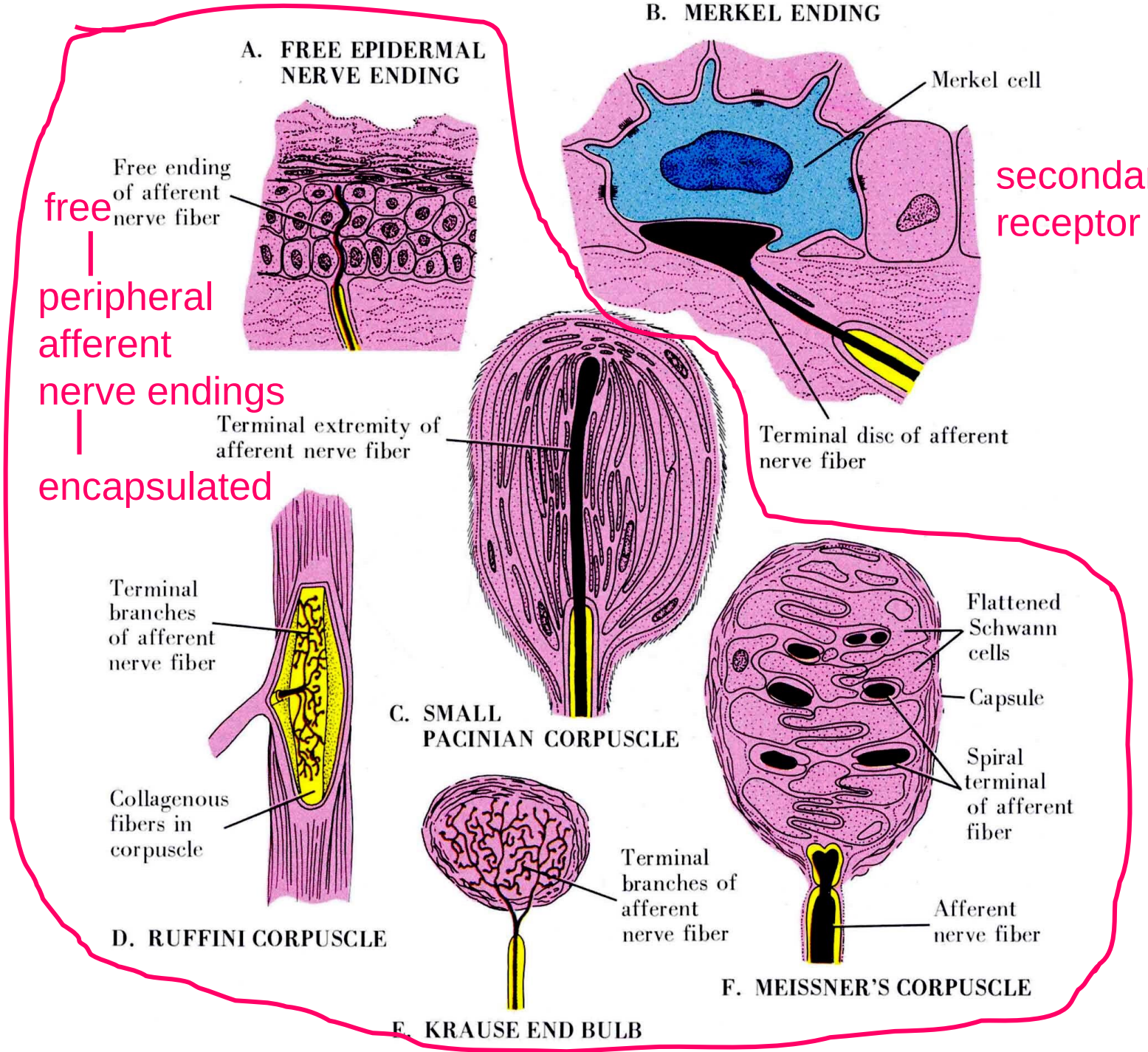


Figure 1. Location and innervation of arterial baroreceptors.



