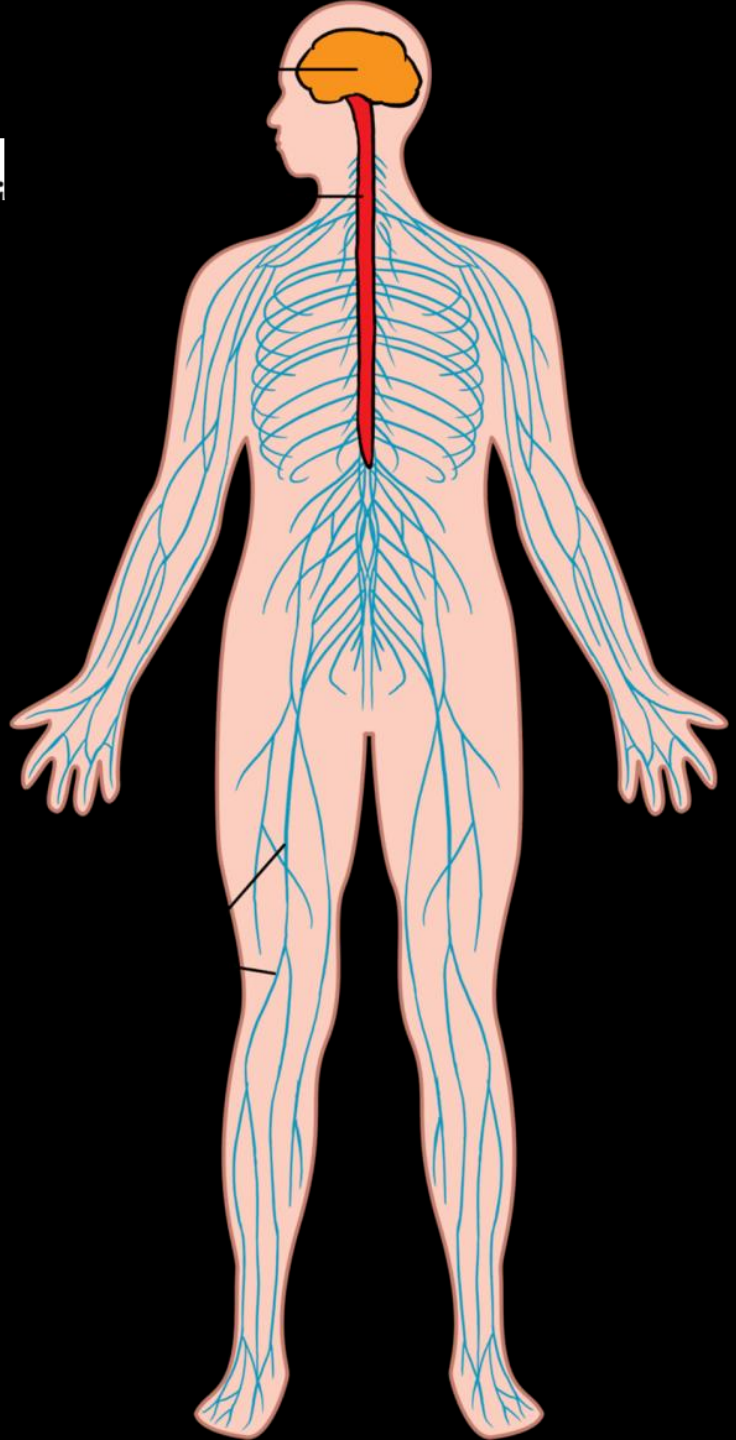
# *Nerve tissue*

# Nerve tissue

Composed of cells with long processes, which form networks and circuits able to receive, process, generate and conduct nerve impulses.

**CNS:** brain, spinal cord

**PNS:** nerves, ganglia



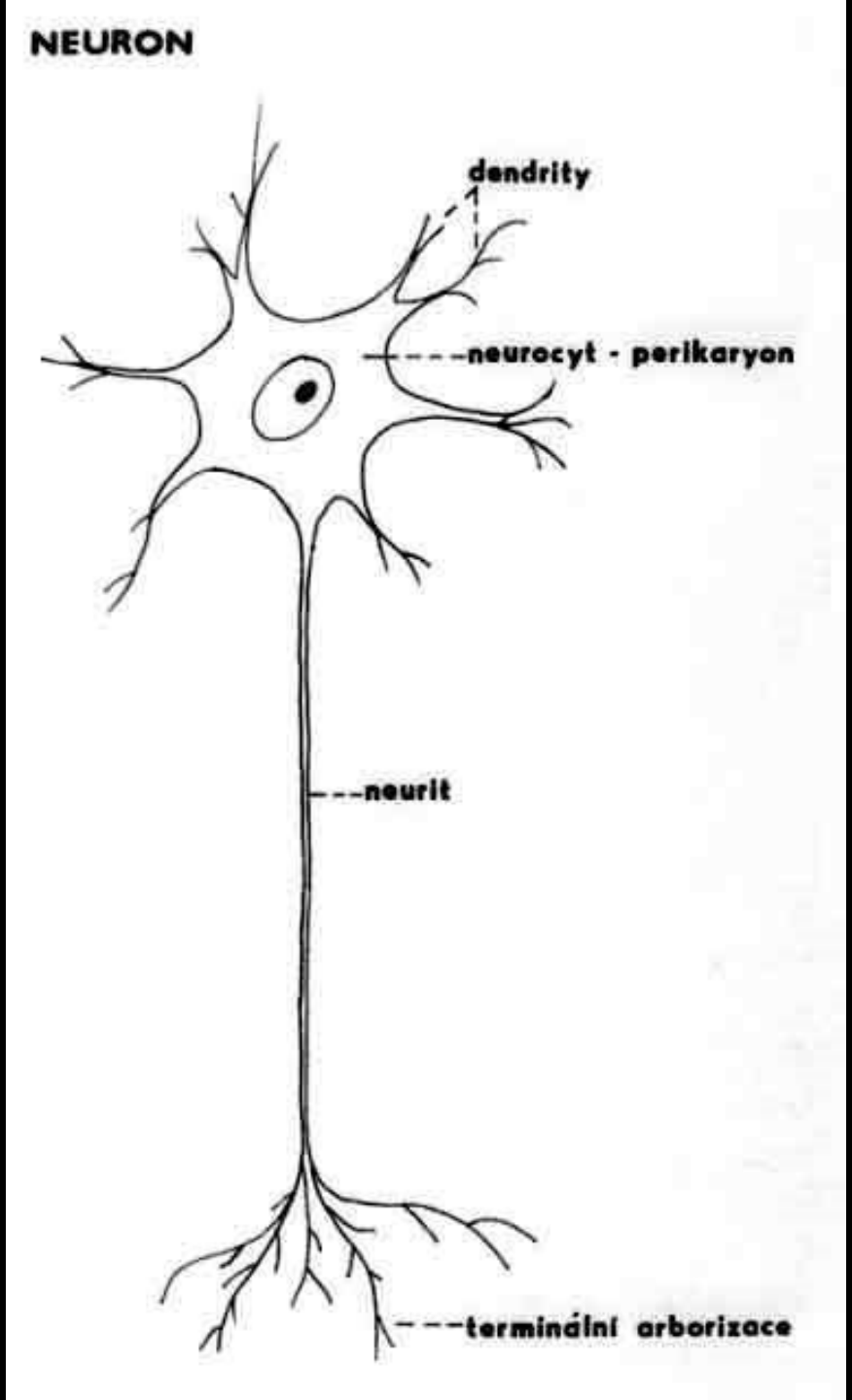
## Nerve tissue cells

- neurons
- glial cells (neuroglia)

