Senses II
smell, taste, ear

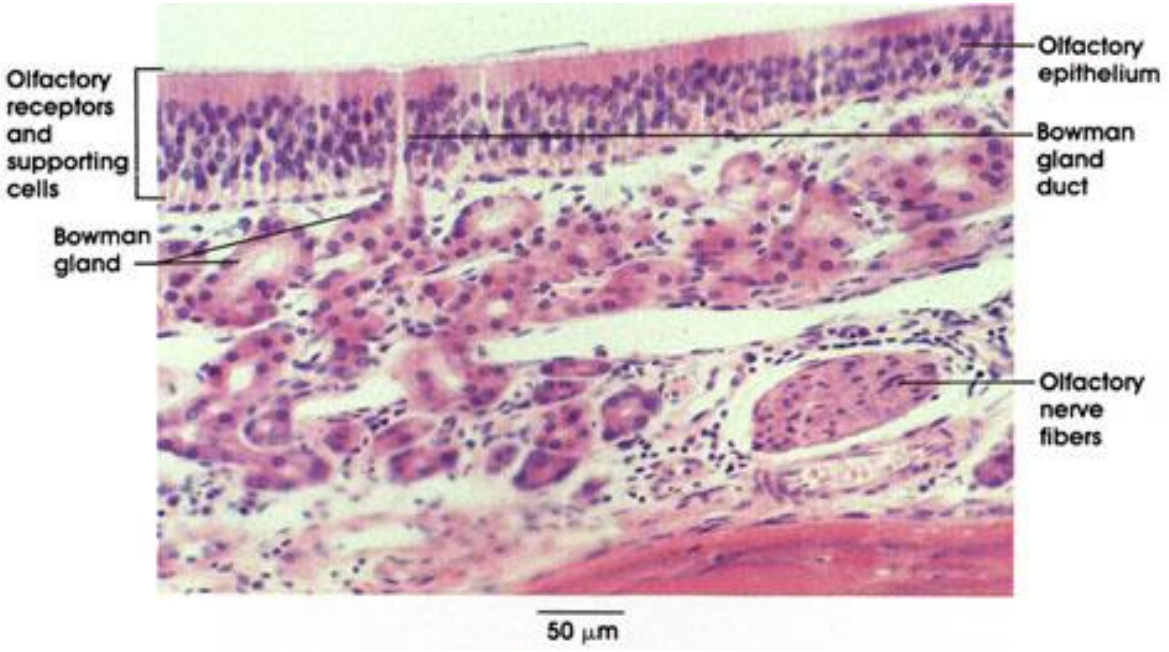
Smell

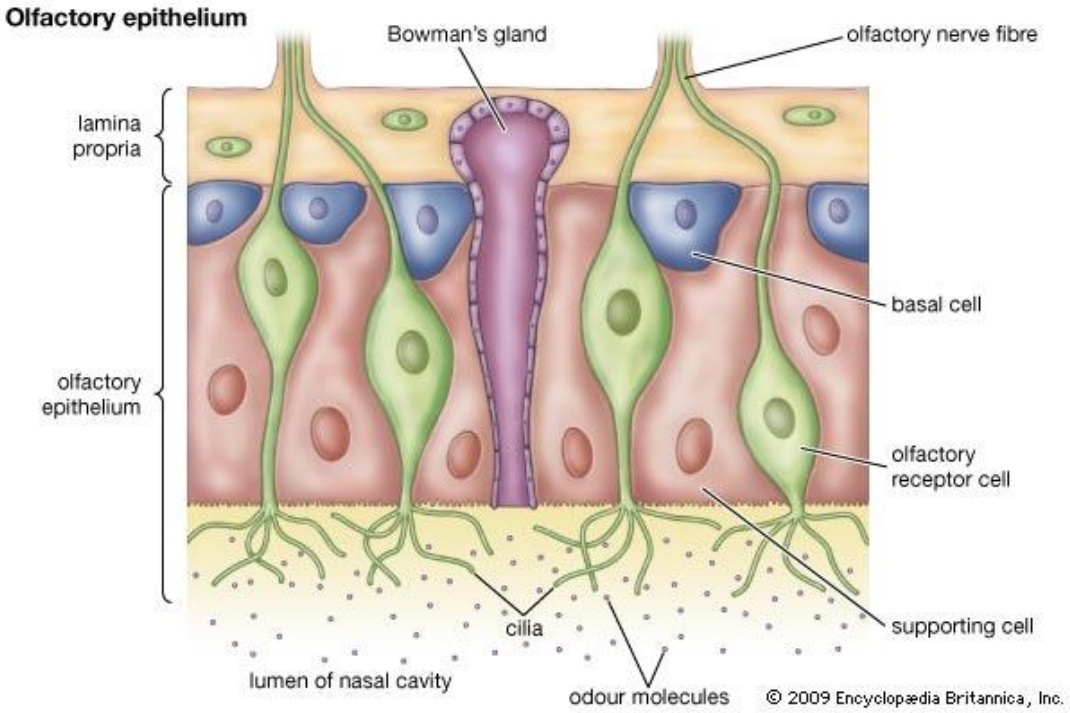
Olfactory epithelium 4 cm2 = regio olfactoria.

- 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



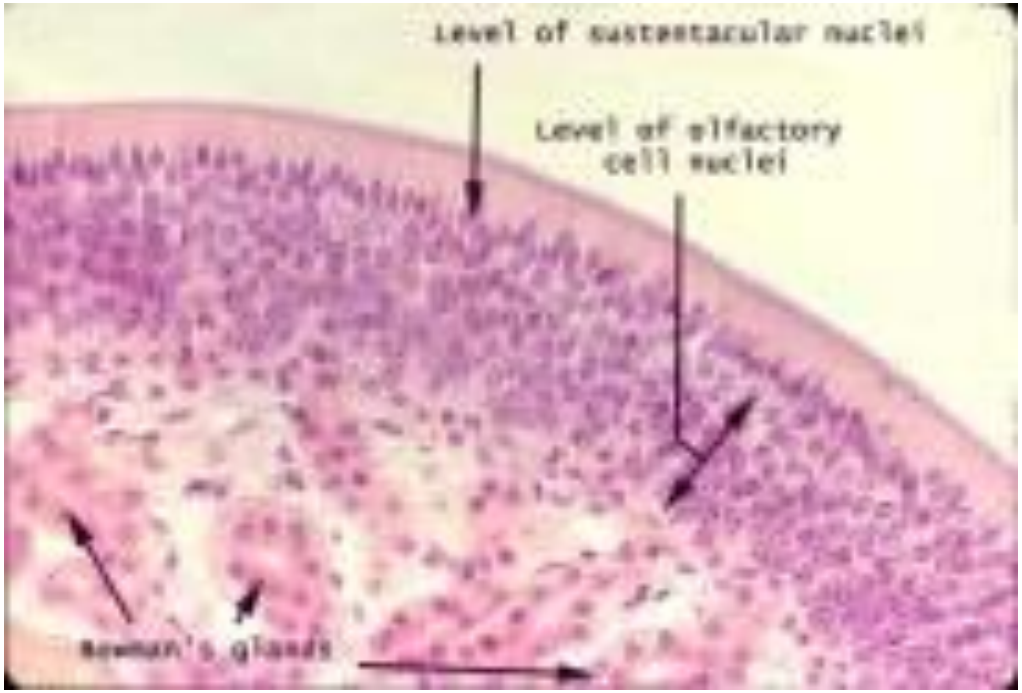


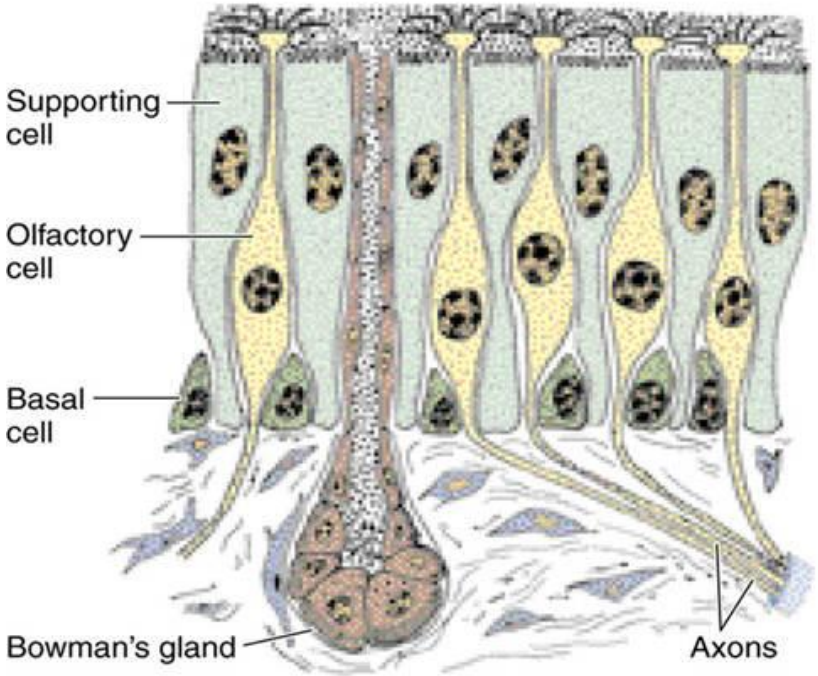
Olfactory cells

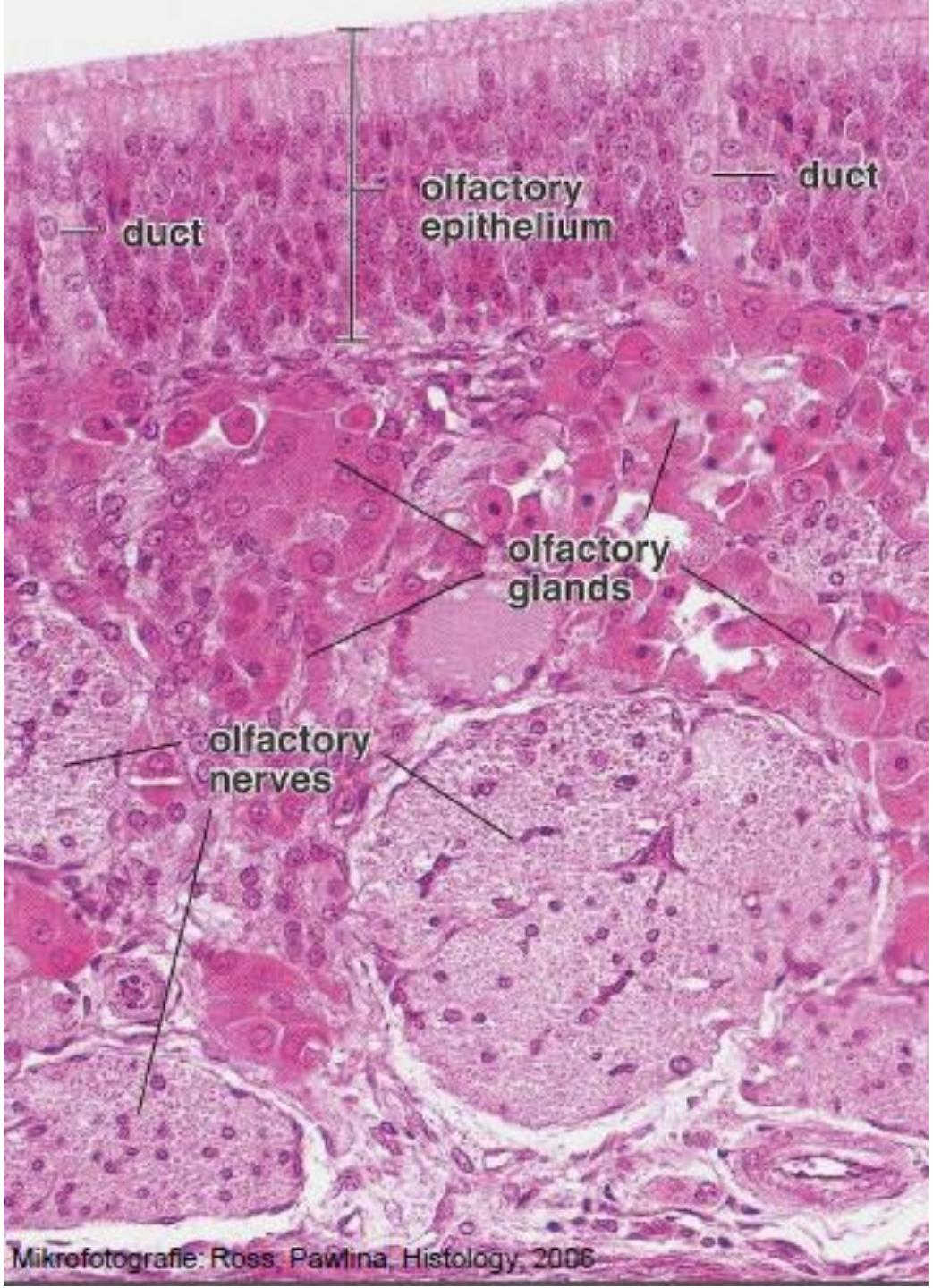
- Bipolar neurons,
- chemoreceptors
- Dendrite with cilia + unmyelinated axon
- => fila olfactoria

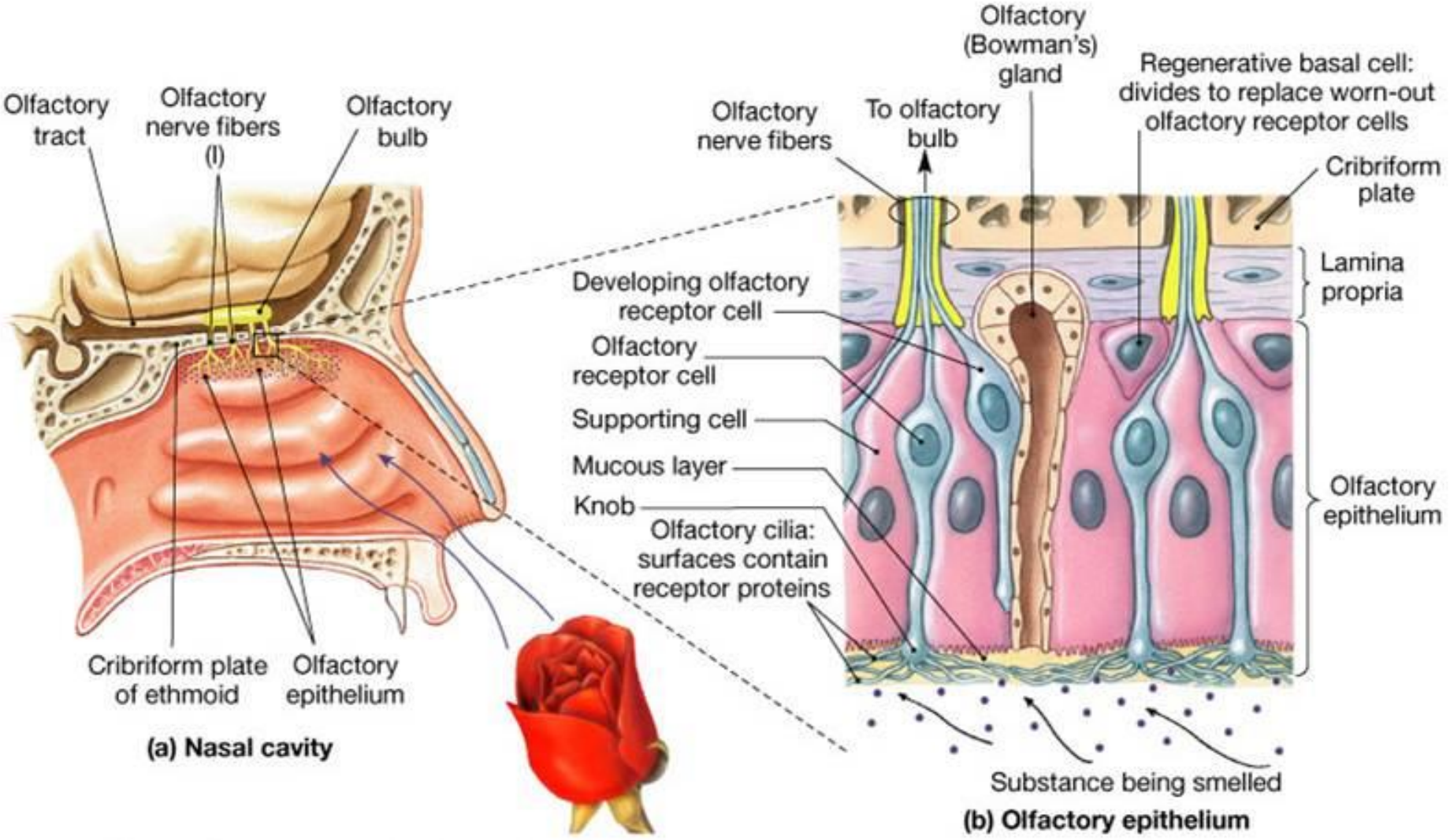
Supporting cells (sustentacular cells)