De Castro's detailed description of the baroreceptors in the carotid sinus (1928).



free

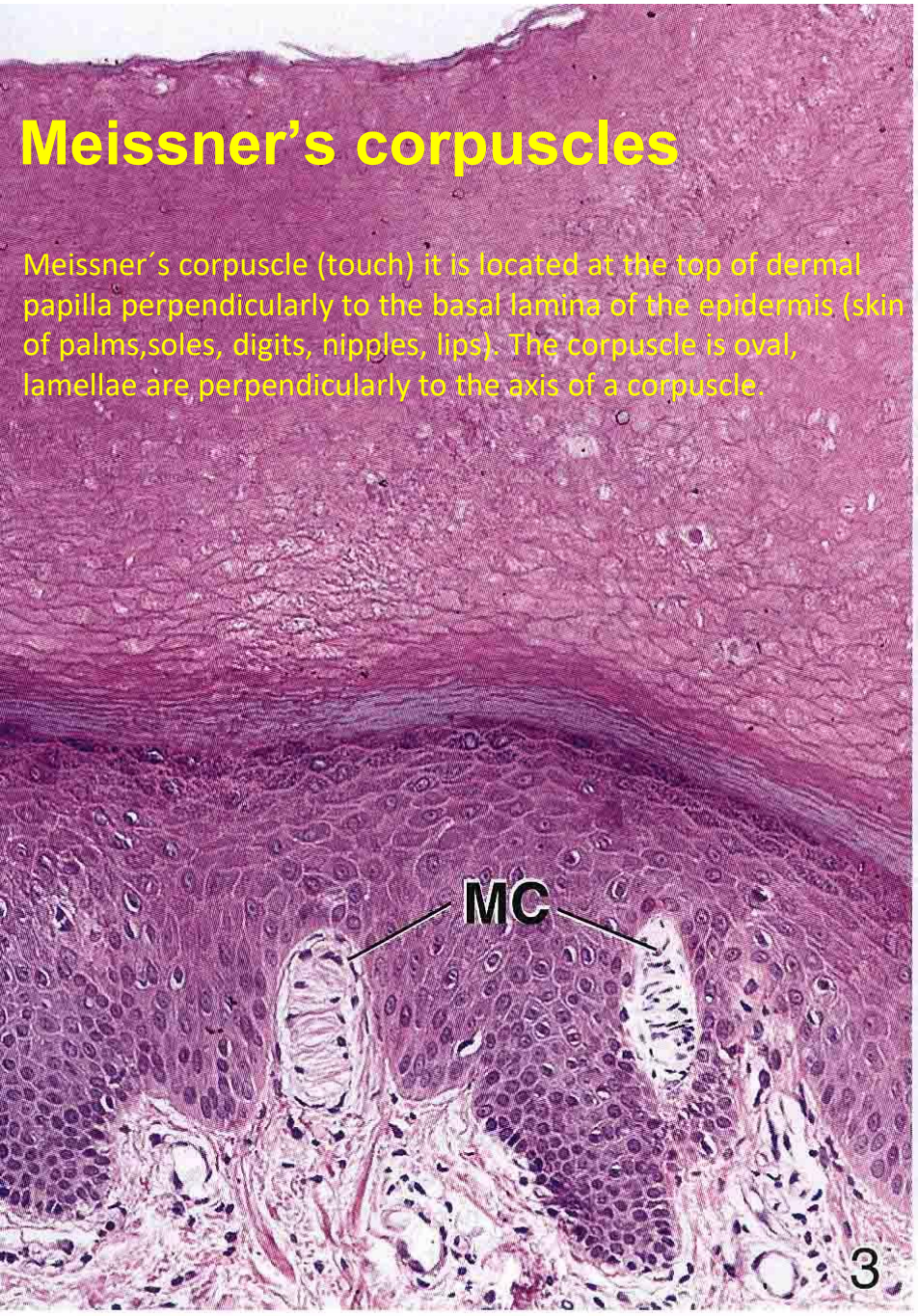
peripheral afferent nerve endings

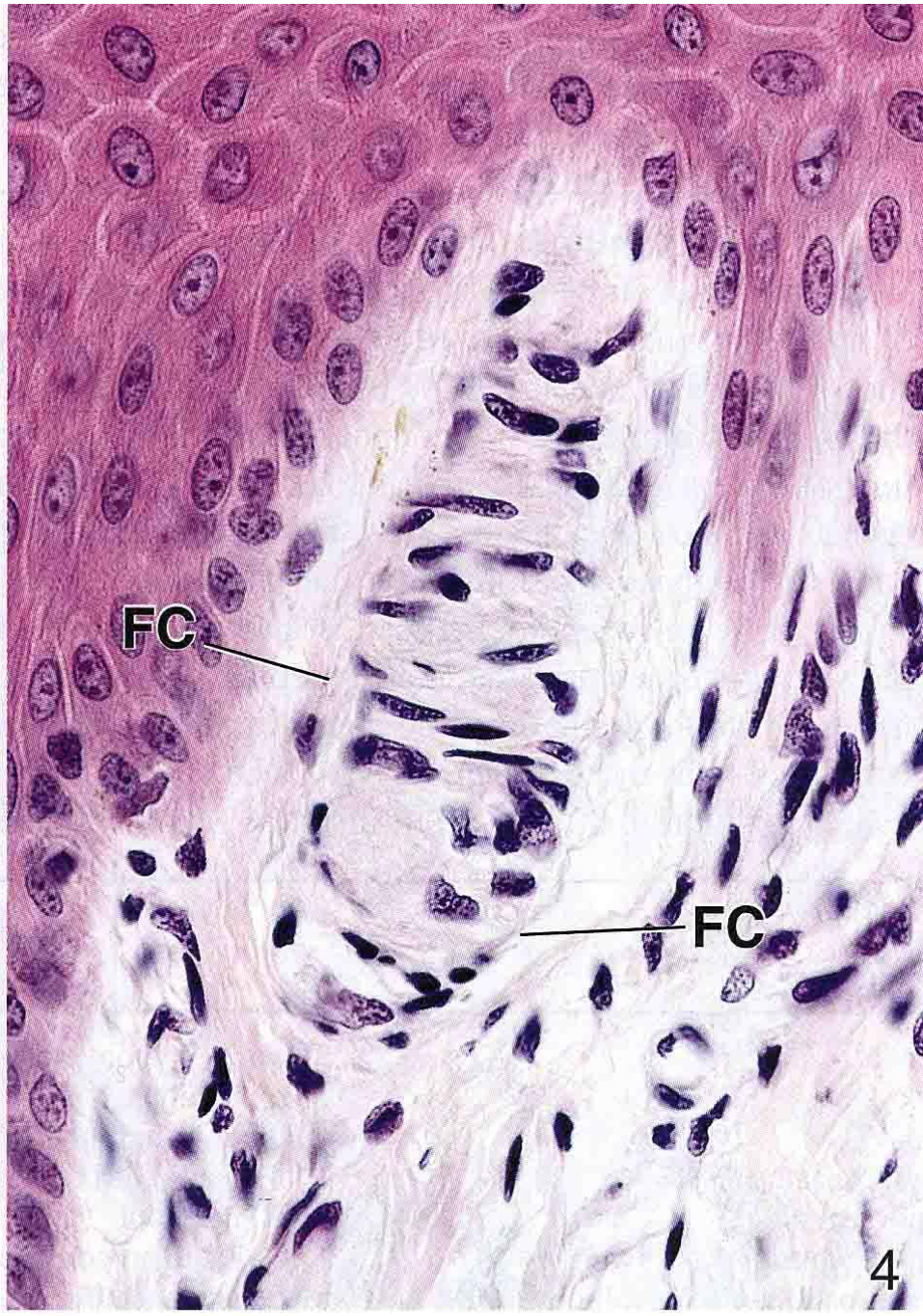
encapsulated

secondary receptor cell

Meissner's corpuscles

Meissner´s corpuscle (touch) it is located at the top of dermal papilla perpendicularly to the basal lamina of the epidermis (skin of palms,soles, digits, nipples, lips). The corpuscle is oval, lamellae are perpendicularly to the axis of a corpuscle.





Ross,M.H., Kaye,G.I., Pawlina,W.: Histology. A text and atlas. 4th Ed. LWW 2003.

Pacinian corpuscles

Vater-Pacinian corpuscle (vibration) is large, oval, located in deep layers of dermis or hypoderm, it is also in mesenteries and periost. It consists of many layers of fibroblasts and Schwann cells alternating with fluid-filed spaces that surround the unmyelinated nerve terminal.