## Extracellular matrix

- negligible volume
- CNS <<< PNS

# Neurons



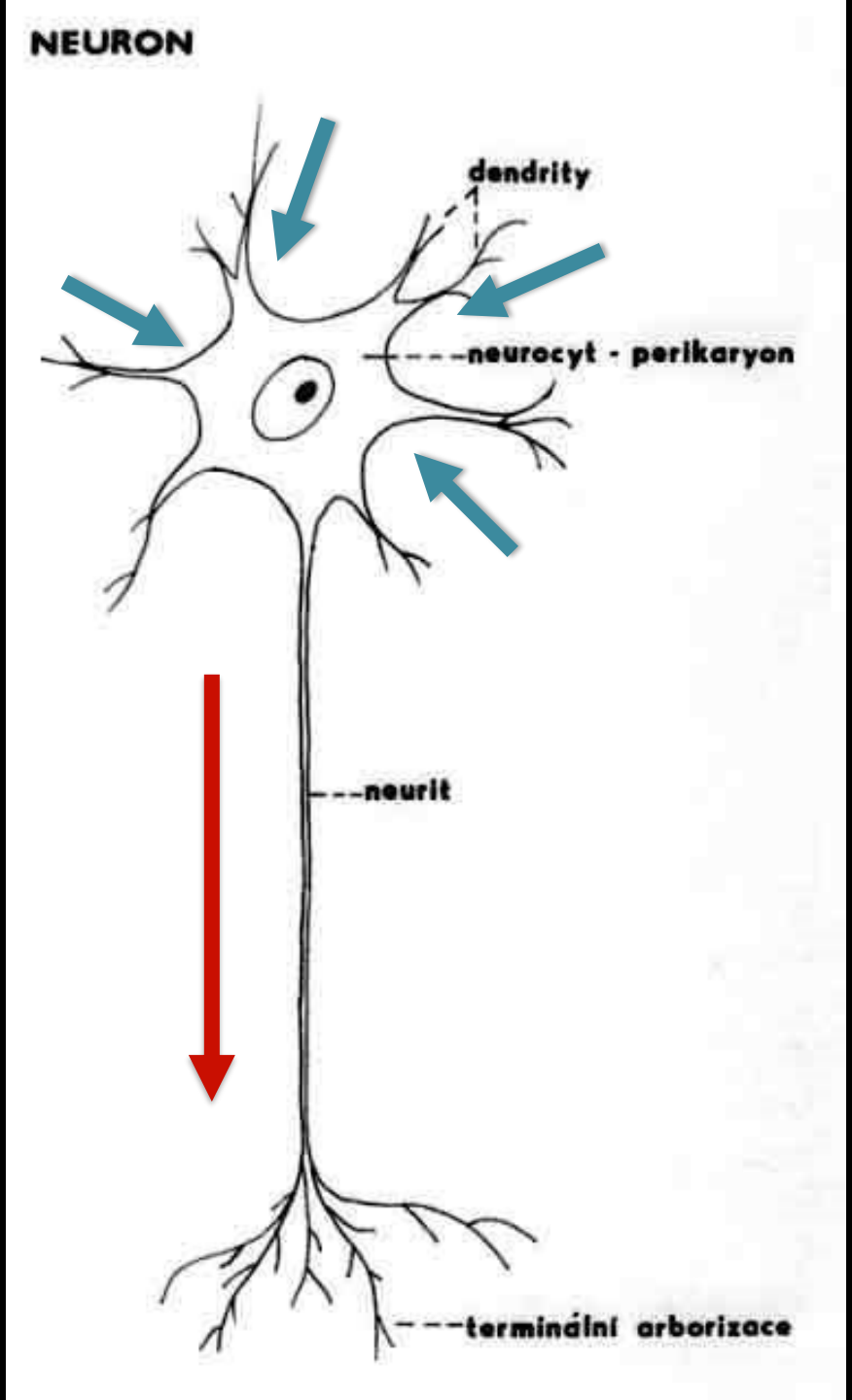

dendrites

neurocyte (perikaryon, cell body)

axon (neurite)

terminal arborization

# Neurons

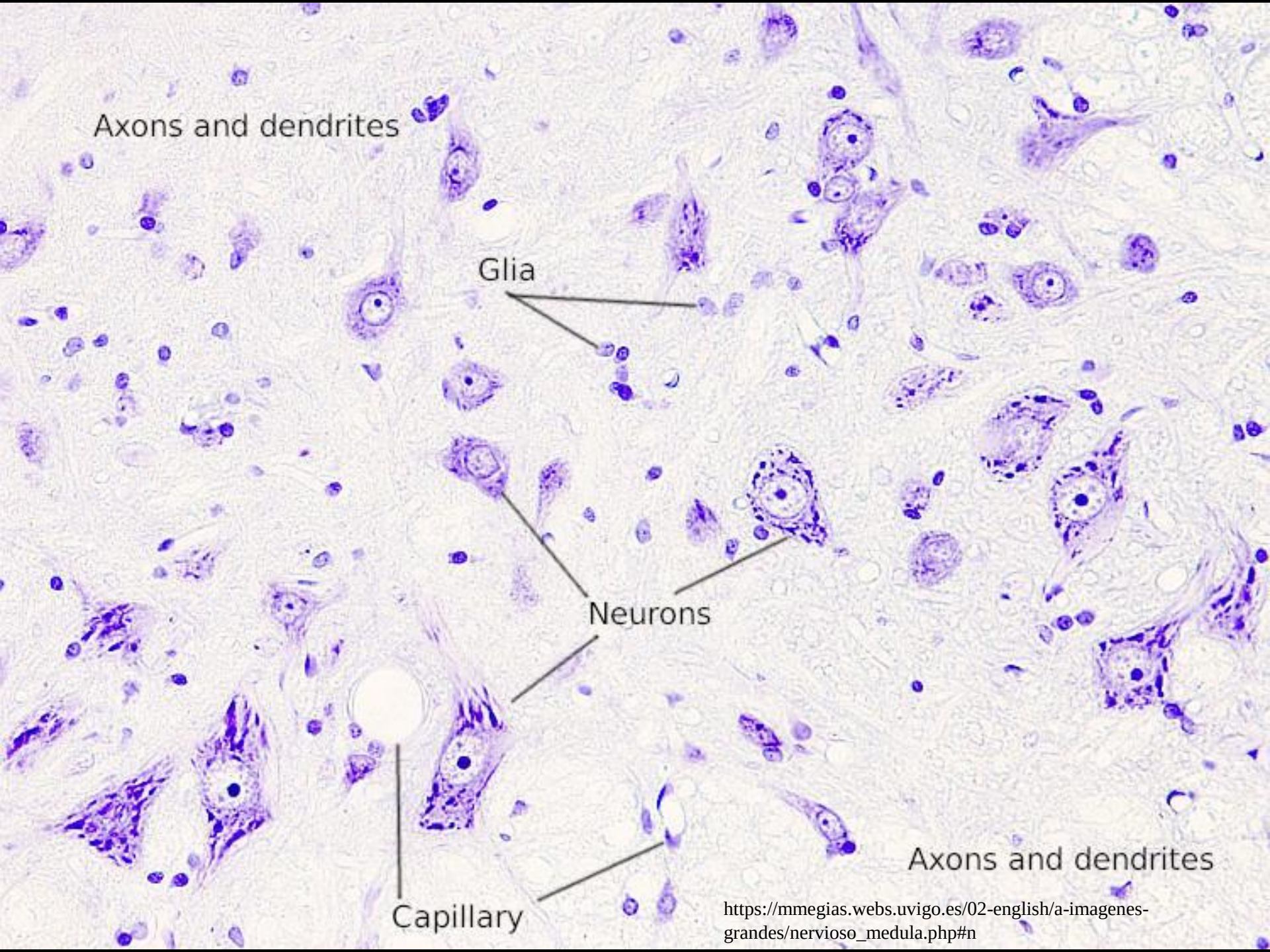



dendrites

neurocyte (perikaryon, cell body)