- Thin base, wide apex
- microvilli
- lipofuscin






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

A1 pars olfactoria mucosae nasi

1 – olfactory epithelium

2 – basal cells

3 – olfactory cells

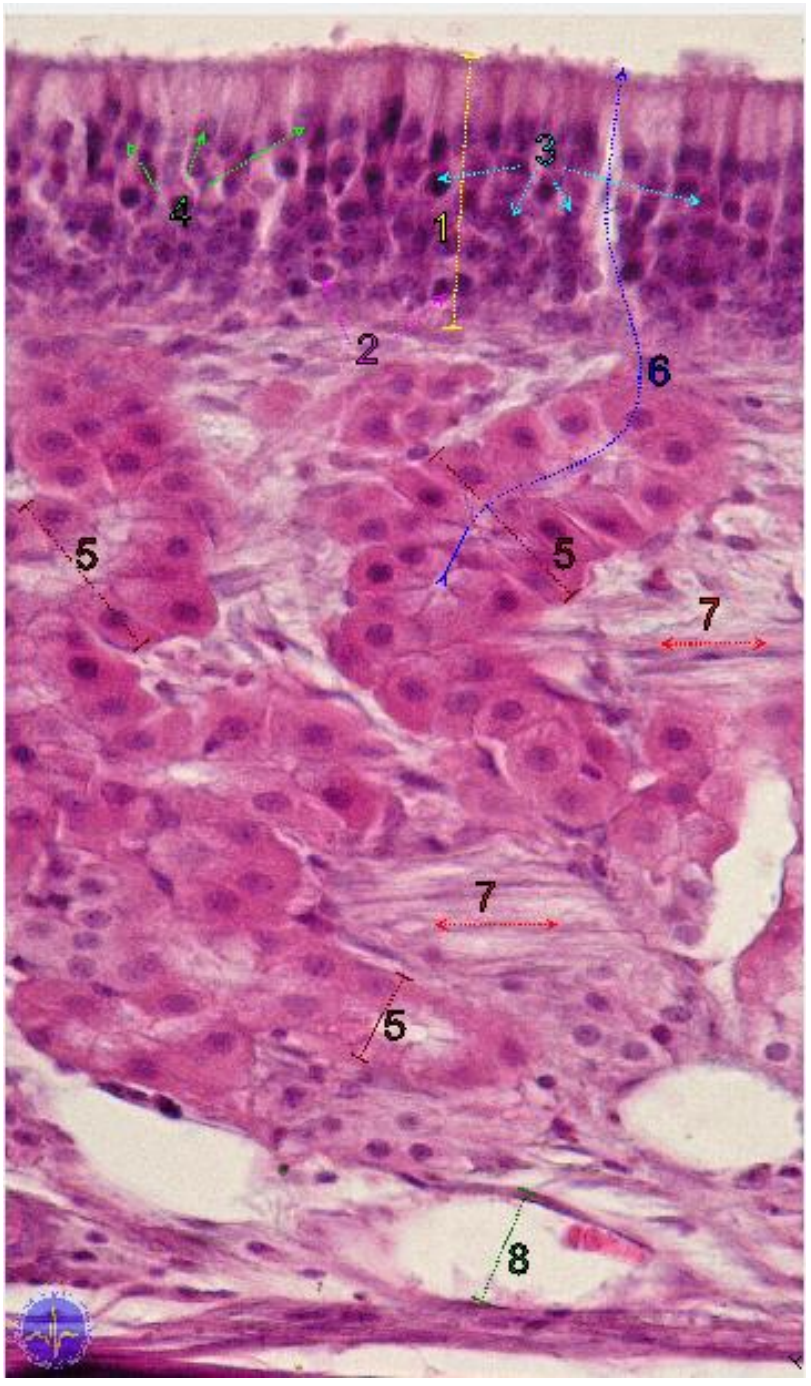
4 – supporting

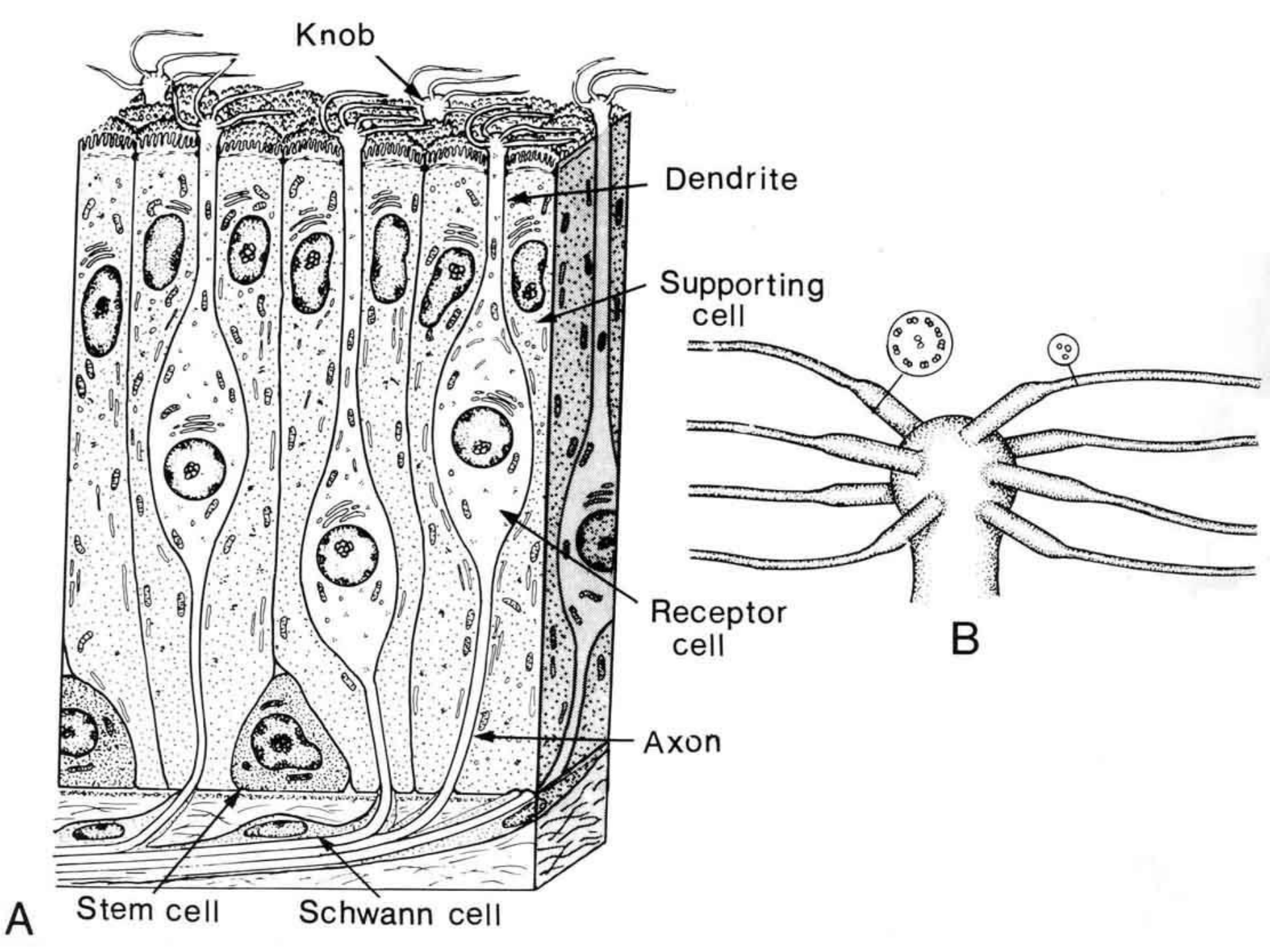
5 – Bowman´s glands

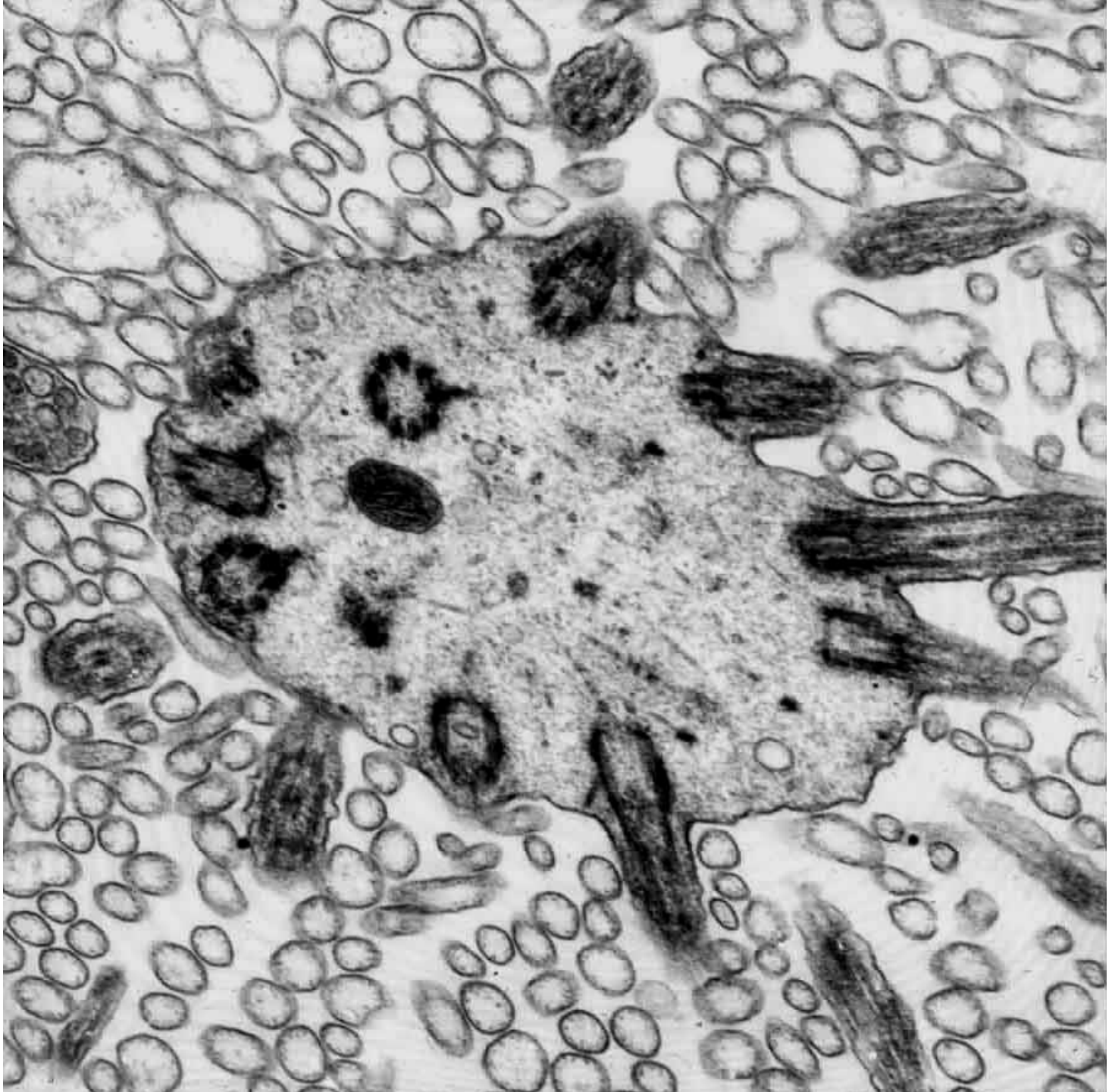
6 – duct

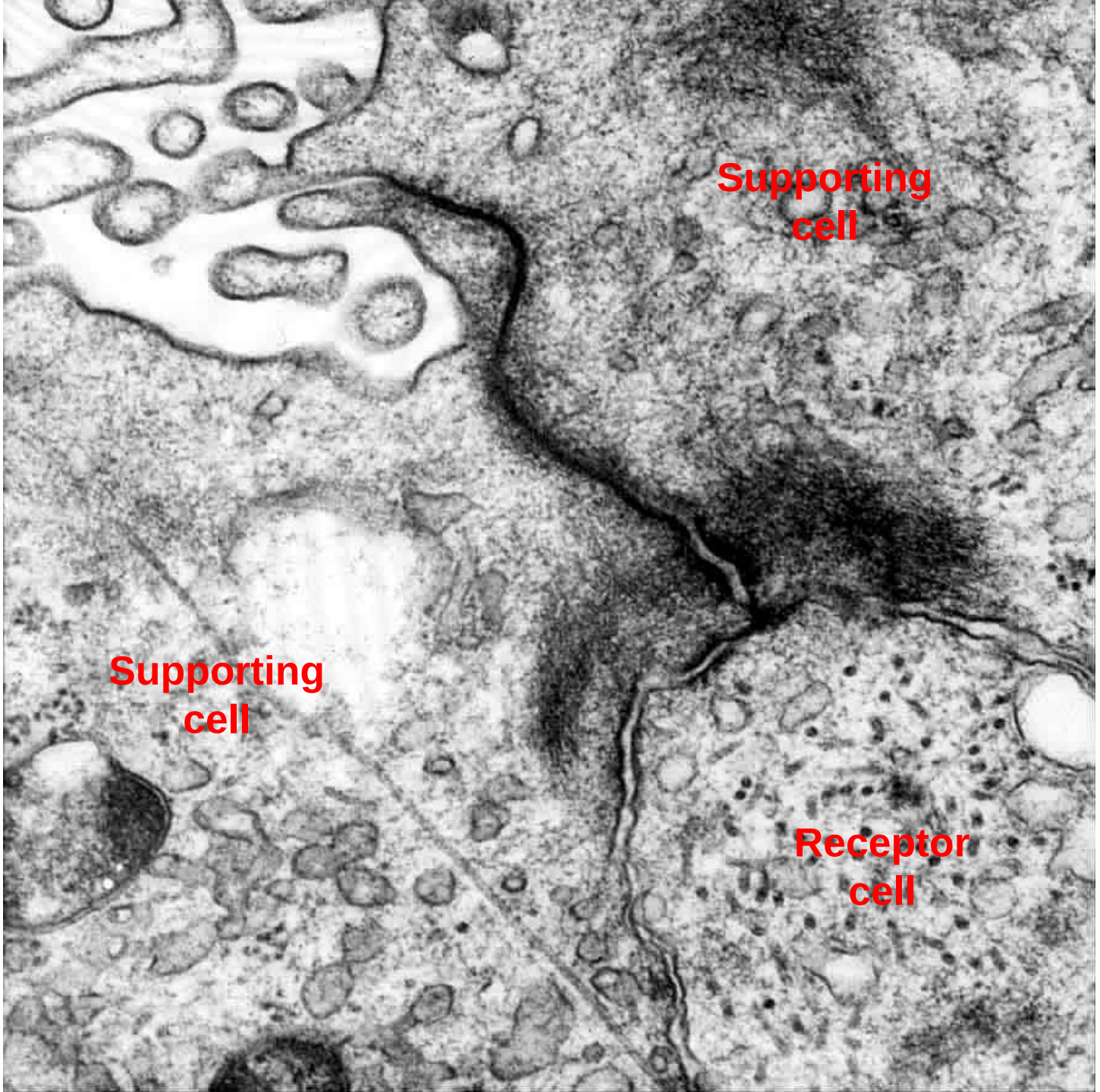
7 – nervs = fila olfactoria

8 – vessel

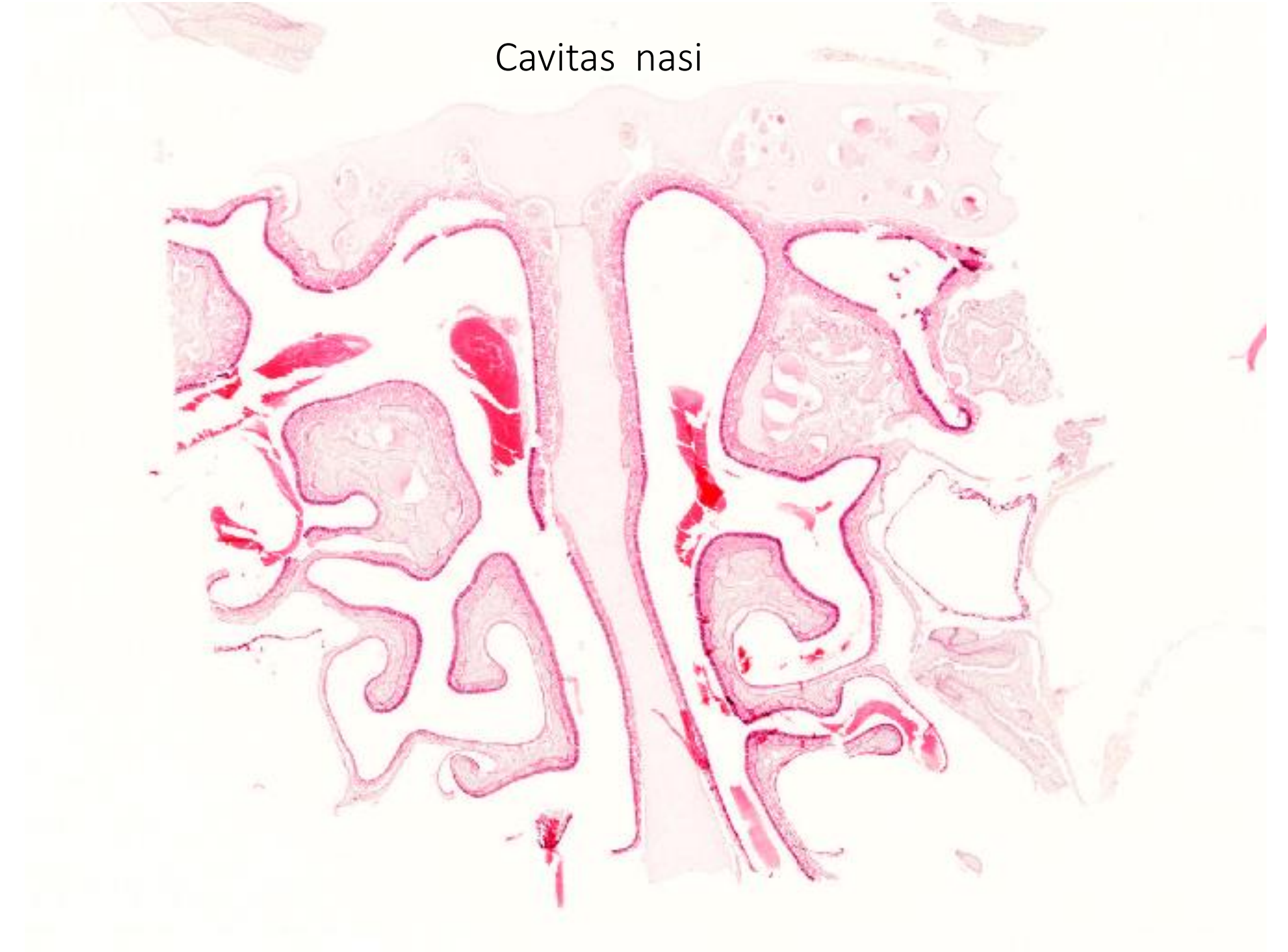


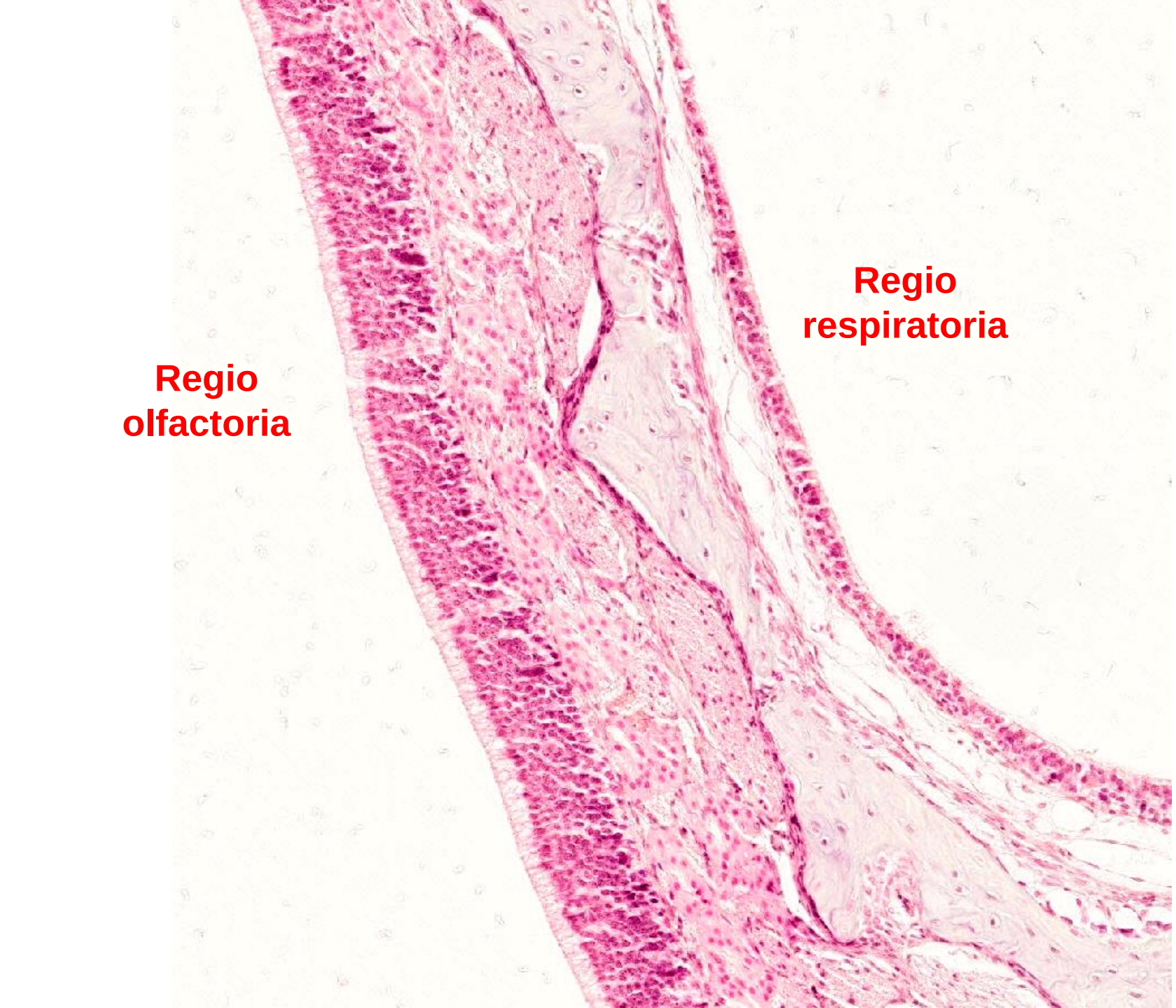

Knob
Dendrite
Supporting cell
Receptor cell
Axon
Stem cell
Schwann cell
A
B

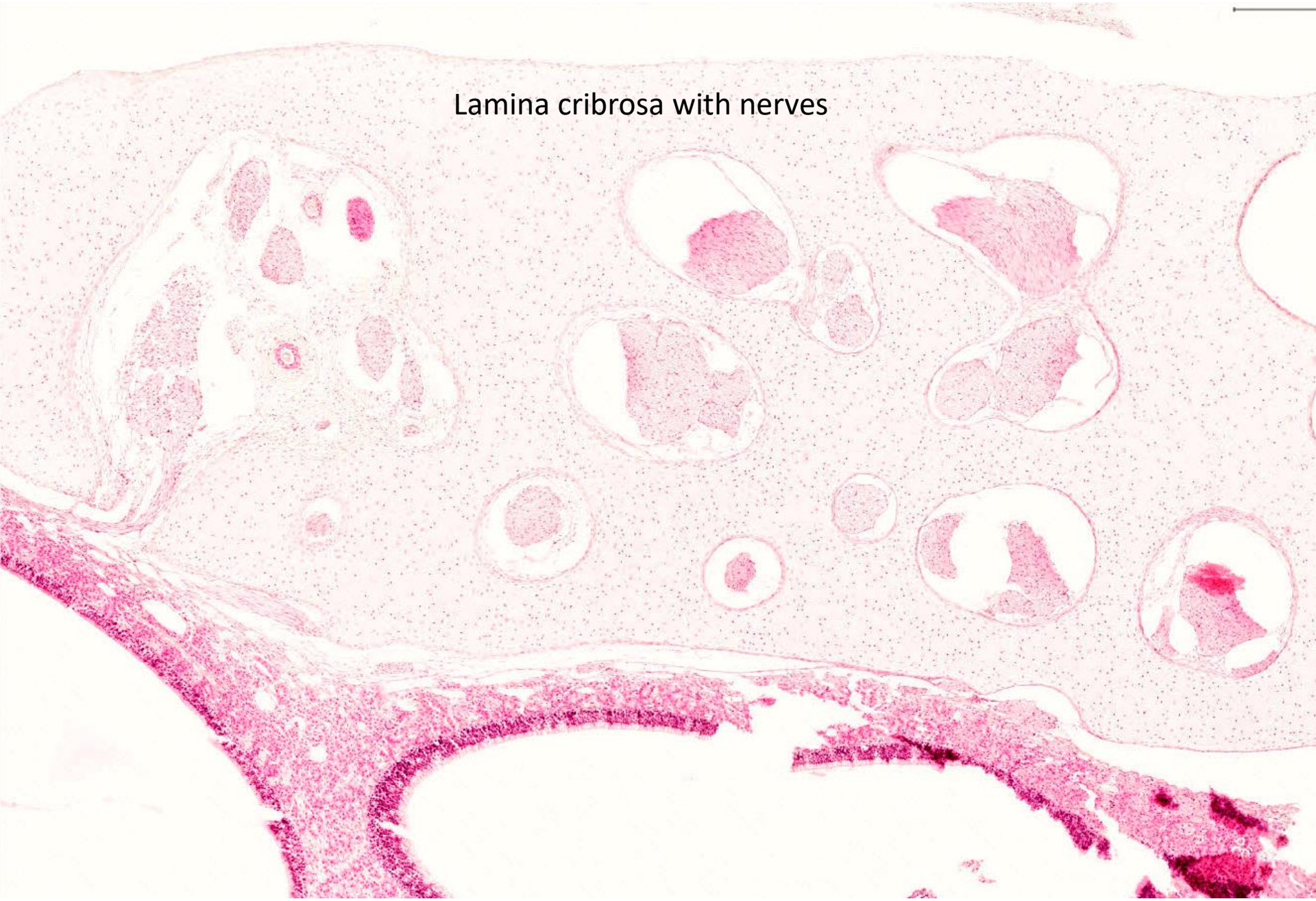



Supporting cell
Supporting cell
Receptor cell

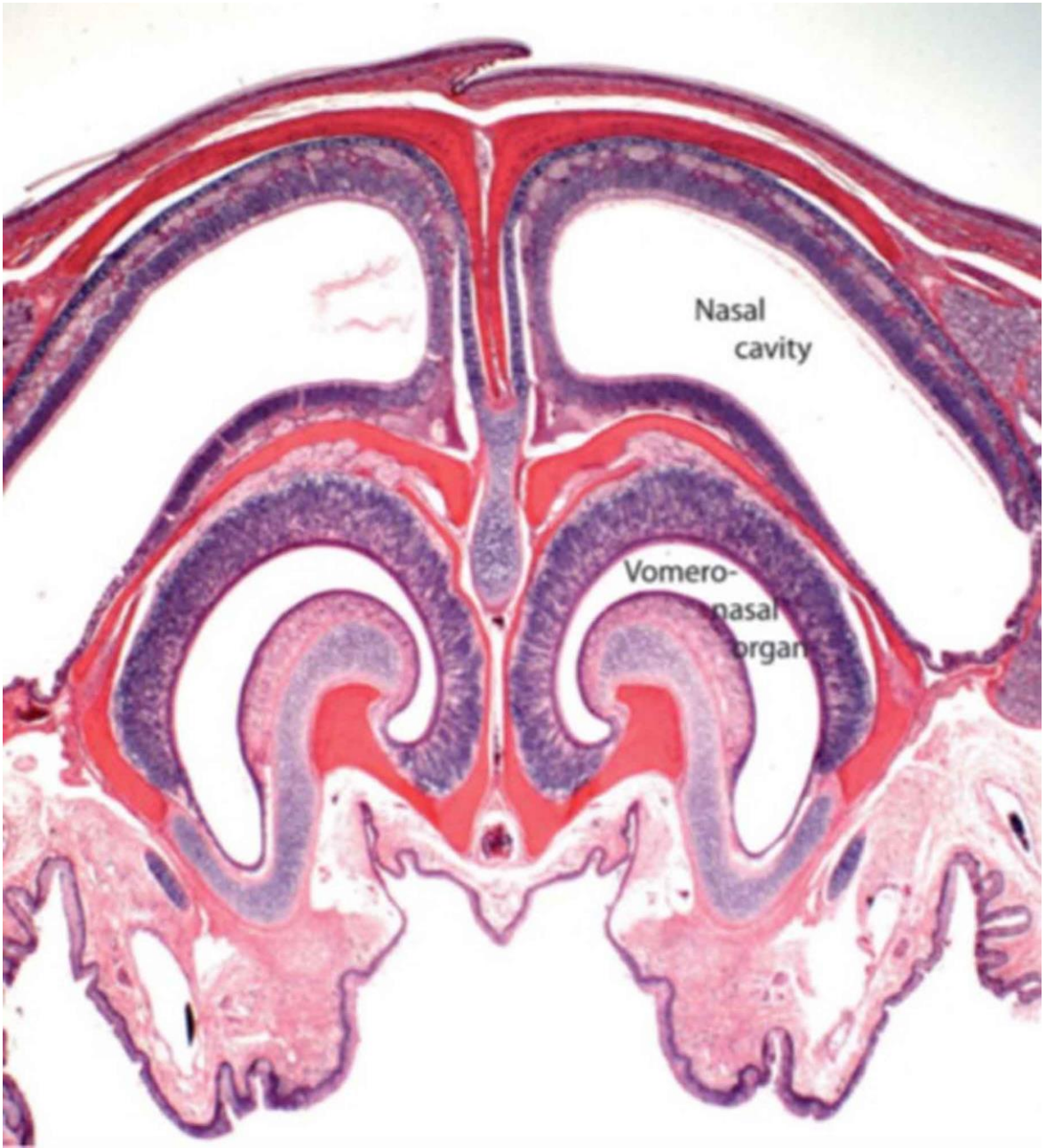
Cavitas nasi

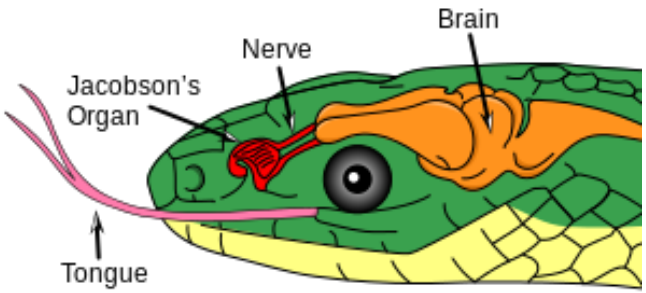



Regio respiratoria
Regio olfactoria

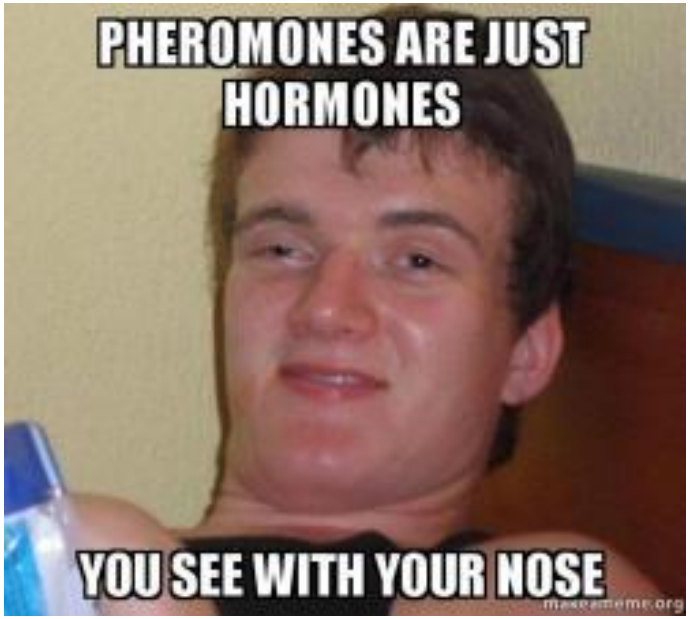

Lamina cribrosa with nerves

Jakobson's vomeronasal organ

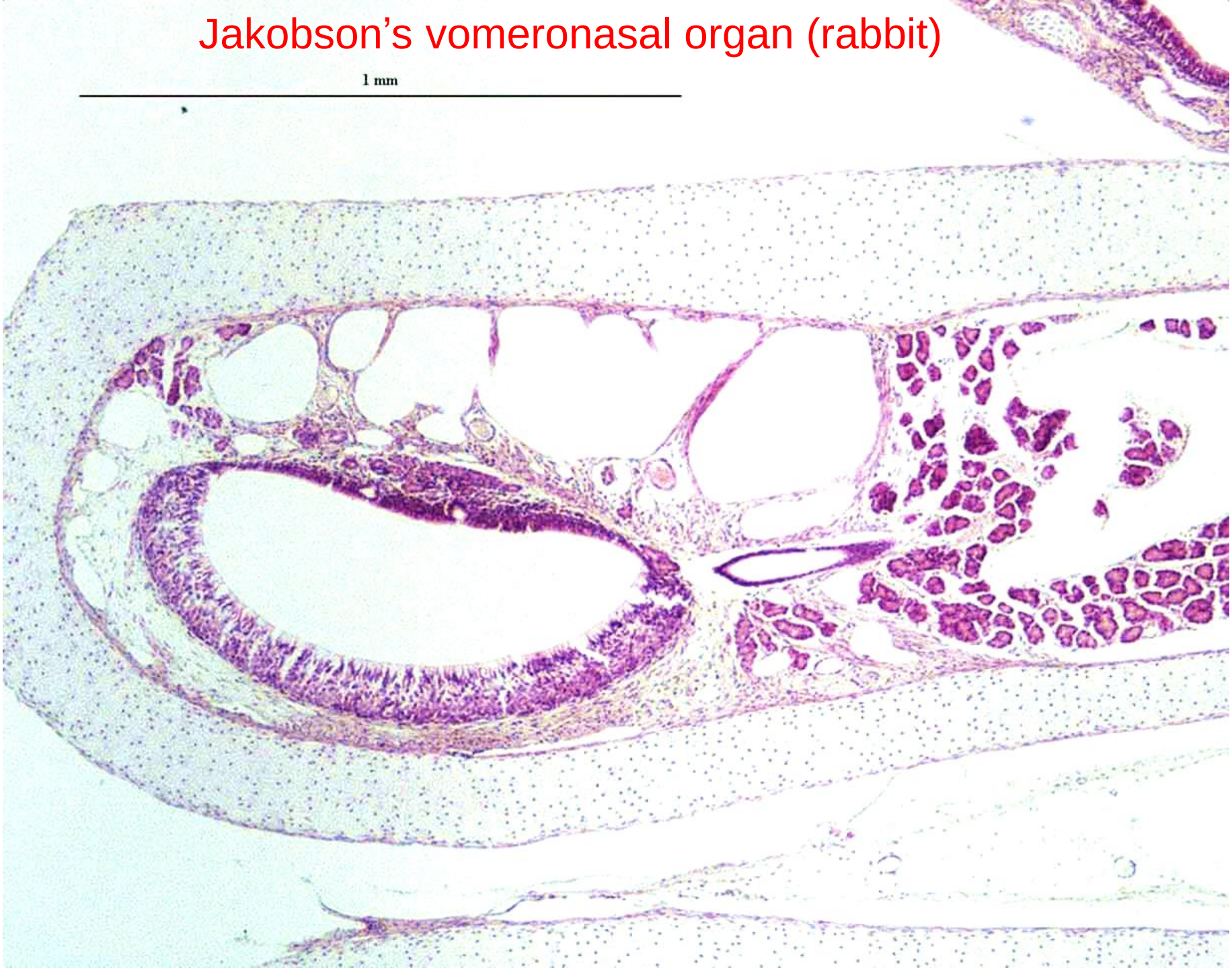




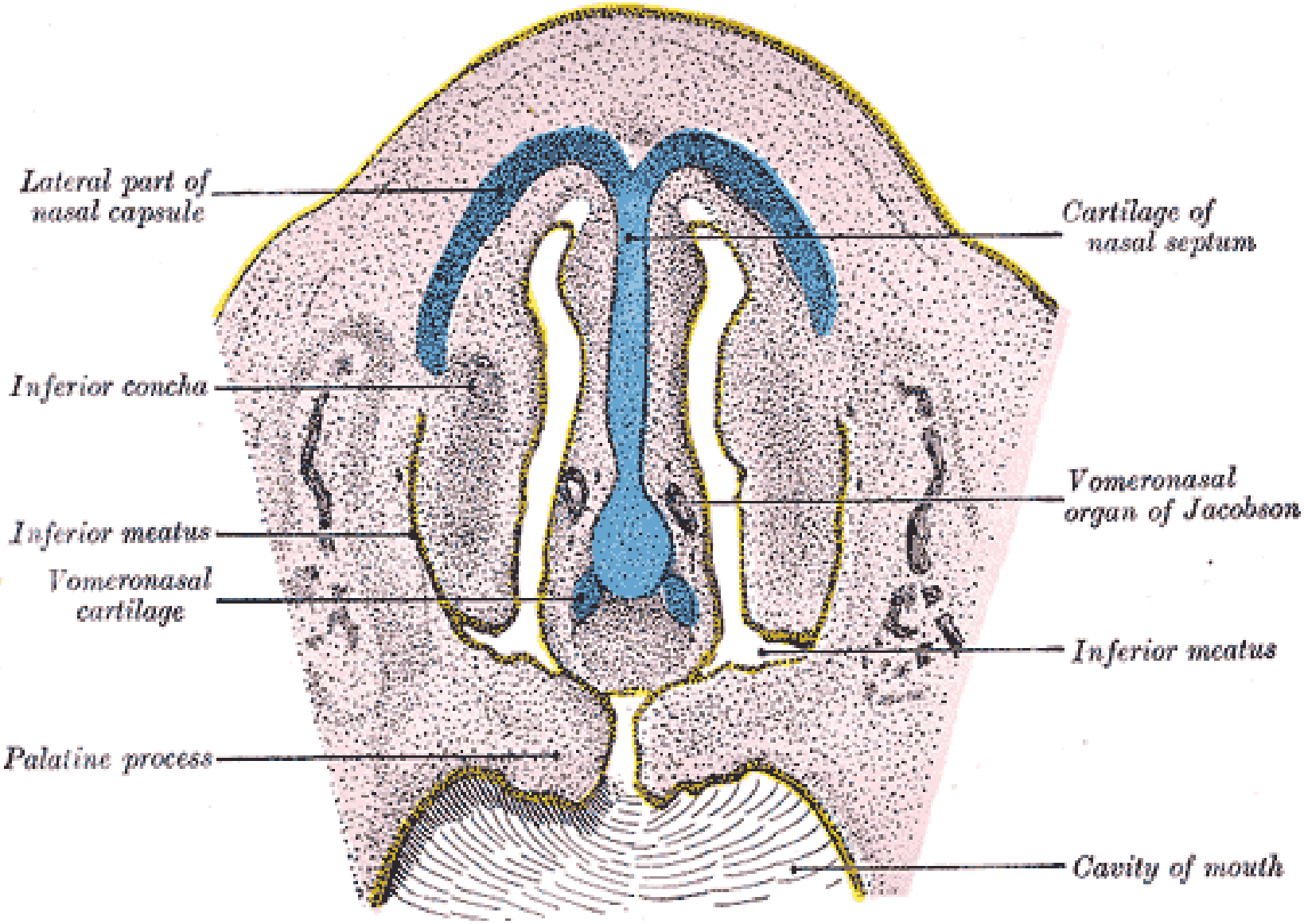
present in all vertebrates, which is essential for intra-specific chemical (Pheromone) communication

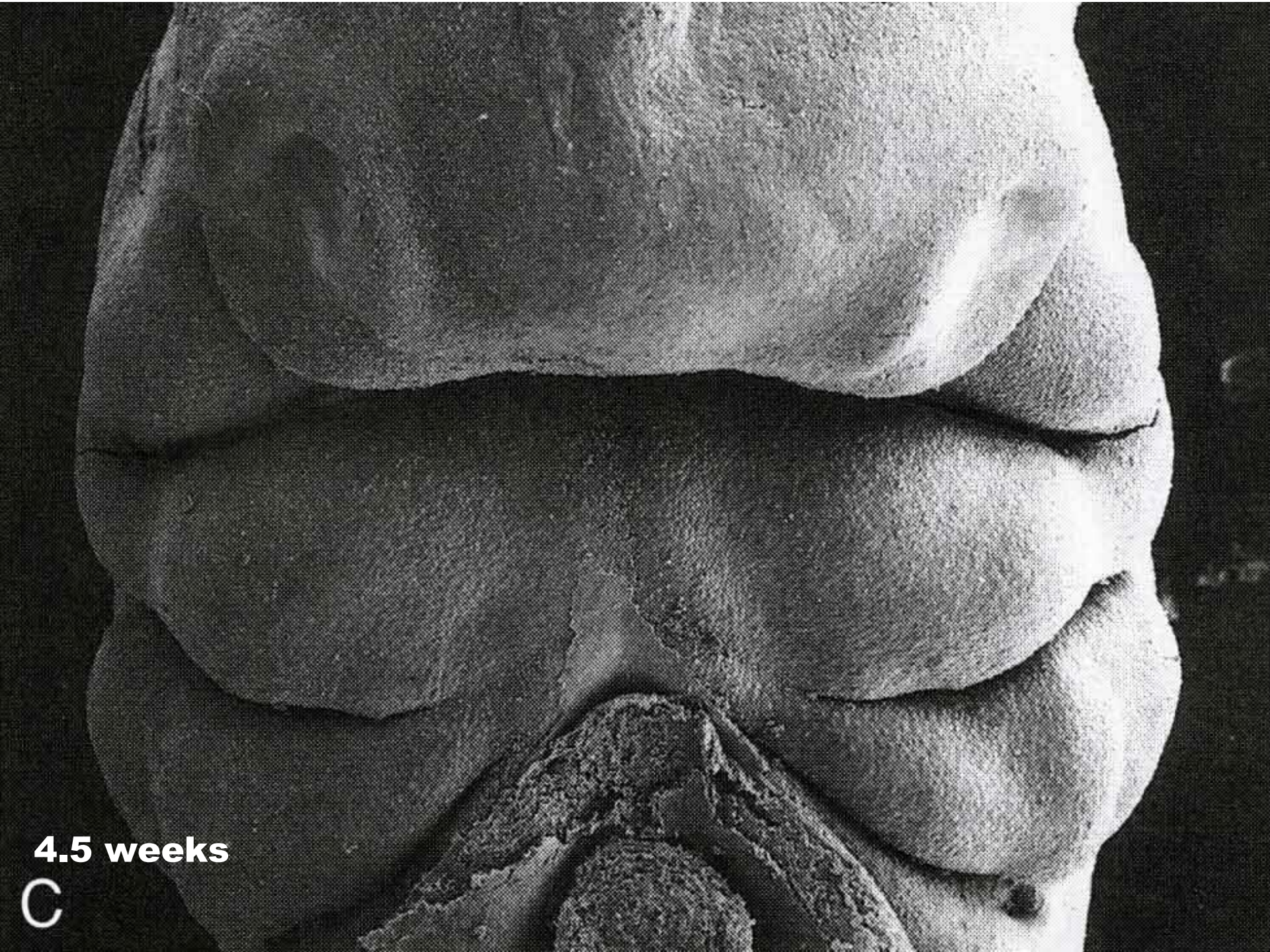


Jakobson’s vomeronasal organ (rabbit)

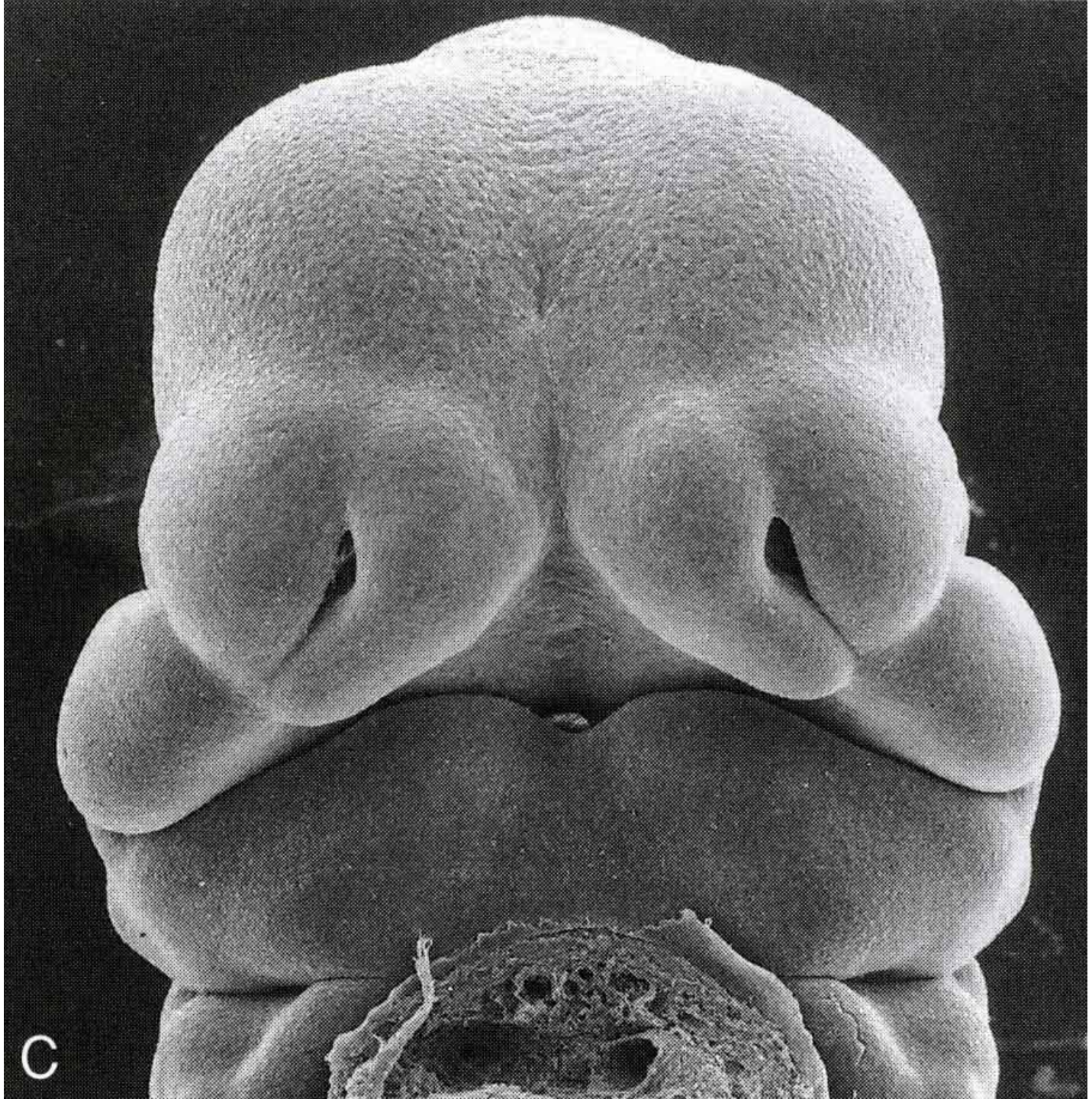


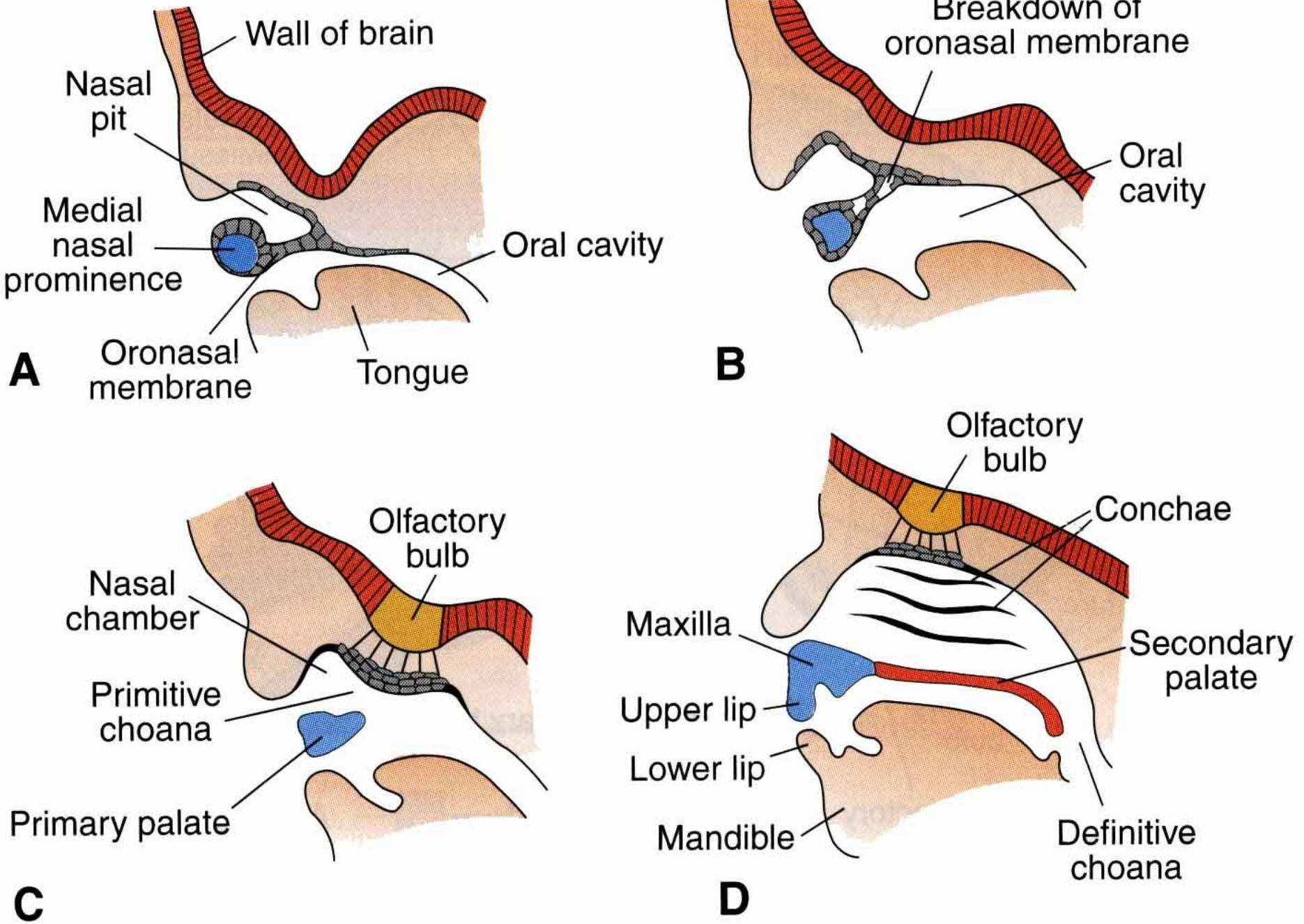
Jakobson’s vomeronasal organ (human embryo)

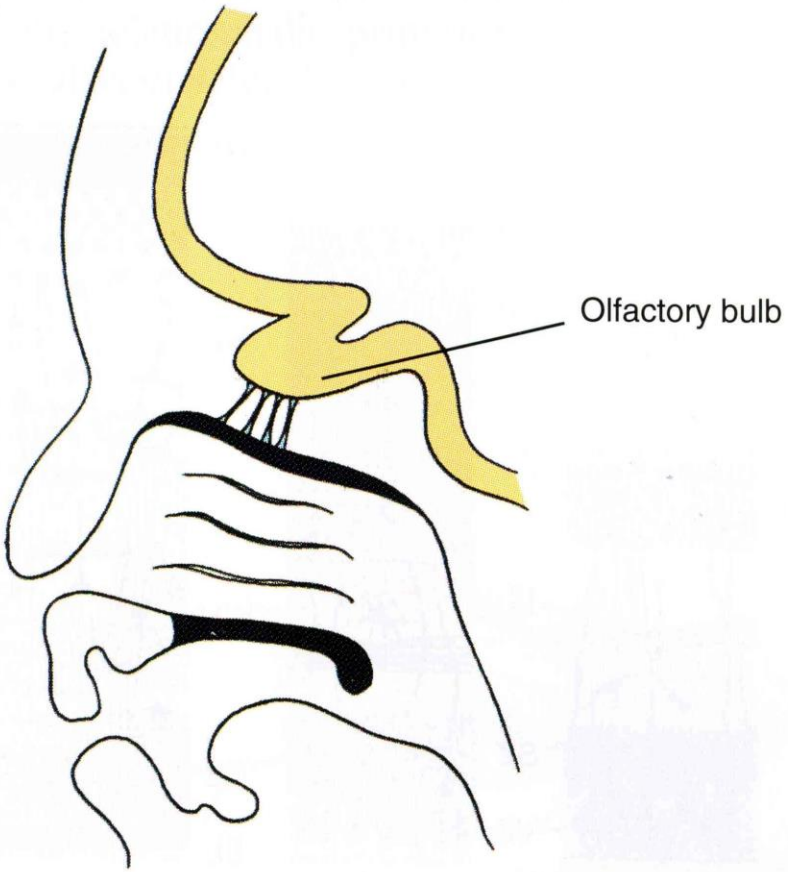



4.5 weeks
C

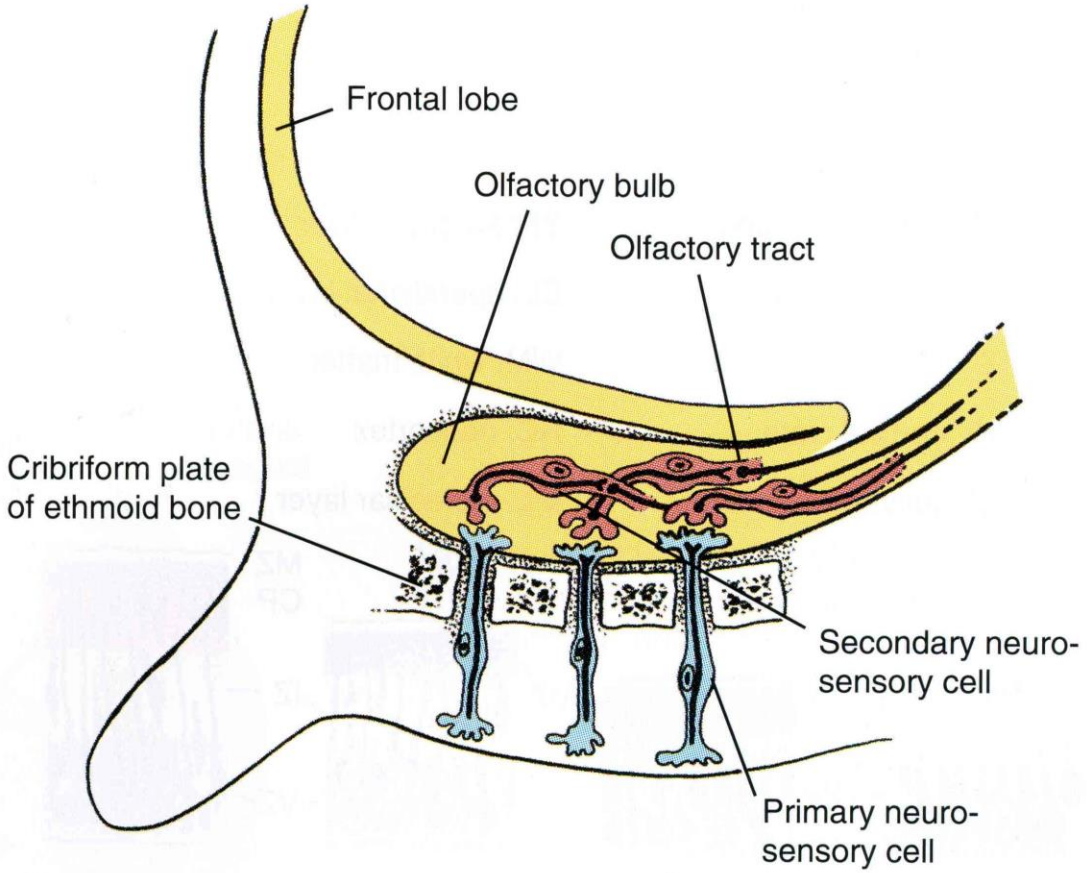
6 weeks




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

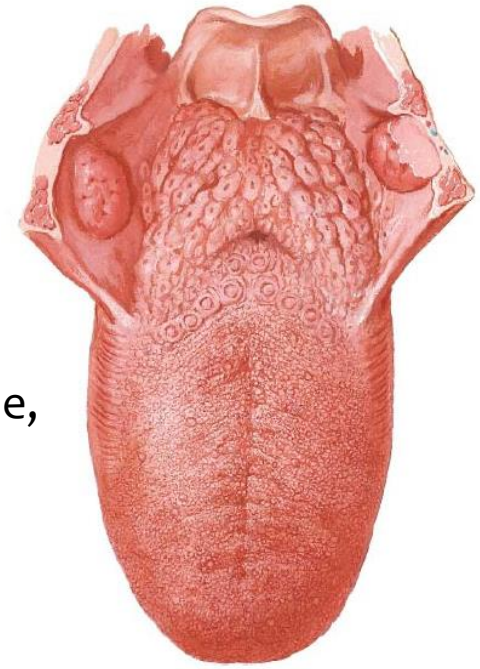


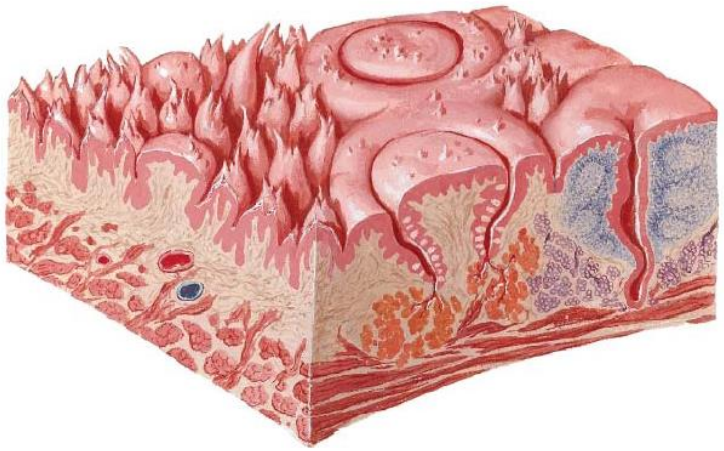
C 10 weeks



D 16 weeks

Taste



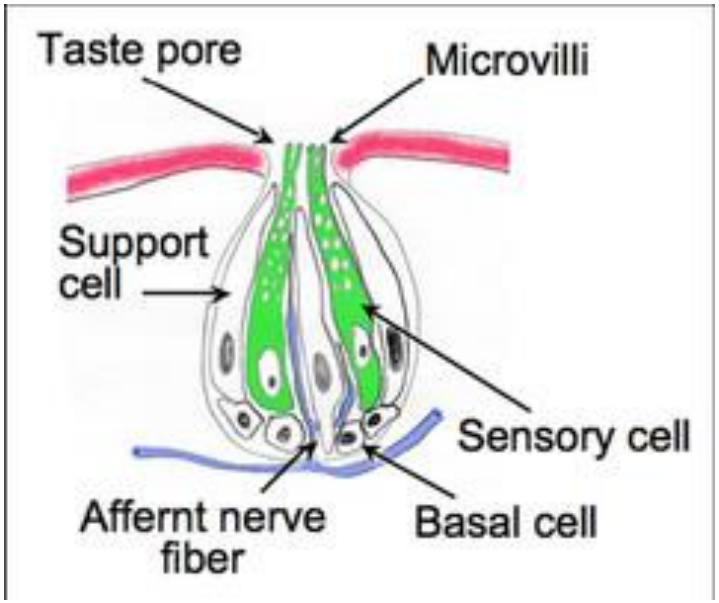


Taste buds on tongue papillae, soft pallate, epiglottis andglossopallatine arches

Taste buds

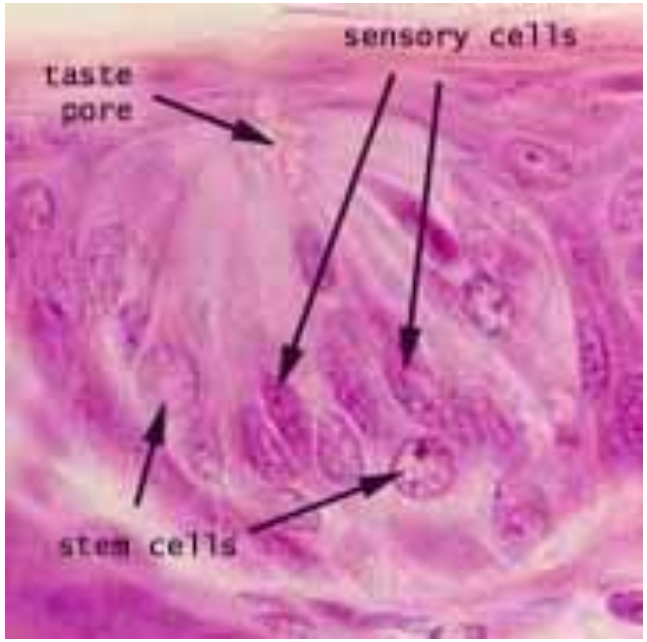
- 5 000 – 10 000
- pore
- 3 types of cells

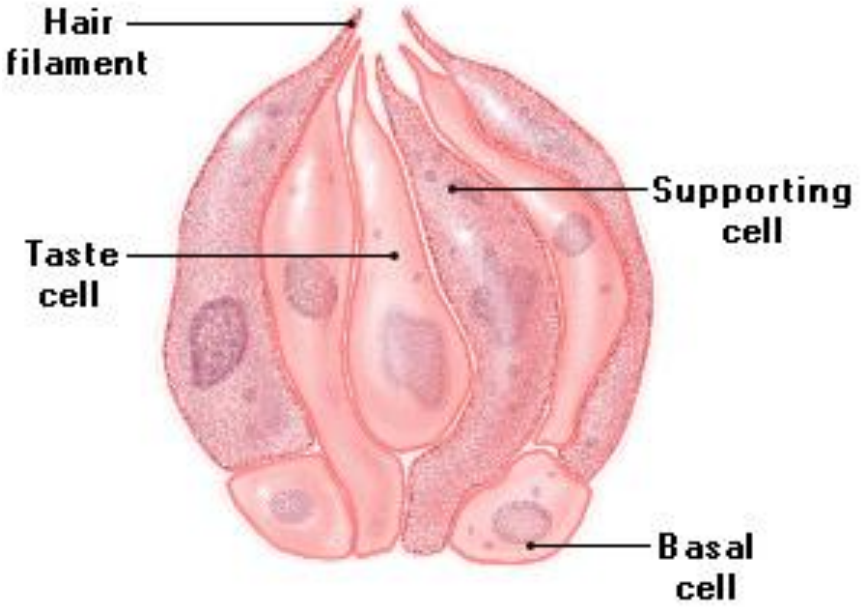
1) Sensory cells
2) Supporting cells
3) Basal cells



Sensory cells

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

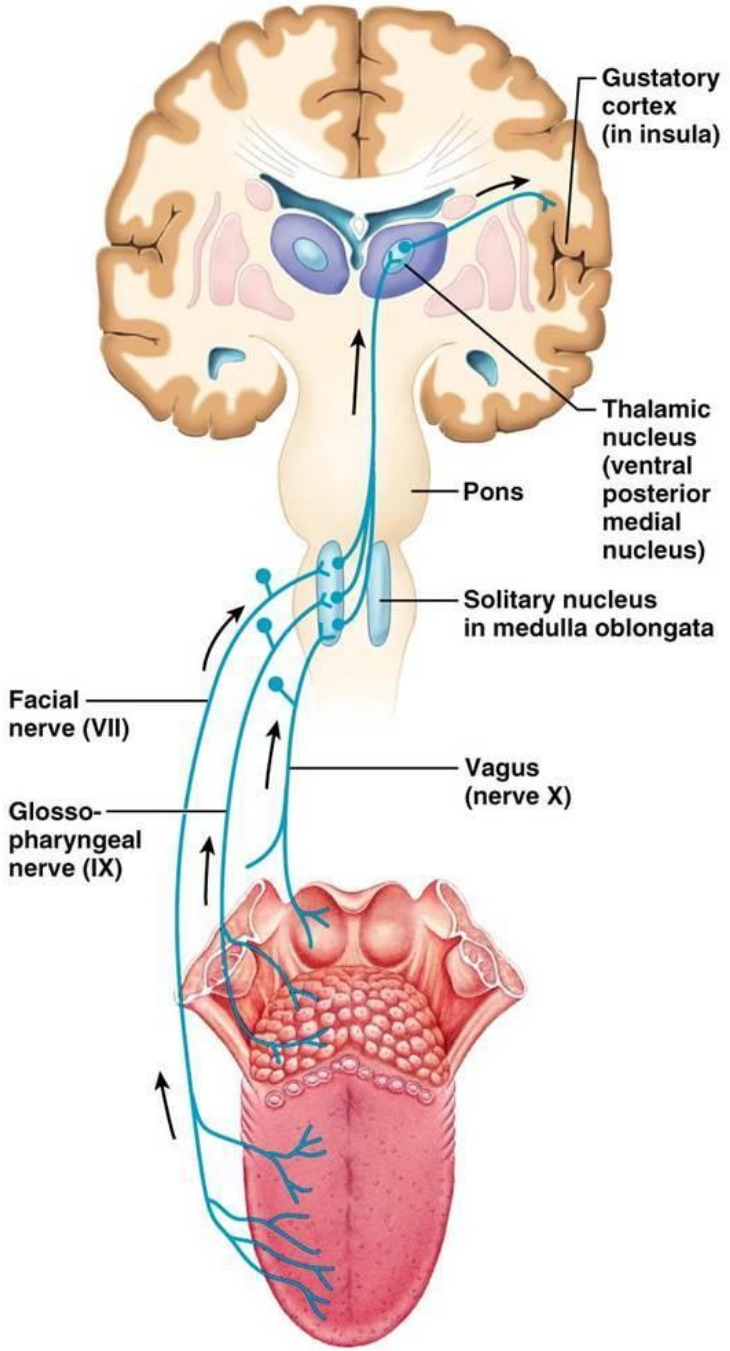


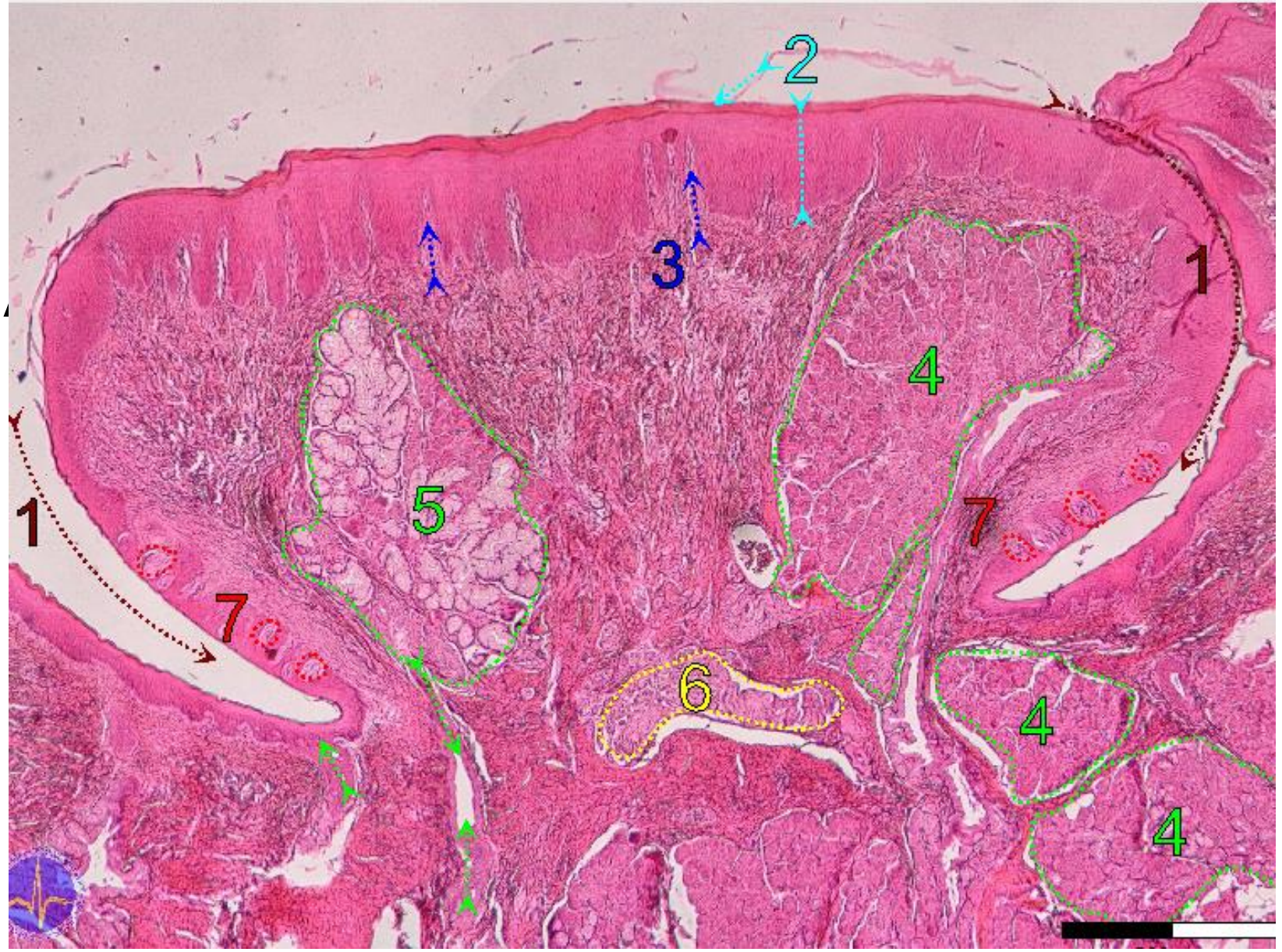


Types:

- bitter, sweet, sour, salty, umami
- Inervation:

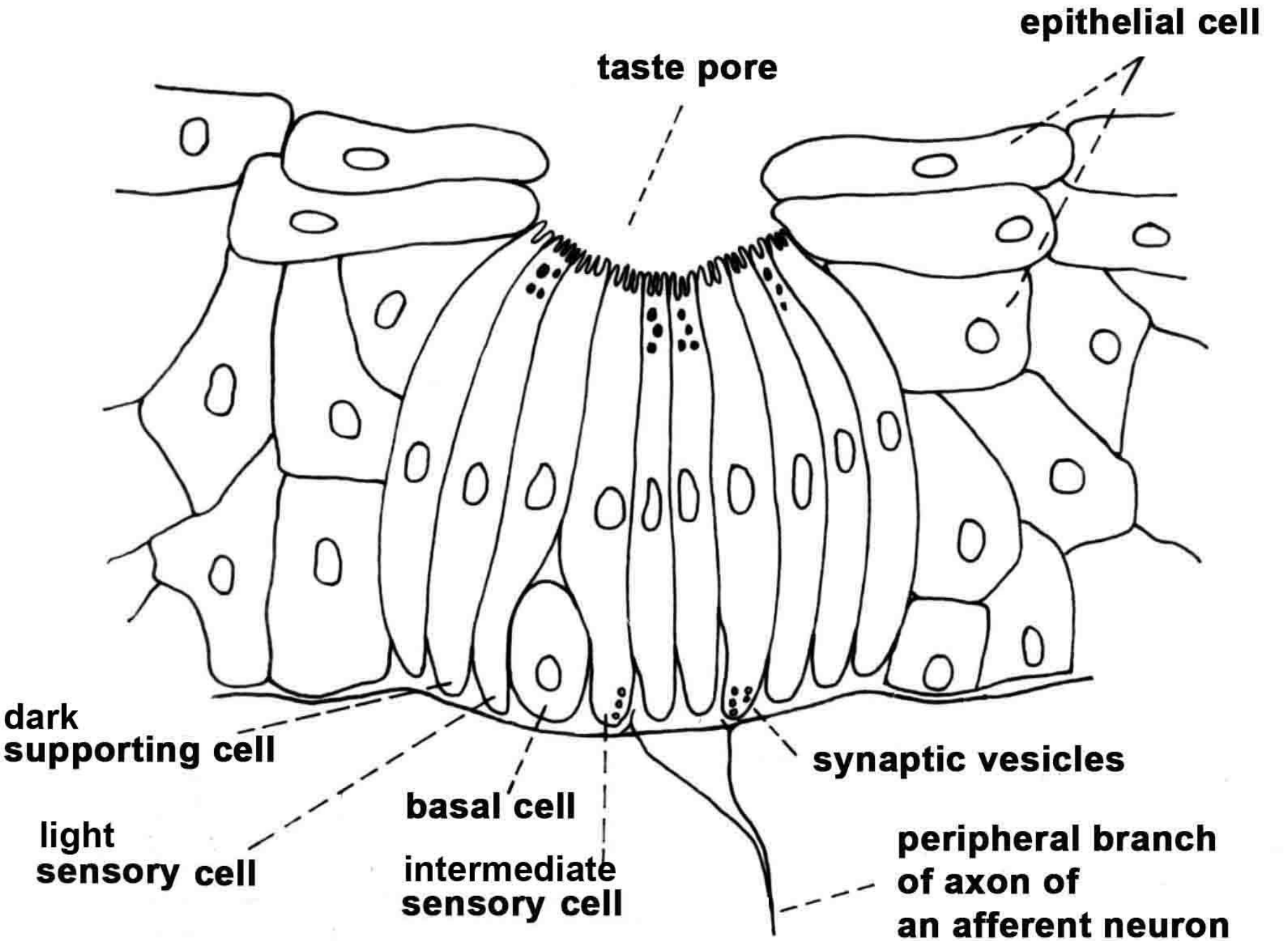
1) VII (n. facialis) – anterior 2/3
2) IX (n. glossopharyngeus) – posterior 1/3 jazyka and pharynx

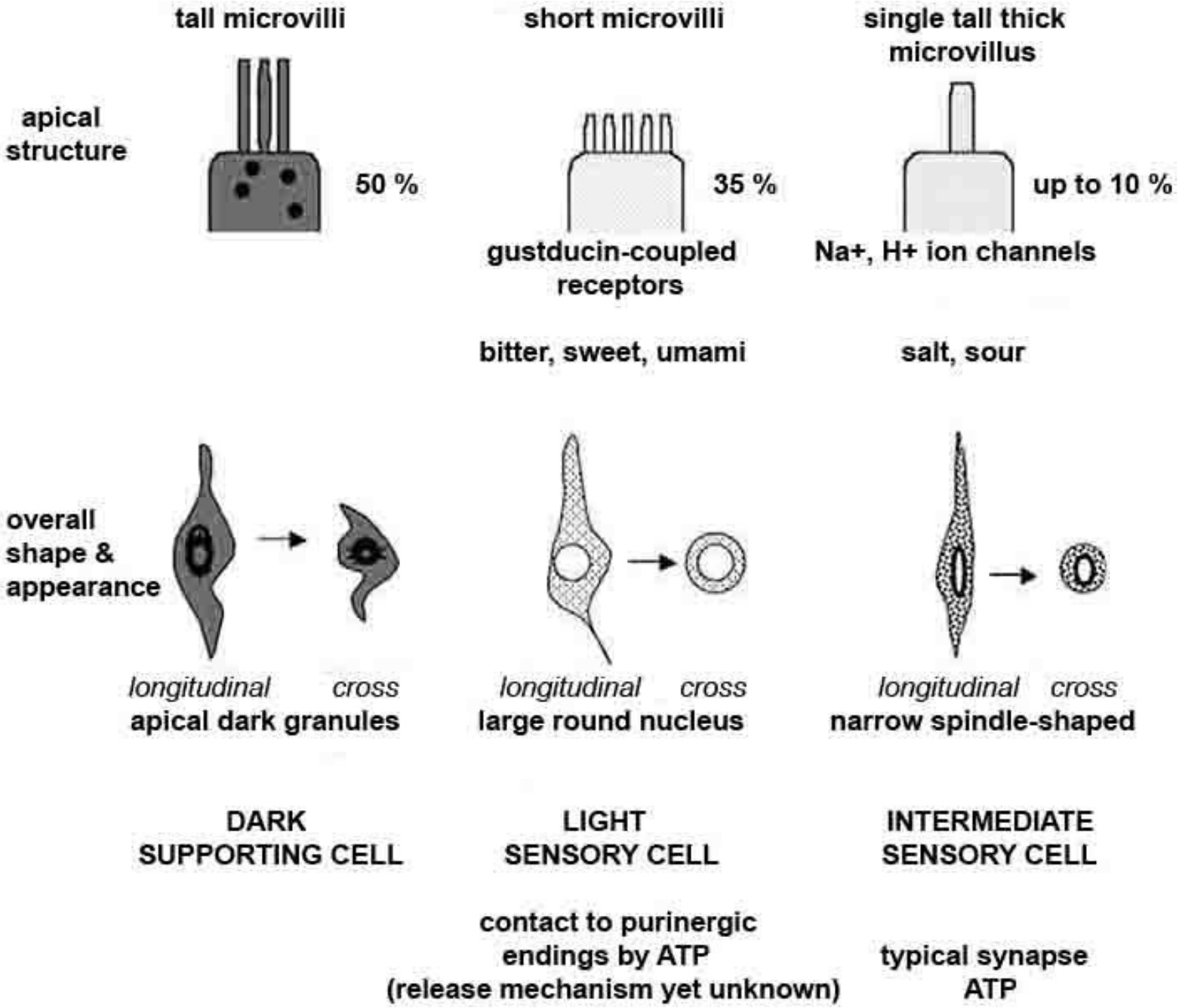




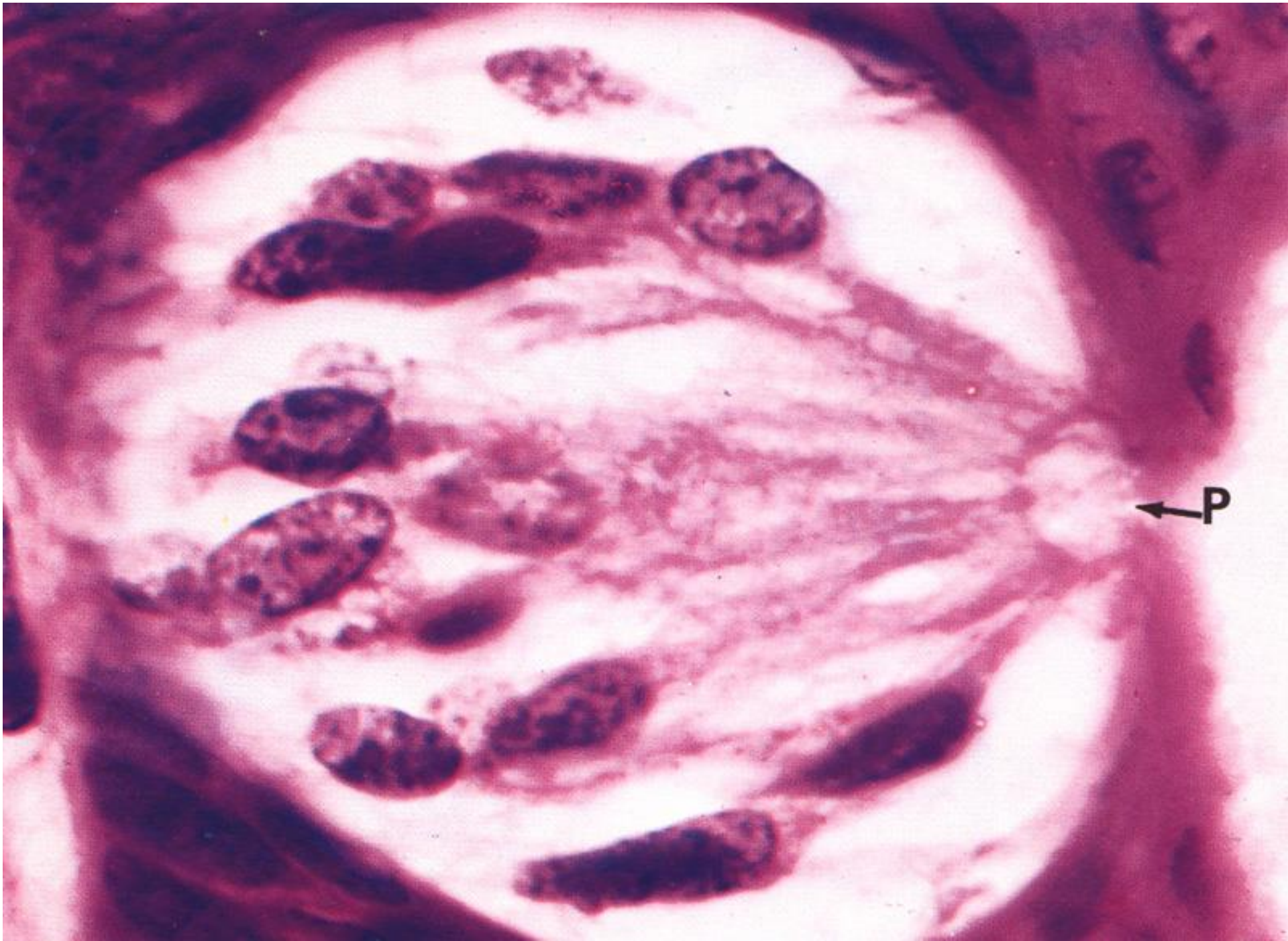
1 – sulcus
2 – epitelhelium
3 – secondary papilly
4 – von Ebner´s serous glands
5 – seromucous glands
6 - nerves
7 – taste buds

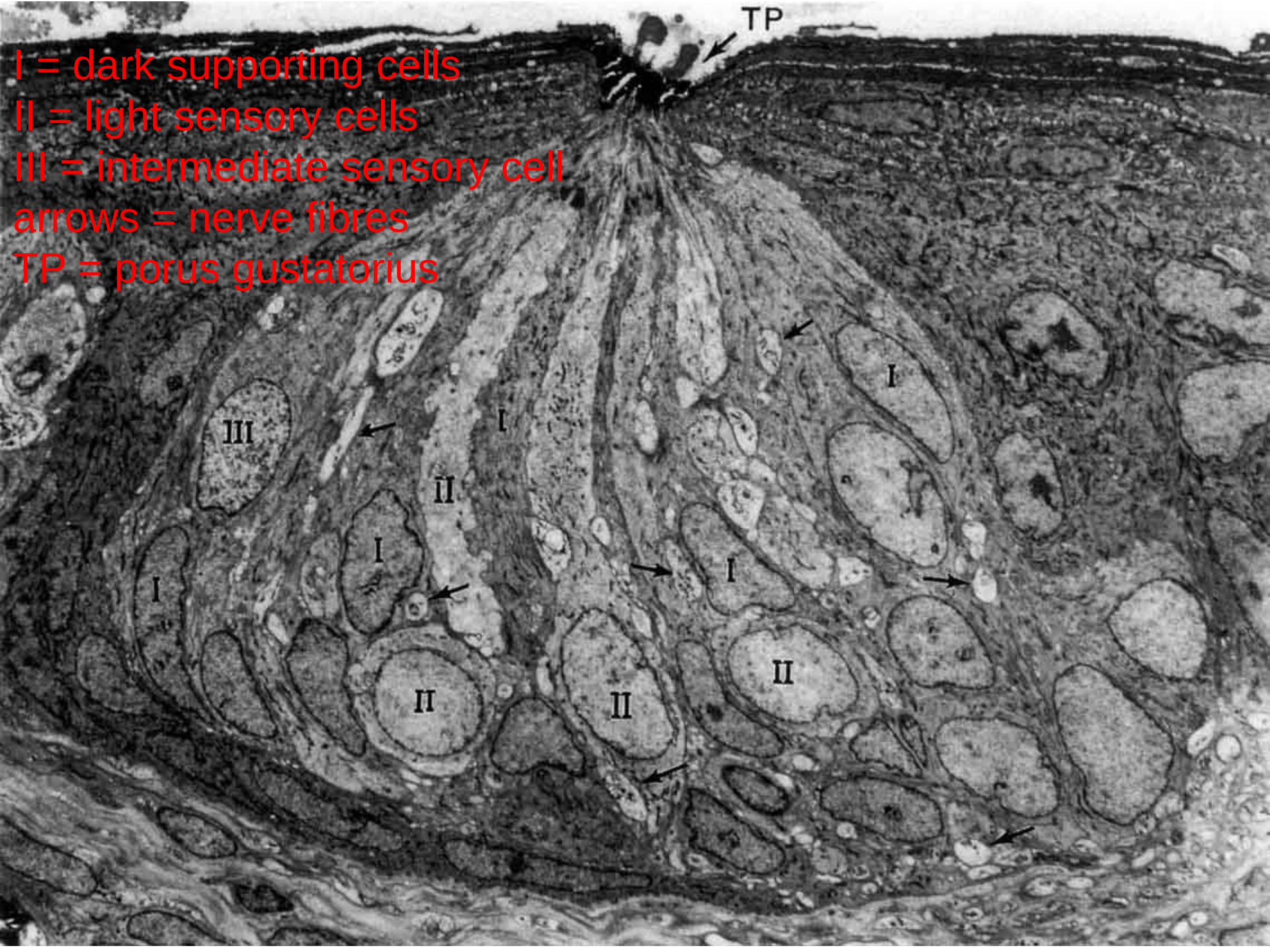
TASTE BUD

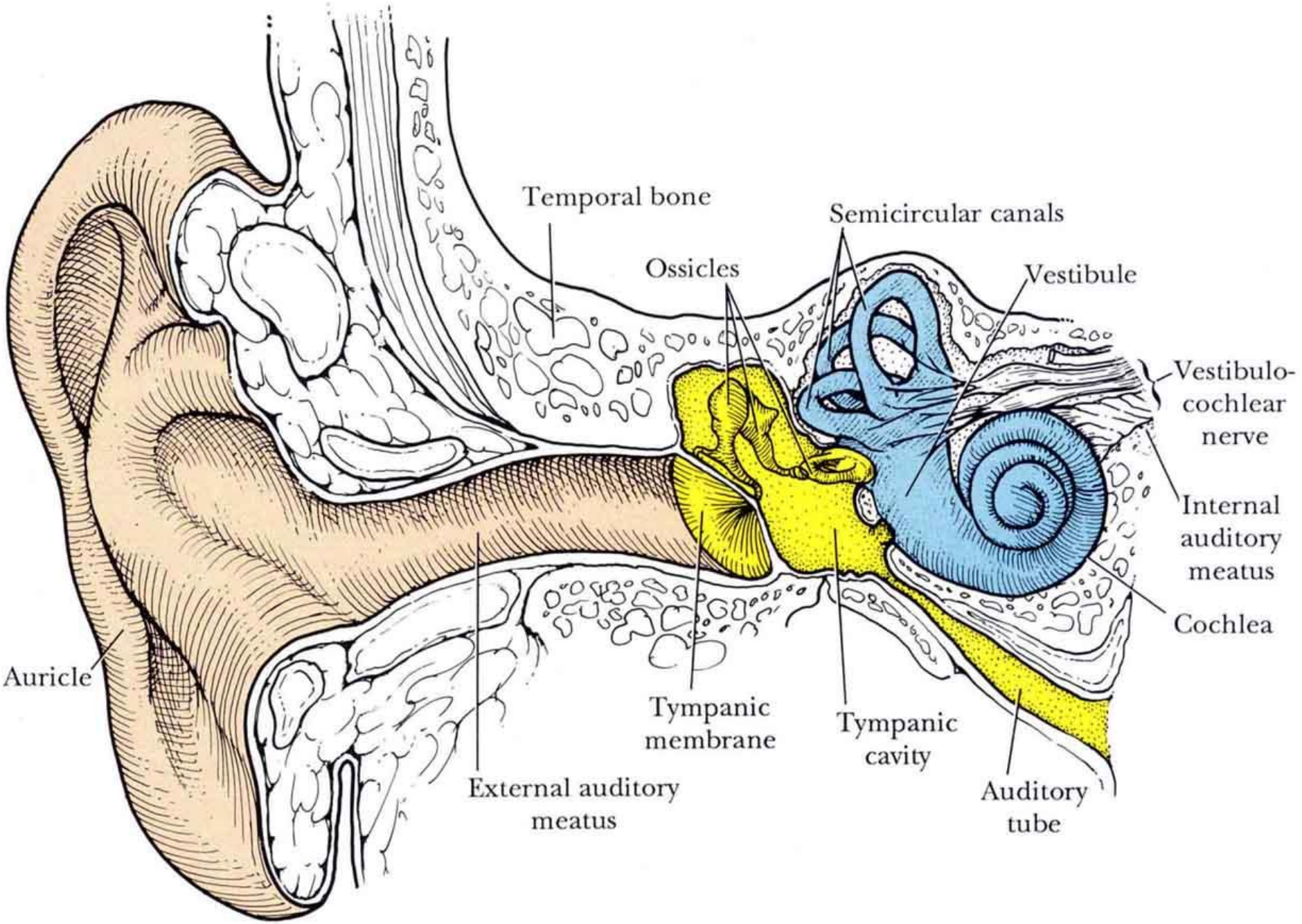

epithelial cell
taste pore
dark
supporting cell
light
sensory cell
basal cell
intermediate
sensory cell
synaptic vesicles
peripheral branch
of axon of
an afferent neuron


tall microvilli
short microvilli
single tall thick microvillus
apical structure
50 %
35 %
up to 10 %
gustducin-coupled receptors
Na+, H+ ion channels
bitter, sweet, umami
salt, sour
overall shape & appearance
longitudinal cross
apical dark granules
longitudinal cross
large round nucleus
longitudinal cross
narrow spindle-shaped
DARK SUPPORTING CELL
LIGHT SENSORY CELL
INTERMEDIATE SENSORY CELL
contact to purinergic endings by ATP (release mechanism yet unknown)
typical synapse ATP

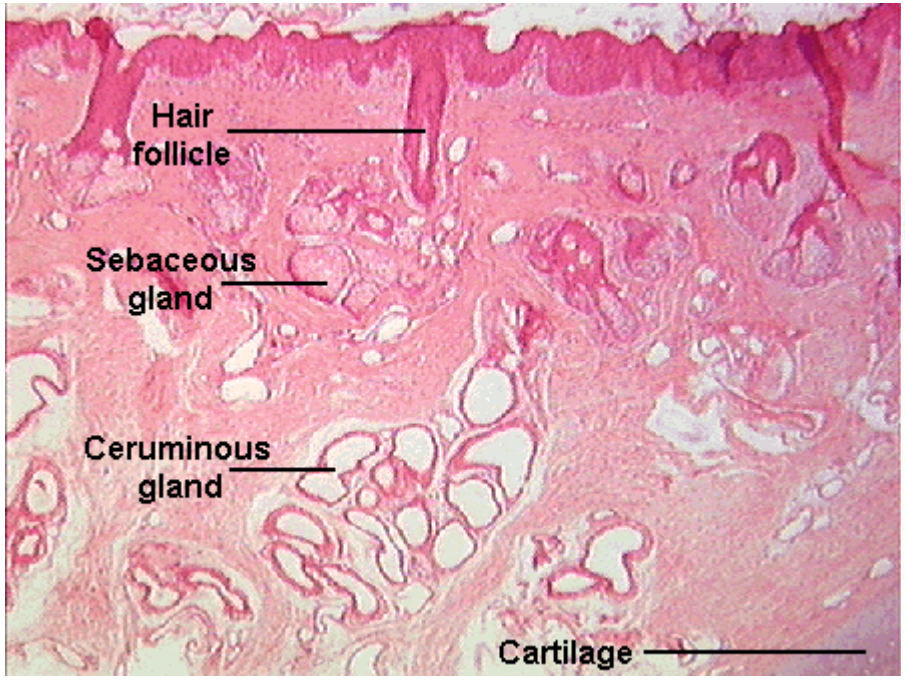

T

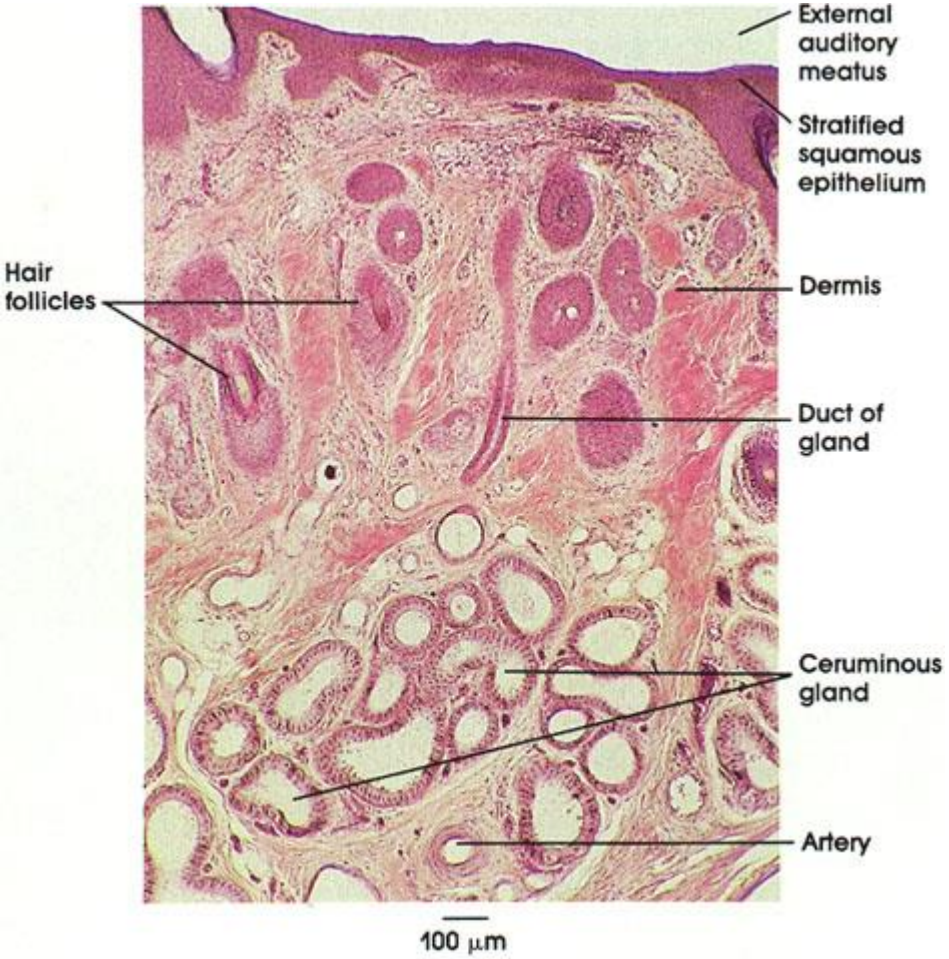

P

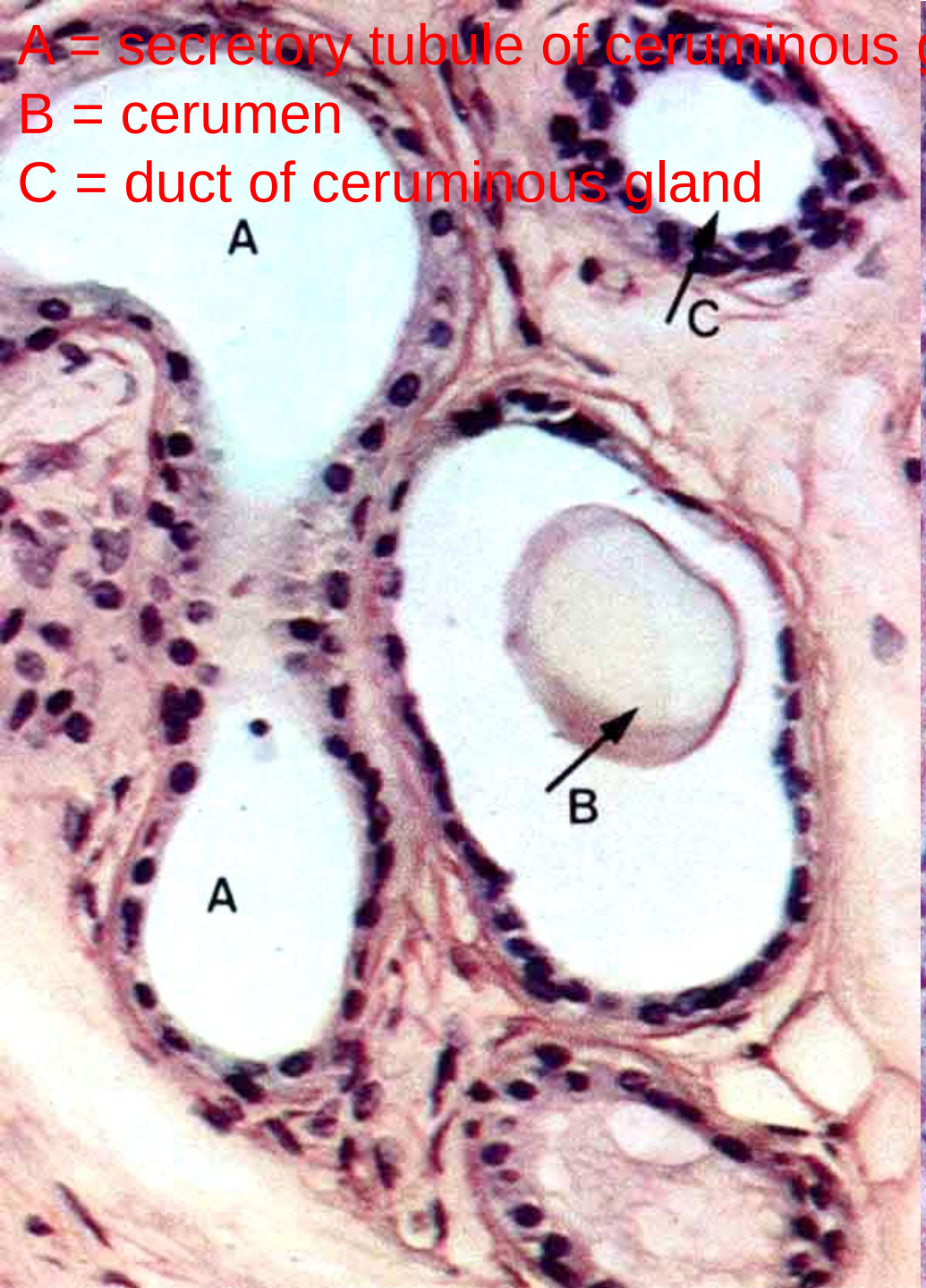

I = dark supporting cells
II = light sensory cells
III = intermediate sensory cell
arrows = nerve fibres
TP = porus gustatorius
TP
III
I
II
I
I
I
I
II
II
II


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

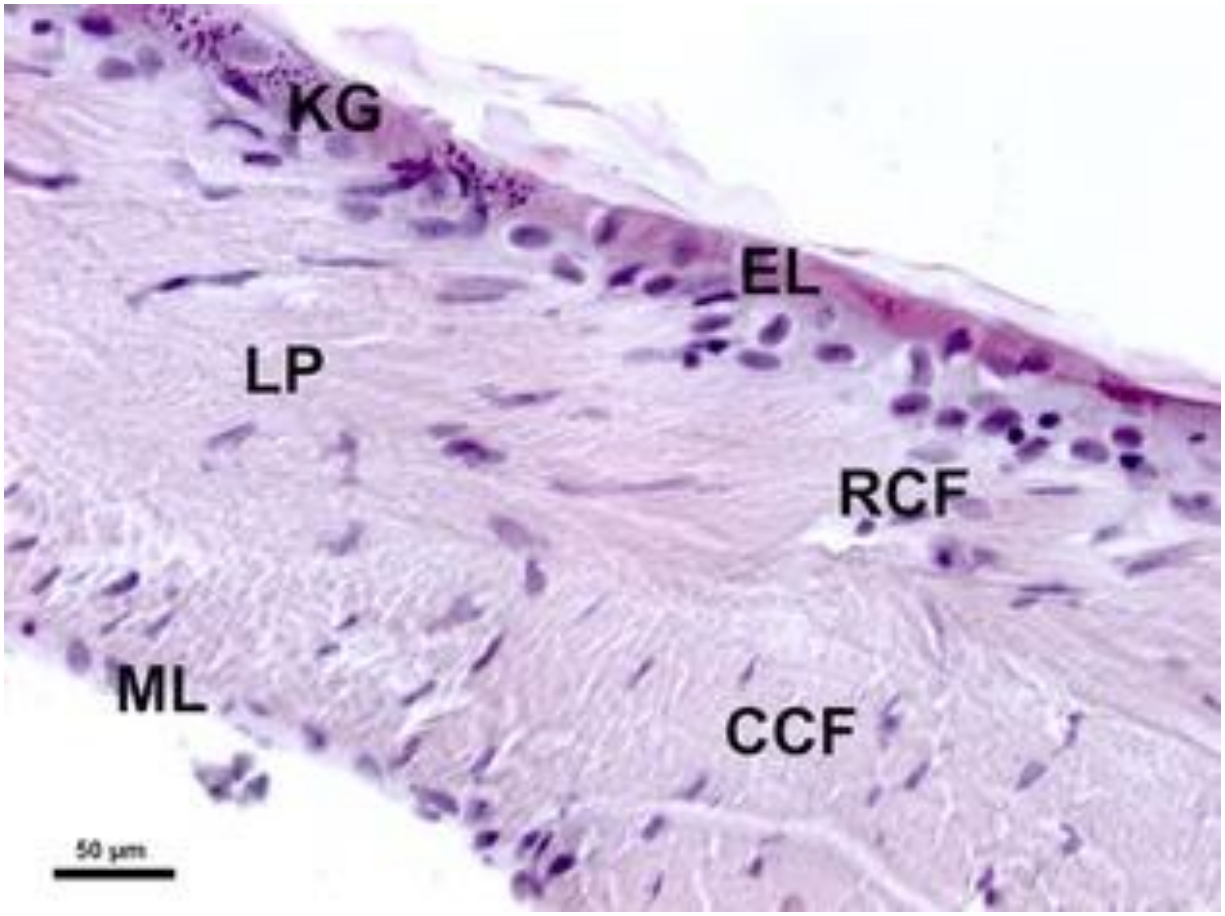
external auditory meatus

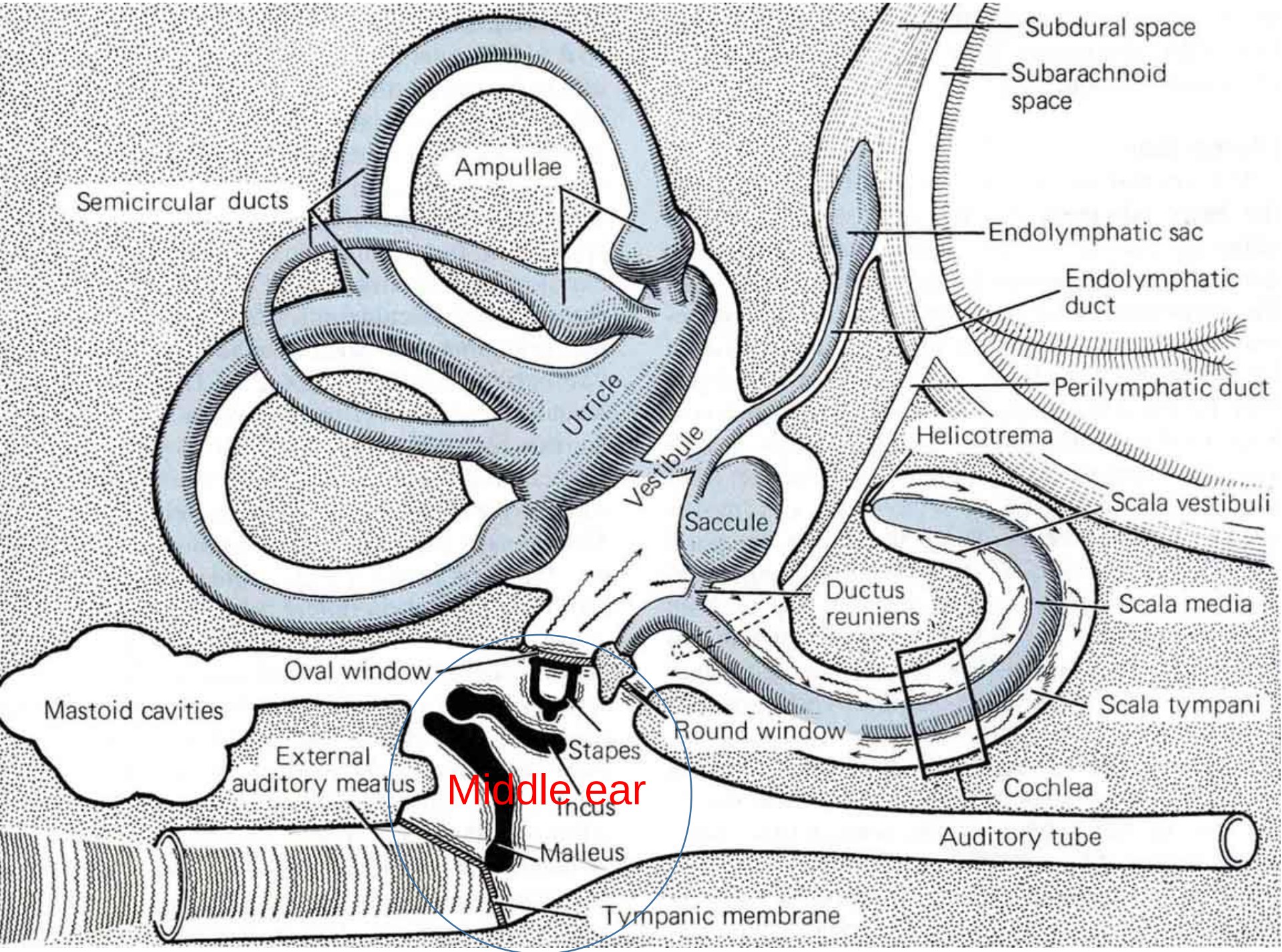




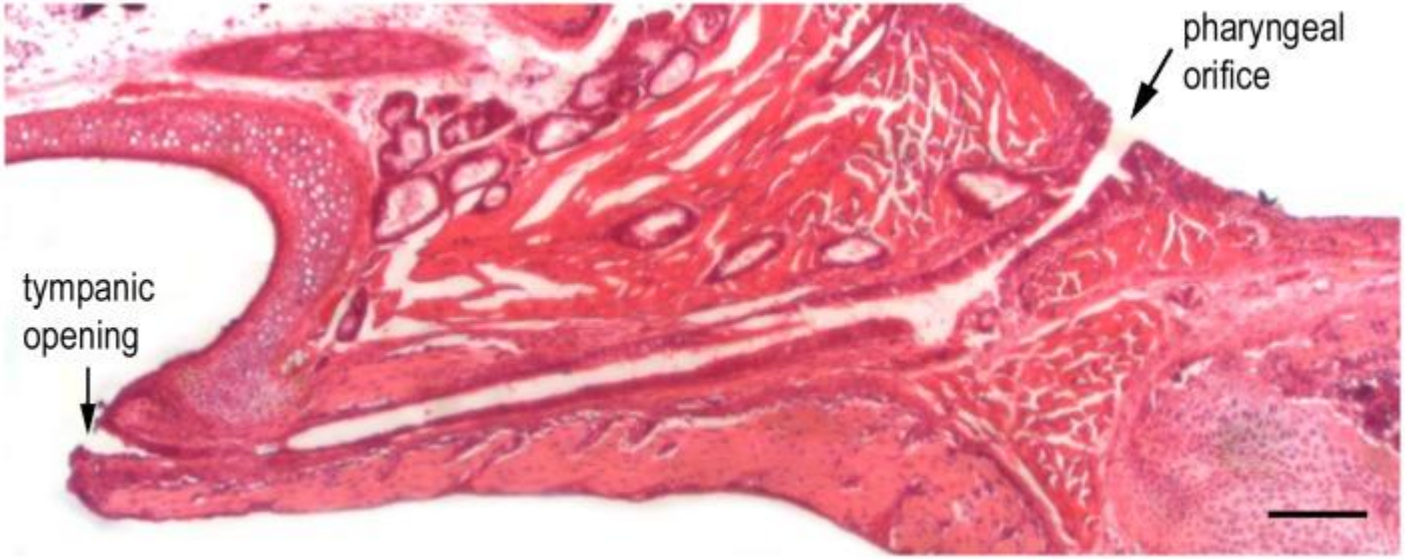

A = secretory tubule of ceruminous gland
B = cerumen
C = duct of ceruminous gland
A
C
B
A

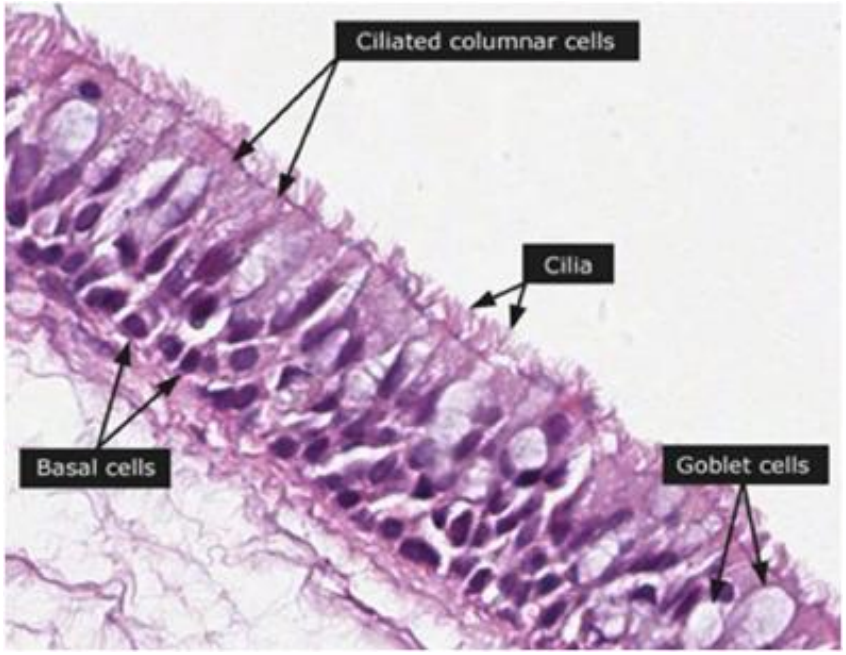
tympanic membrane
EL = epidermal layer
LP = lamina propria
ML = mucosa- simple cuboidal epithelium



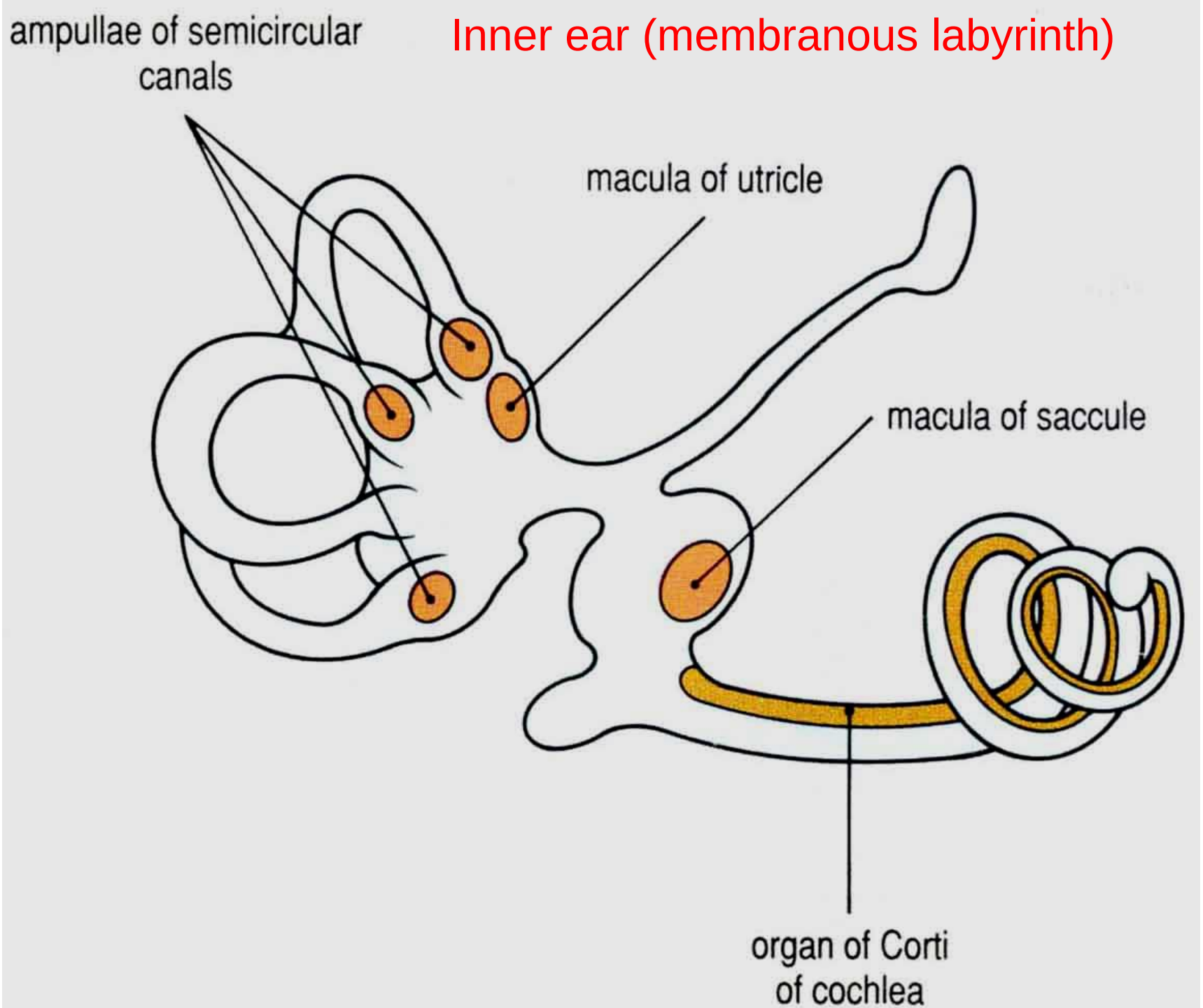

Subdural space
Subarachnoid space
Ampullae
Semicircular ducts
Endolymphatic sac
Endolymphatic duct
Perilymphatic duct
Utricle
Vestibule
Helicotrema
Saccule
Scala vestibuli
Ductus reuniens
Scala media
Oval window
Mastoid cavities
Scala tympani
Round window
Stapes
External auditory meatus
Middle ear
Cochlea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

Eustachian tube

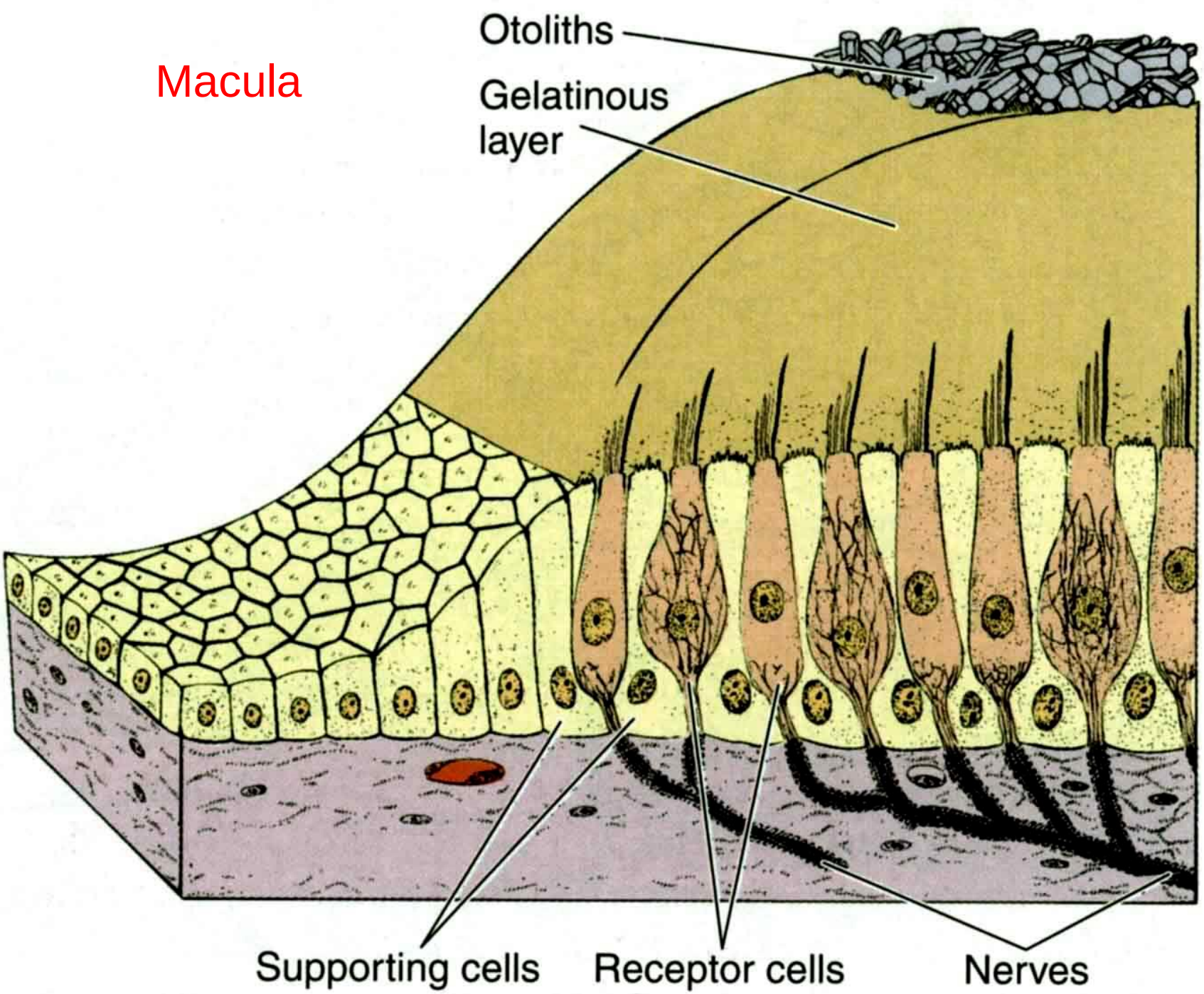




Inner ear (membranous labyrinth)

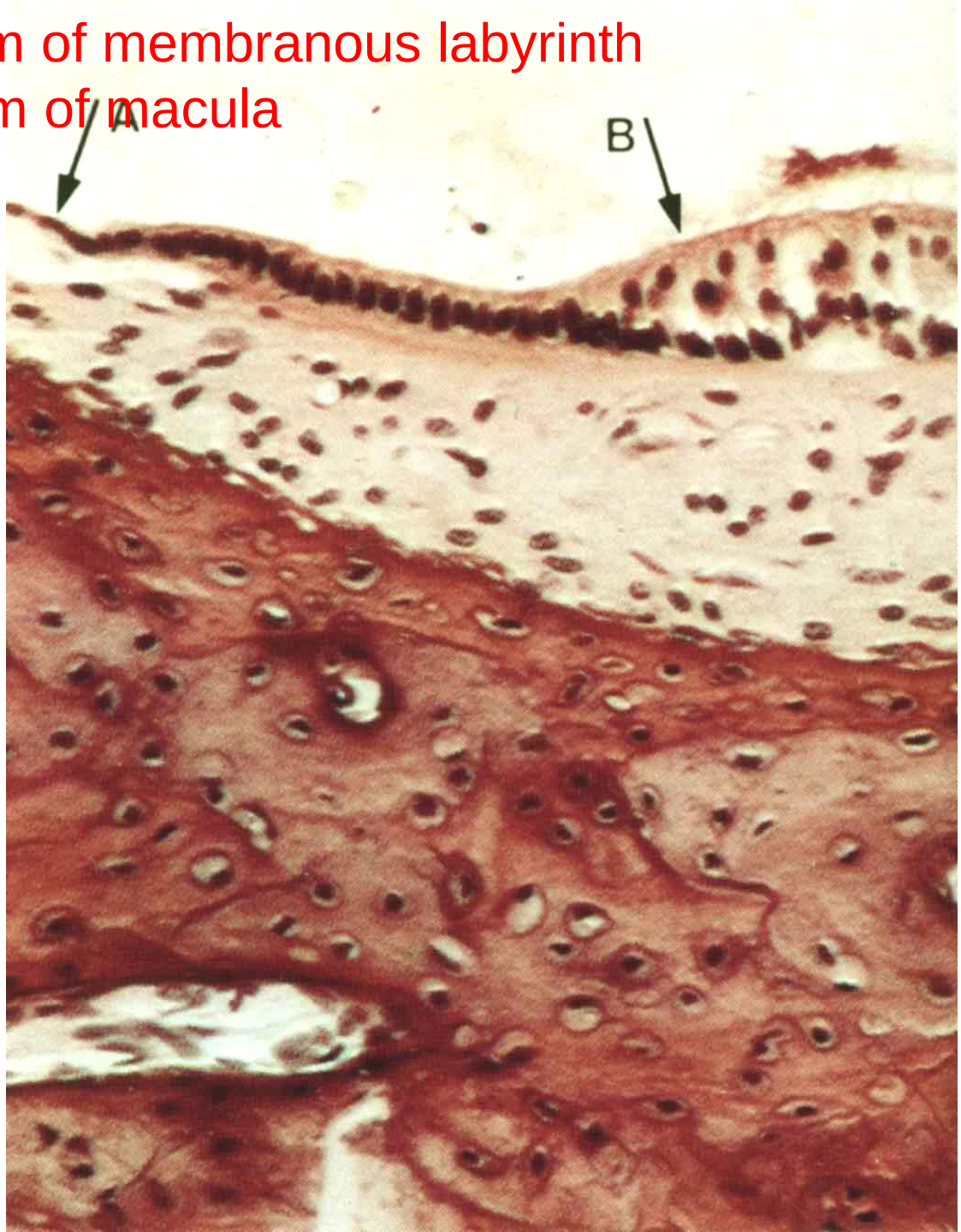


Macula

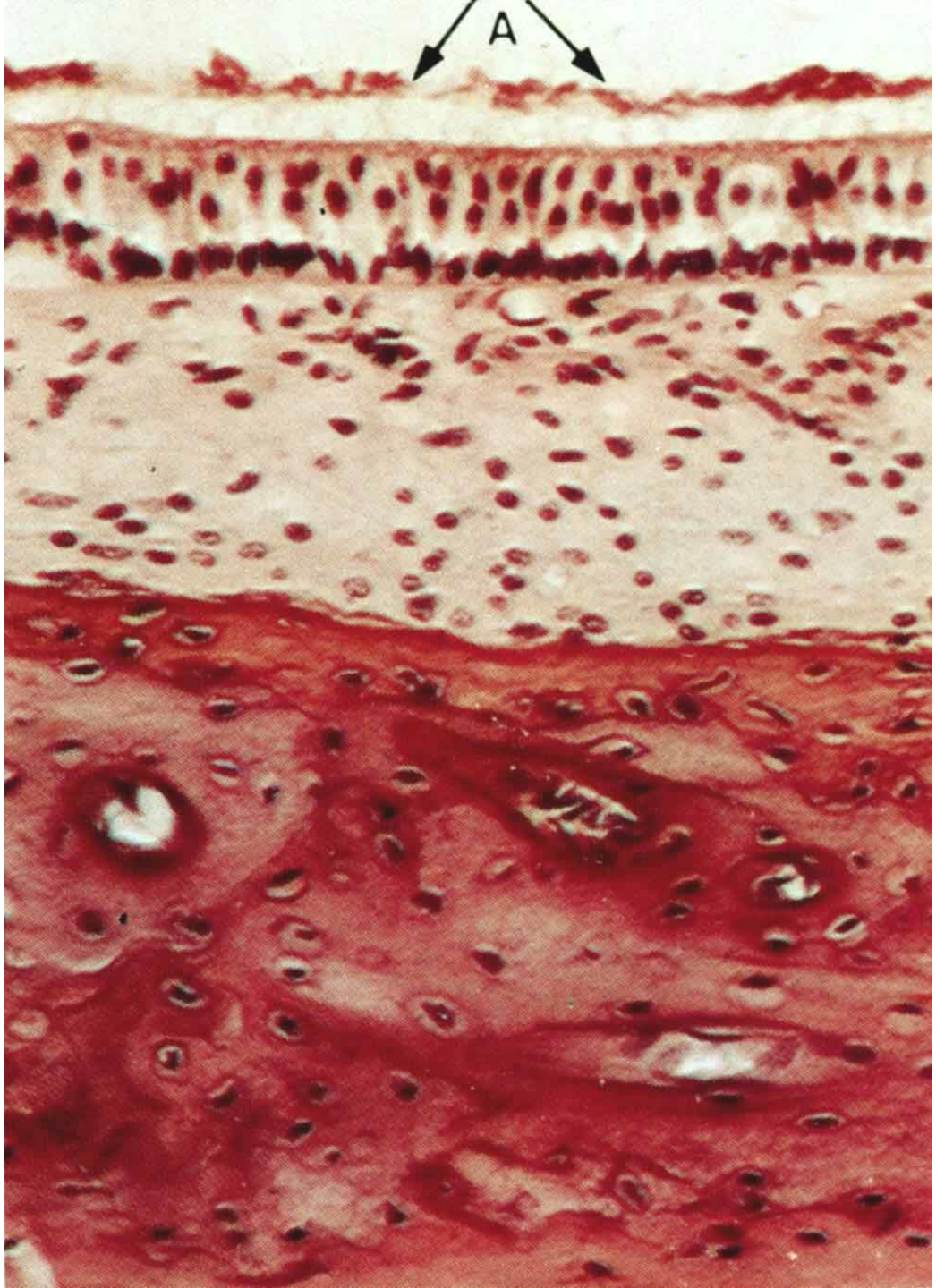

Otoliths
Gelatinous layer
Supporting cells
Receptor cells
Nerves

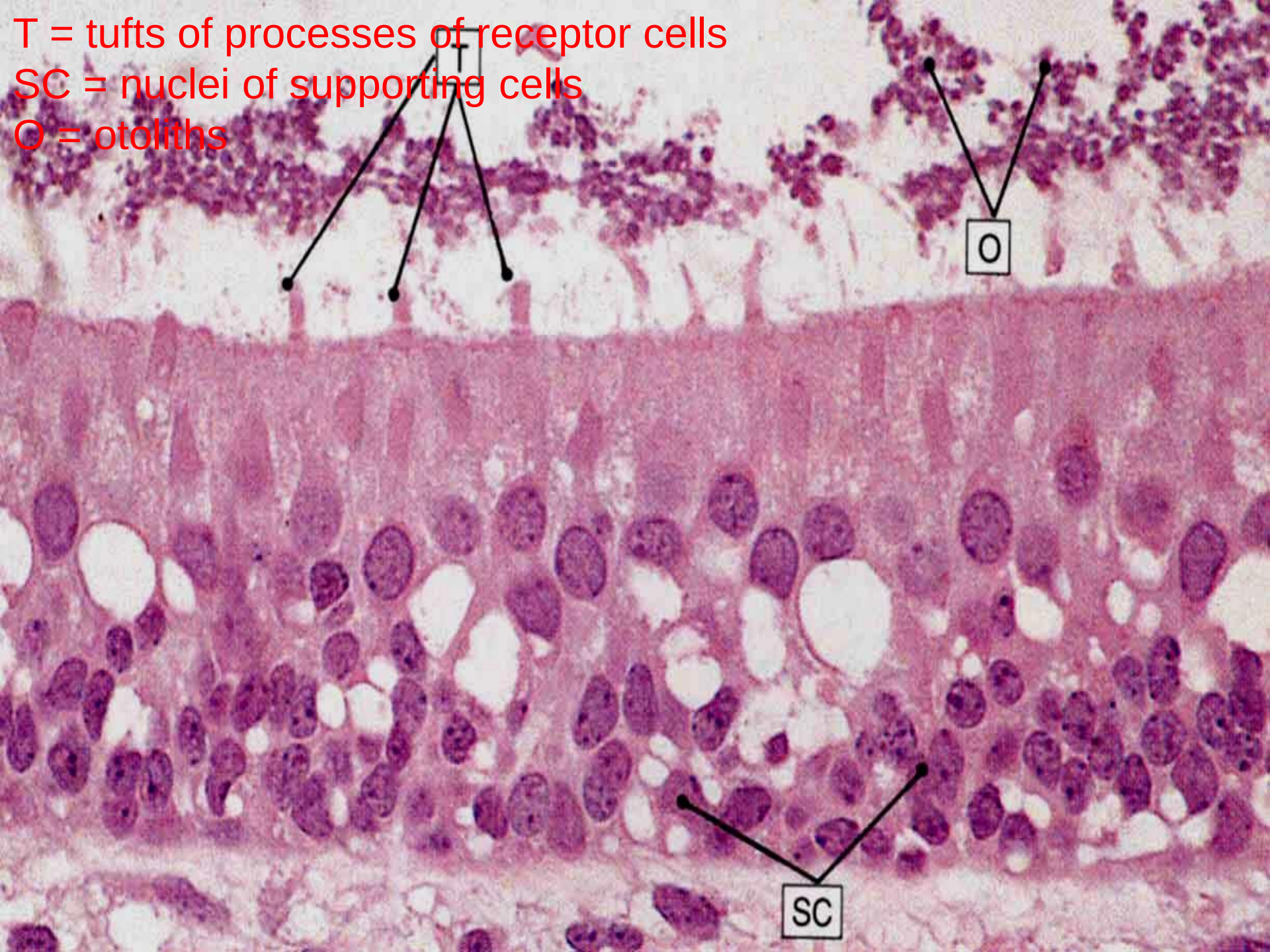
A = epithelium of membranous labyrinth

B = epithelium of macula

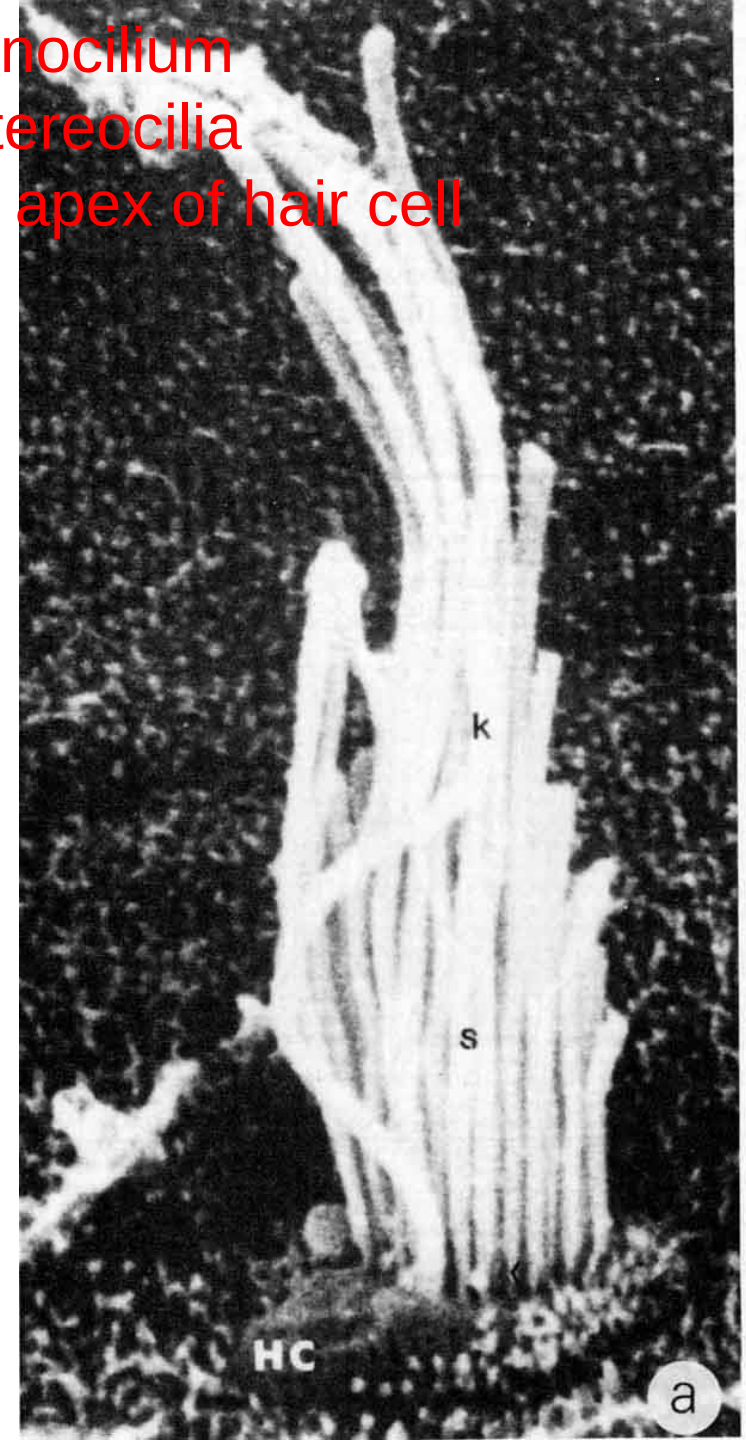


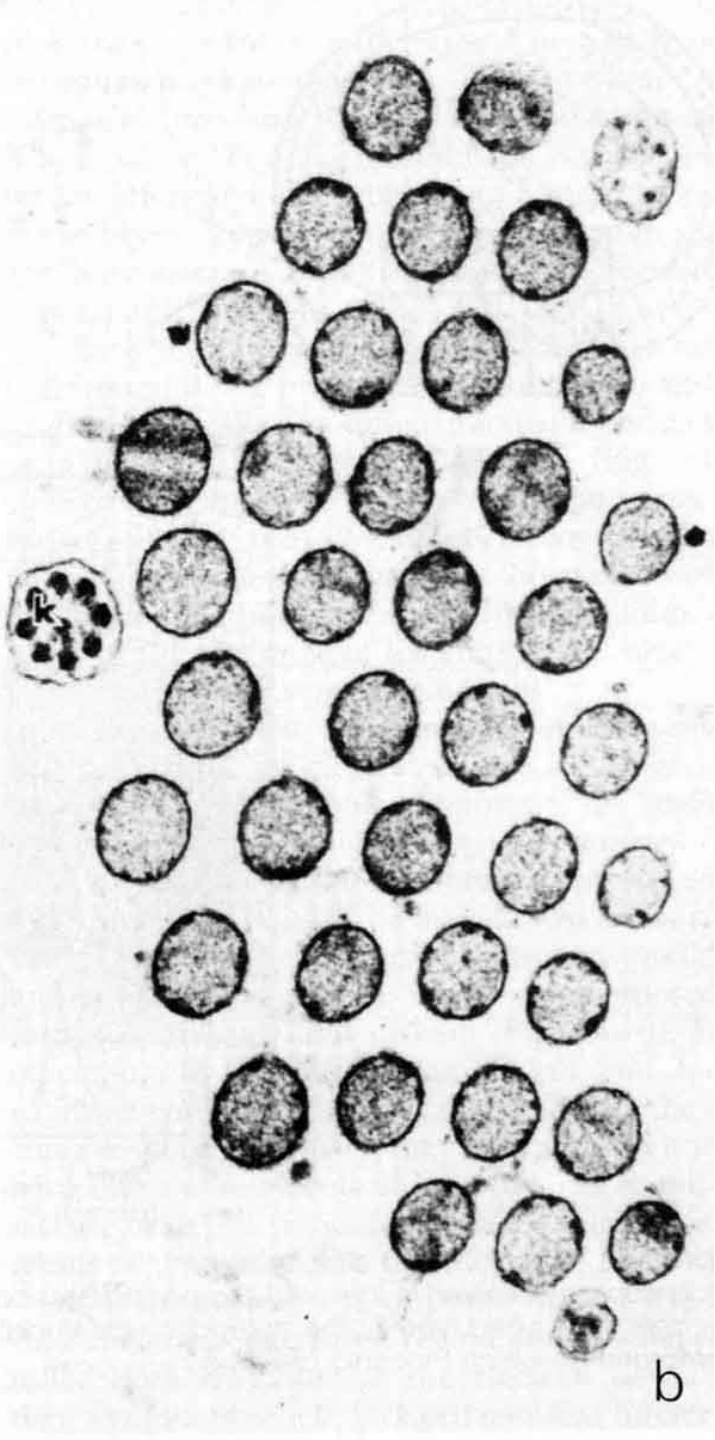
A = otoliths



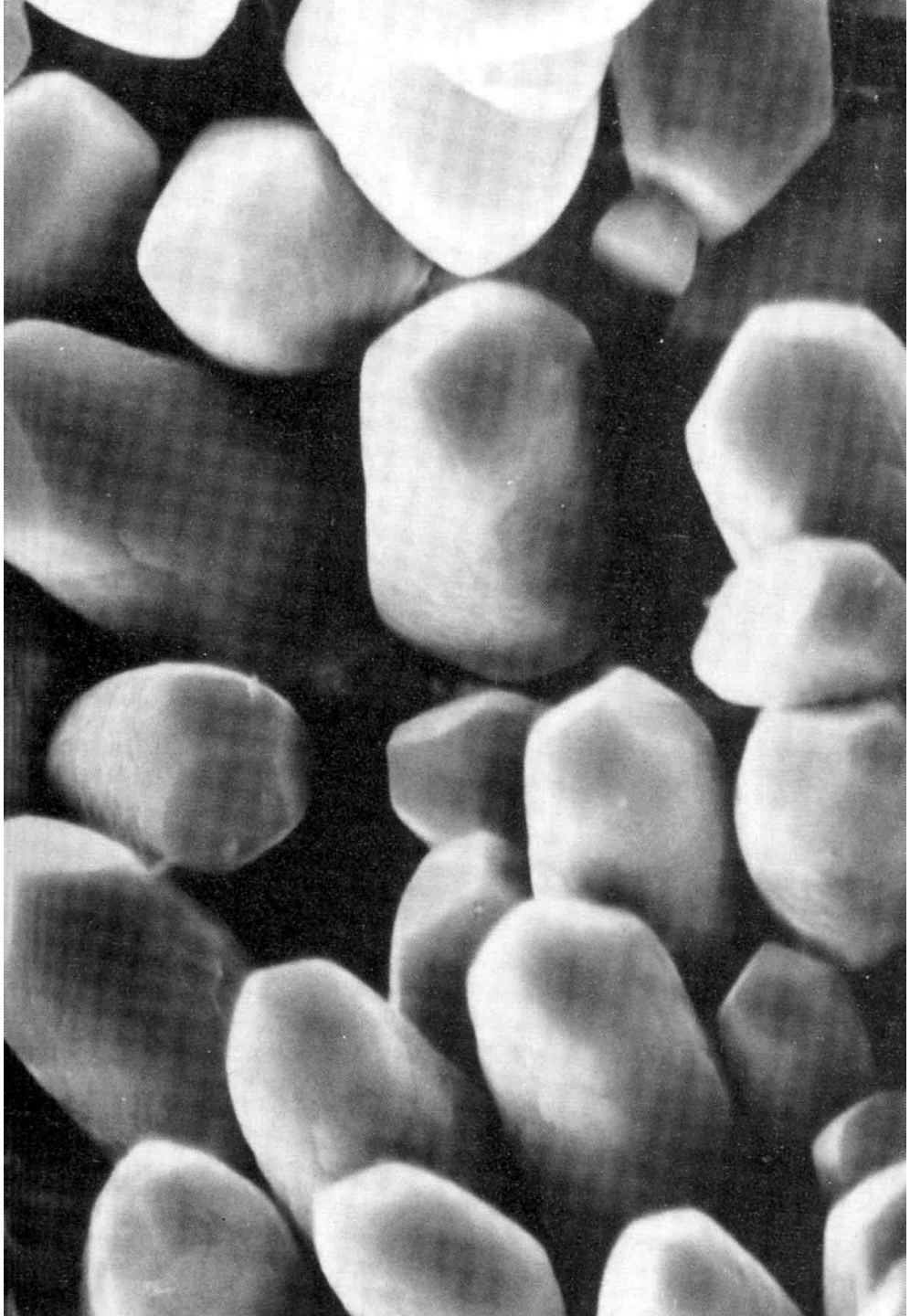

T = tufts of processes of receptor cells
SC = nuclei of supporting cells
O = otoliths
T
O
SC

k = kinocilium
s = stereocilia
HC = apex of hair cell

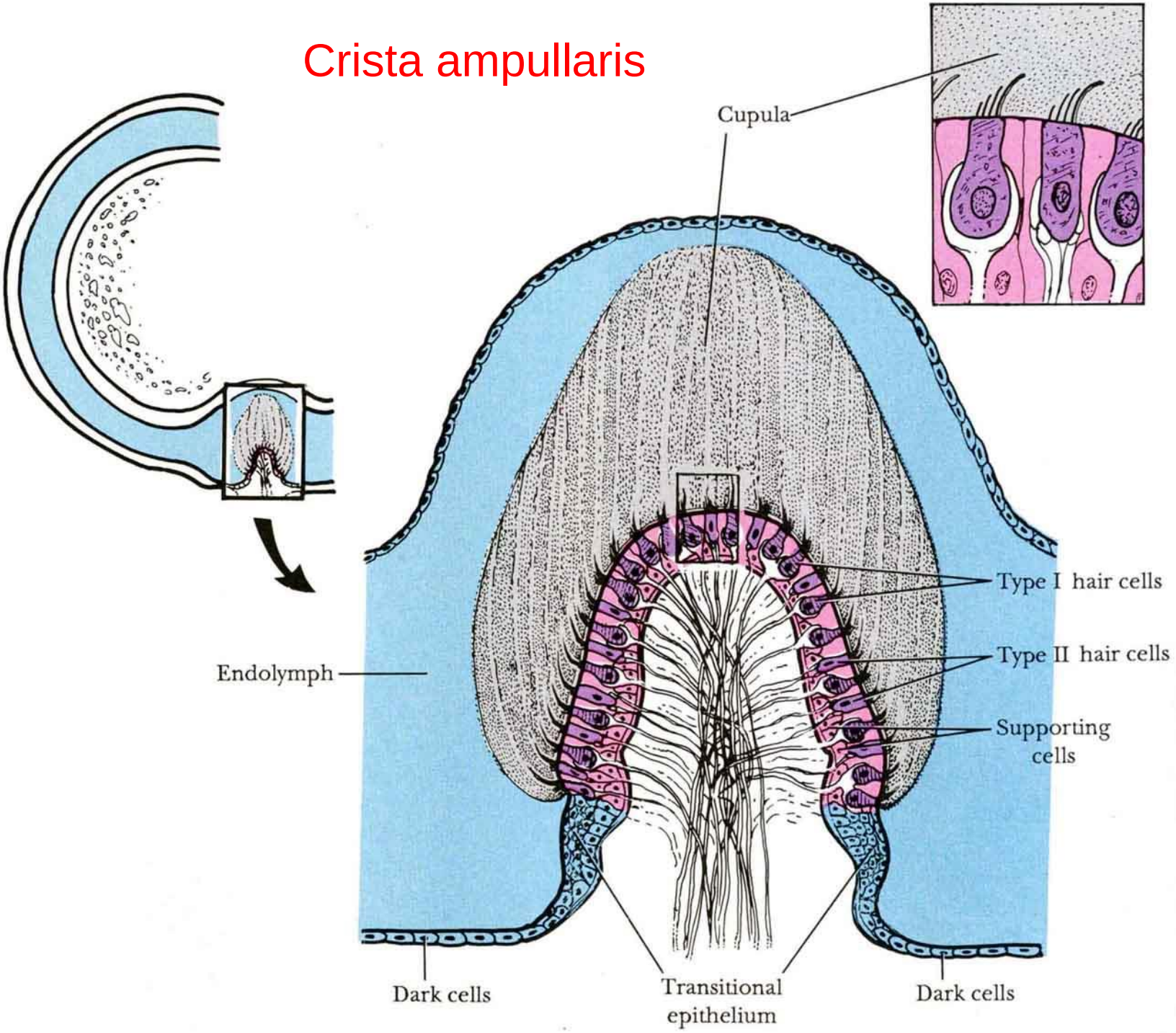




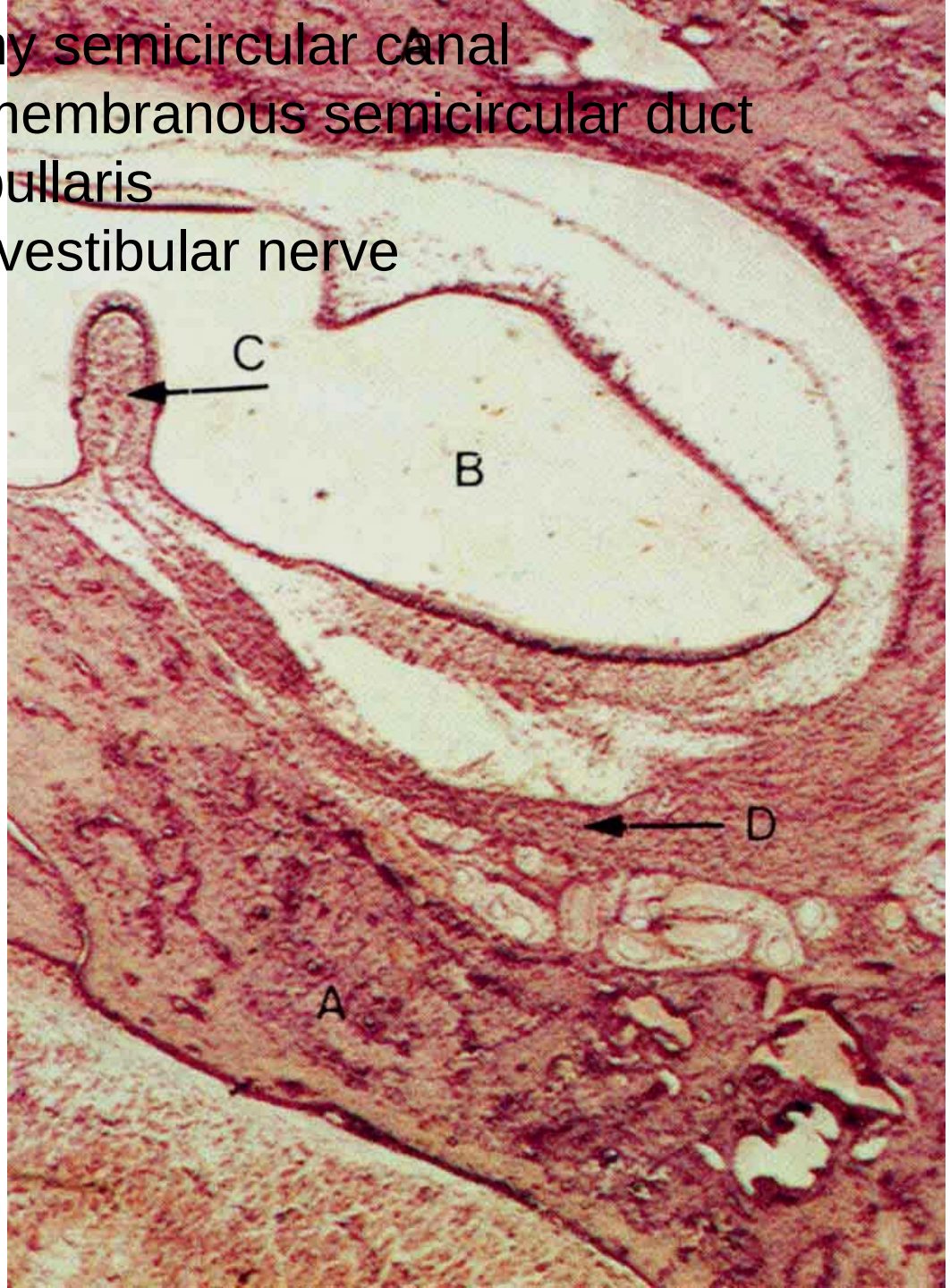
otoliths



Crista ampullaris

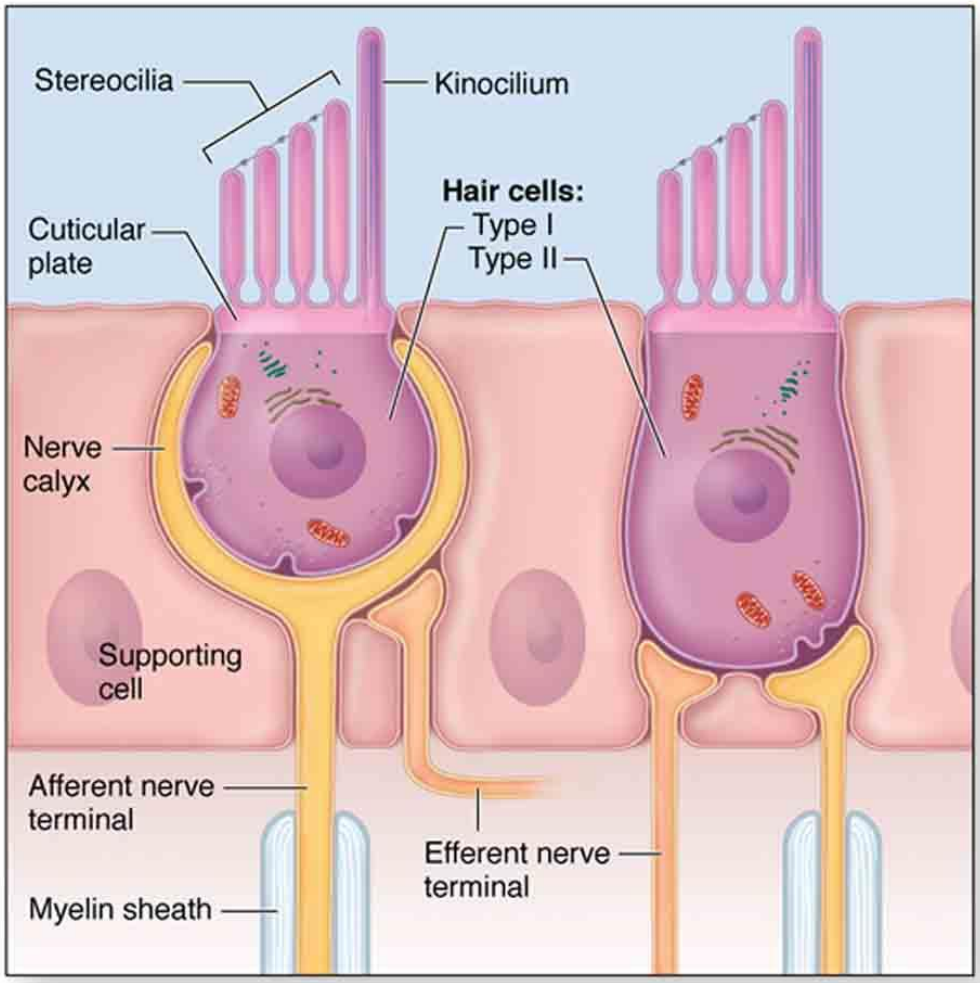


A = wall of bony semicircular canal
B = lumen of membranous semicircular duct
C = crista ampullaris
D = branch of vestibular nerve

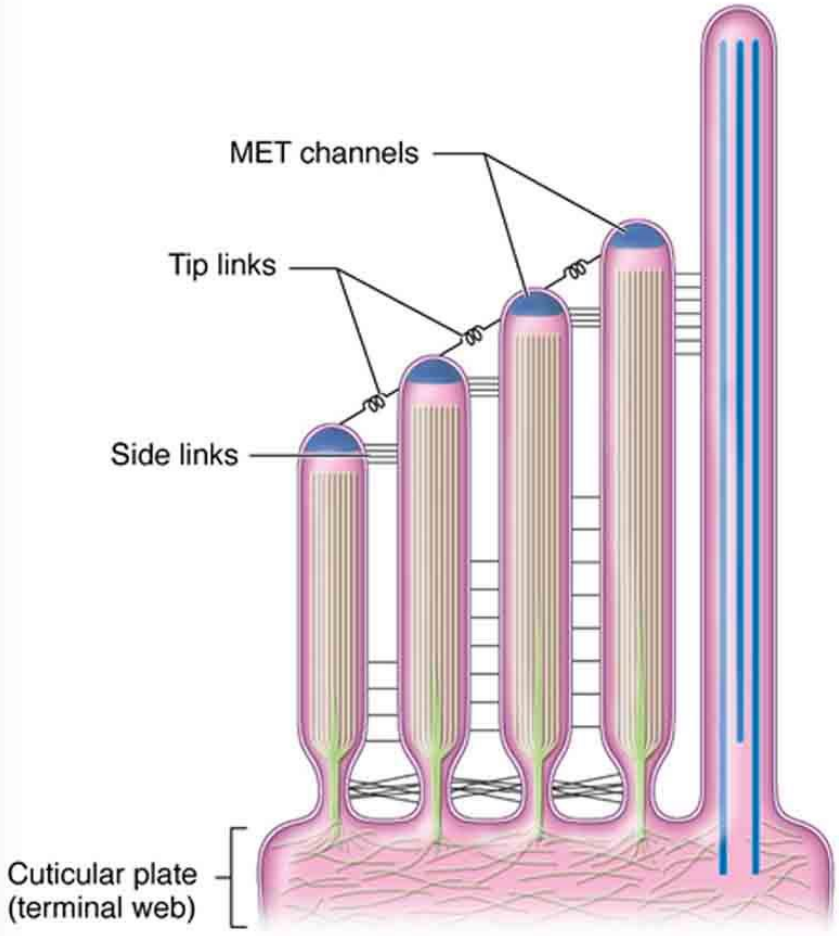


cupula

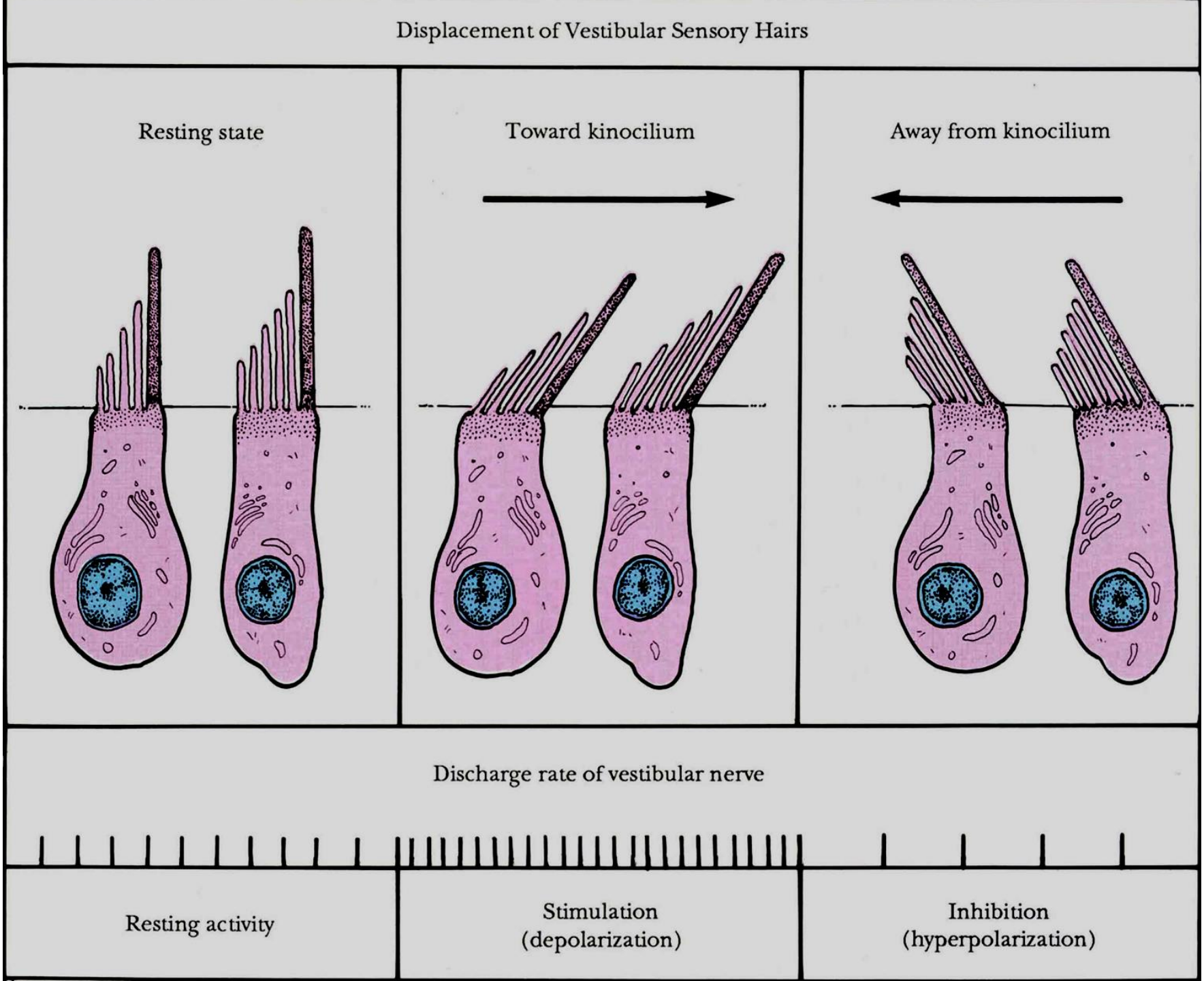
Types of hair cells (same in maculae and cristae)