axon (neurite)

terminal arborization



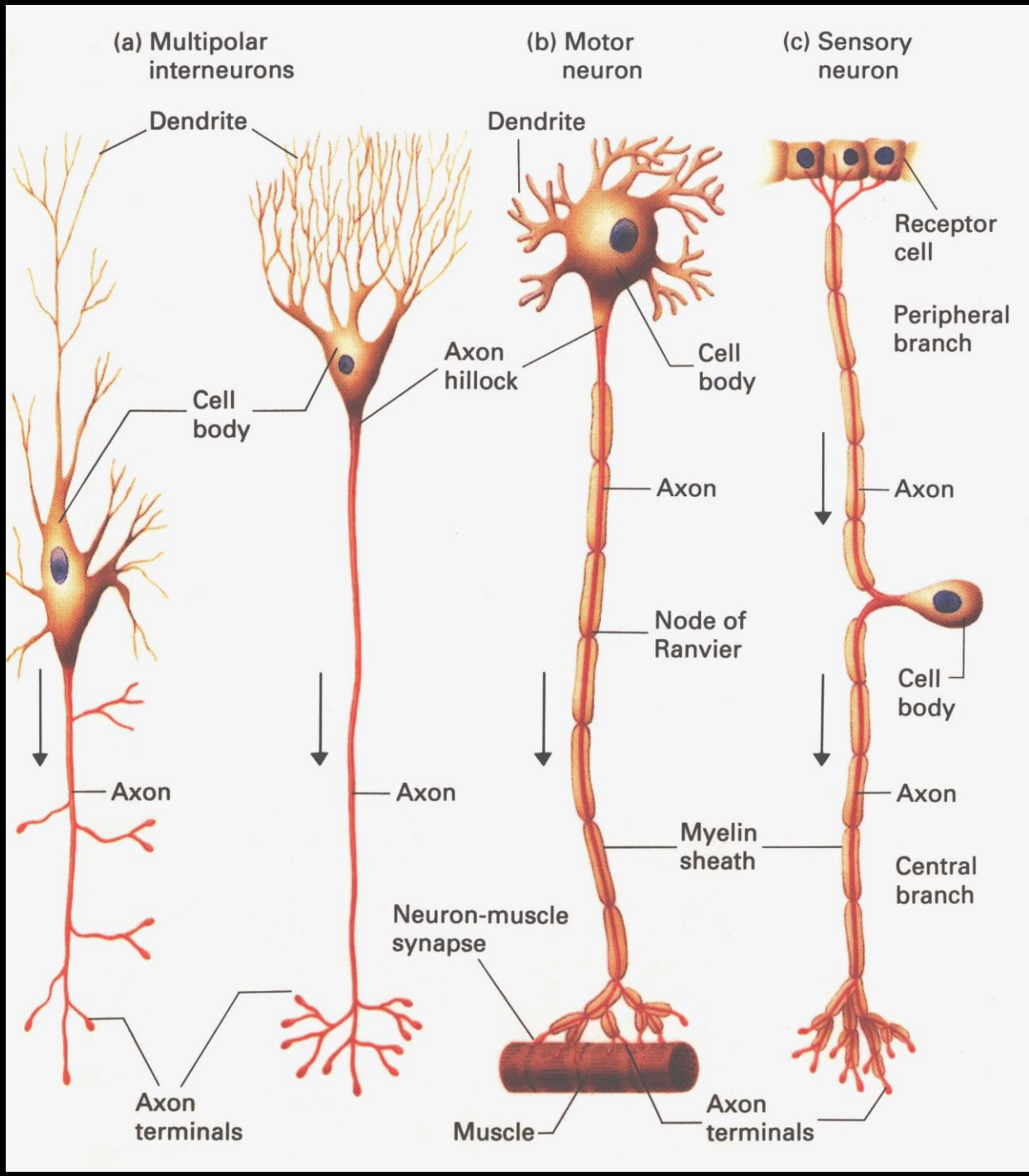

https://mmegias.webs.uvigo.es/02-english/a-imagenes-grandes/nervioso_medula.php#n

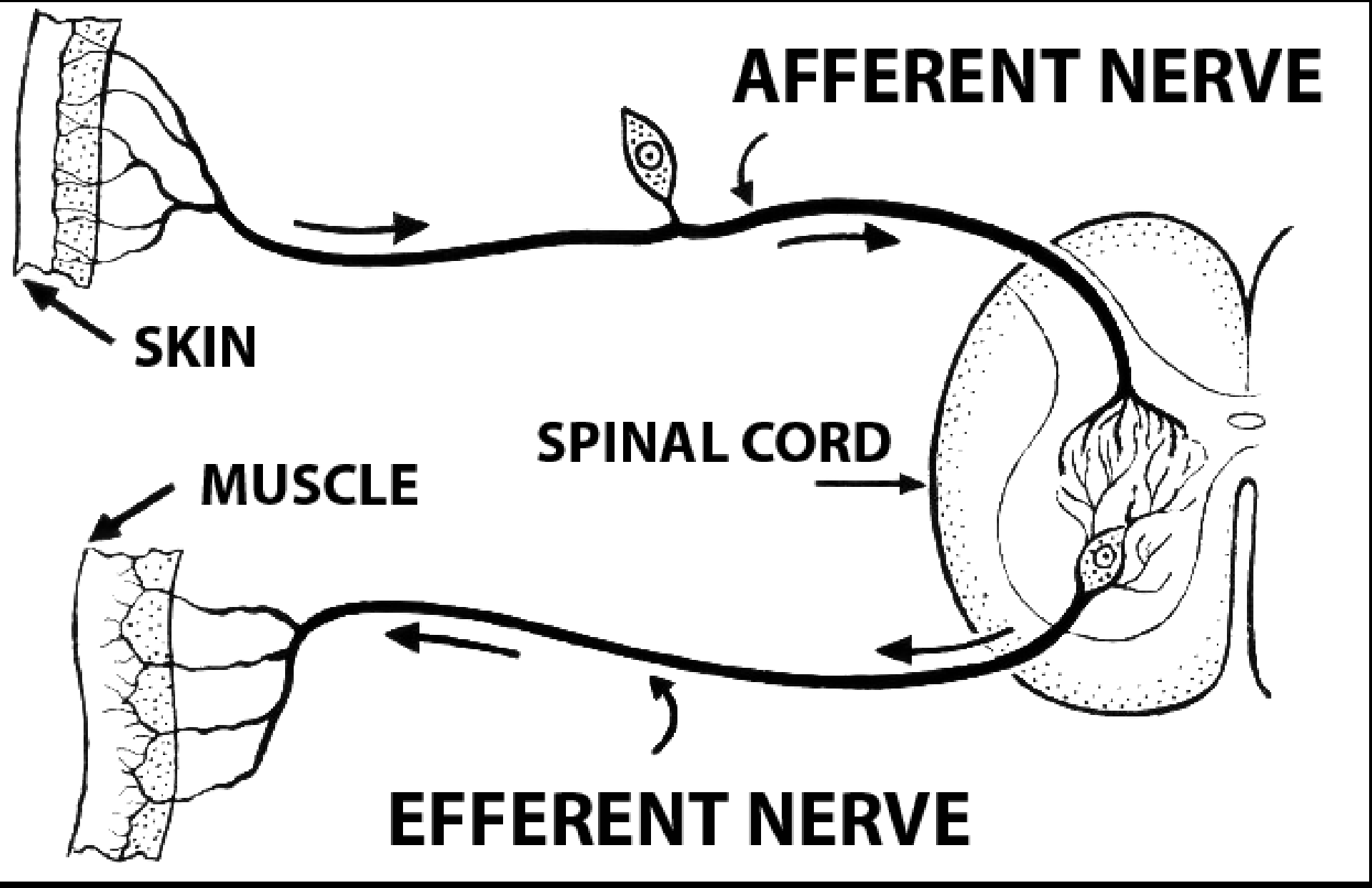
# Classification of neurons

- according to number of processes
  - bipolar
  - multipolar
  - pseudounipolar

- according to lenght of axon
  - Golgi type I
  - Golgi type II

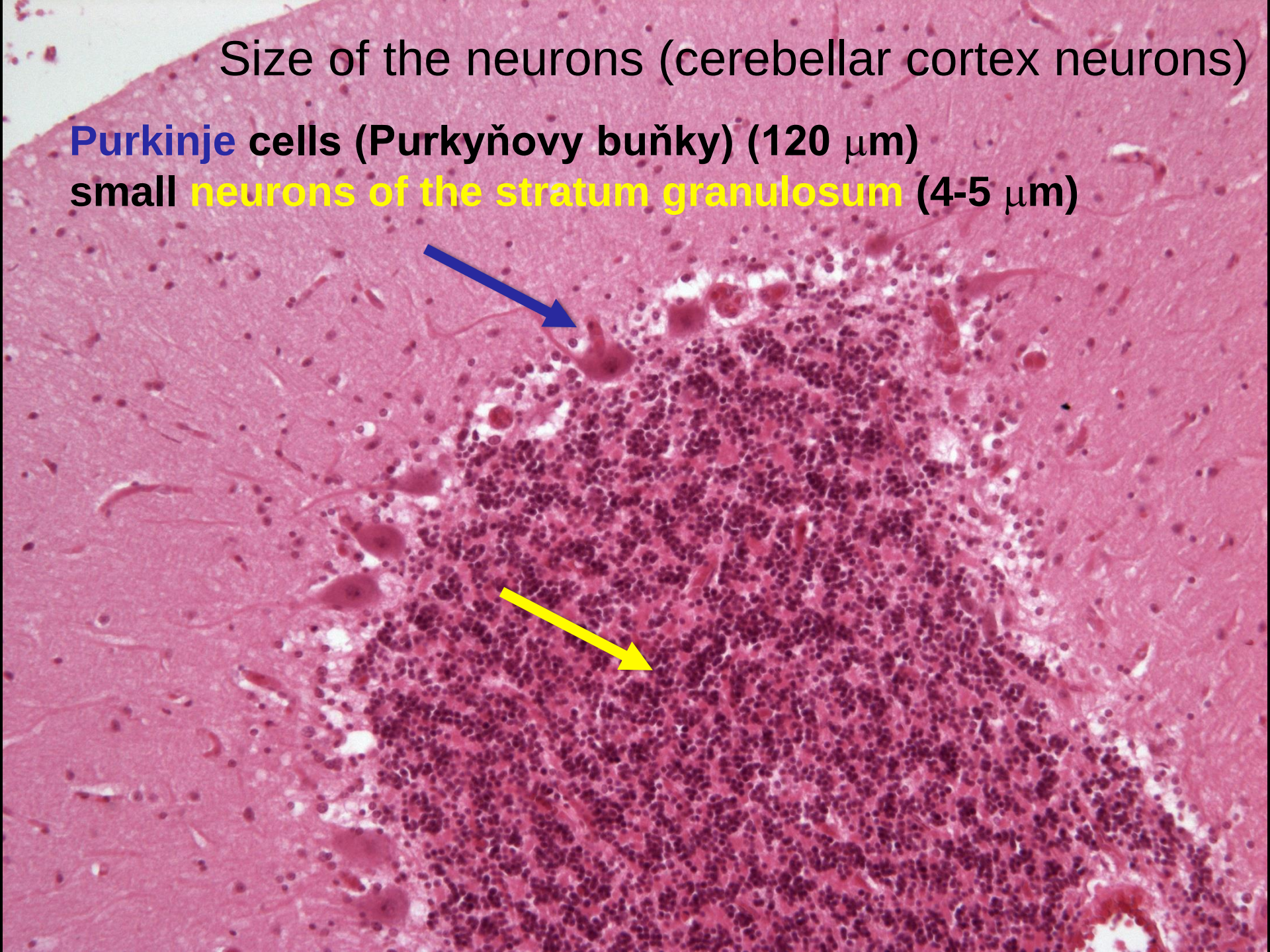
- according to function
  - afferent (sensitive)
  - efferent (motor)
  - interneurons