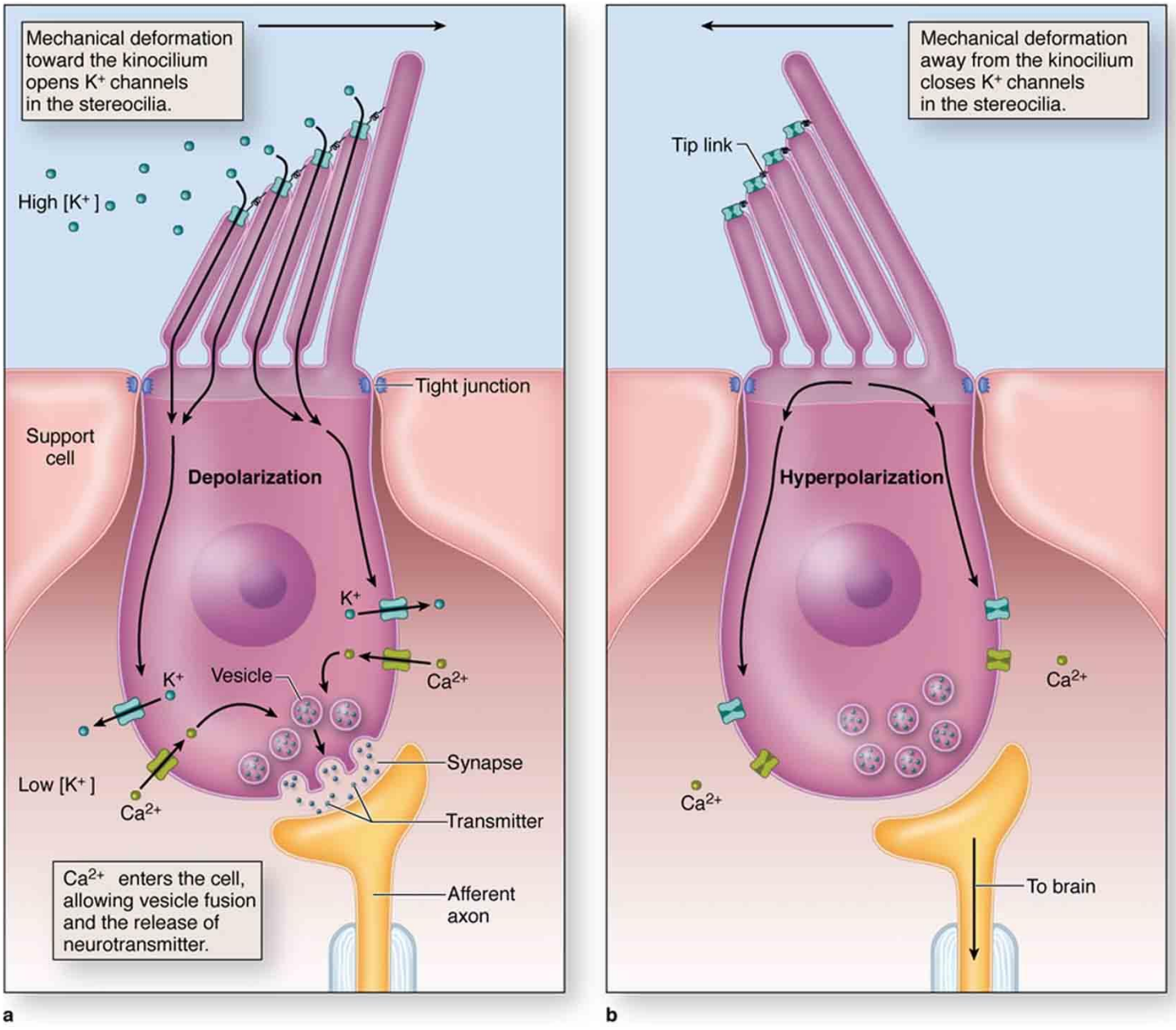


a



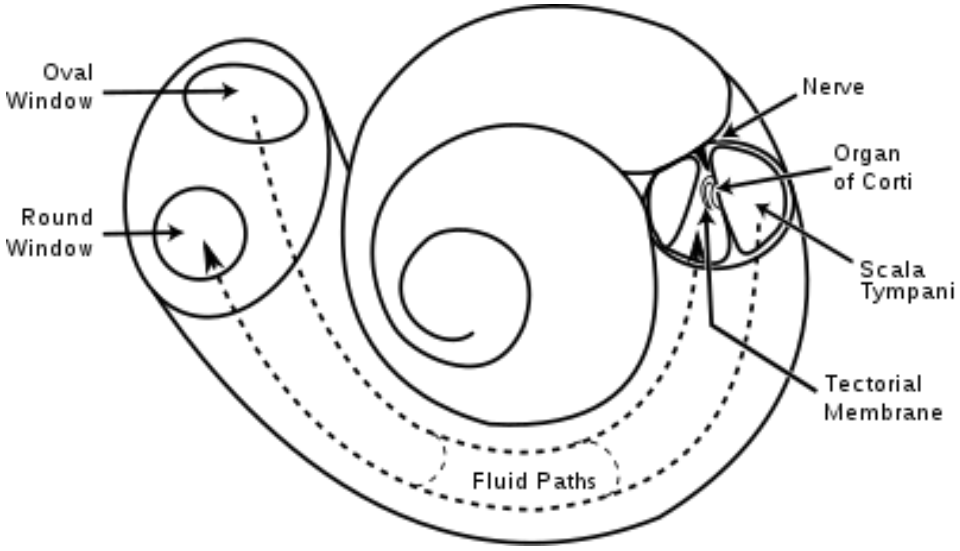
b

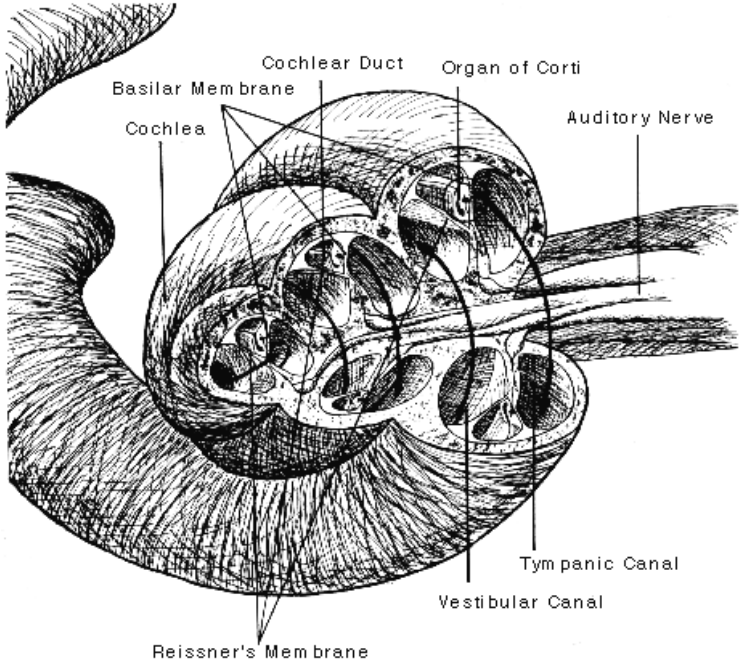

Displacement of Vestibular Sensory Hairs
Resting state
Toward kinocilium
Away from kinocilium
Discharge rate of vestibular nerve
Resting activity
Stimulation
(depolarization)
Inhibition
(hyperpolarization)


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

Corti organ (cochlear apparatus)

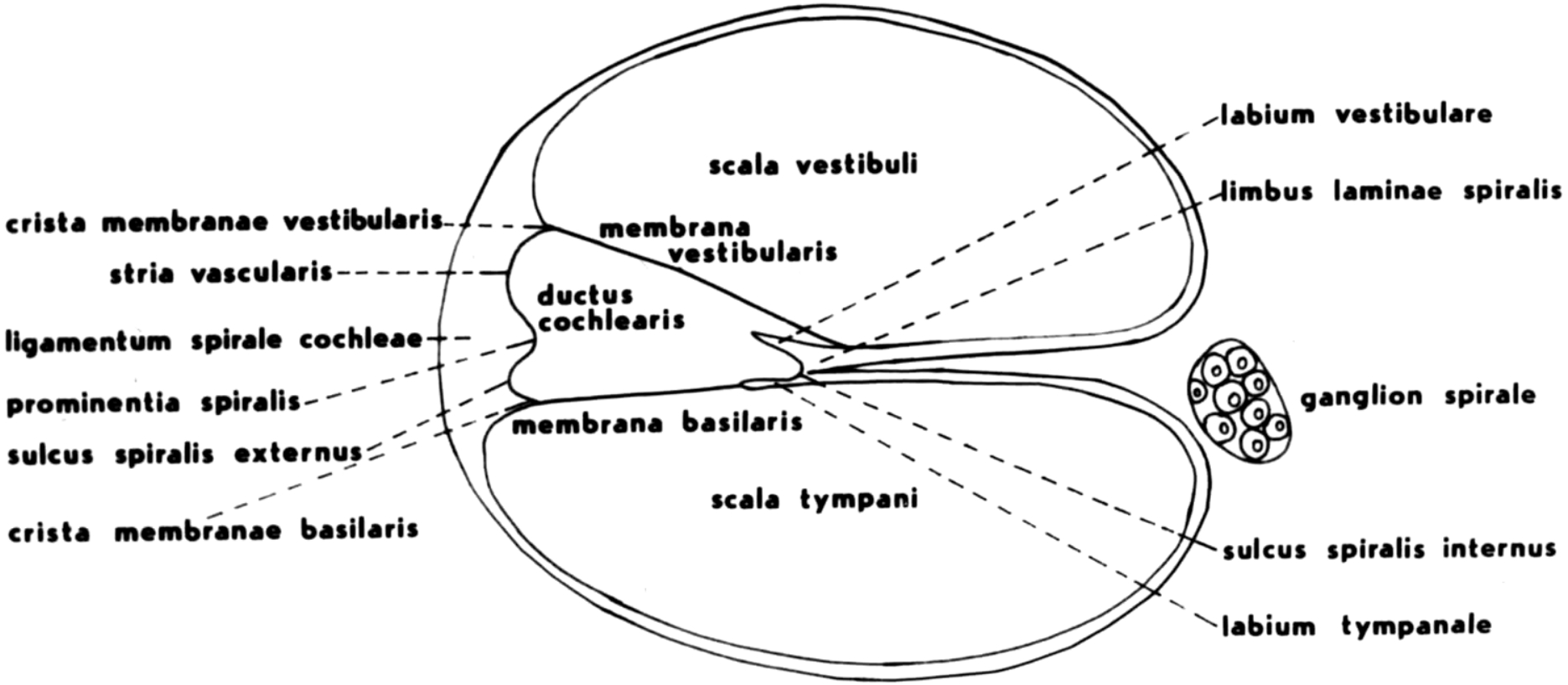
Cochlea

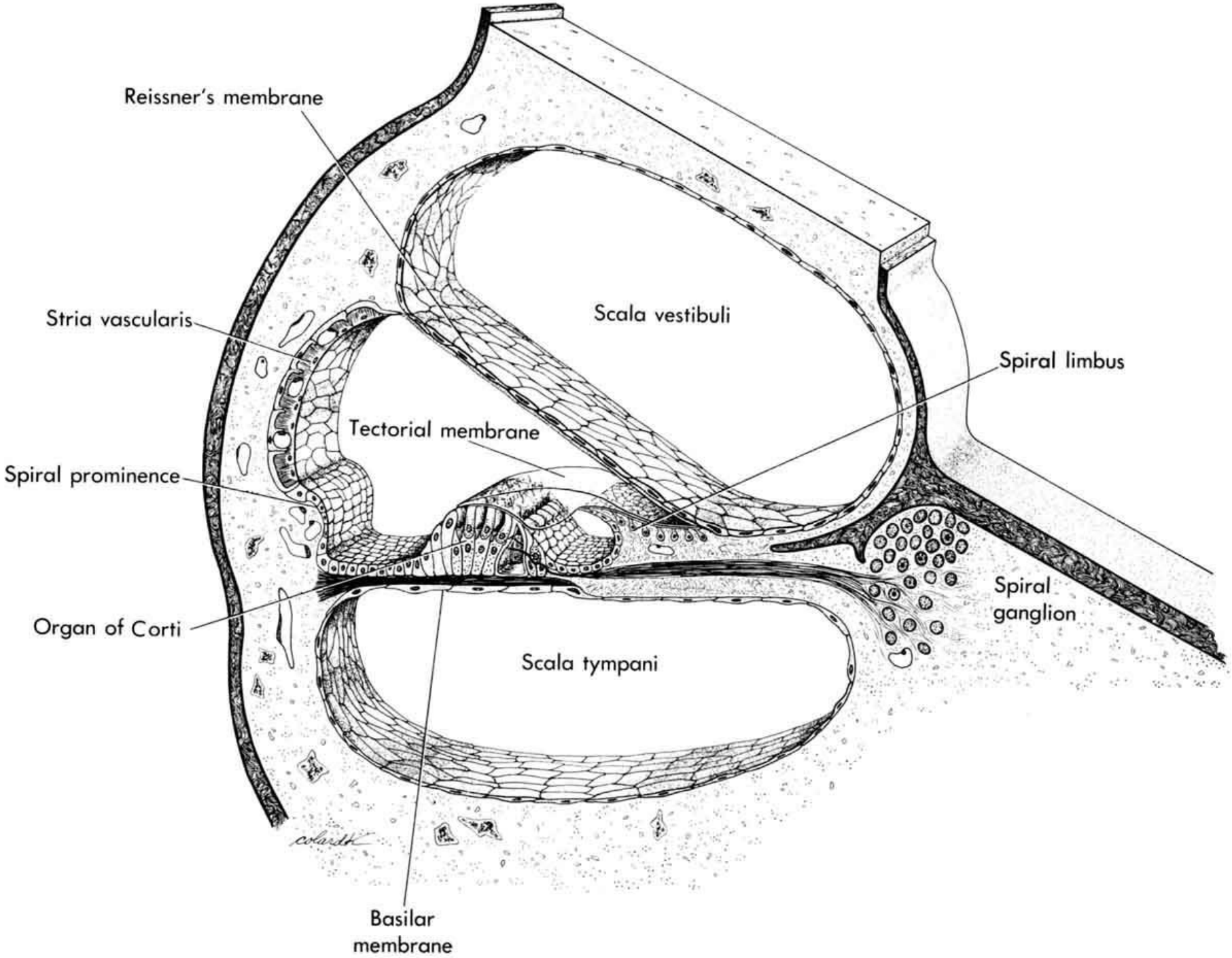

Oval Window
Round Window
Nerve
Organ of Corti
Scala Tympani
Tectorial Membrane
Fluid Paths


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

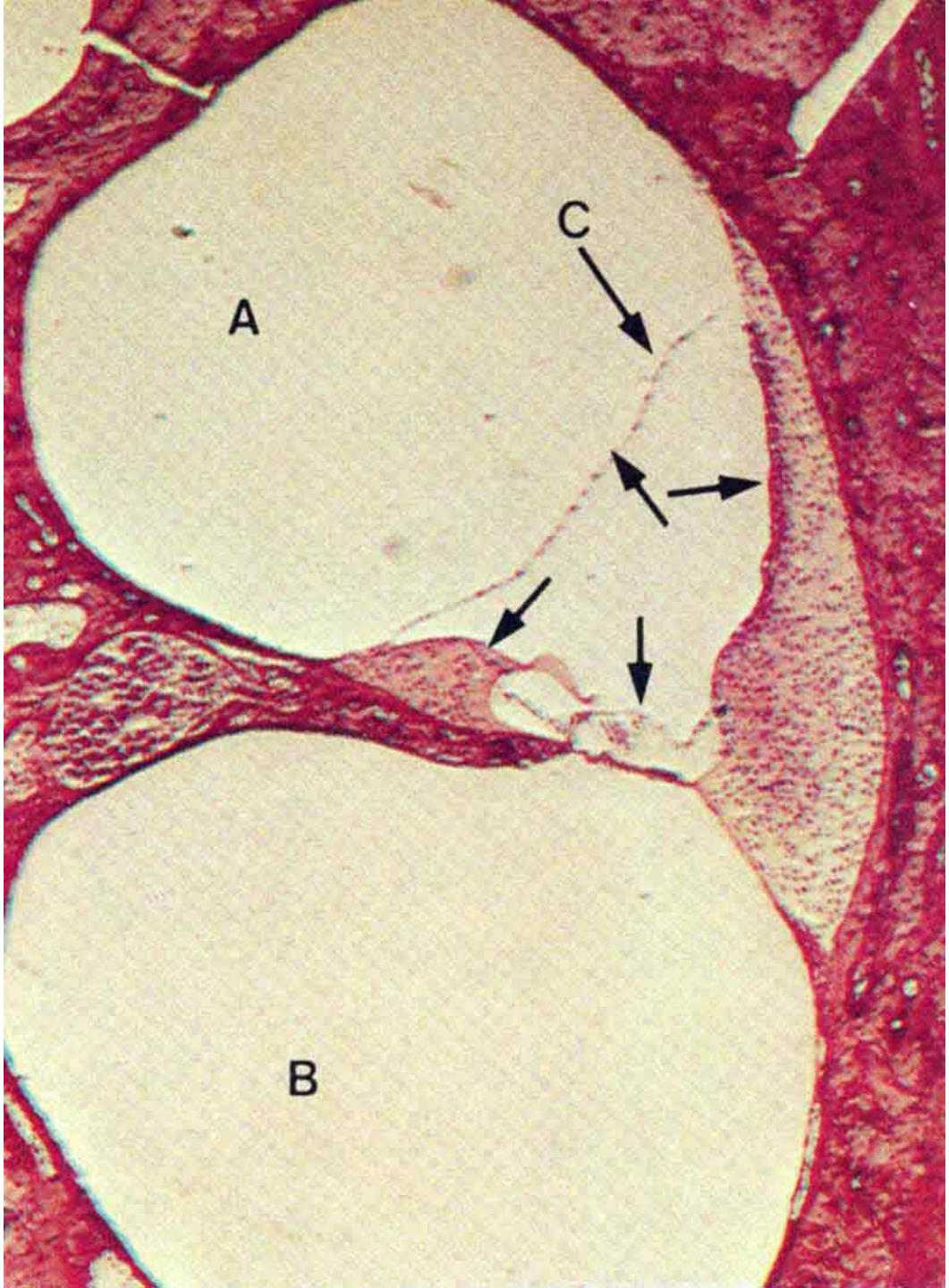

G
SV
SM
ST
G
G
SV
SM
G
ST

TRANSVERSE SECTION OF COCHLEA

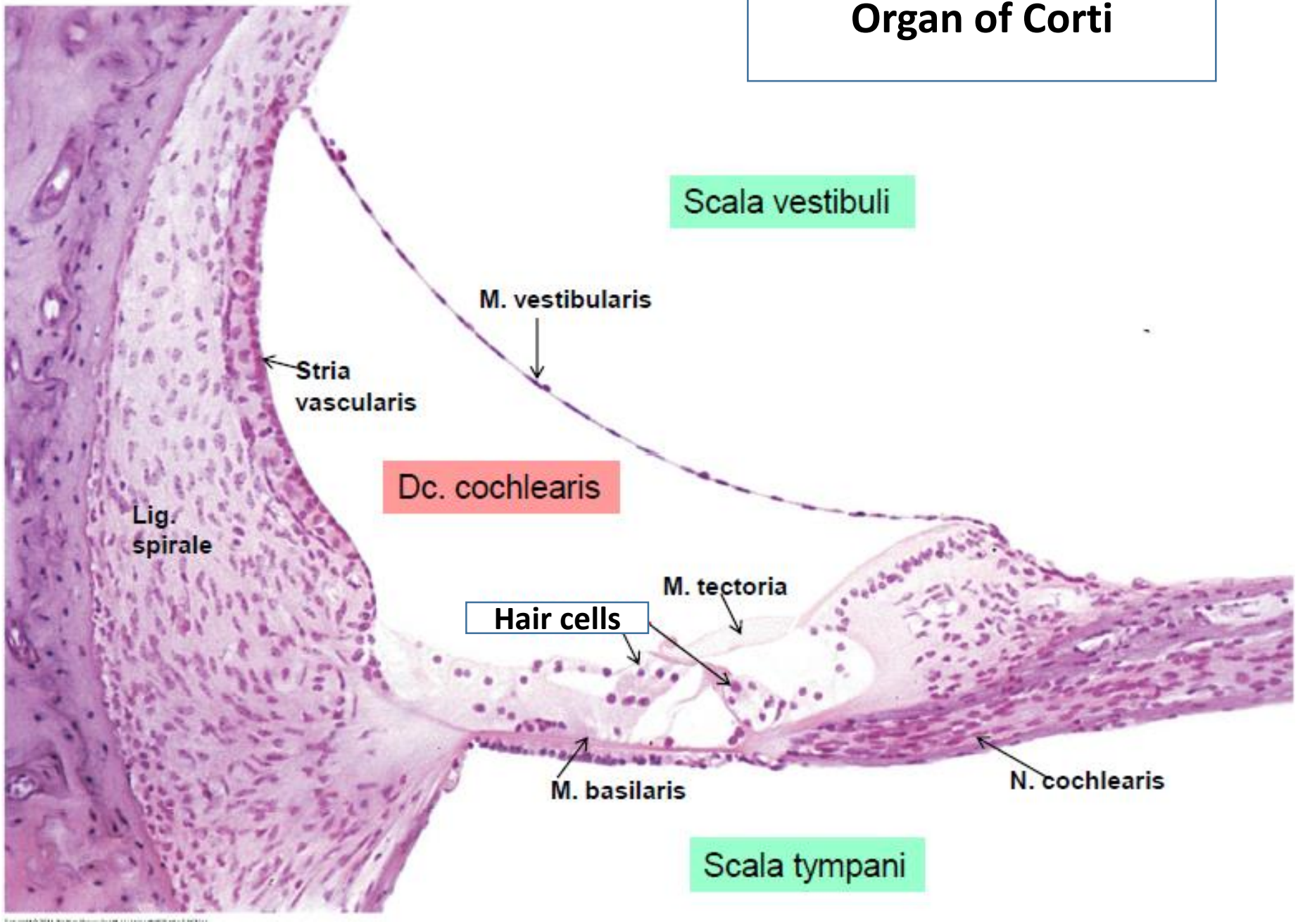


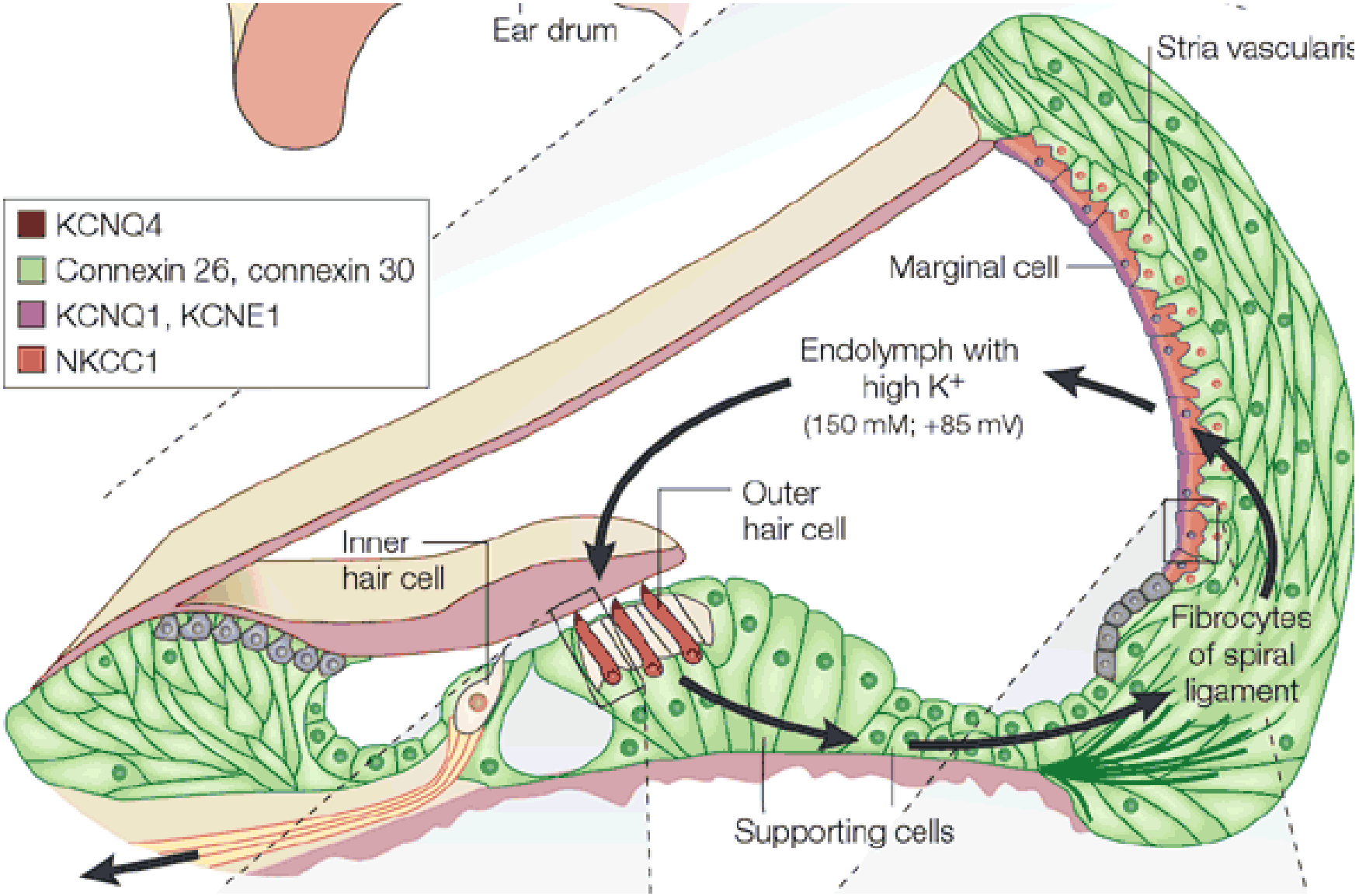

Reissner's membrane
Stria vascularis
Scala vestibuli
Spiral limbus
Tectorial membrane
Spiral prominence
Organ of Corti
Spiral ganglion
Scala tympani
Basilar membrane

A = scala vestibuli
B = scala tympani
C = membrana vestibularis
arrows = epithelium of ductus cochlearis



Organ of Corti

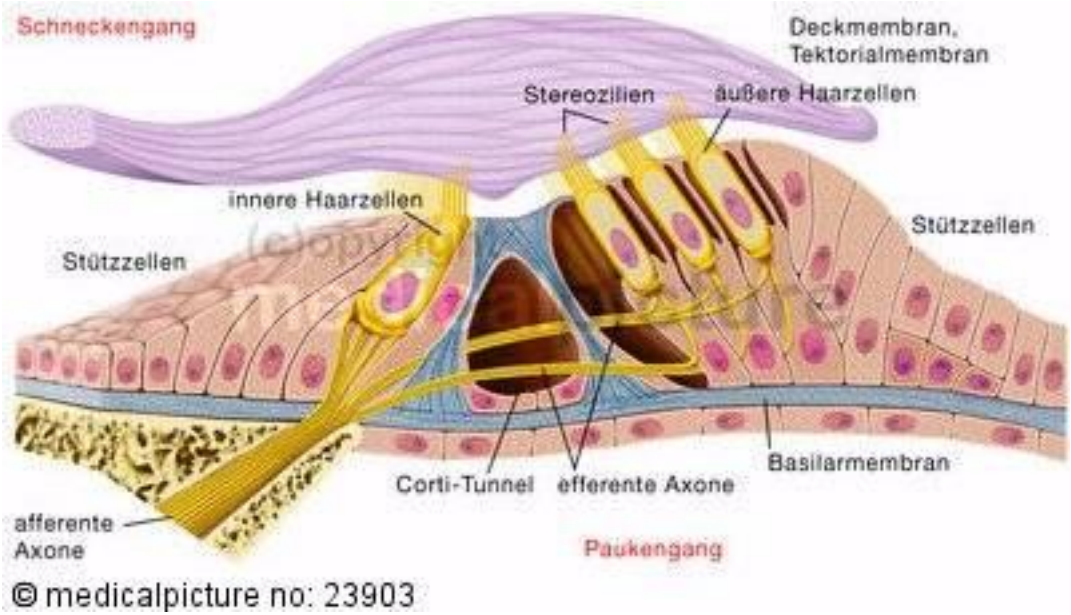



Ear drum
Stria vascularis
KCNQ4
Connexin 26, connexin 30
KCNQ1, KCNE1
NKCC1
Marginal cell
Endolymph with
high K+
(150 mM; +85 mV)
Outer
hair cell
Inner
hair cell
Fibrocytes
of spiral
ligament
Supporting cells

Spaces

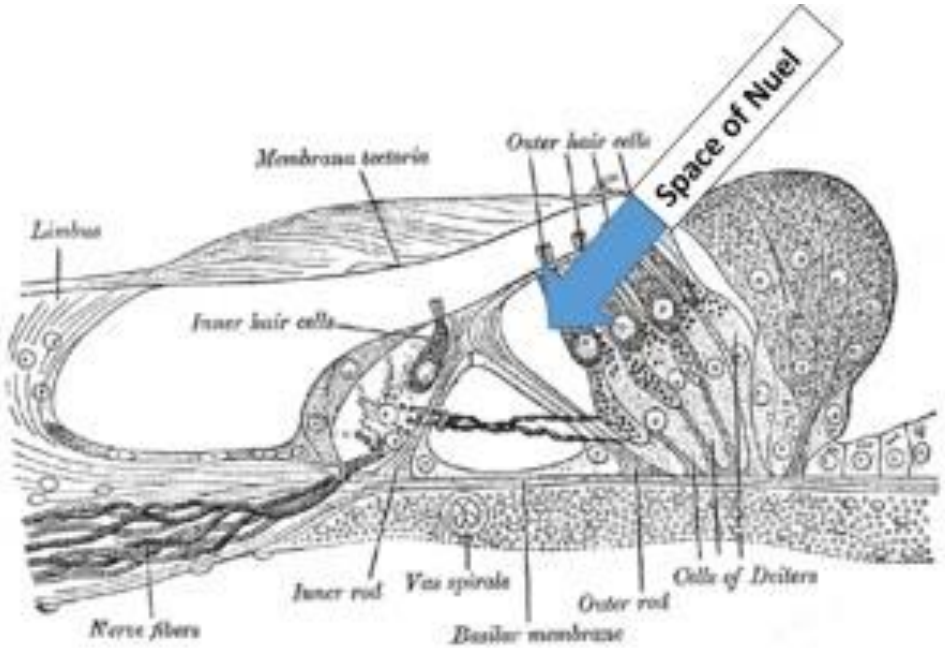
Nuel's space = the space between the outer pillar cell and the first row of phalanx cells and hair cells

tunnel of Corti = space between pillar cells

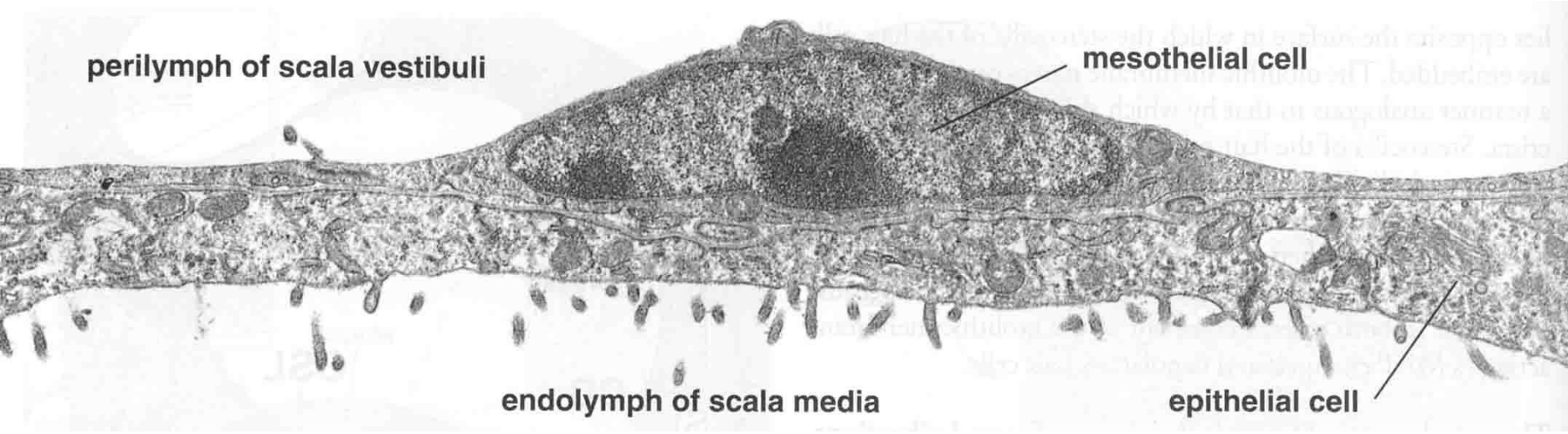


Course of the nerve:

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



Membrana vestibularis (Reissner's membrane)



stria vascularis

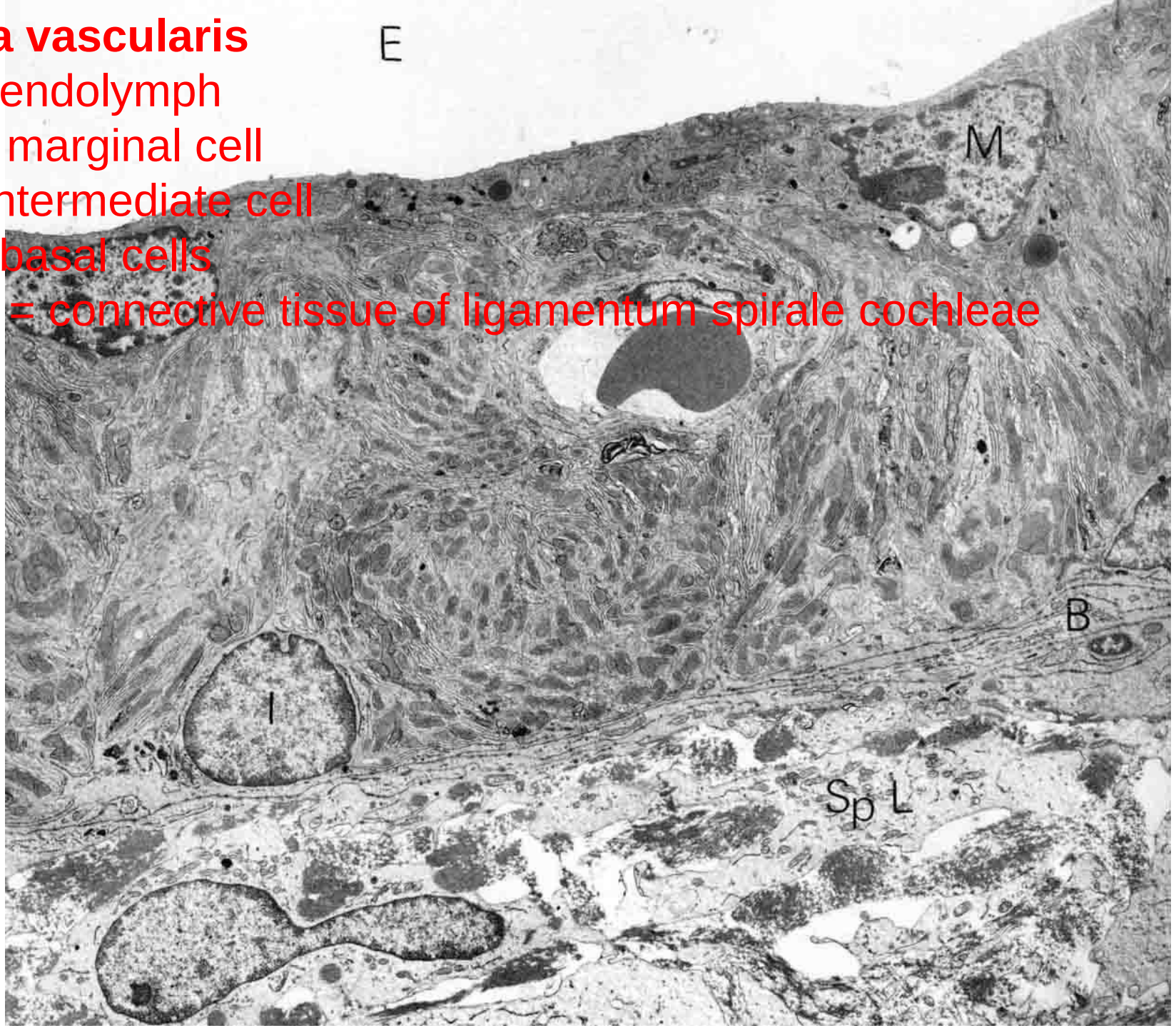
E = endolymph

M = marginal cell

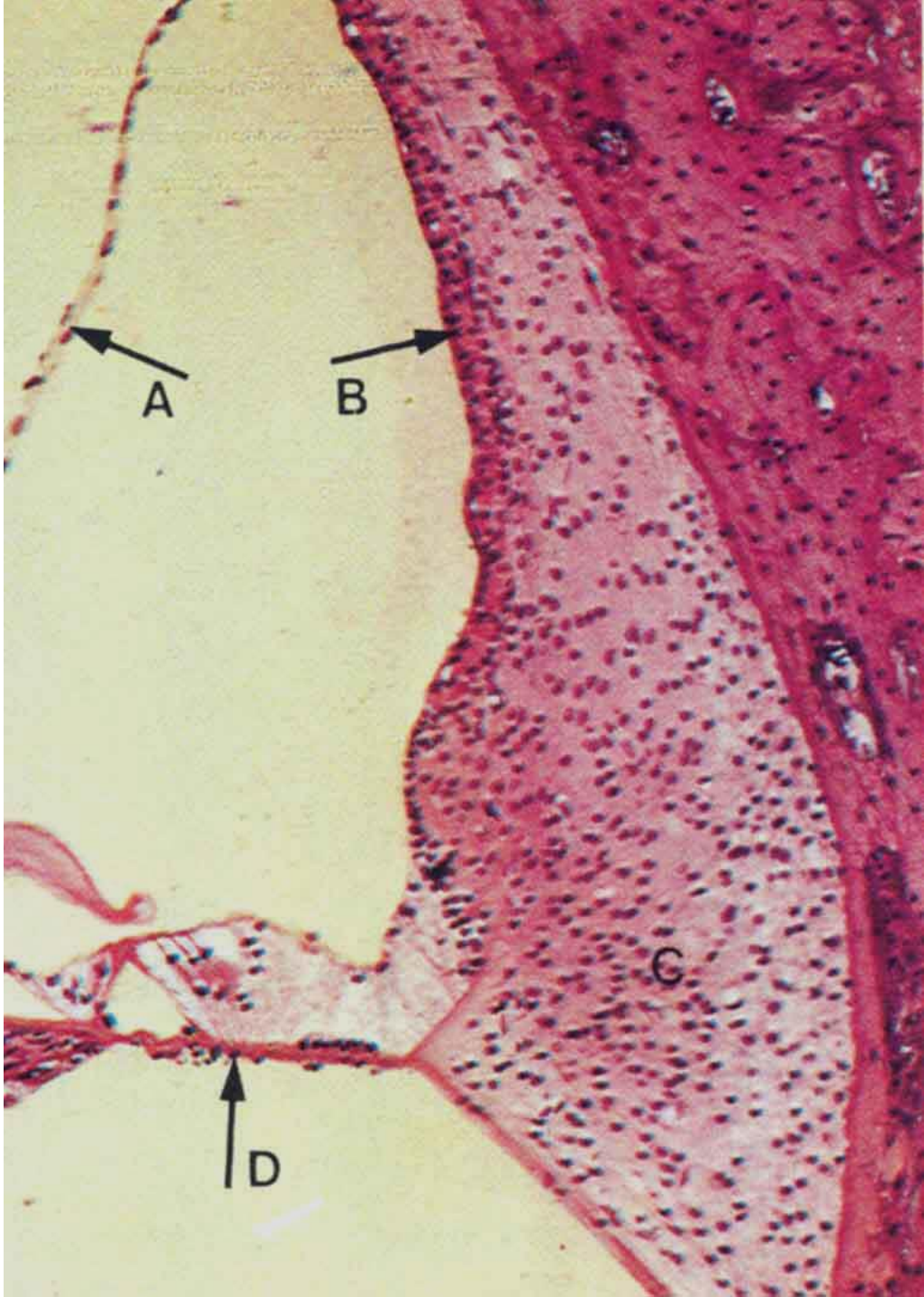
I = intermediate cell

B = basal cells

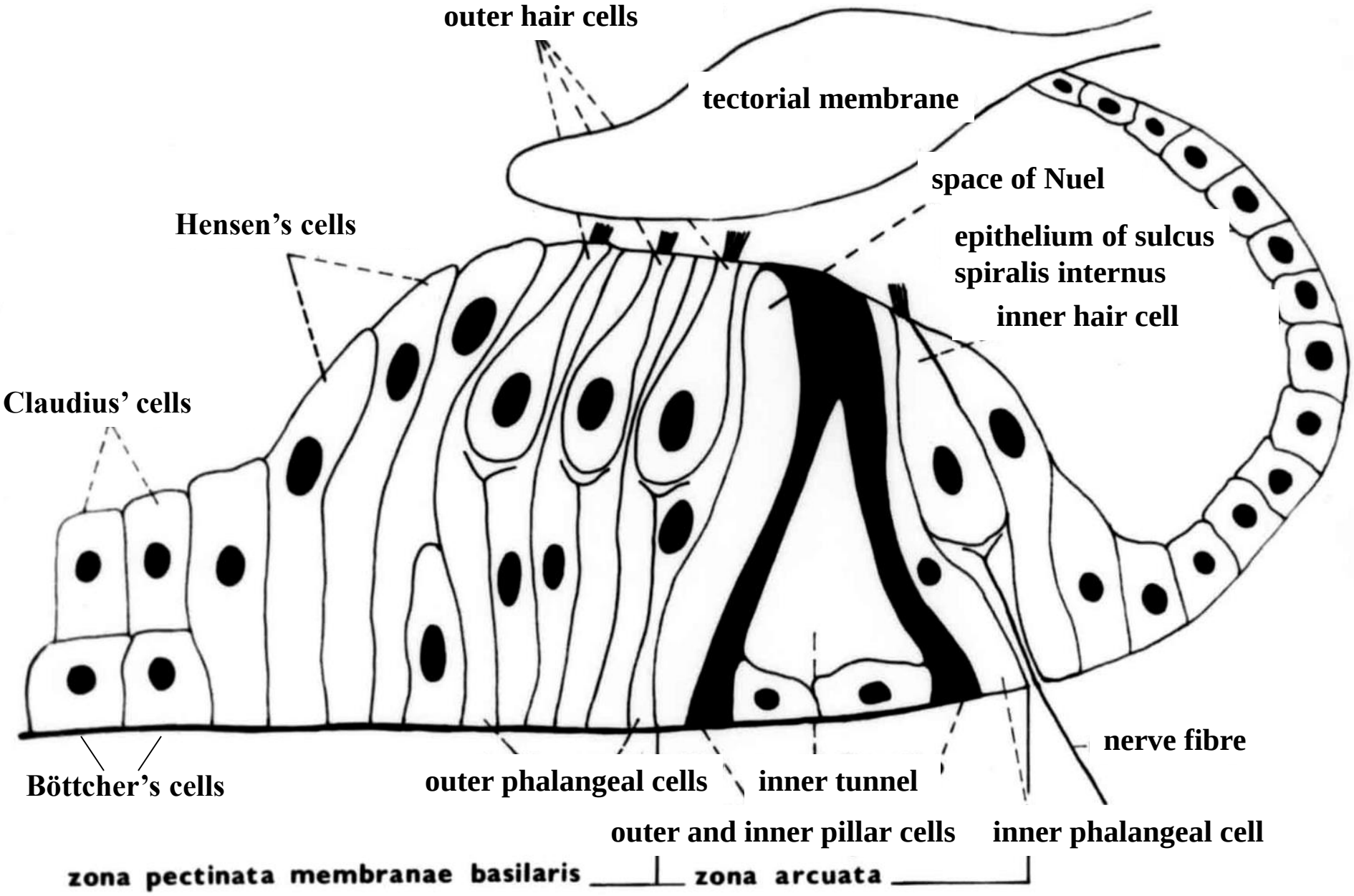
SpL = connective tissue of ligamentum spirale cochleae