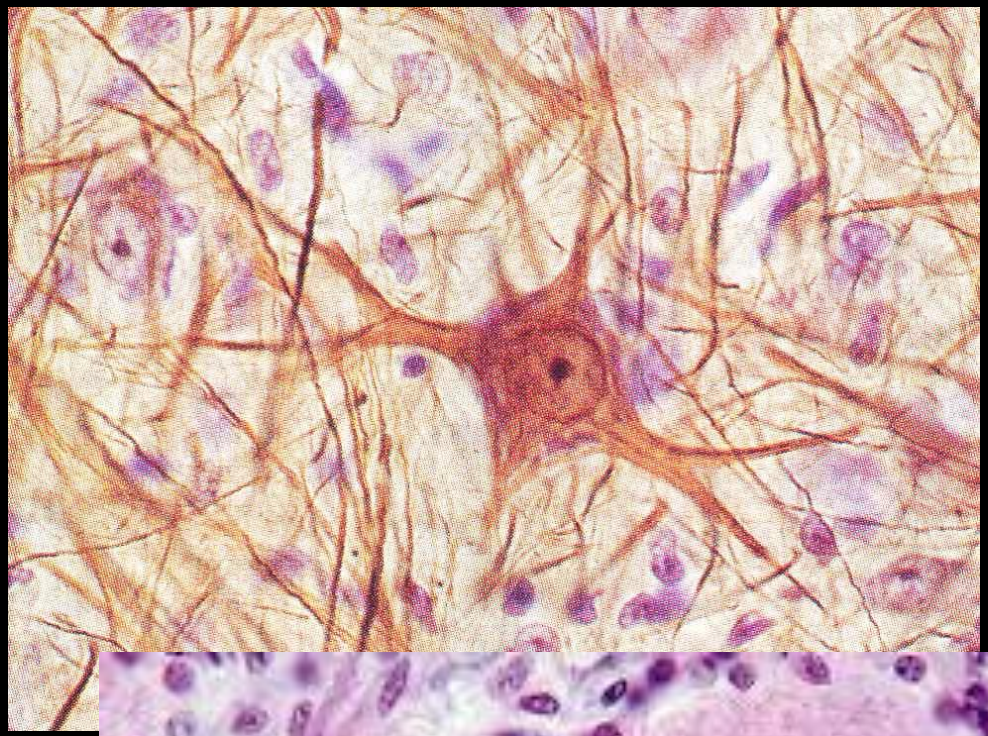

AFFERENT NERVE
SKIN
SPINAL CORD
MUSCLE
EFFERENT NERVE

# Size of the neurons (cerebellar cortex neurons)

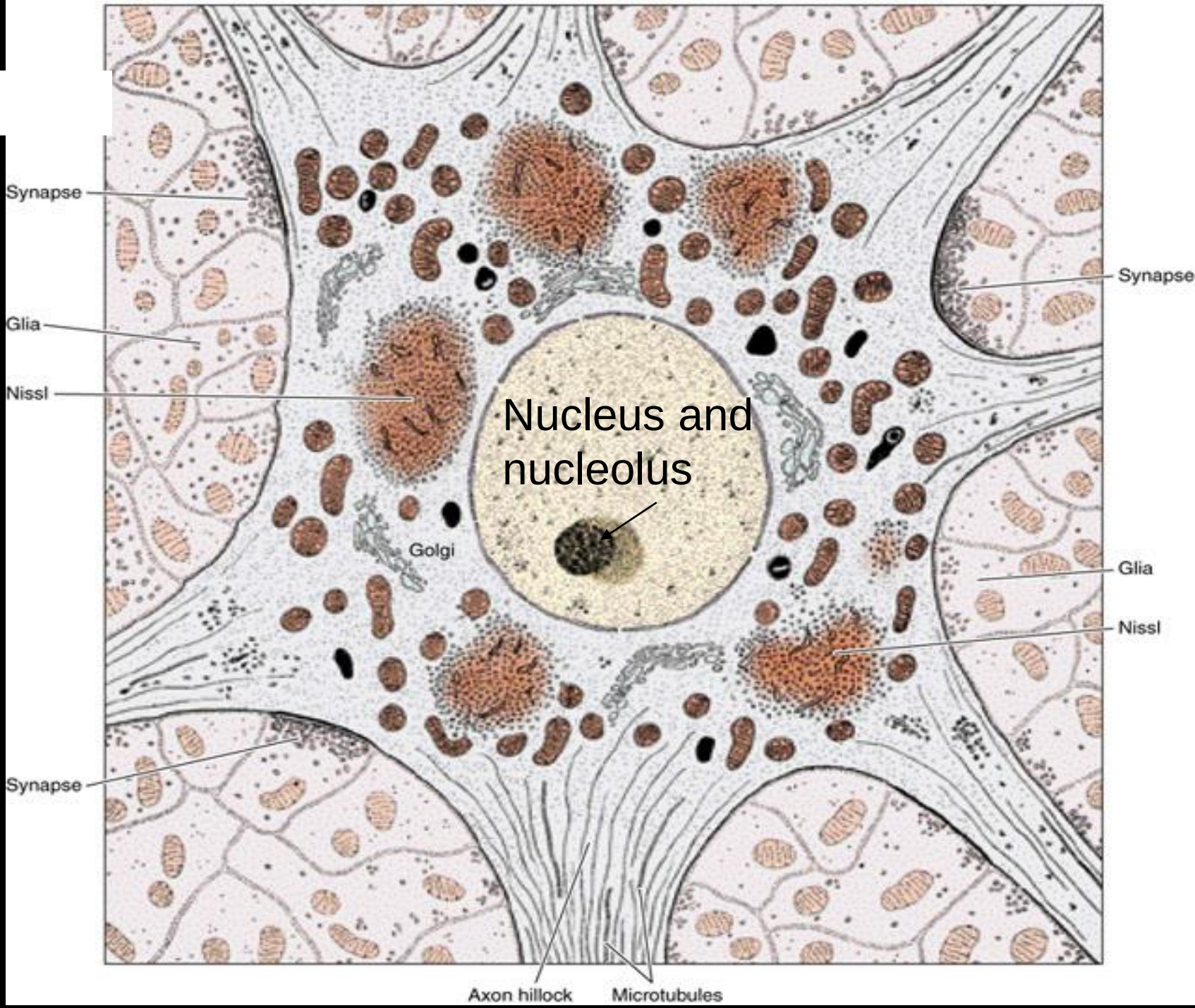
**Purkinje cells (Purkyňovy buňky) (120 μm)**
**small neurons of the stratum granulosum (4-5 μm)**

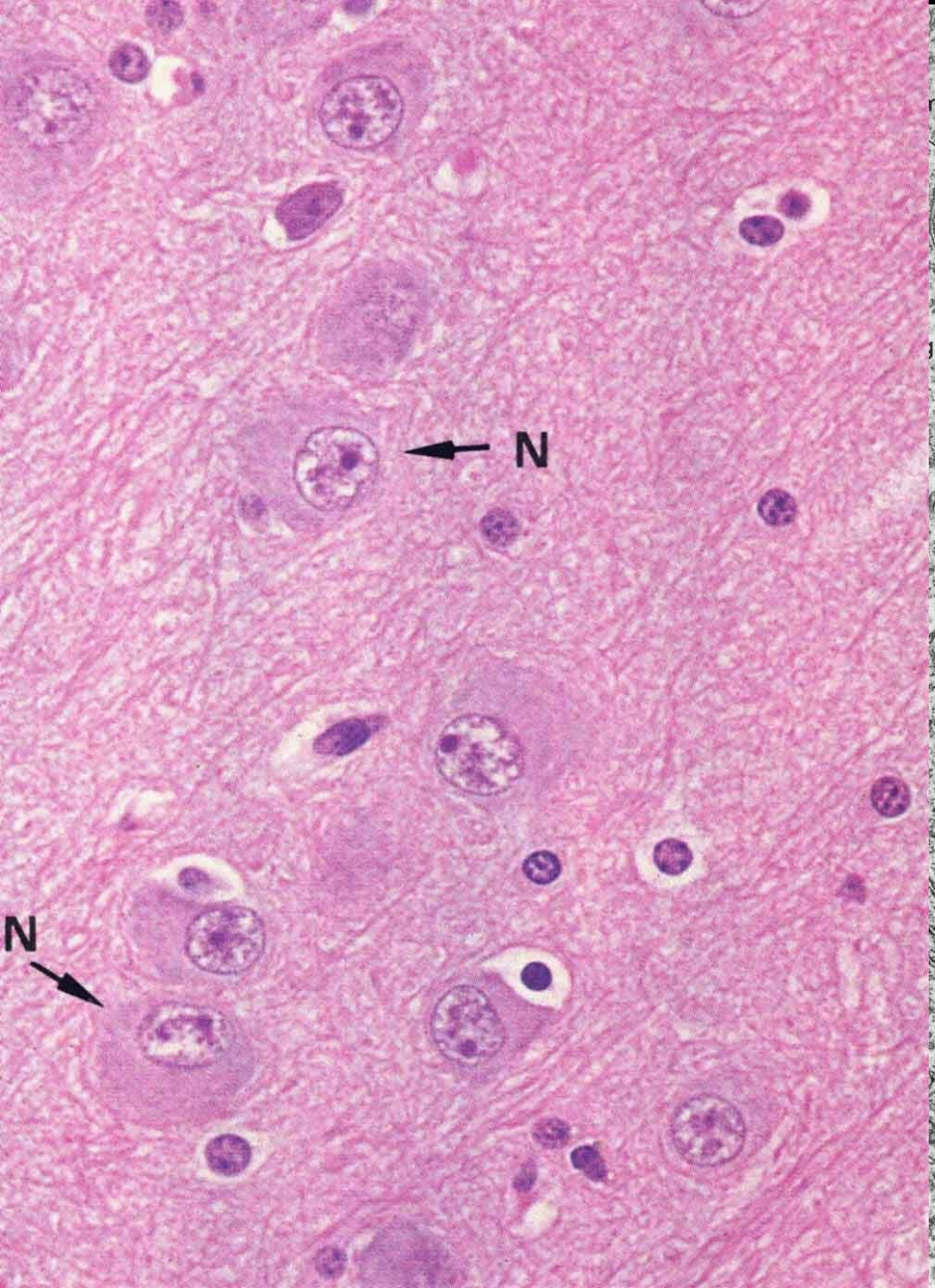


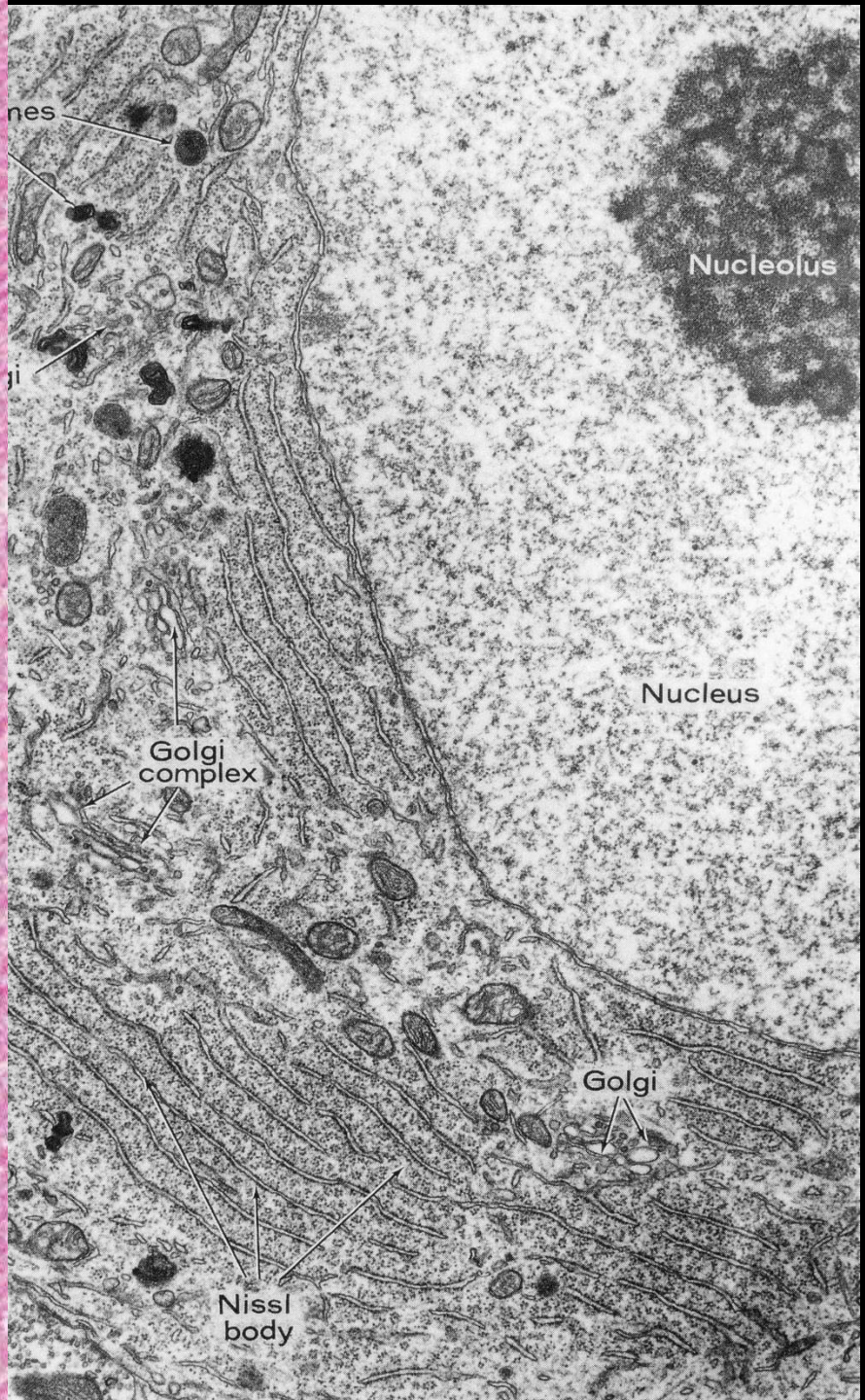
# Neuronal body (forms)



# Body


Synapse
Glia
Nissl
Nucleus and nucleolus
Golgi
Synapse
Glia
Nissl
Synapse
Axon hillock
Microtubules