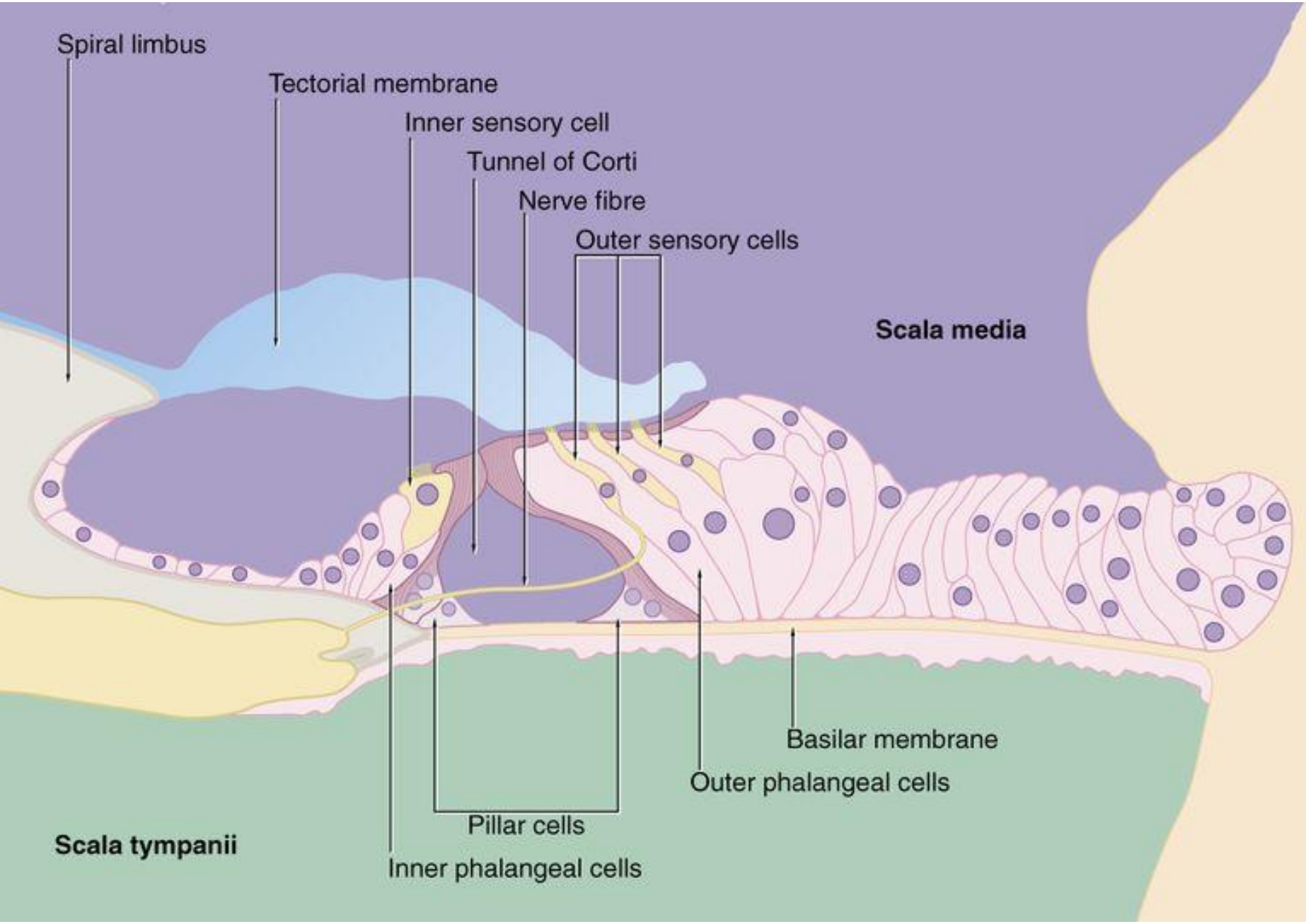


A = membrana vestibularis
B = stria vascularis
C = ligamentum spirale cochleae
D = membrana basilaris

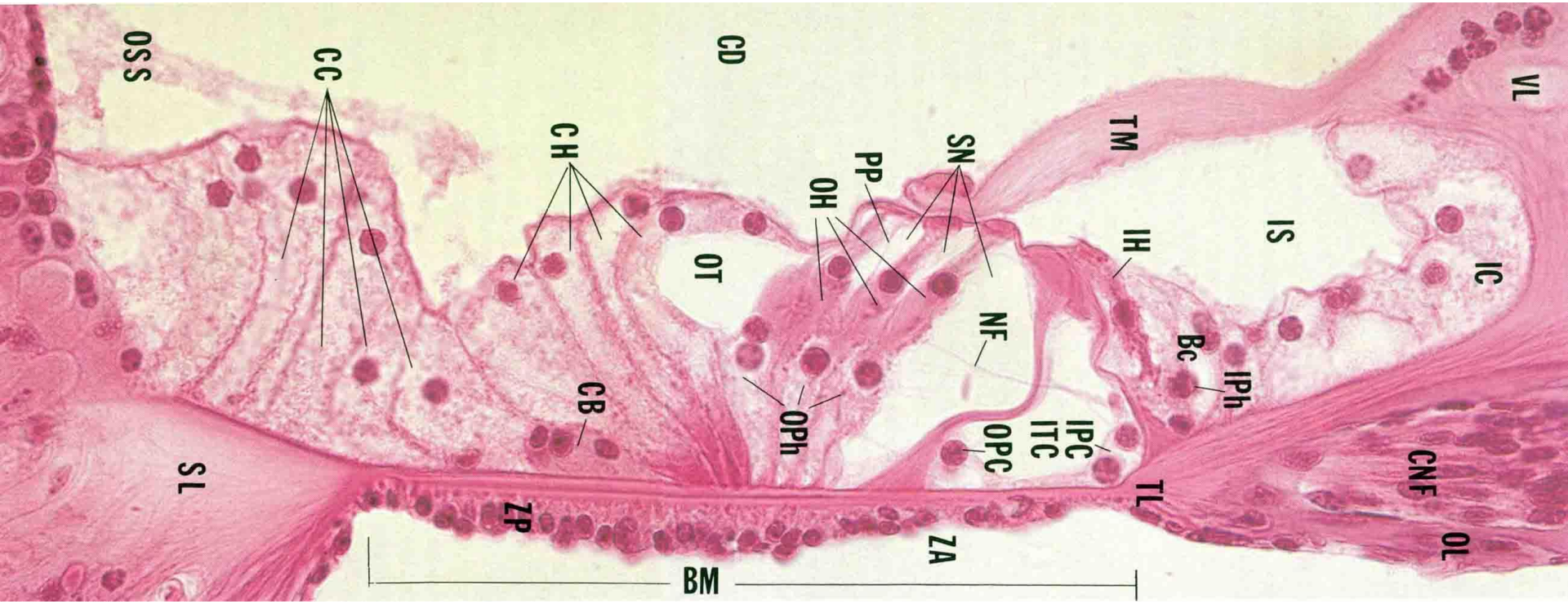


ORGAN OF CORTI

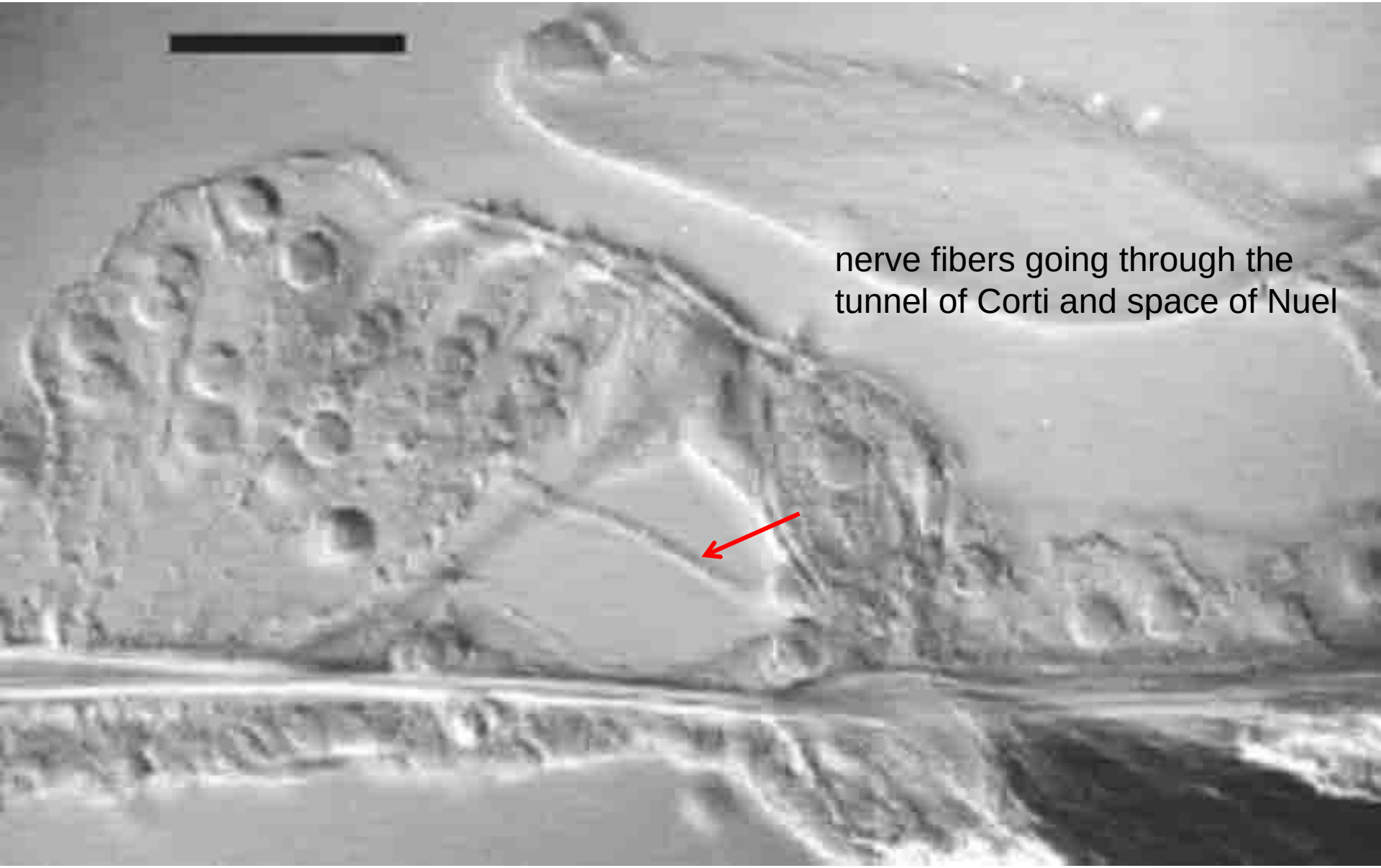


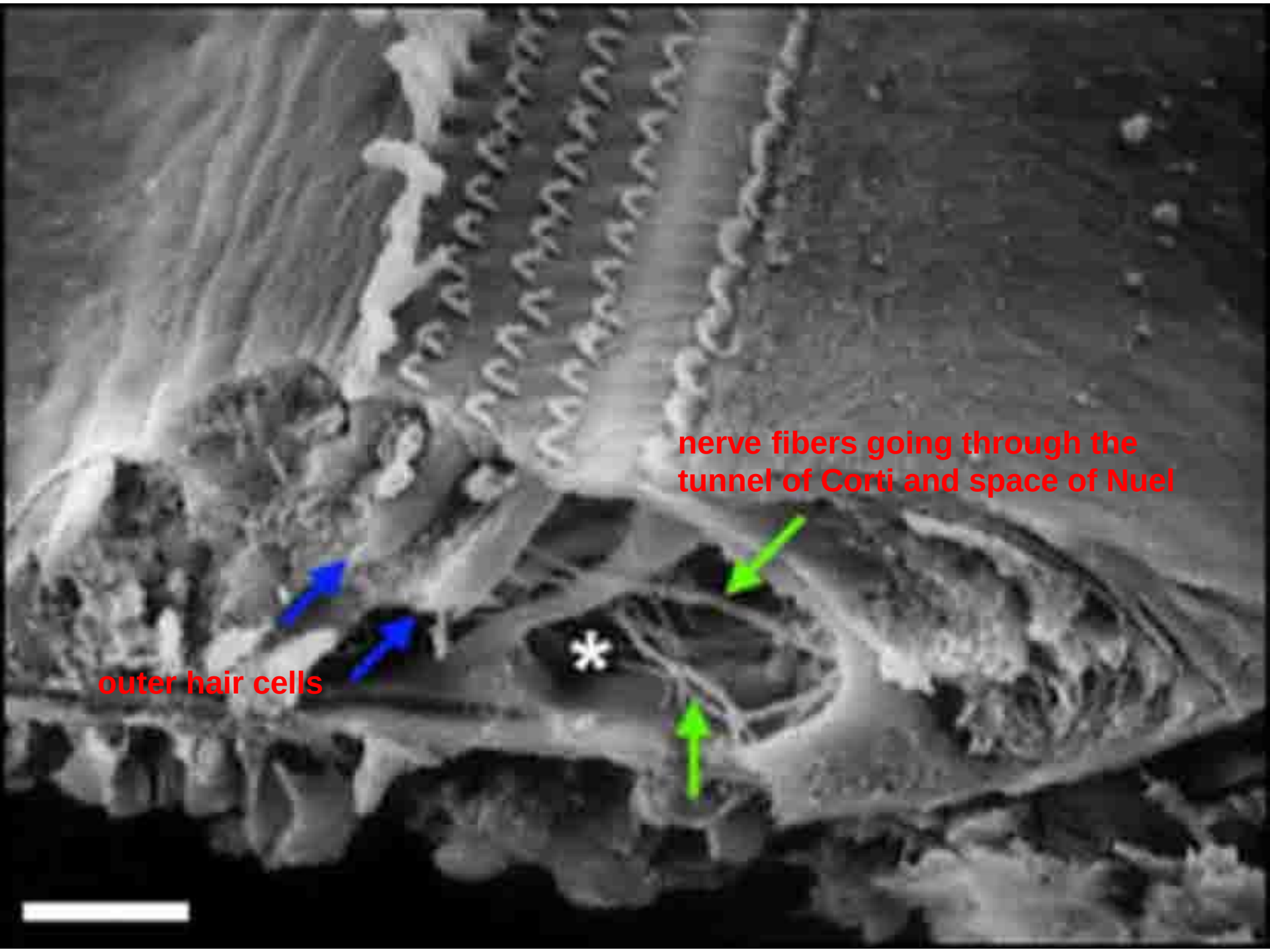

Spiral limbus
Tectorial membrane
Inner sensory cell
Tunnel of Corti
Nerve fibre
Outer sensory cells
Scala media
Basilar membrane
Outer phalangeal cells
Pillar cells
Scala tympanii
Inner phalangeal cells

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


nerve fibers going through the
tunnel of Corti and space of Nuel


nerve fibers going through the
tunnel of Corti and space of Nuel
outer hair cells

inner hair cell

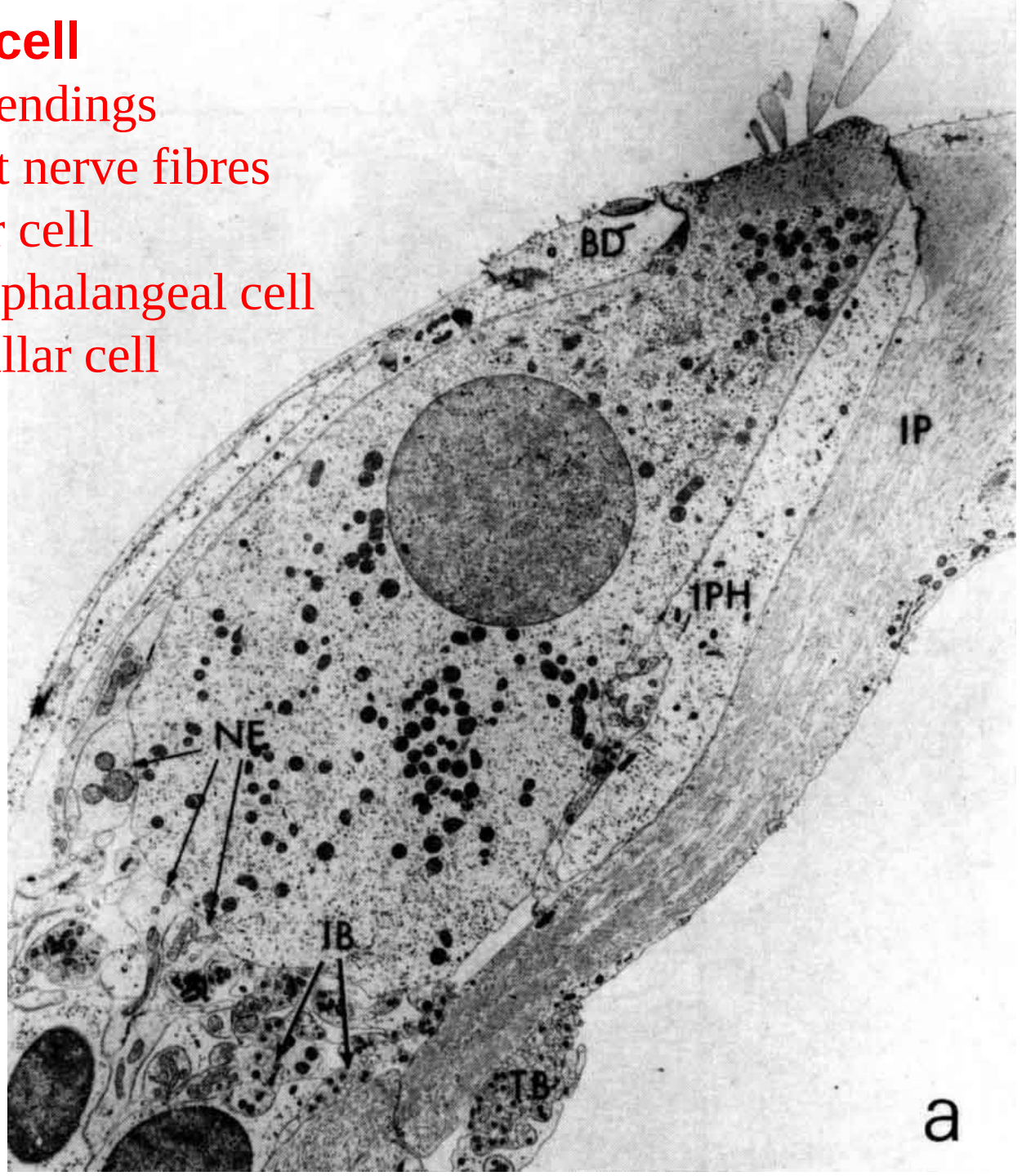
NE = nerve endings

IB = afferent nerve fibres

BD = border cell

IPH = inner phalangeal cell

IP = inner pillar cell

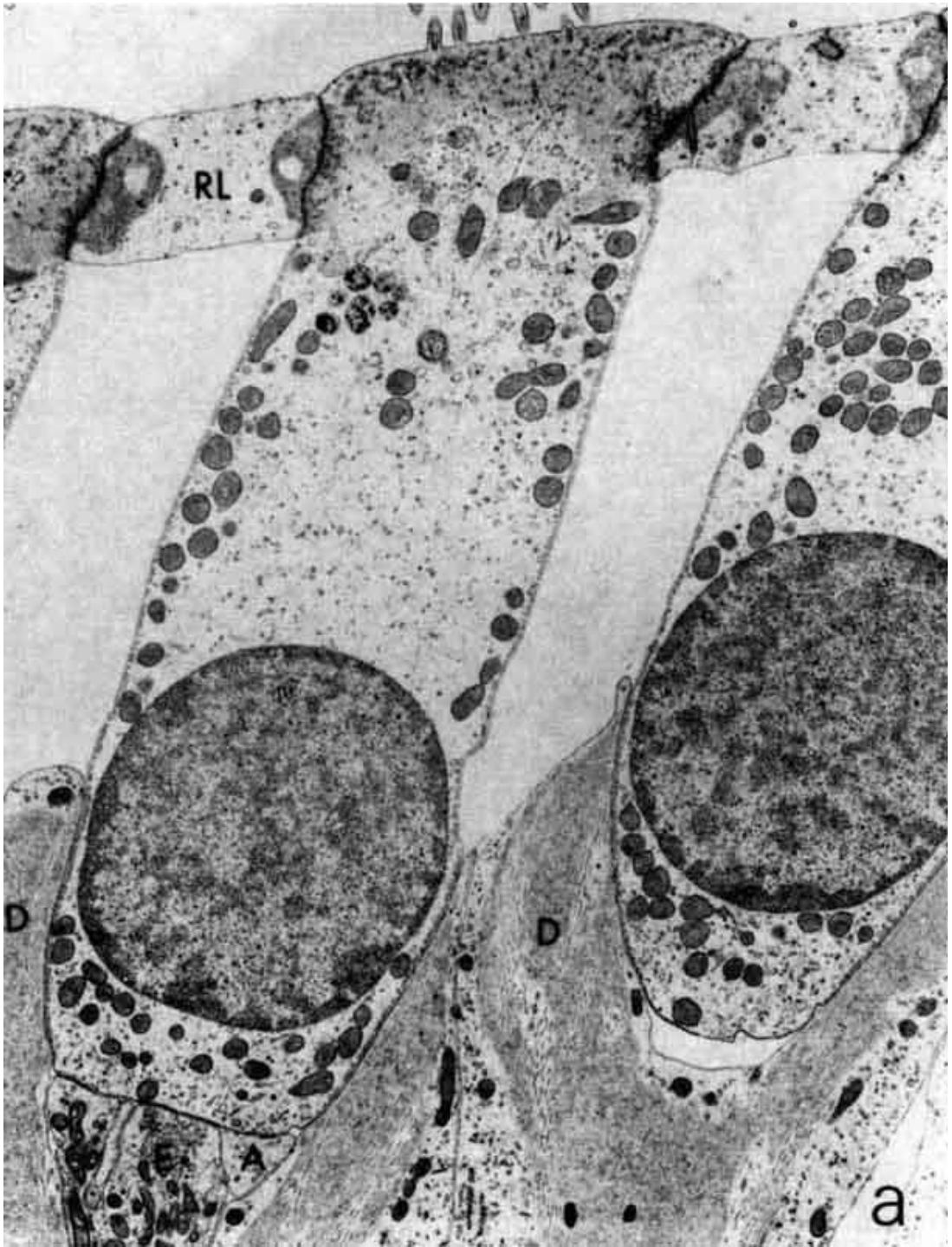


outer hair cells

E,A = nerve endings

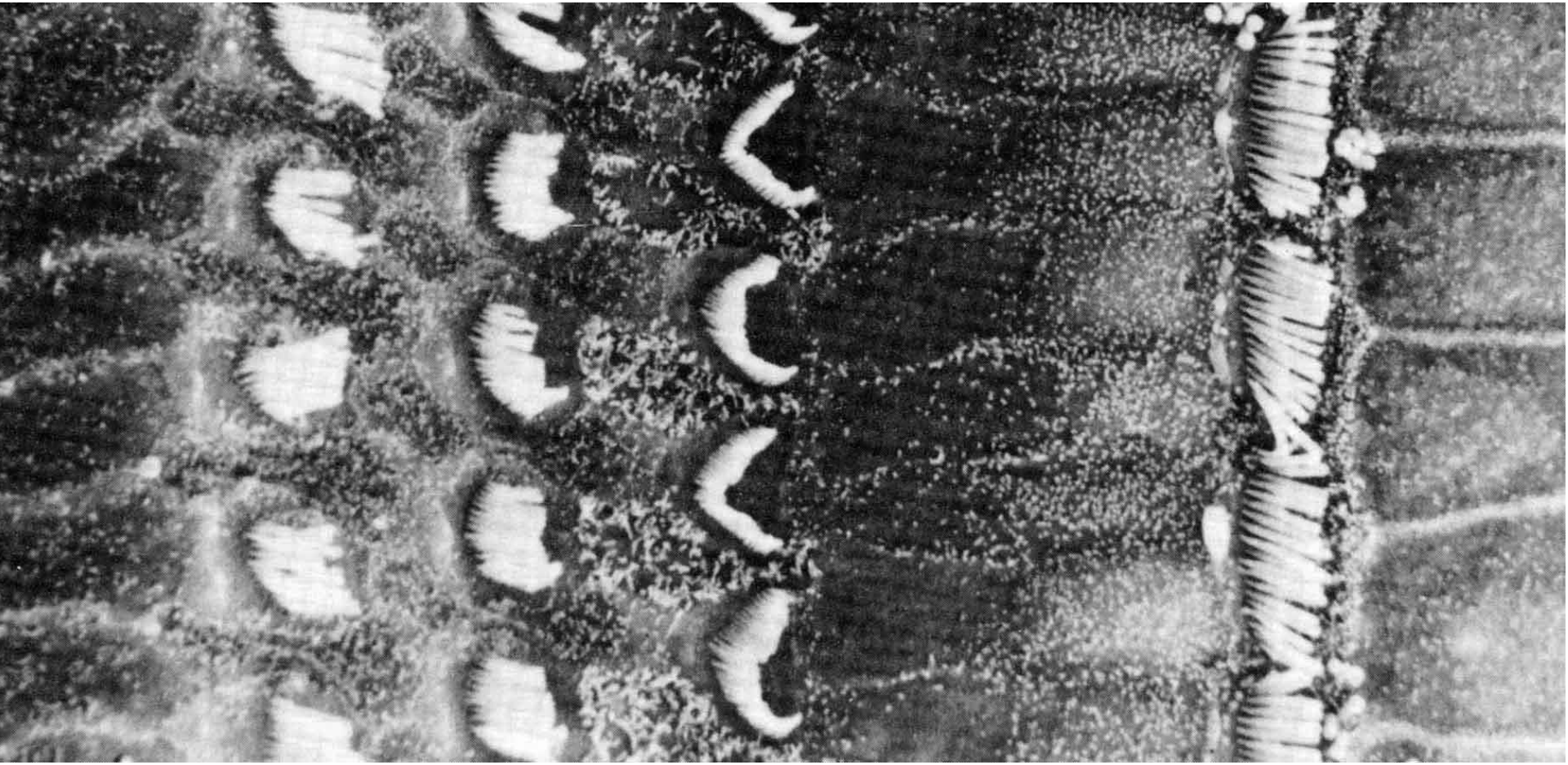
D = Deiters' cells

RL = distended end of process of Deiters' cell

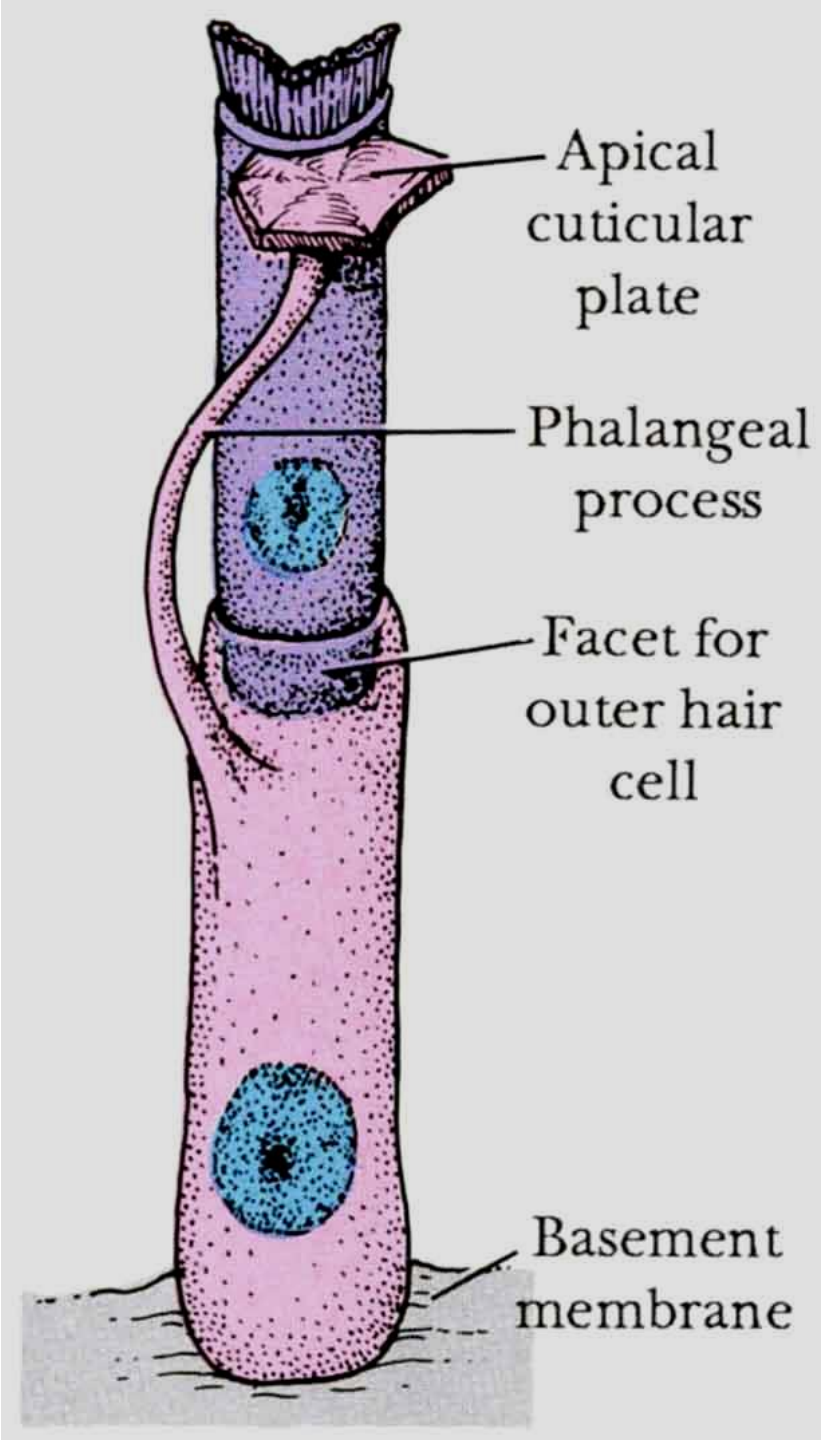


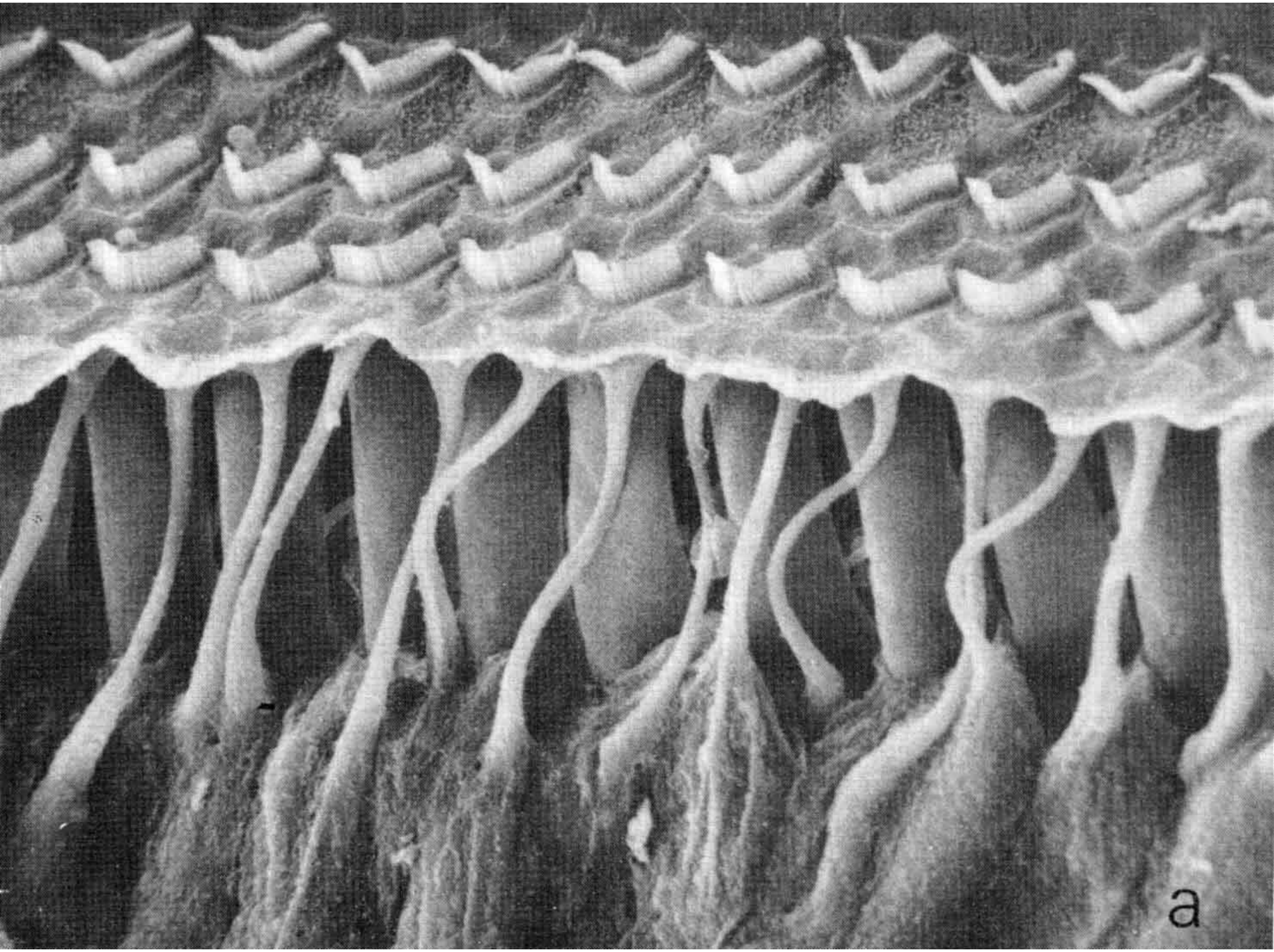
outer hair cells

inner hair cells

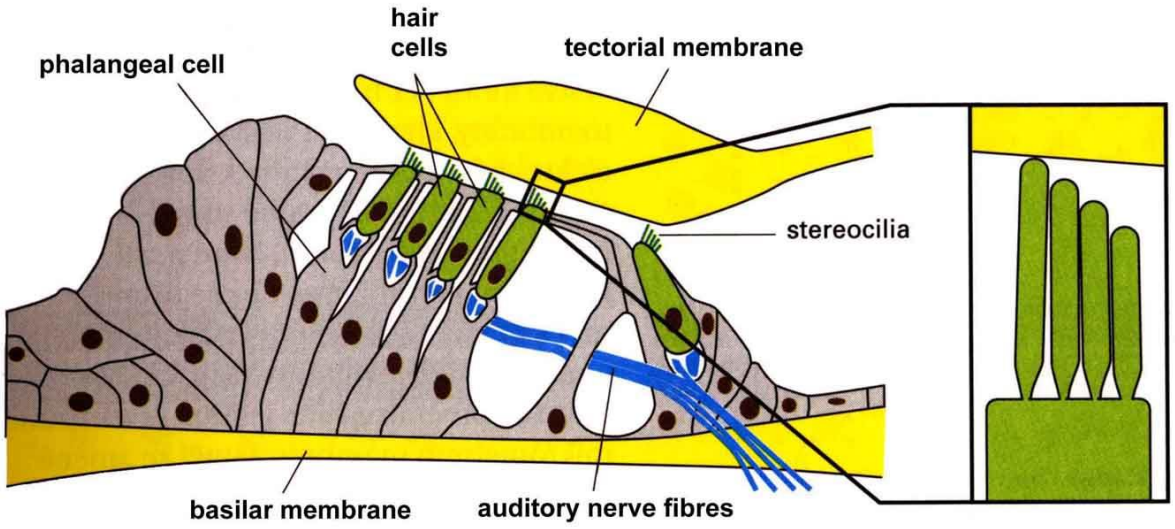


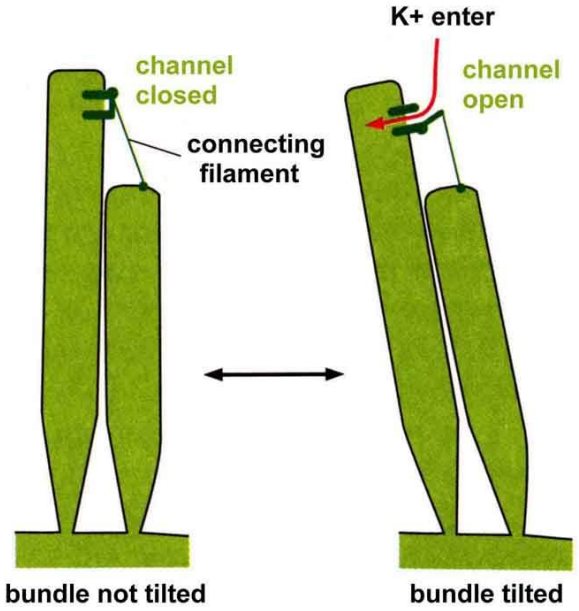
Deiters' cell

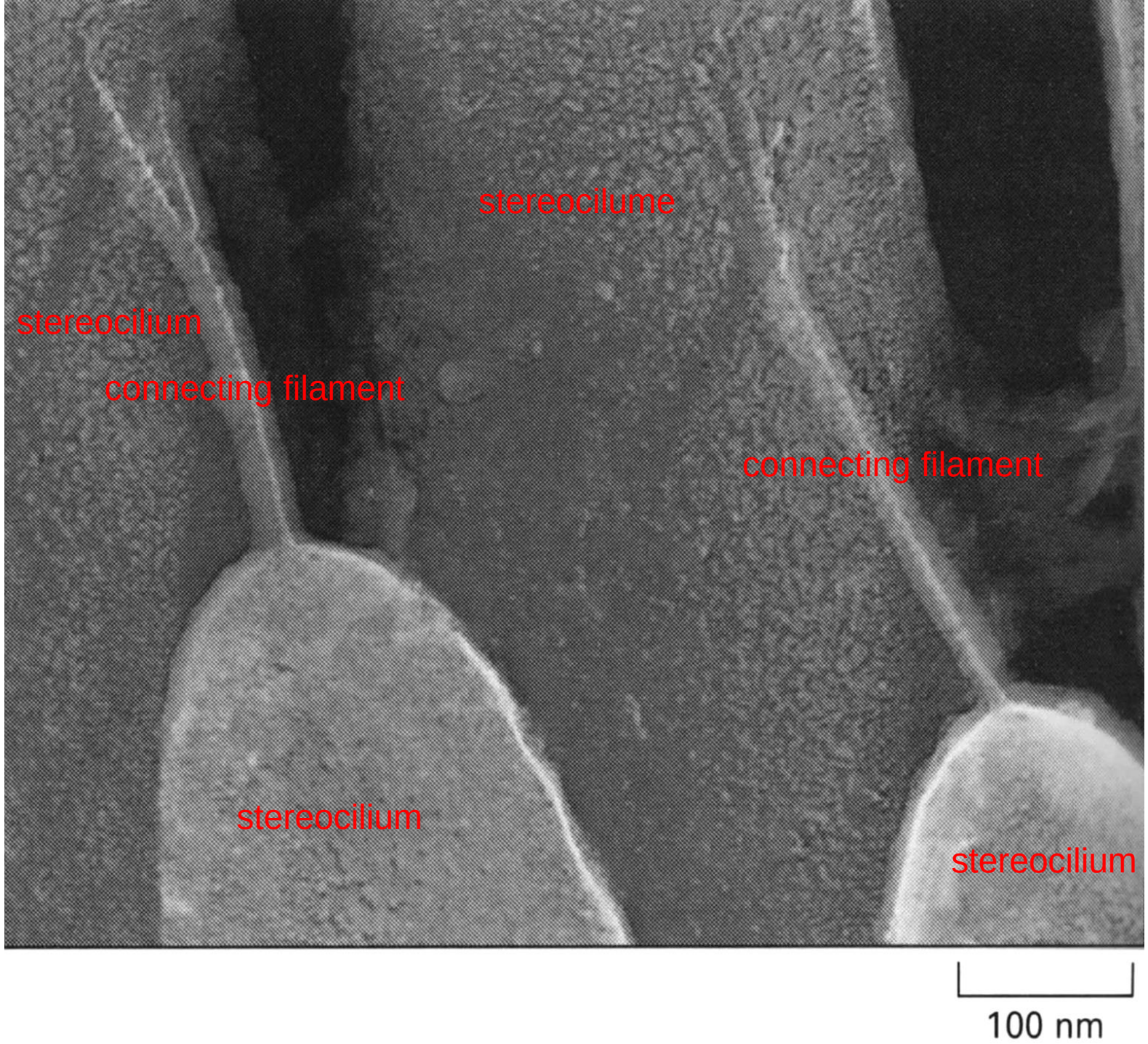


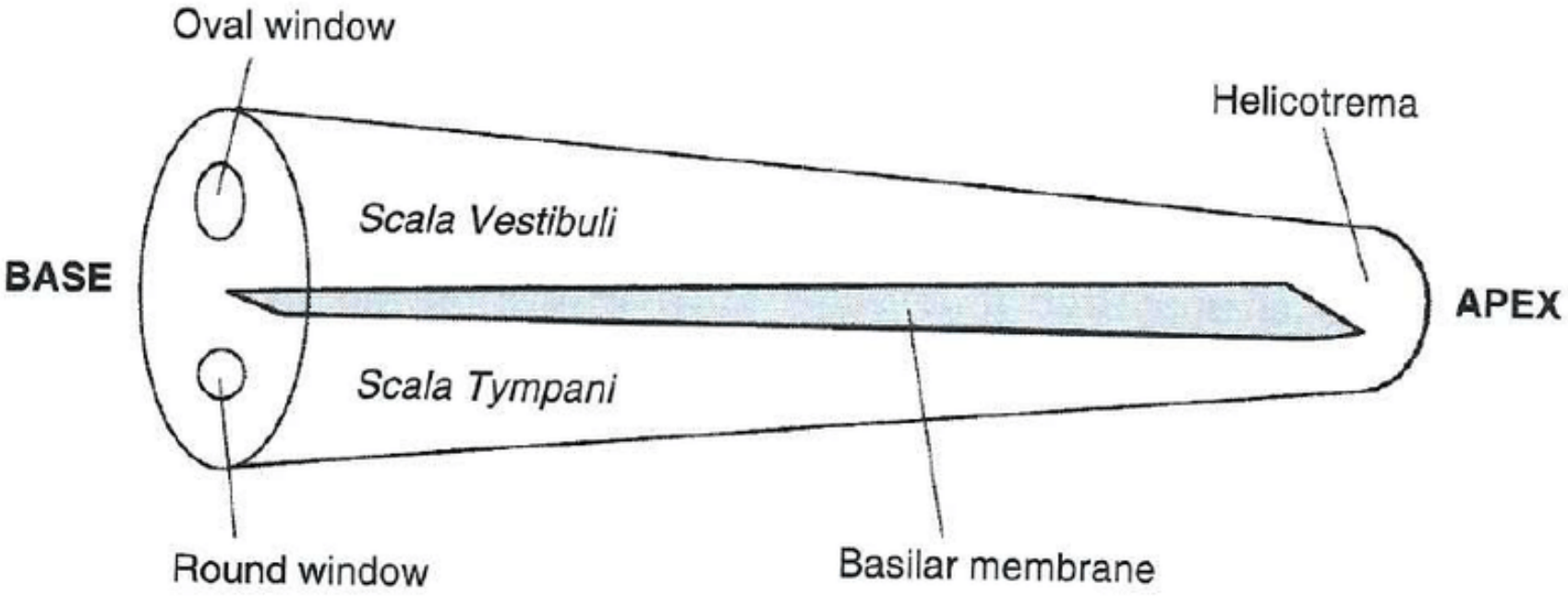

a

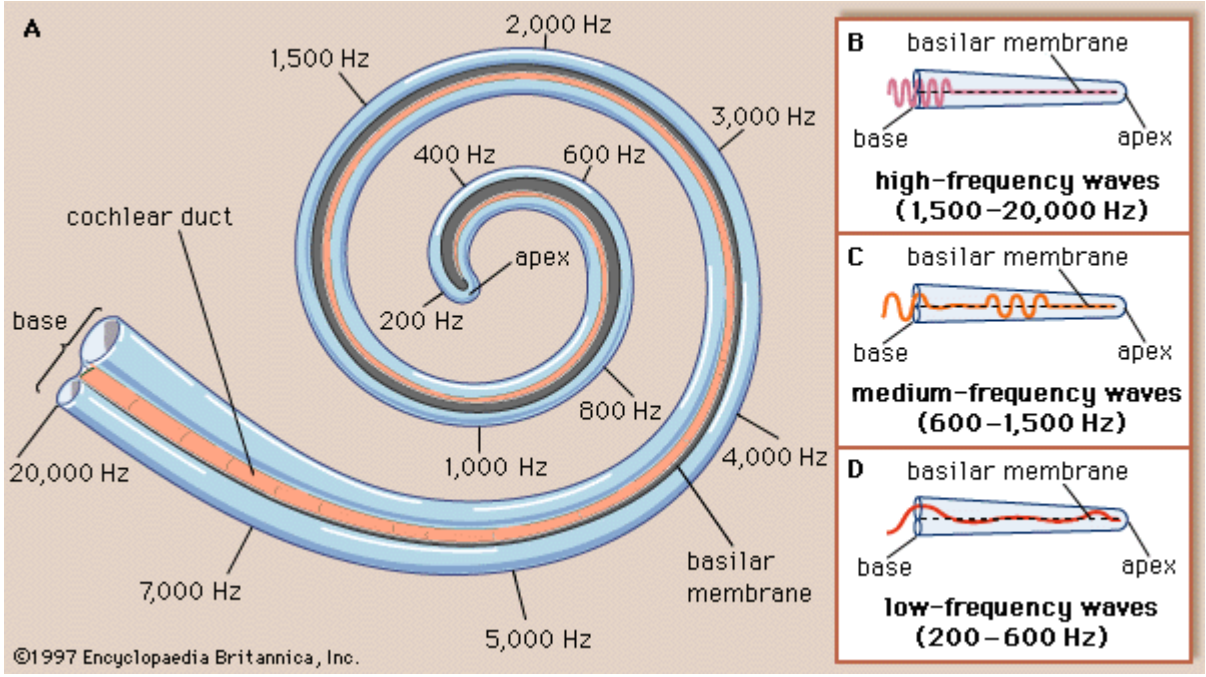
Mechanism of activation of hair cells



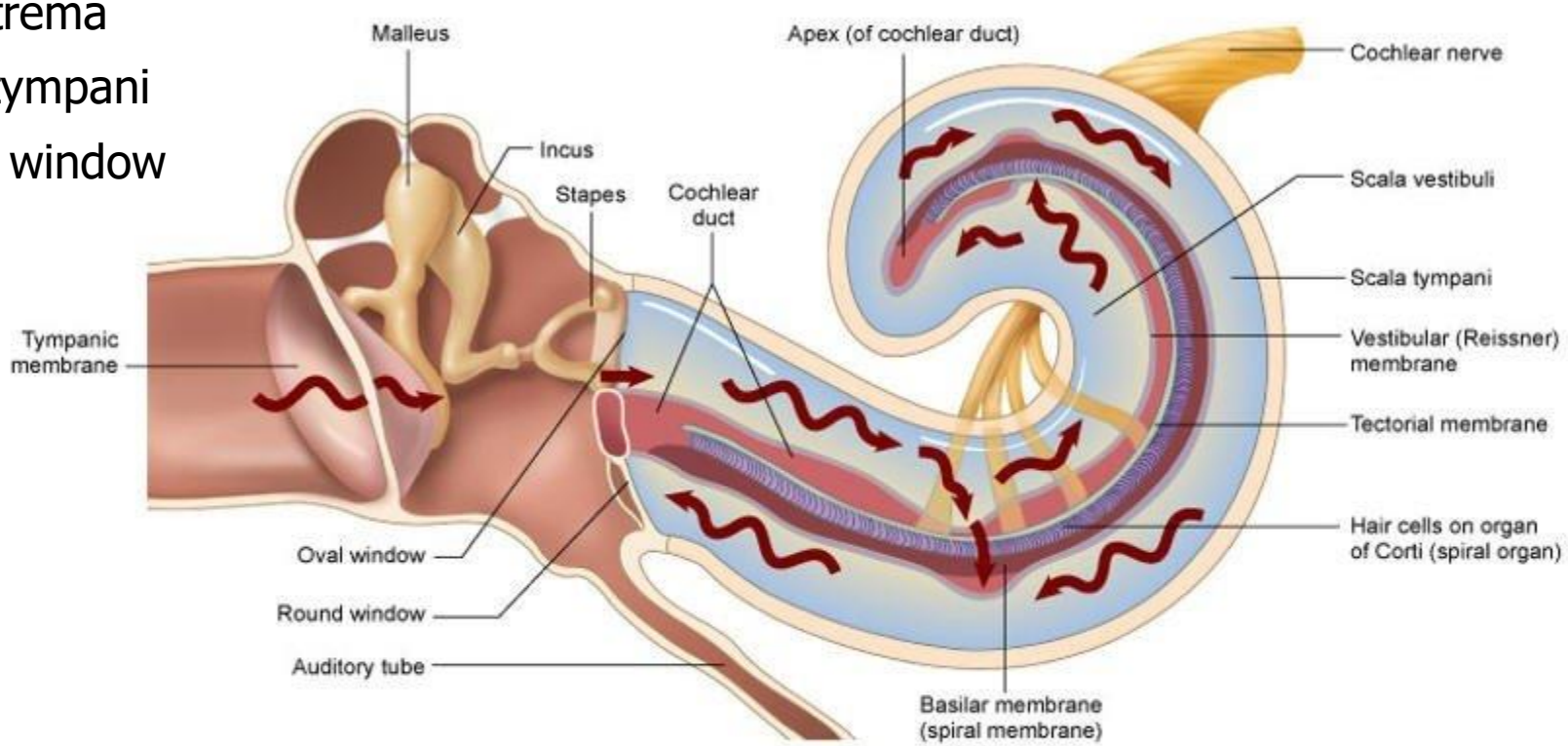


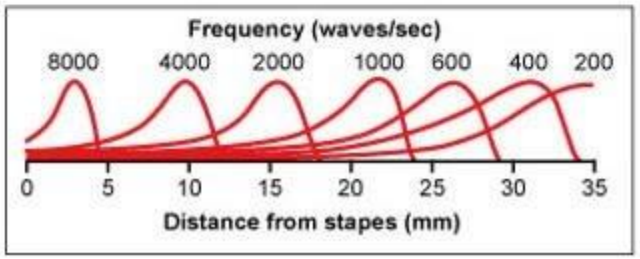

stereocilume
stereocilium
connecting filament
connecting filament
stereocilium
stereocilium
100 nm