N
N

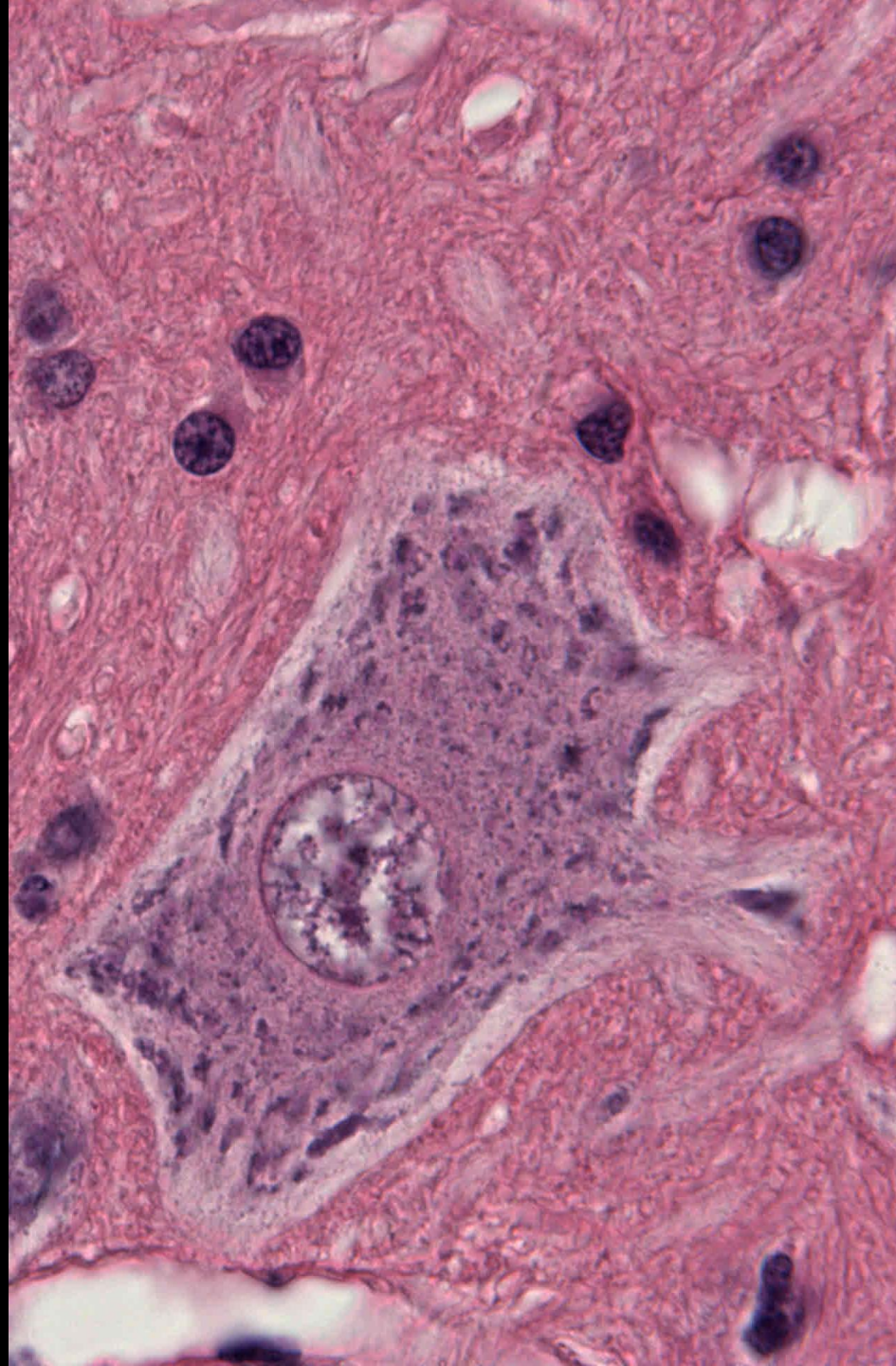

Nucleolus
Nucleus
Golgi complex
Golgi
Nissl body

**NEUROCYTE**
**(CELL BODY, PERIKARYON)**
**trophic centre of a neuron**

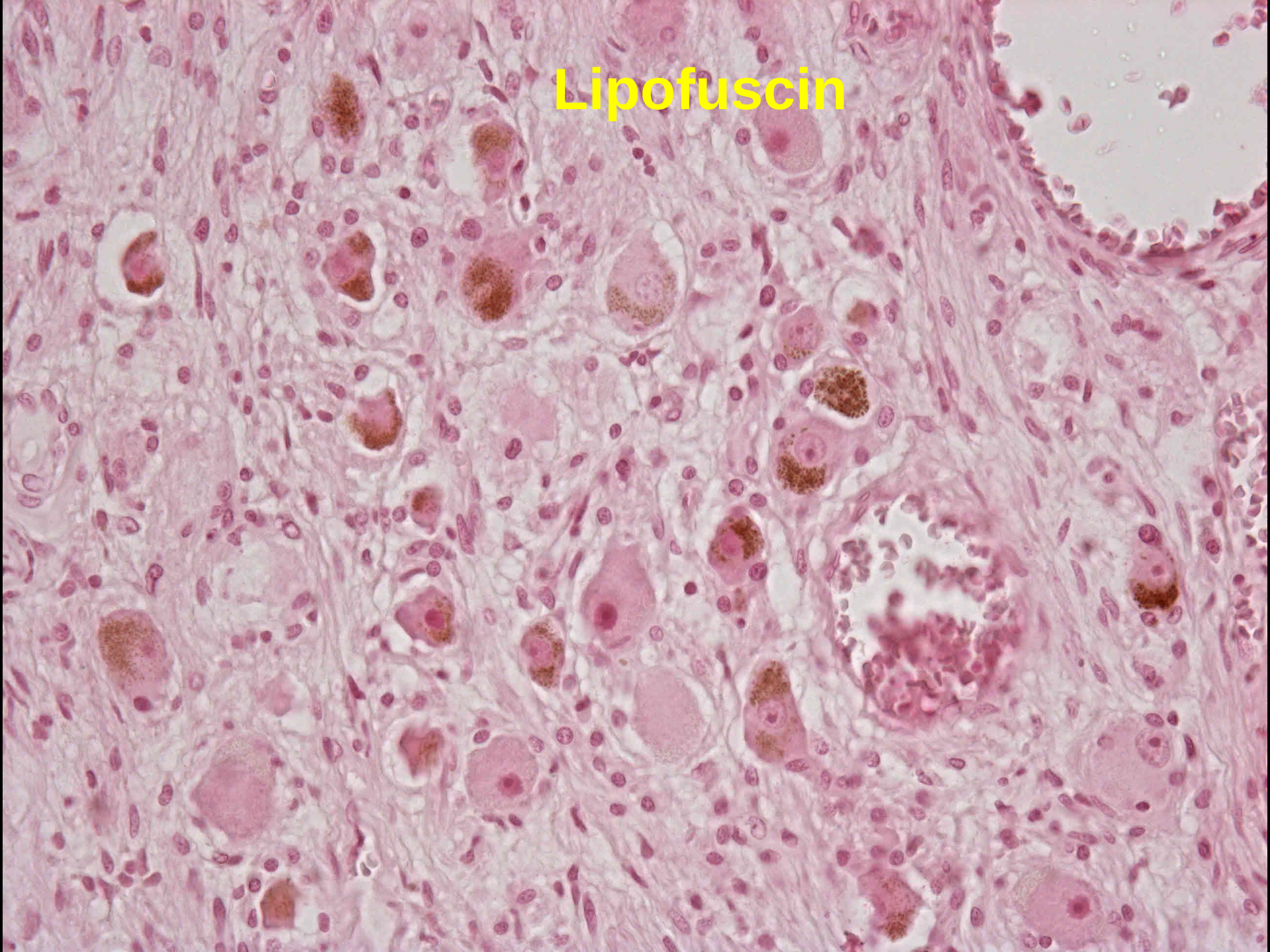
**aerobic glucose metabolism**

**active transporters GLUT-3**
**- from the space of neuropil**
**via astrocytes (storage of**
**energy for 2 - 3 minutes)**