Oval window
Helicotrema
BASE
Scala Vestibuli
APEX
Scala Tympani
Round window
Basilar membrane

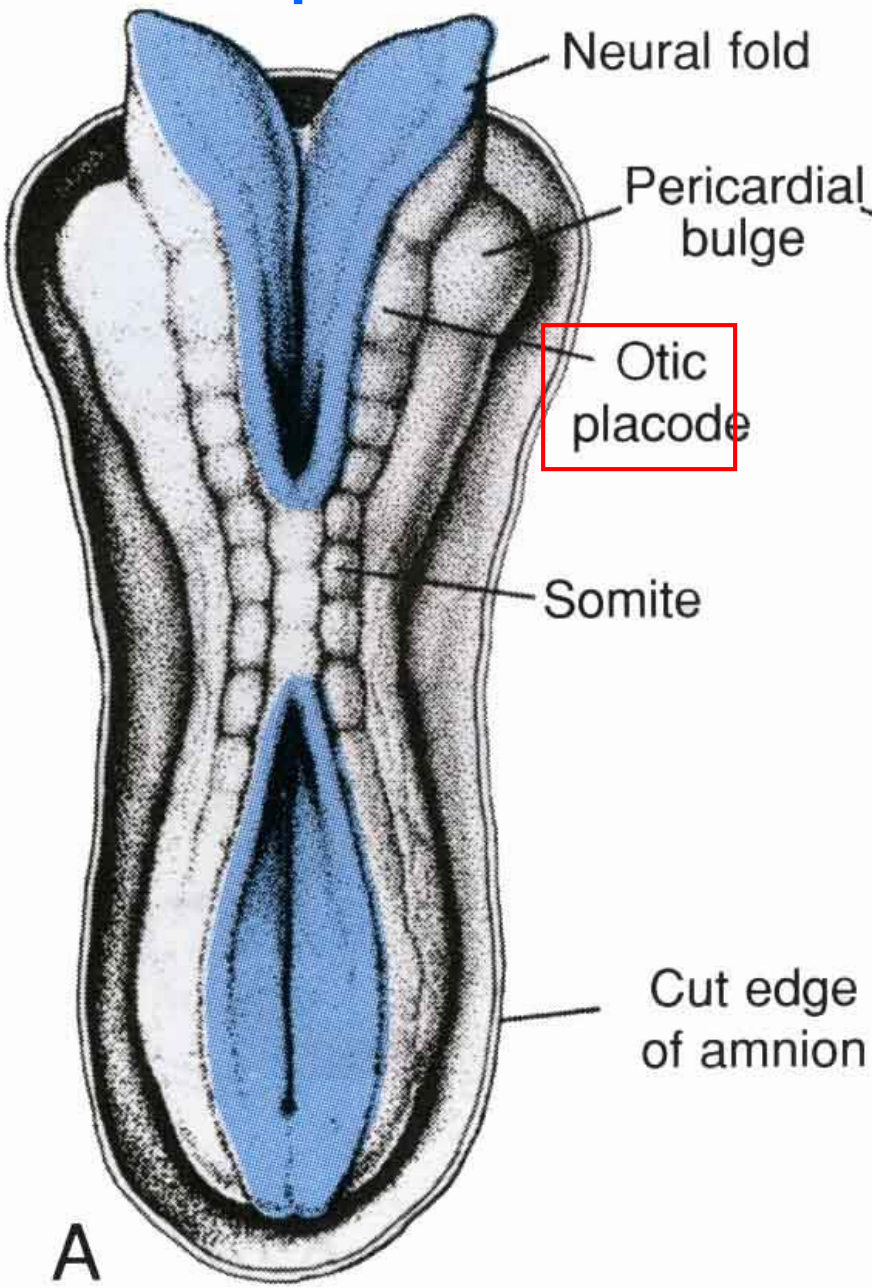

A
2,000 Hz
1,500 Hz
3,000 Hz
400 Hz
600 Hz
cochlear duct
apex
200 Hz
base
800 Hz
20,000 Hz
1,000 Hz
4,000 Hz
basilar membrane
7,000 Hz
5,000 Hz
©1997 Encyclopaedia Britannica, Inc.
B
basilar membrane
base
apex
high-frequency waves (1,500–20,000 Hz)
C
basilar membrane
base
apex
medium-frequency waves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

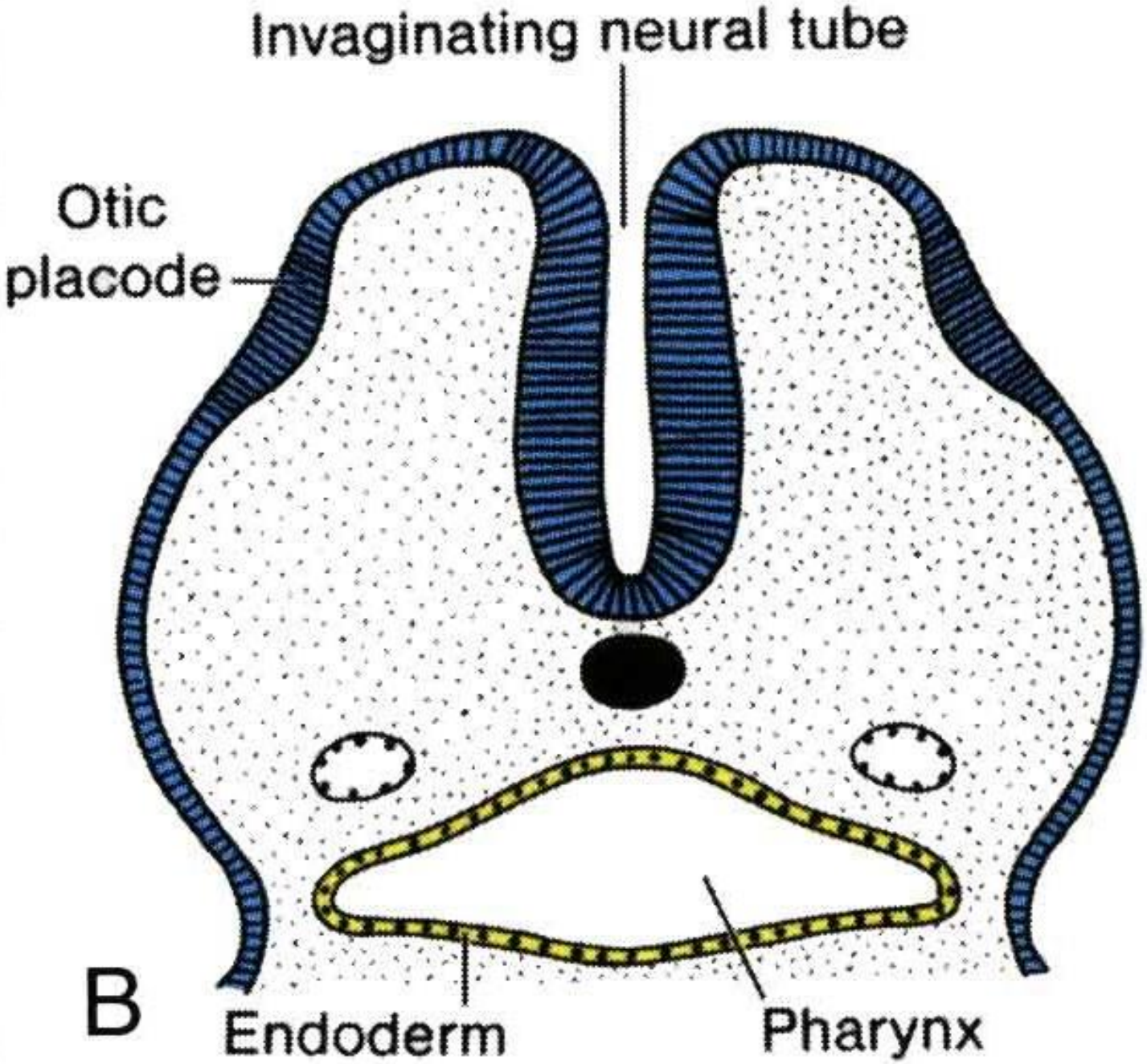
- Tympanic membrane
- ossicles
- Oval window
- Scala vestibuli
- Helicotrema
- Scala tympani
- Round window

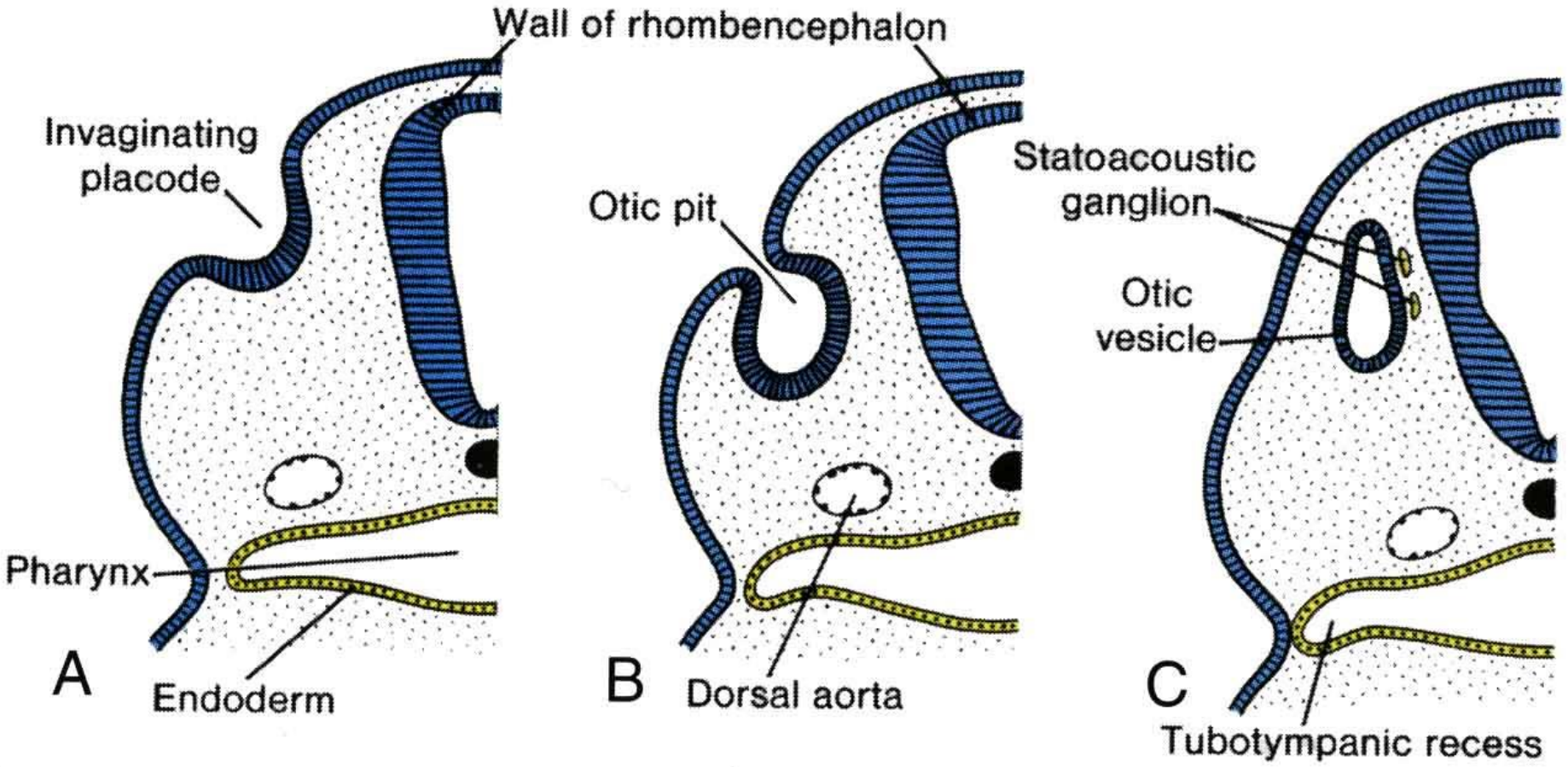


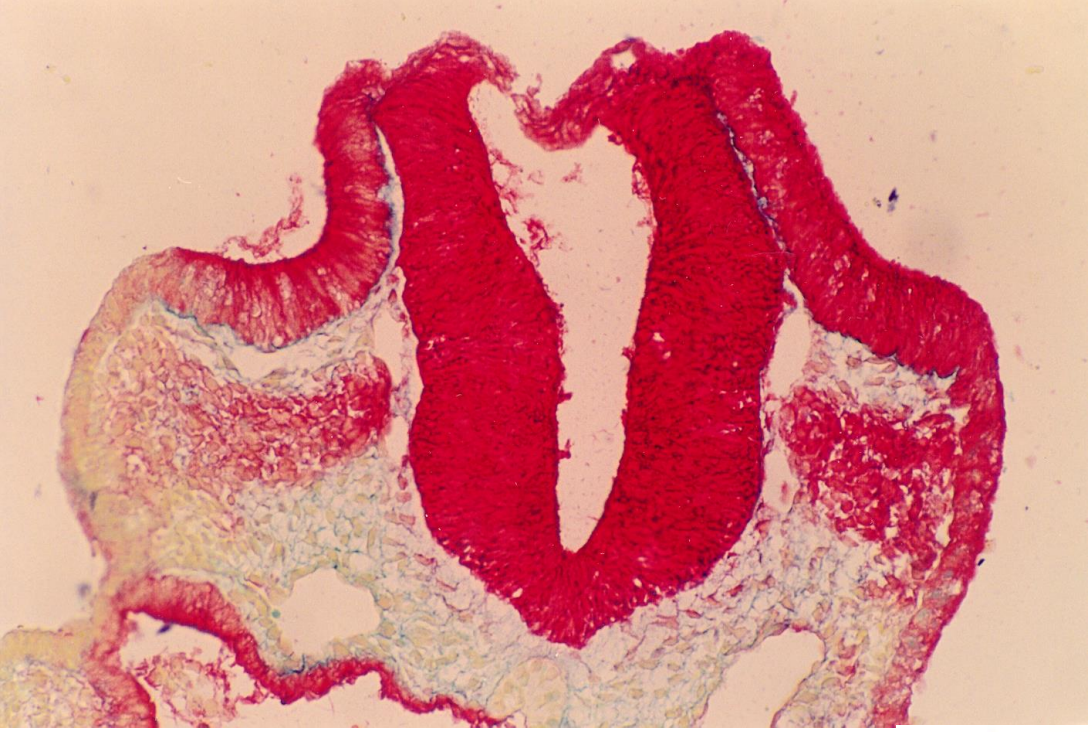


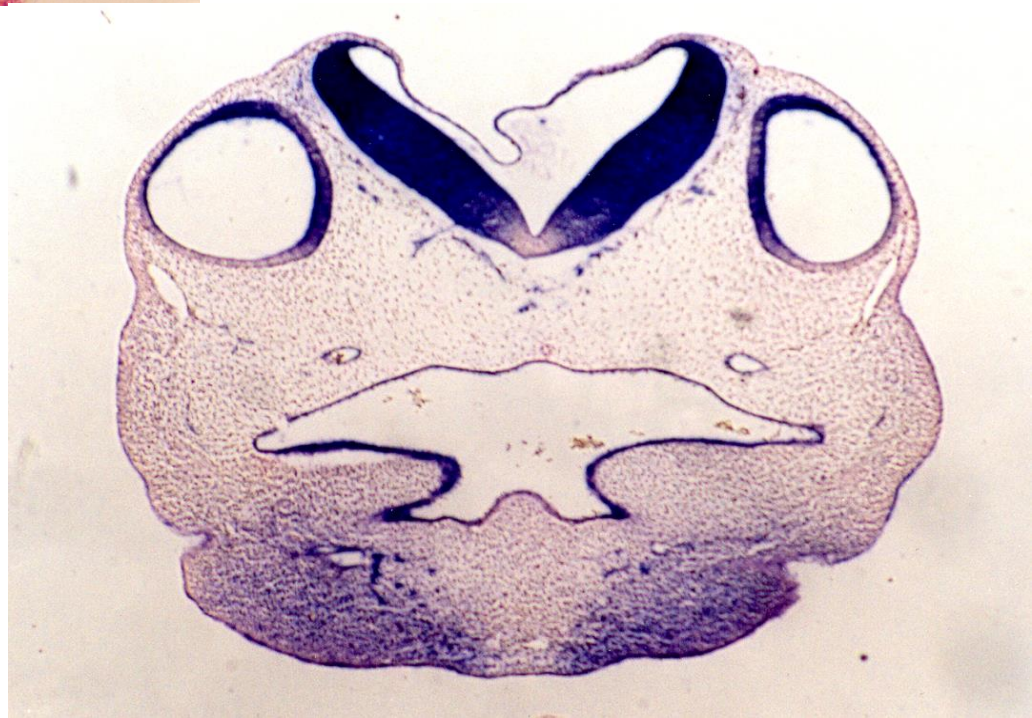
Development of ear

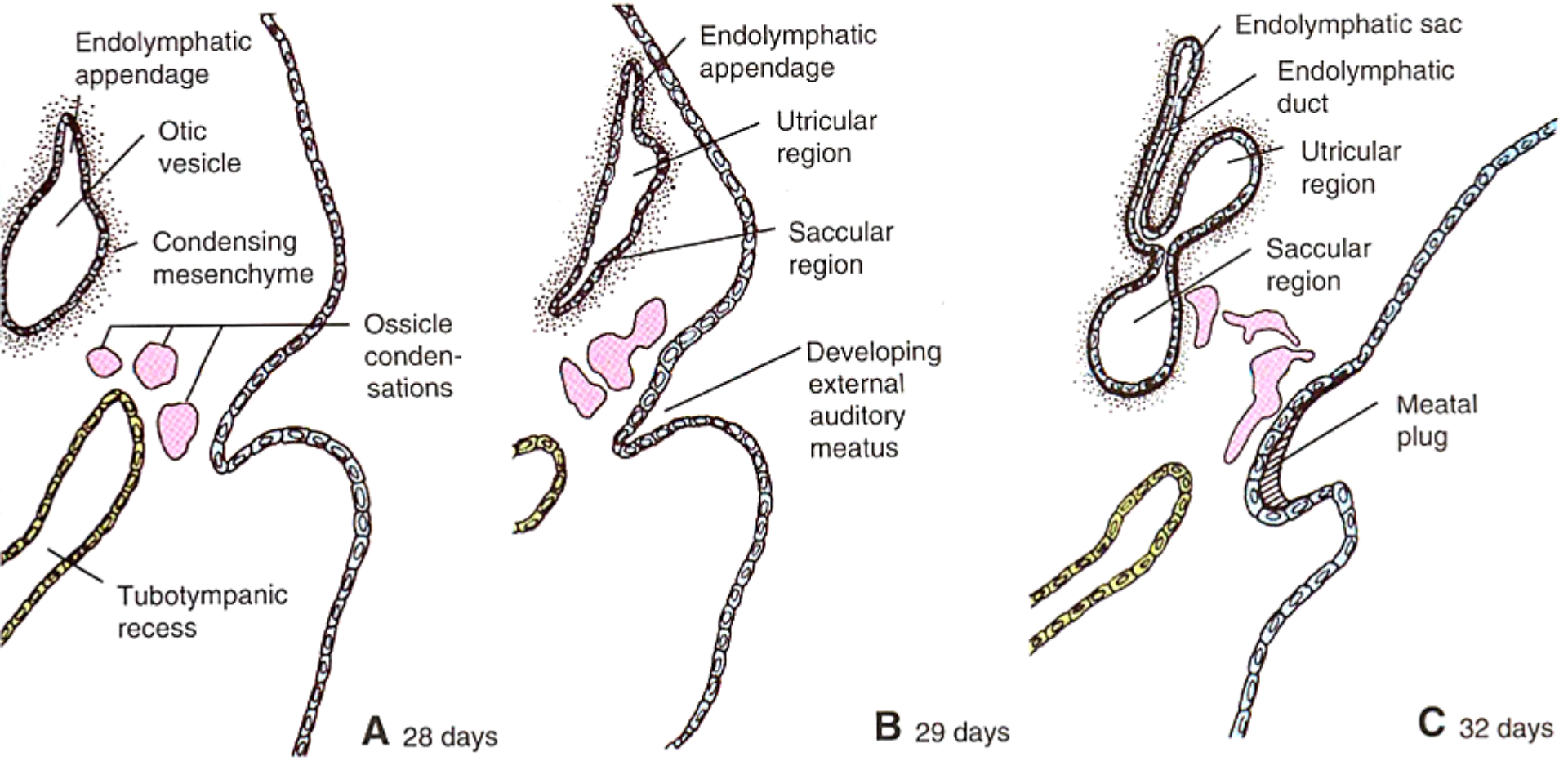


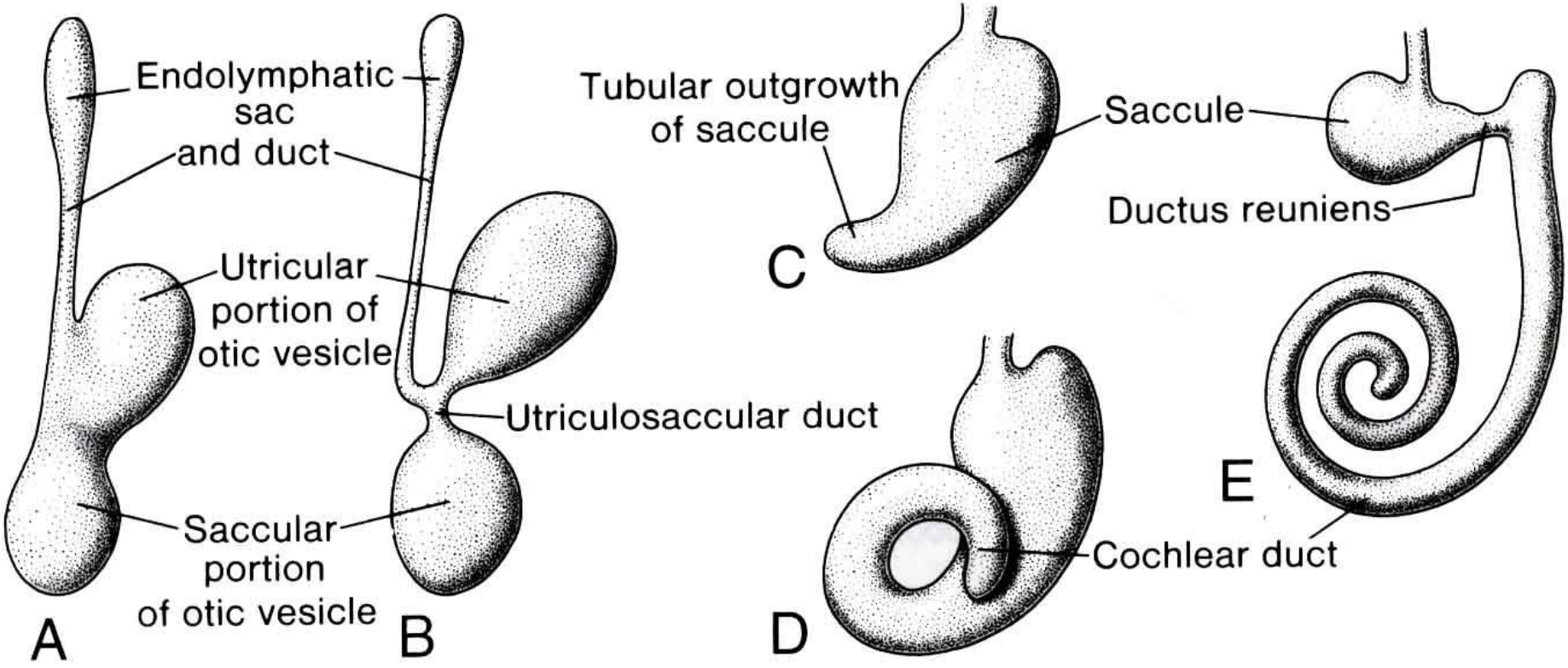

Invaginating neural tube
Otic placode
B
Endoderm
Pharynx

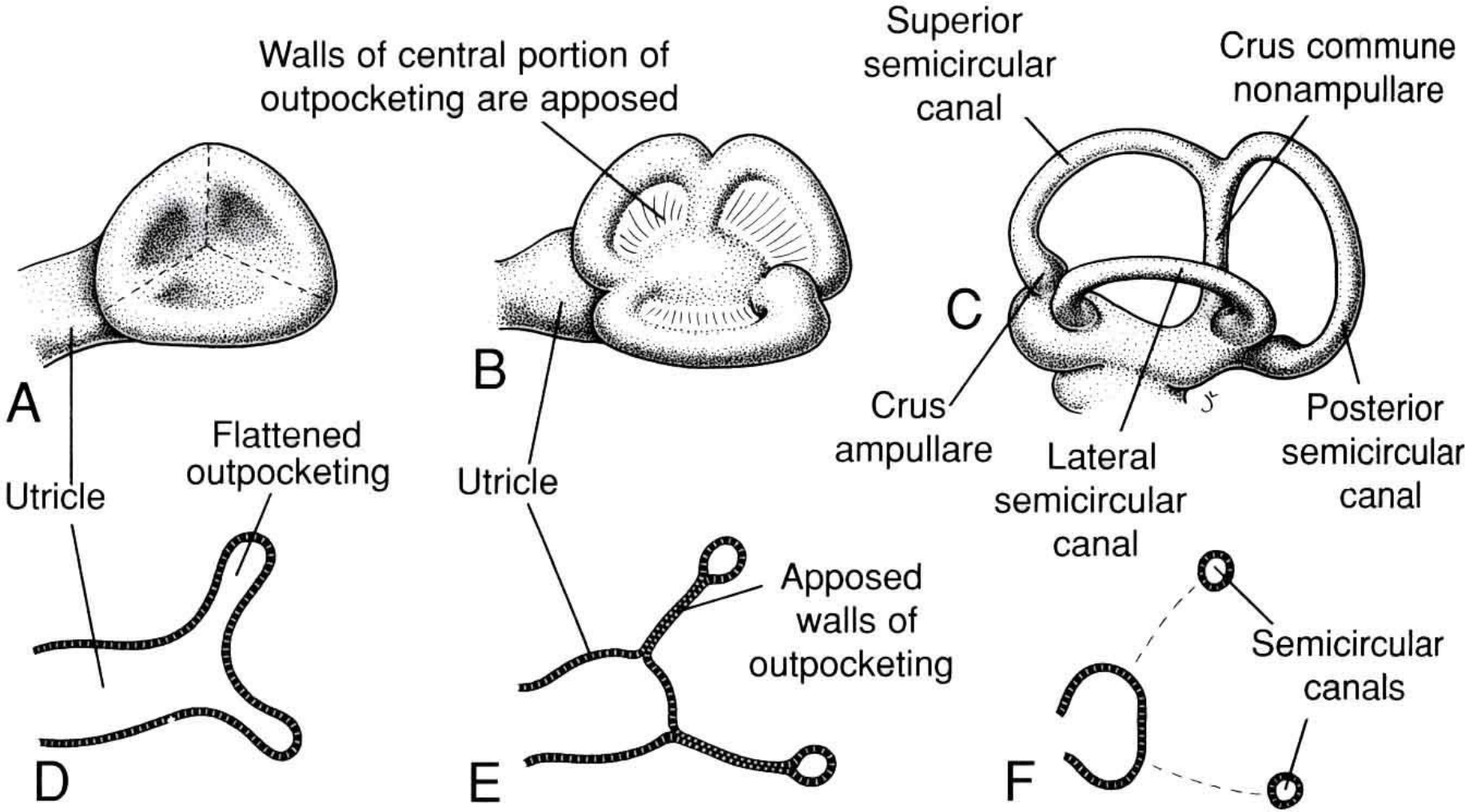

Wall of rhombencephalon
Invaginating placode
Pharynx
A
Endoderm
Otic pit
B
Dorsal aorta
Statoacoustic ganglion
Otic vesicle
C
Tubotympanic recess

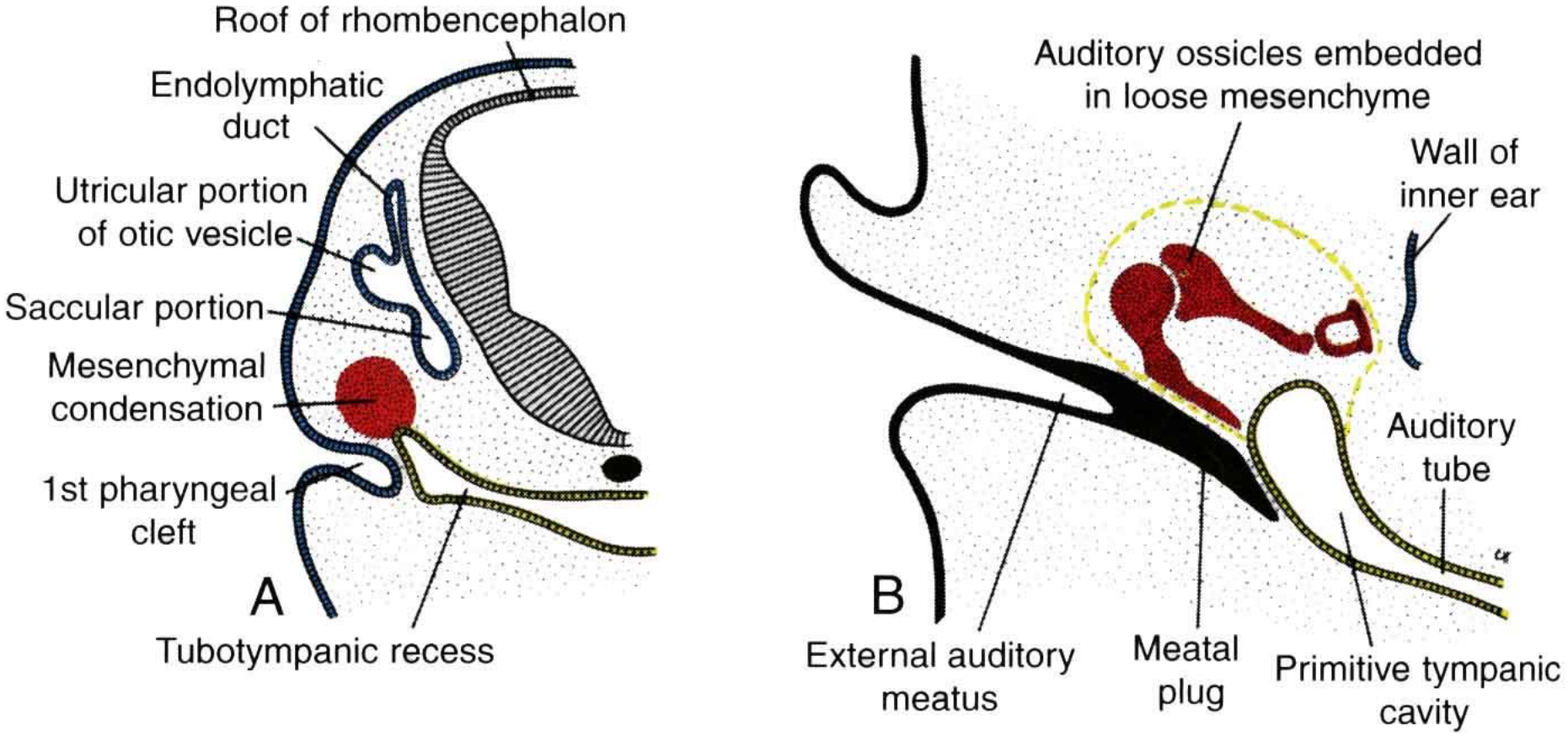


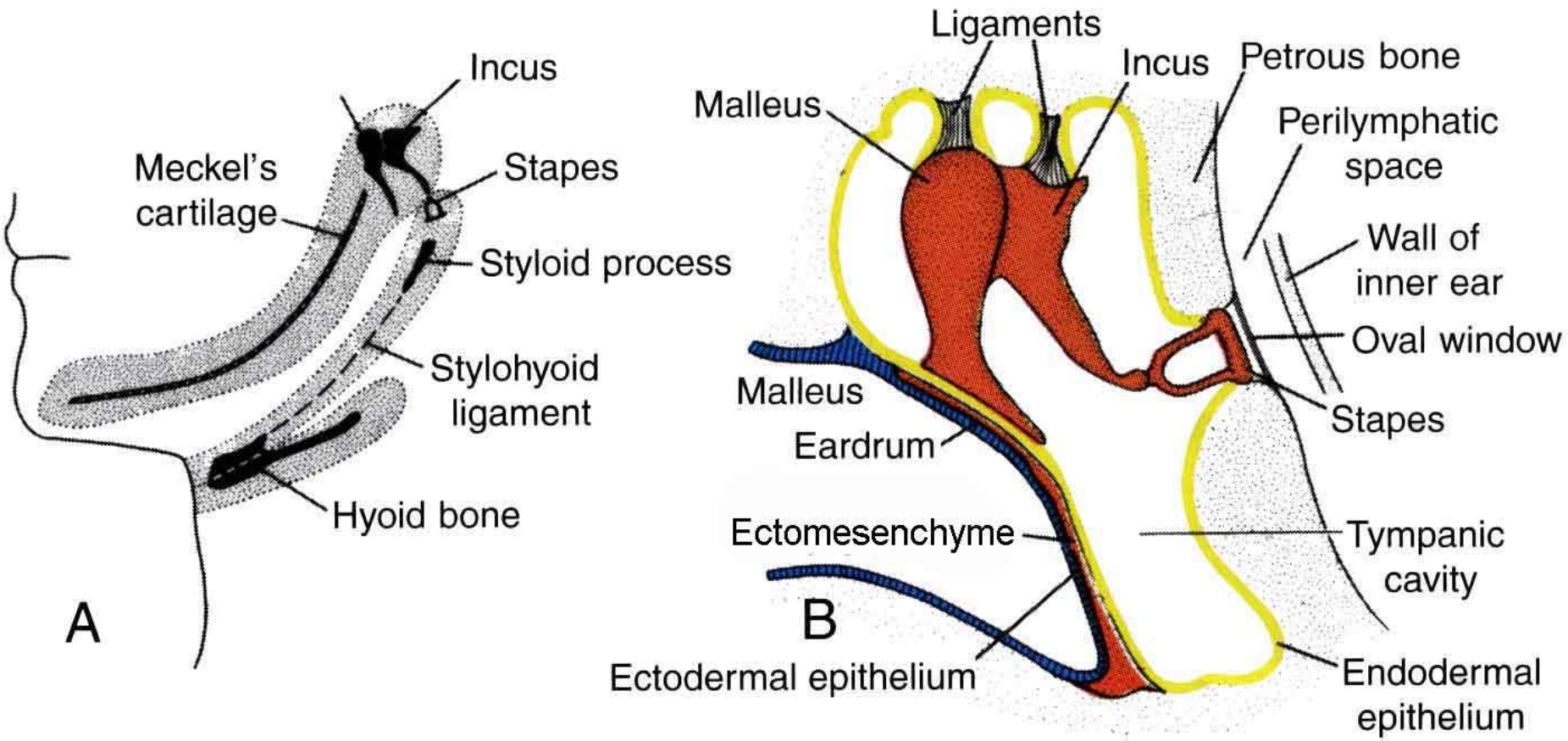


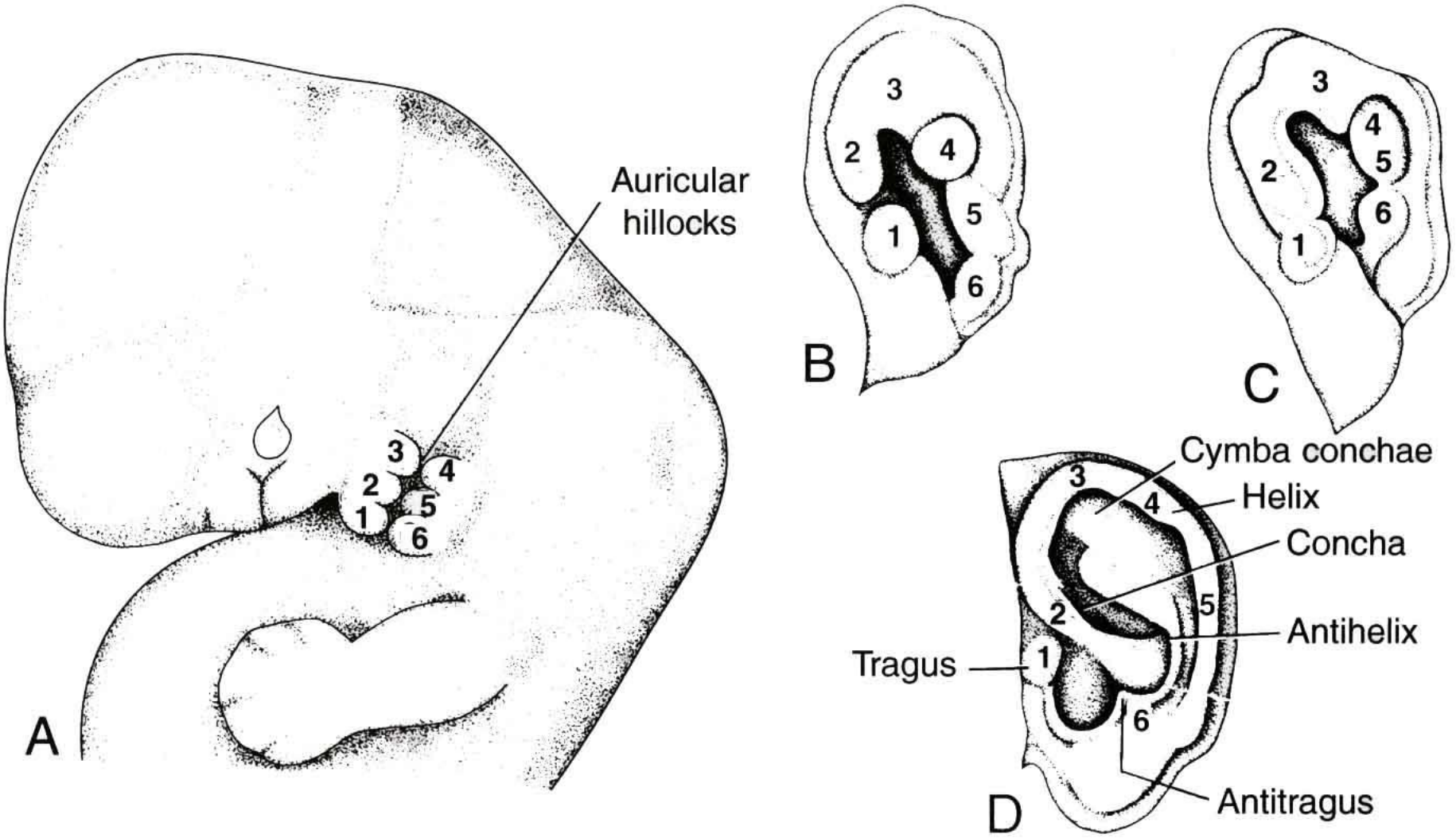

Endolymphatic appendage
Otic vesicle
Condensing mesenchyme
Ossicle condensations
Tubotympanic recess
A 28 days
Endolymphatic appendage
Utricular region
Saccular region
Developing external auditory meatus
B 29 days
Endolymphatic sac
Endolymphatic duct
Utricular region
Saccular region
Meatal plug
C 32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


Endolymphatic sac and duct
Utricular portion of otic vesicle
Saccular portion of otic vesicle
A
B
Utriculosaccular duct
Tubular outgrowth of saccule
C
Saccule
Ductus reuniens
D
E
Cochlear duct

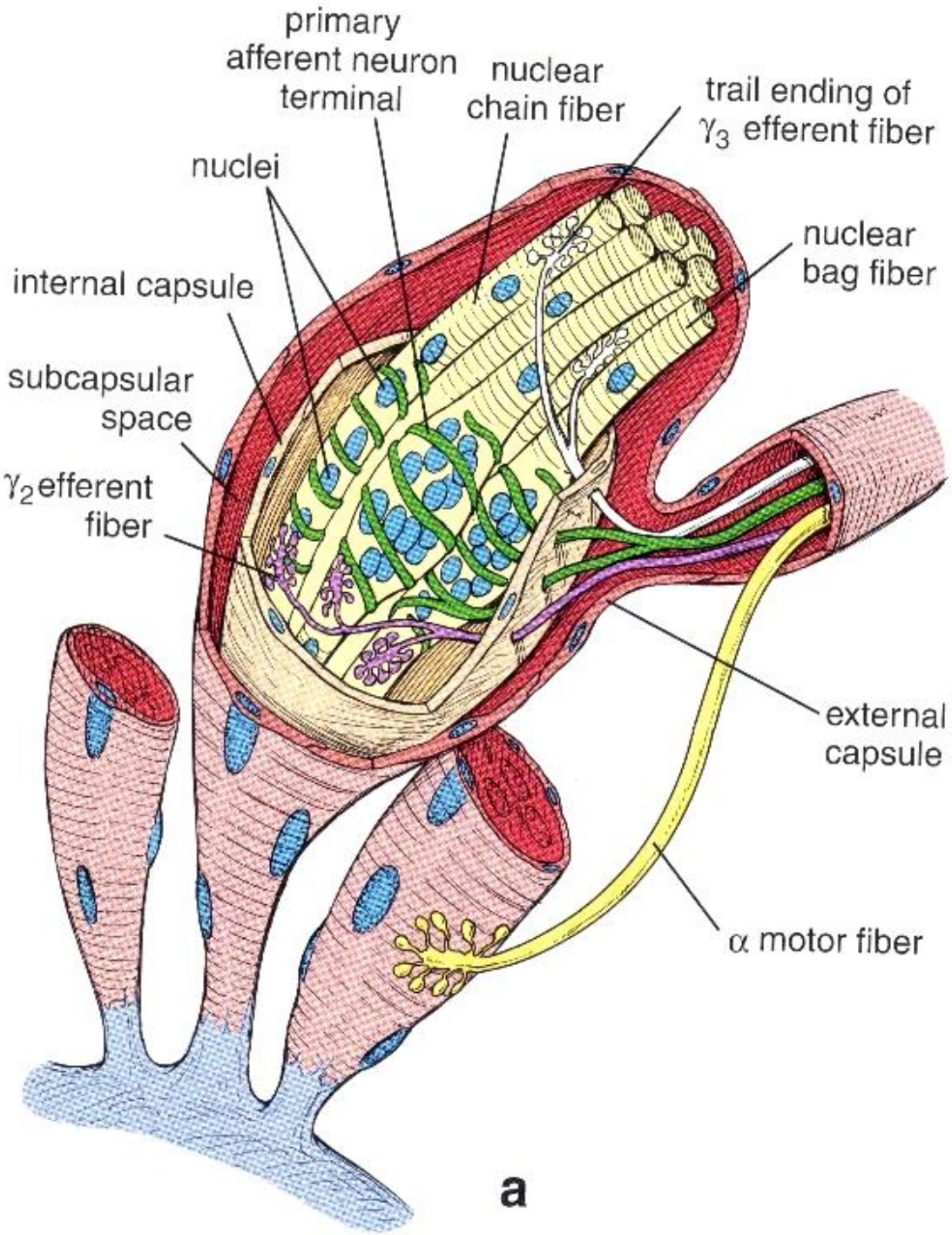

Walls of central portion of outpocketing are apposed
Superior semicircular canal
Crus commune nonampullare
A
B
C
Utricle
Flattened outpocketing
Utricle
Crus ampullare
Lateral semicircular canal
Posterior semicircular canal
Apposed walls of outpocketing
Semicircular canals
D
E
F


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

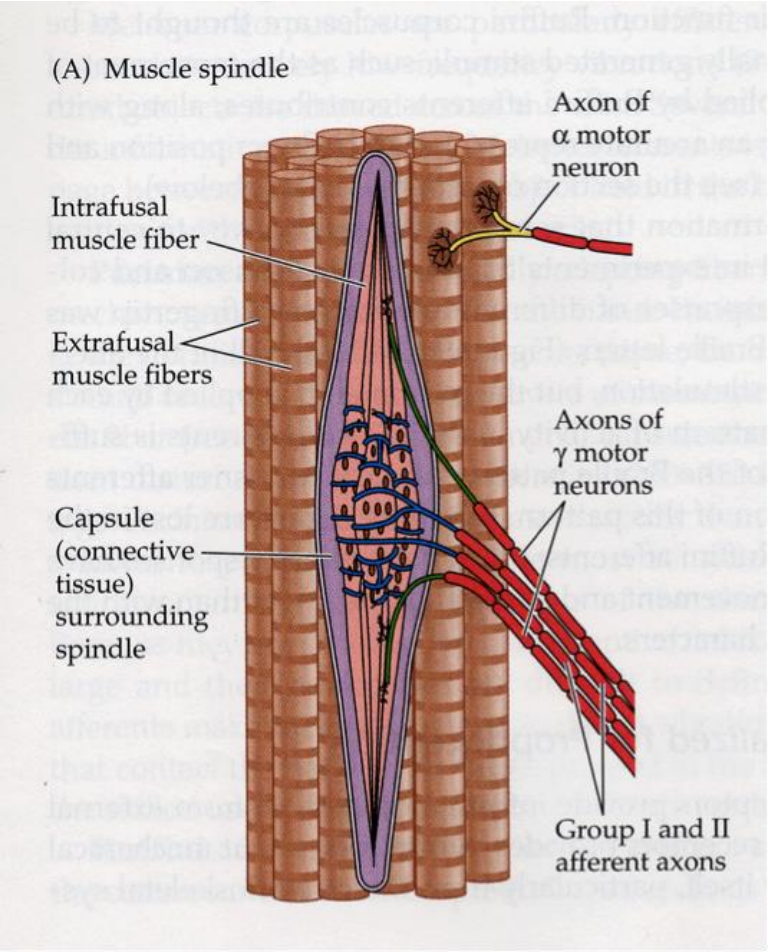

Auricular hillocks
A
B
C
D
Cymba conchae
Helix
Concha
Antihelix
Tragus
Antitragus
1
2
3
4
5
6

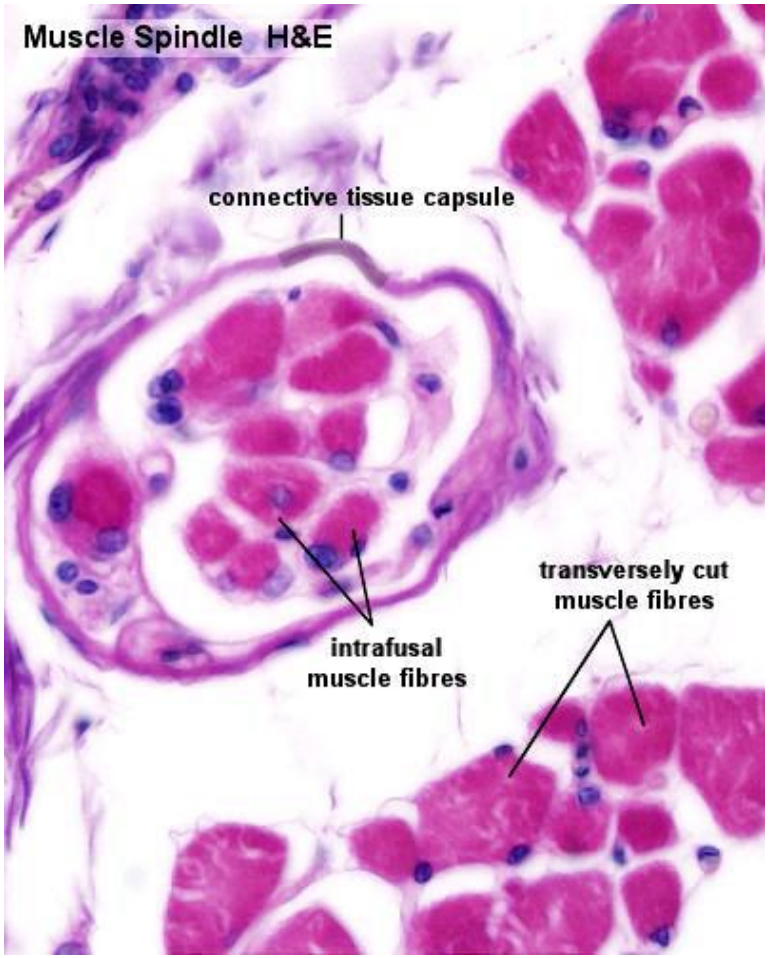
Muscle spindle, Golgi tendon organ (peripheral proprioceptors)

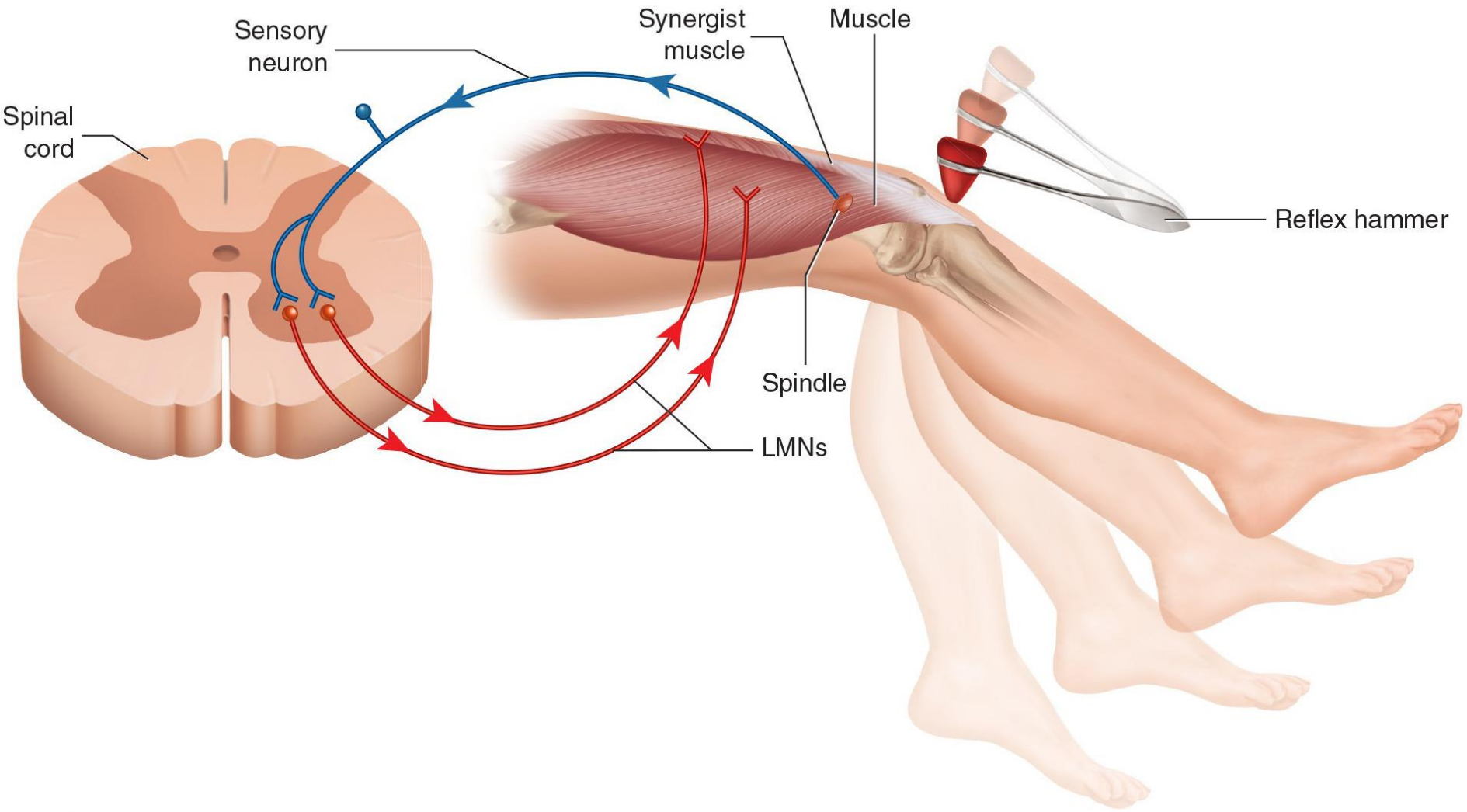

primary
afferent neuron
terminal
nuclear
chain fiber
trail ending of
γ_3 efferent fiber
nuclei
nuclear
bag fiber
internal capsule
subcapsular
space
γ_2 efferent
fiber
external
capsule
α motor fiber
a

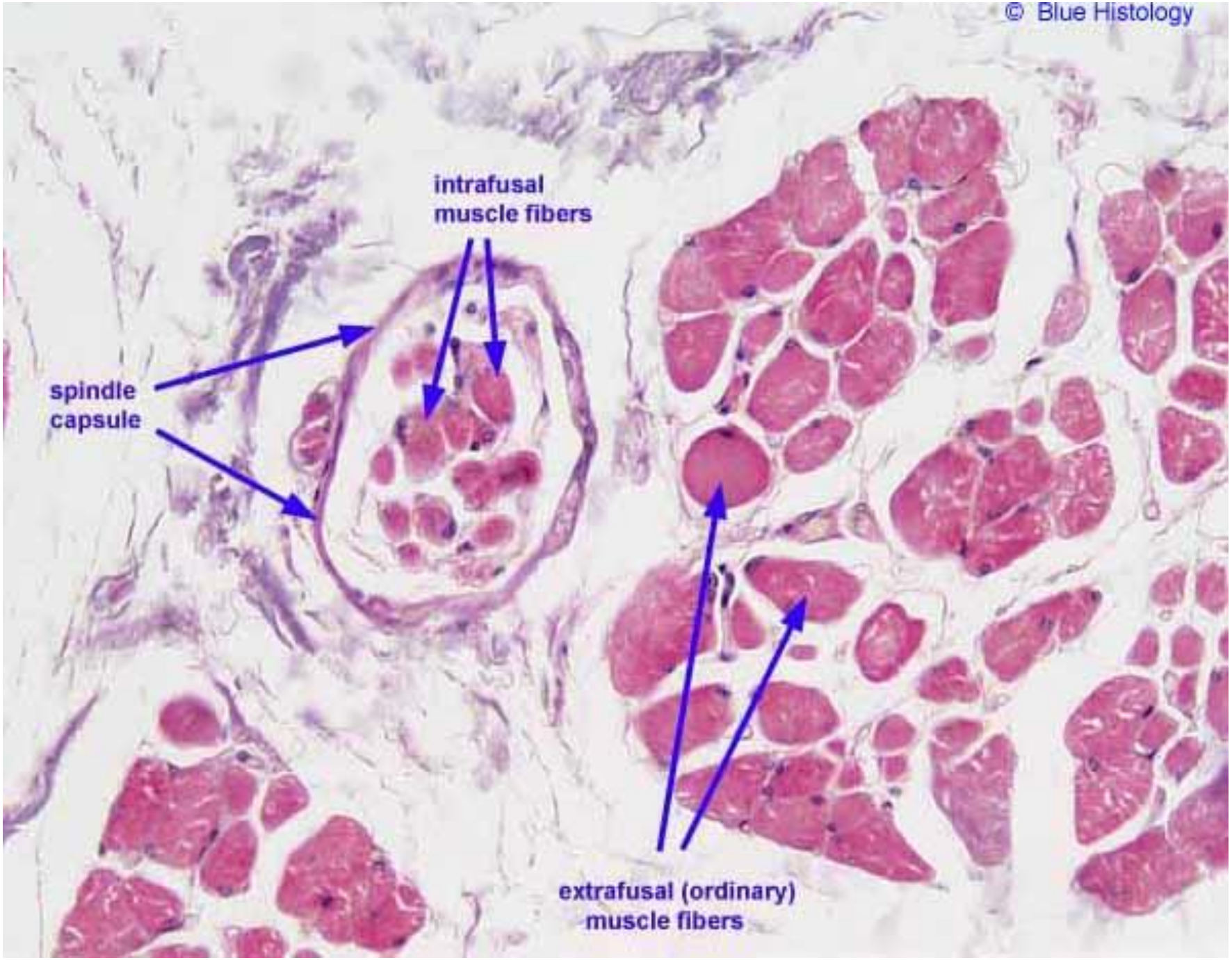
Muscle spindle

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



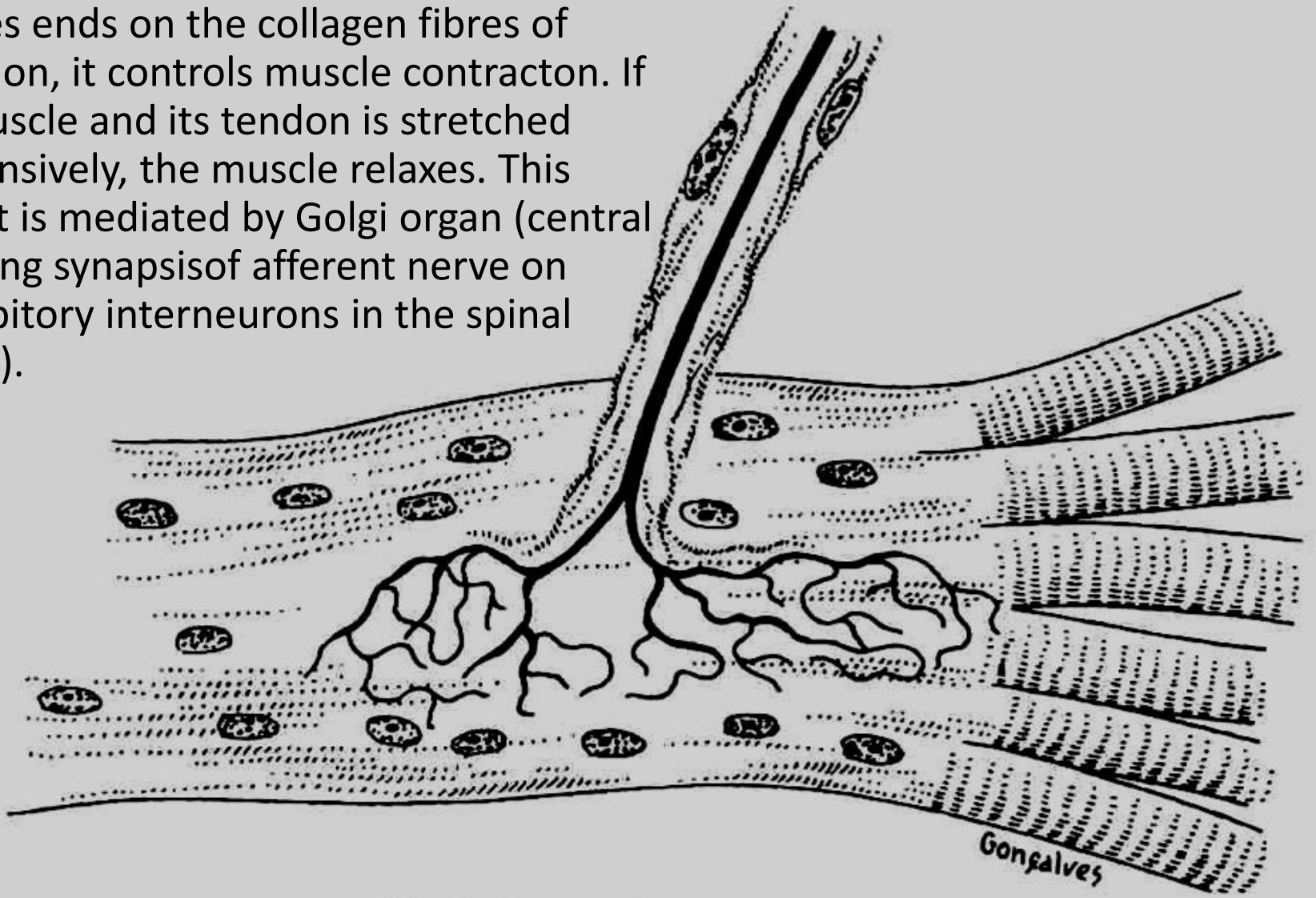





© Blue Histology
intrafusal
muscle fibers
spindle
capsule
extrafusal (ordinary)
muscle fibers

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).

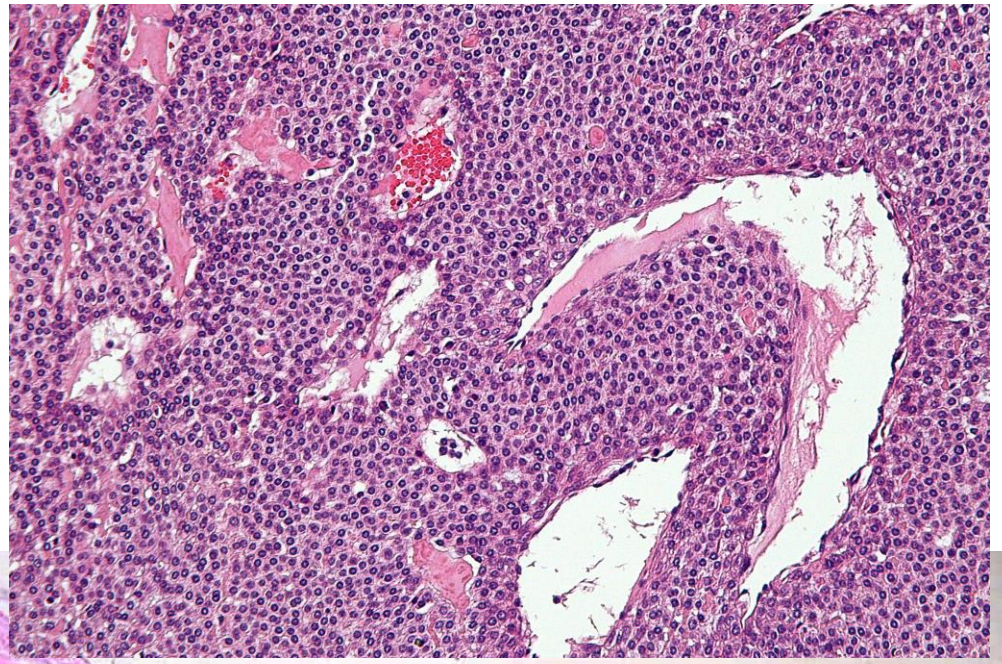


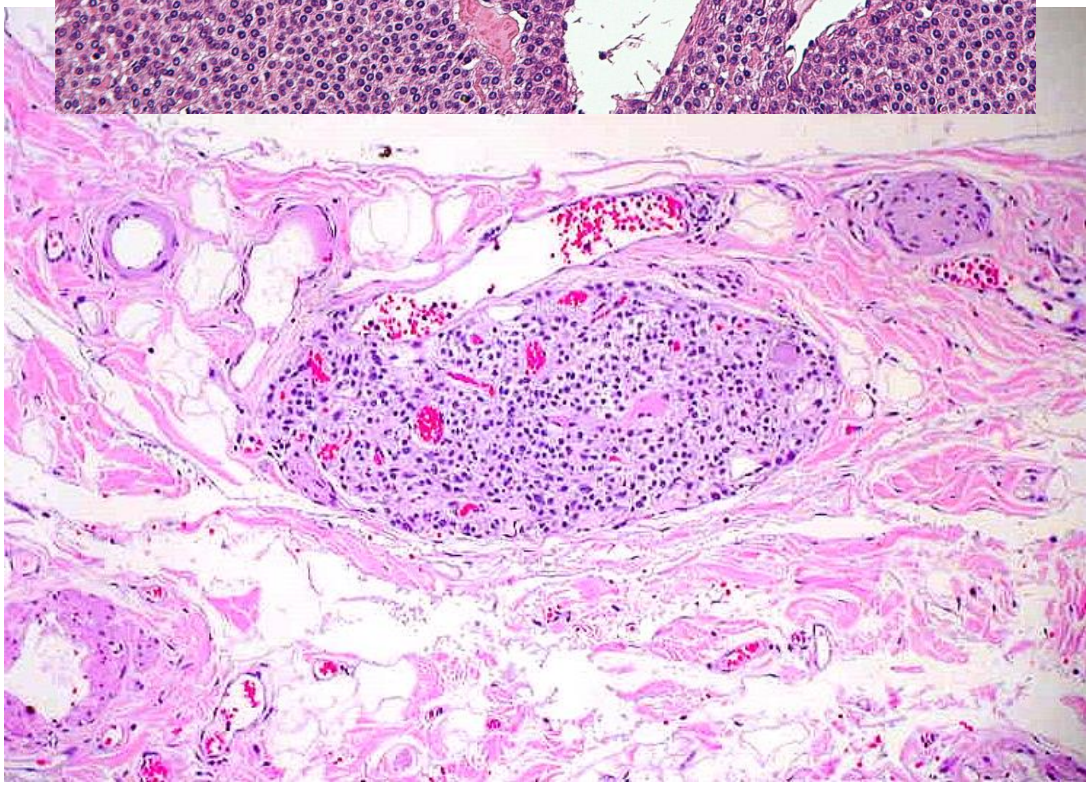
Golgi tendon organ

Receptors of deep sensation

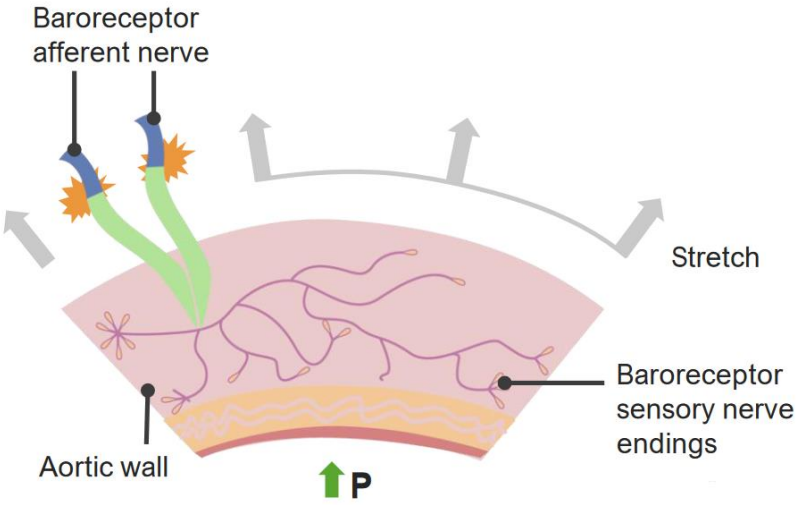
Paraganglia are clusters of **endocrine cells** (similar to adrenal medulla cells) that are scattered in the connective tissue around large vessels, autonomic nerves, and near sympathetic ganglia. They originate from the neuroectoderm (neural crest). Paraganglia belong to the sympathetic nervous system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



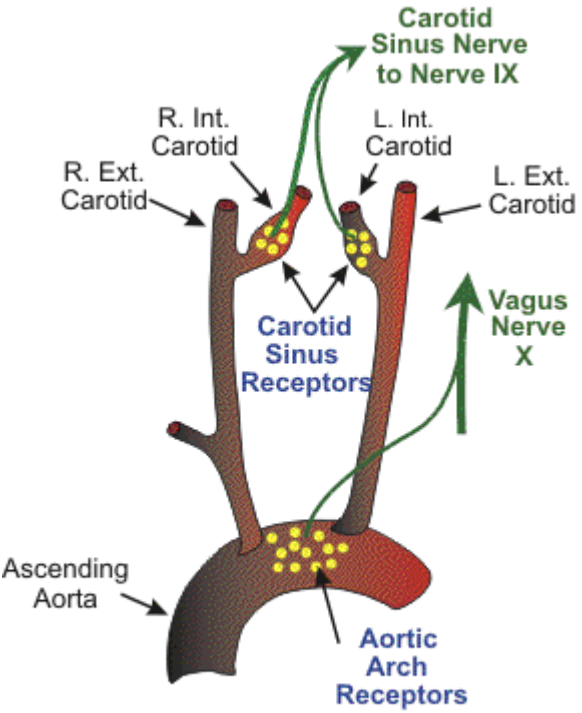
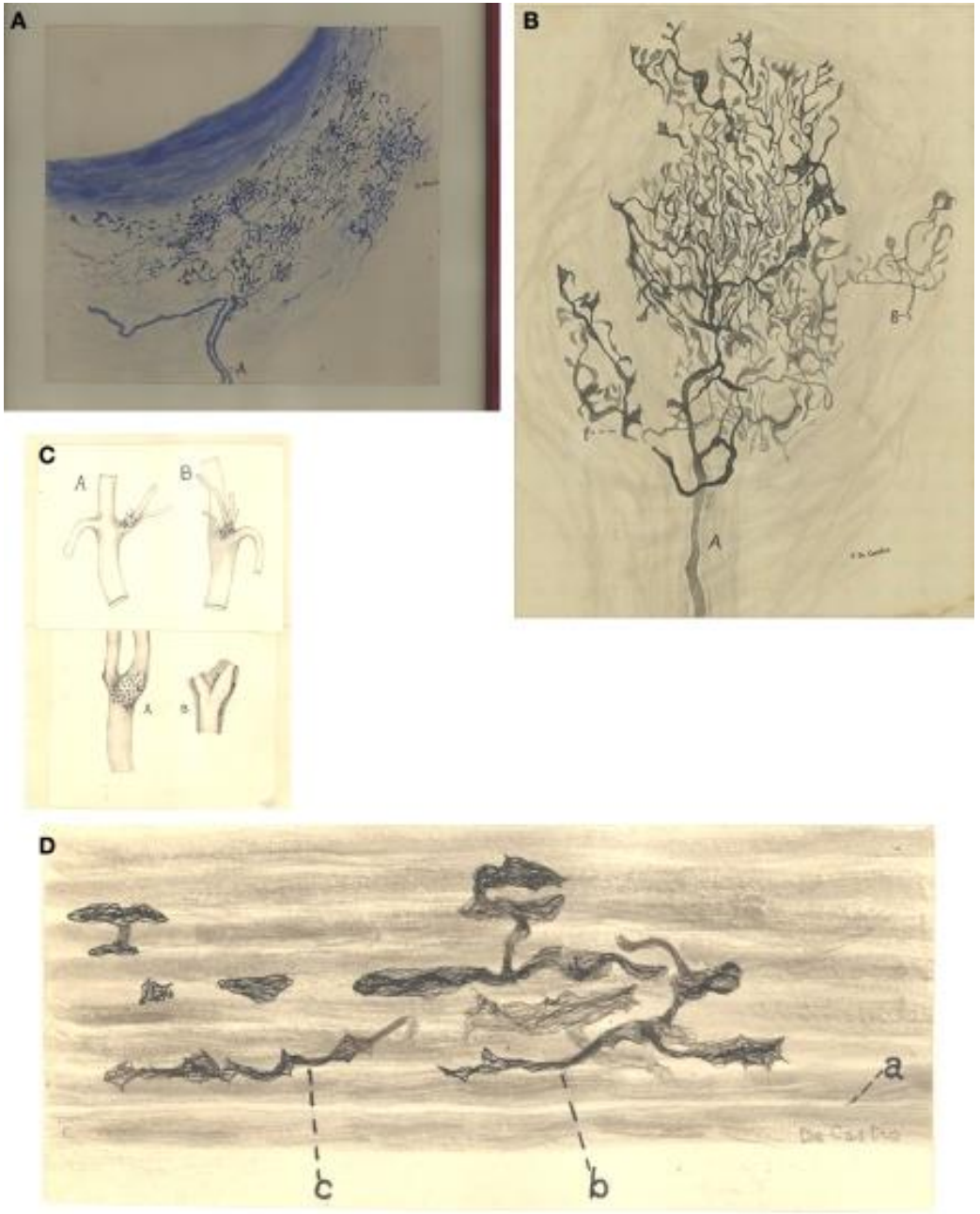
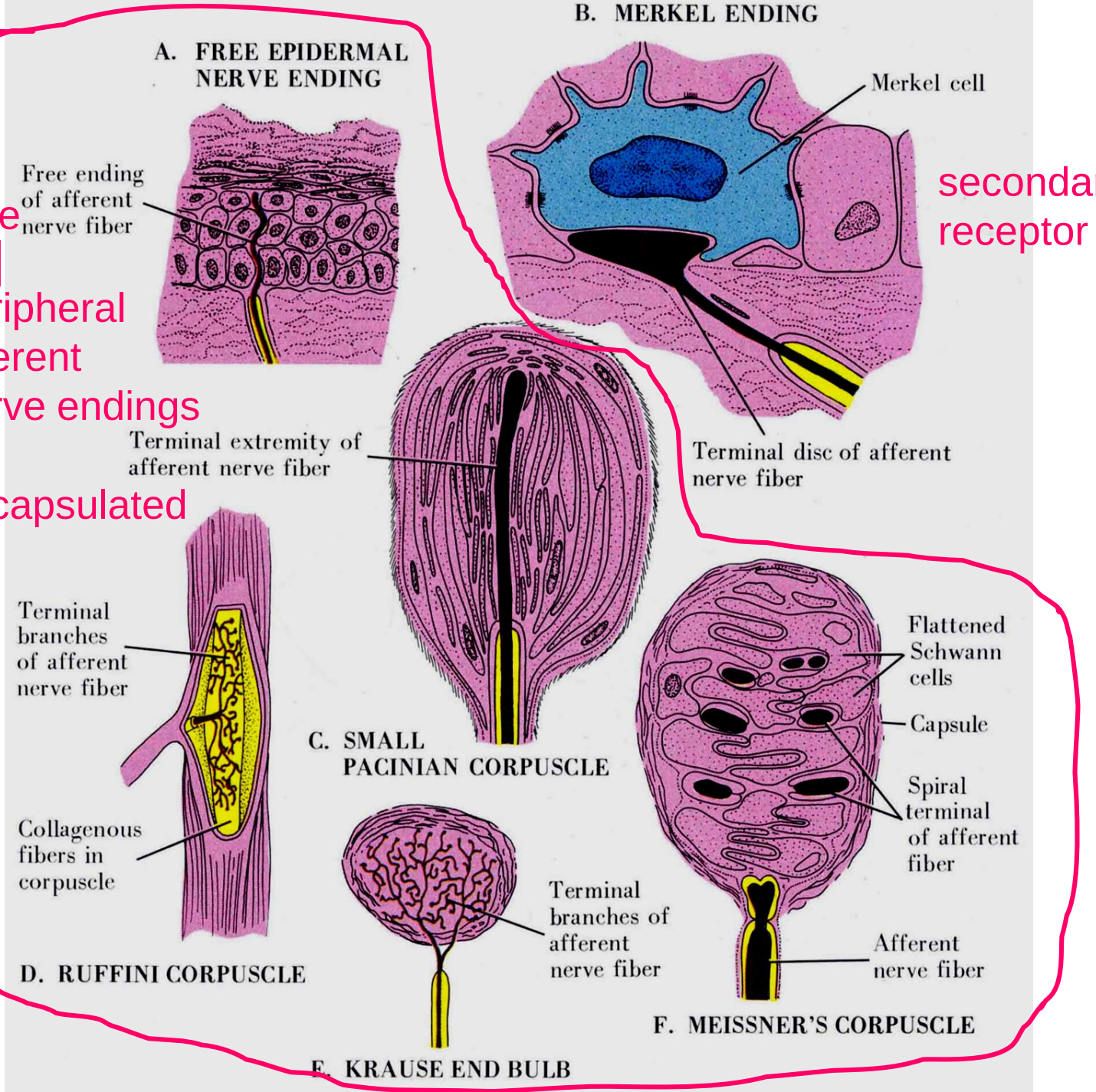


Figure 1. Location and innervation of arterial baroreceptors.



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



free

peripheral

afferent

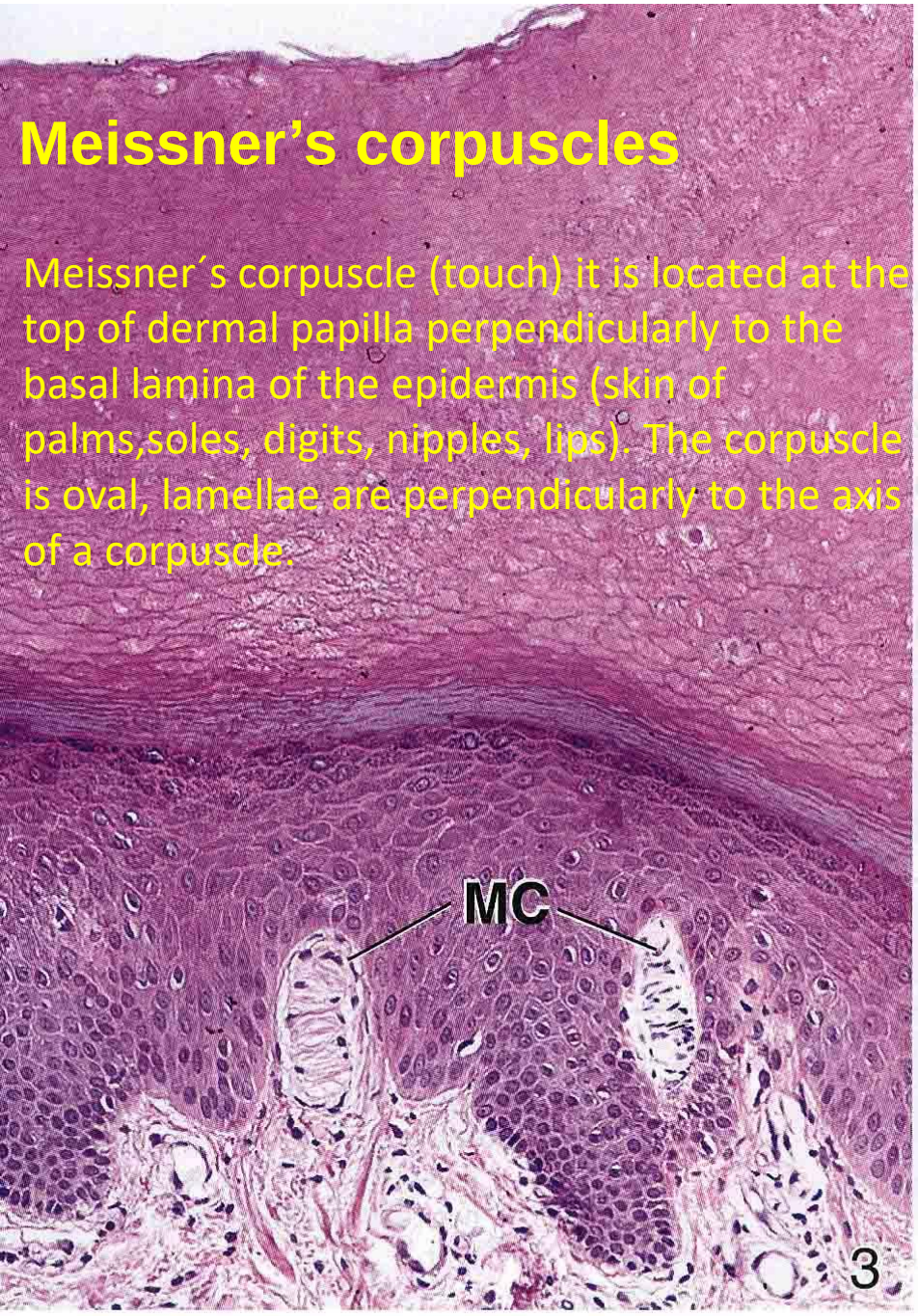
nerve endings

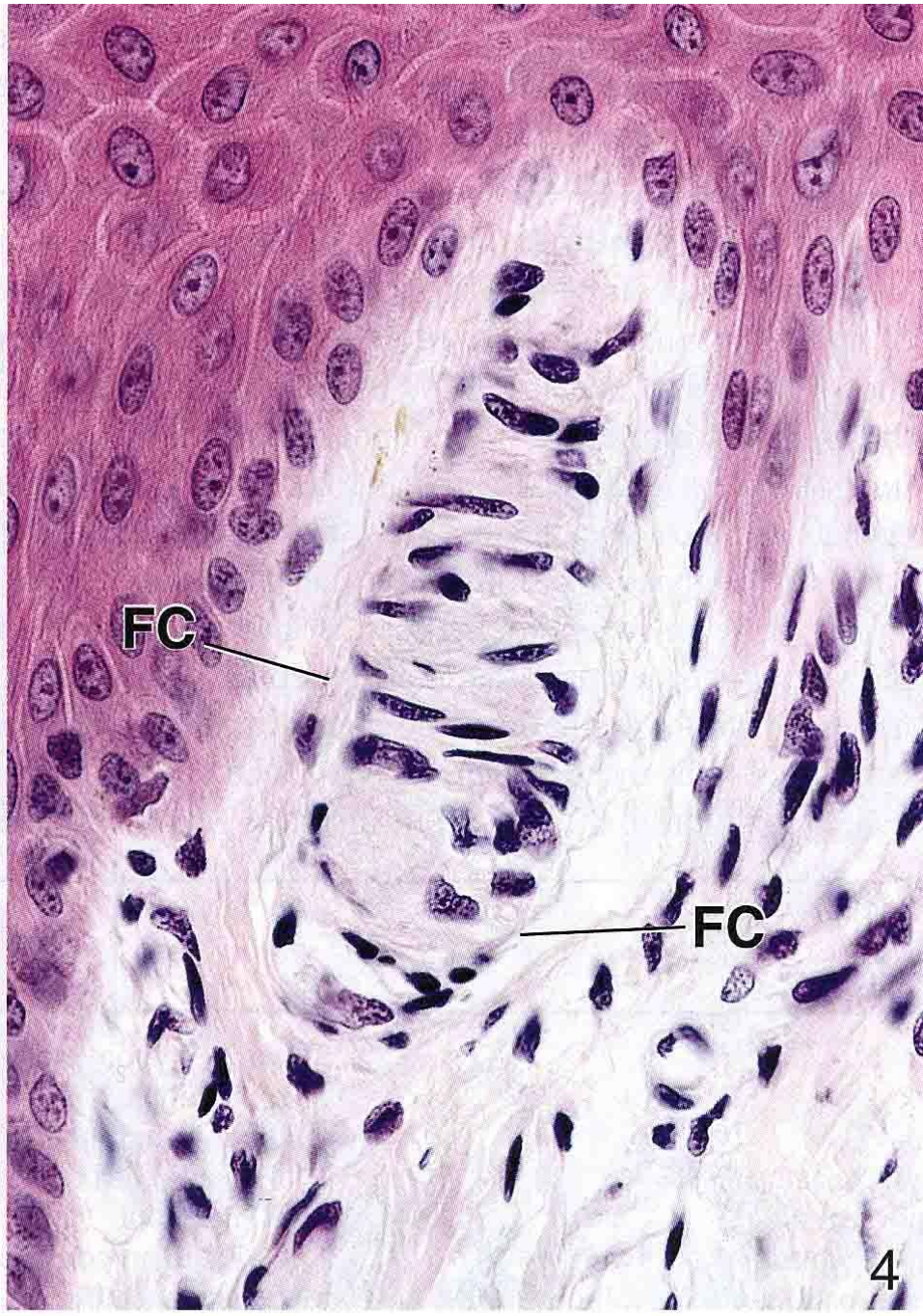
encapsulated

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.