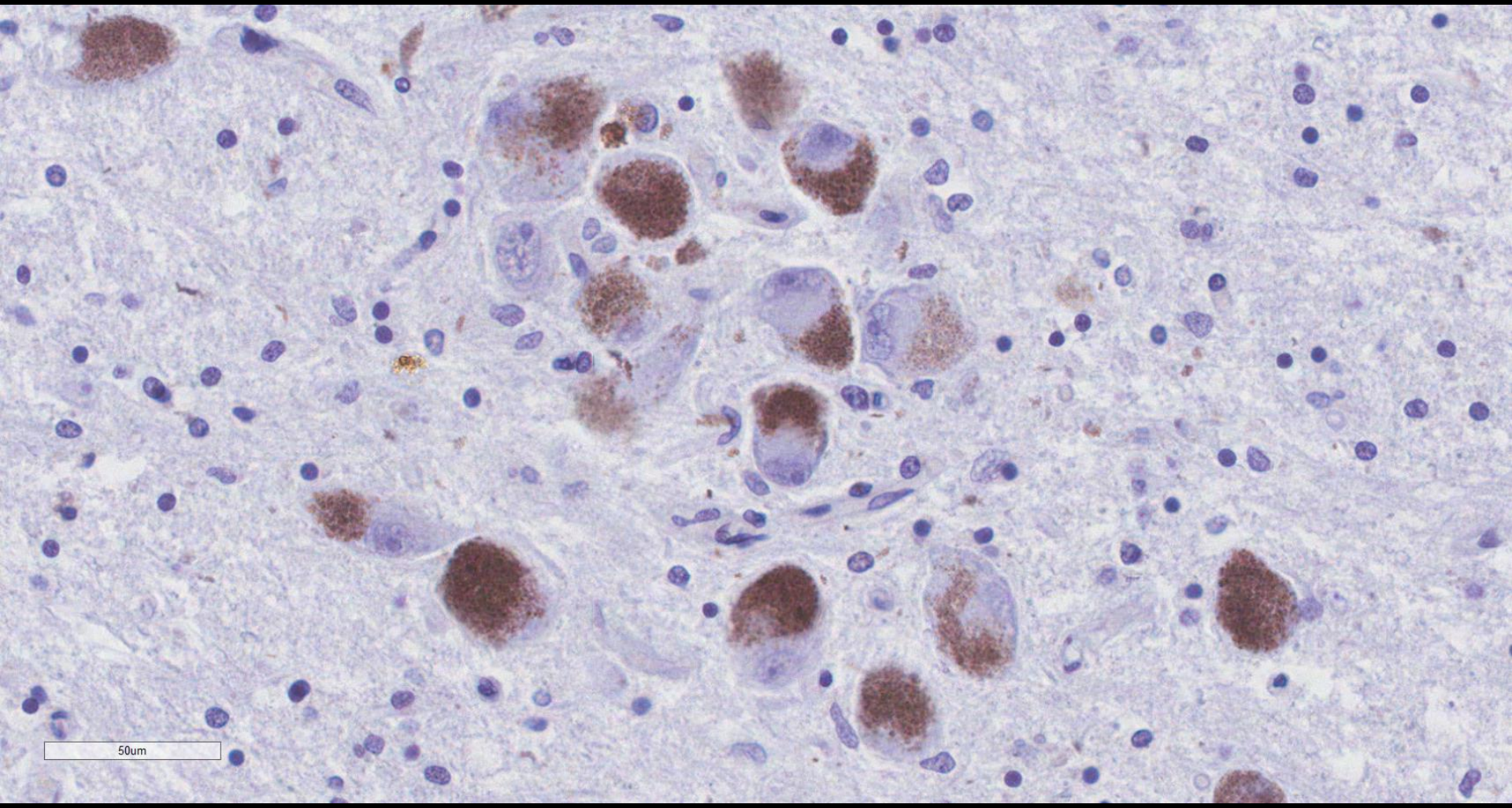
**integration of impulses**

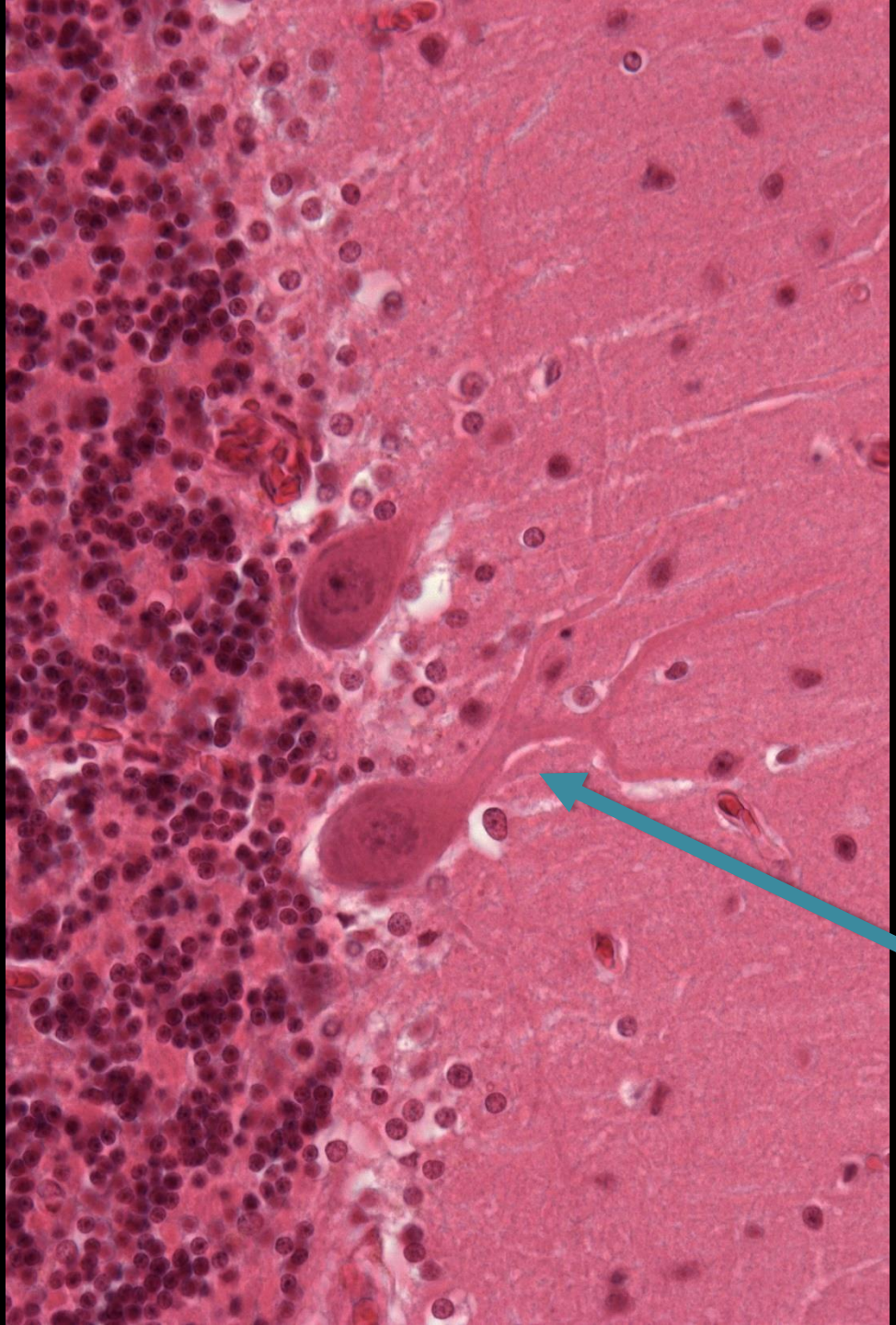



Nissl substance


Lipofuscin

# Neuromelanin

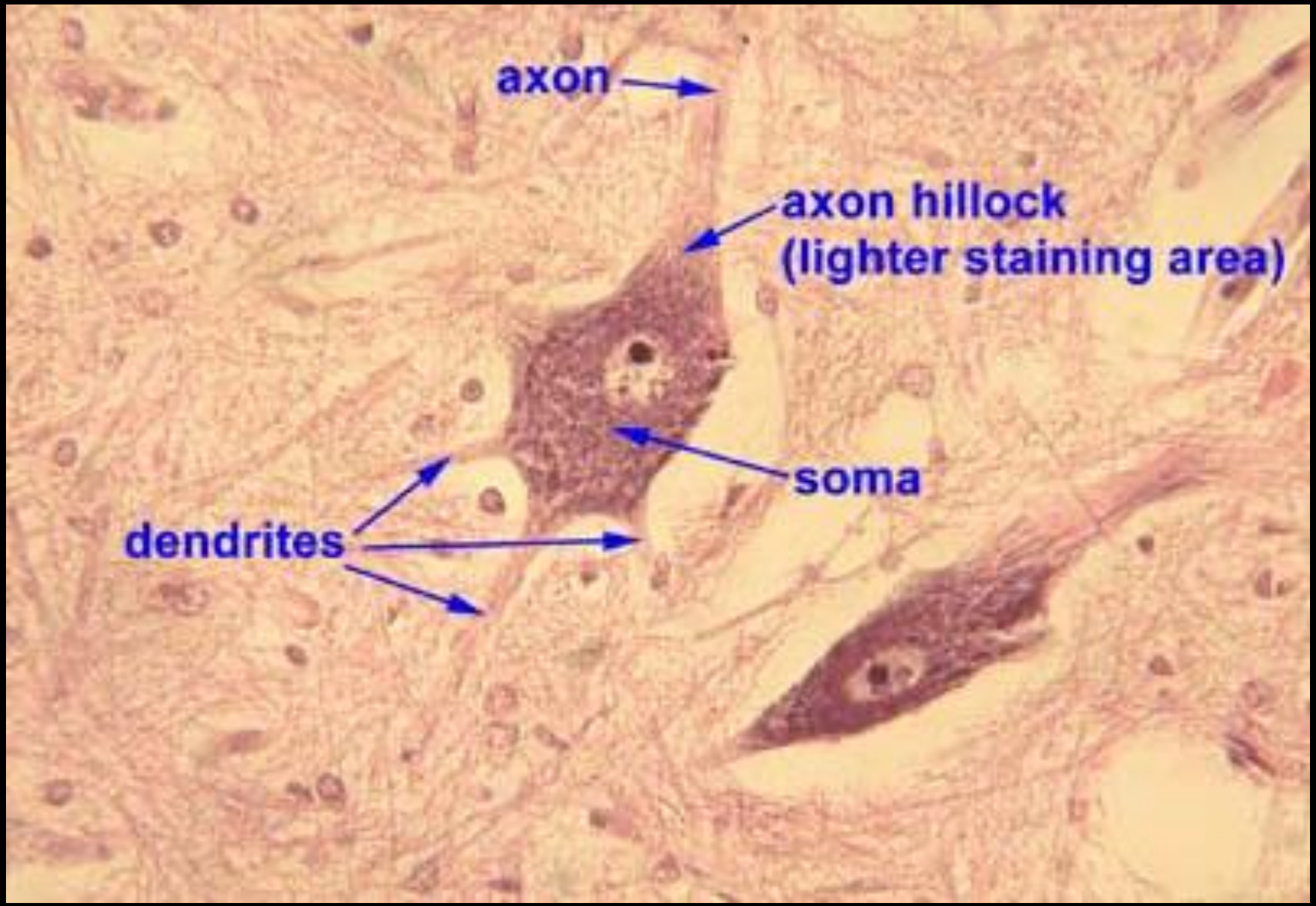


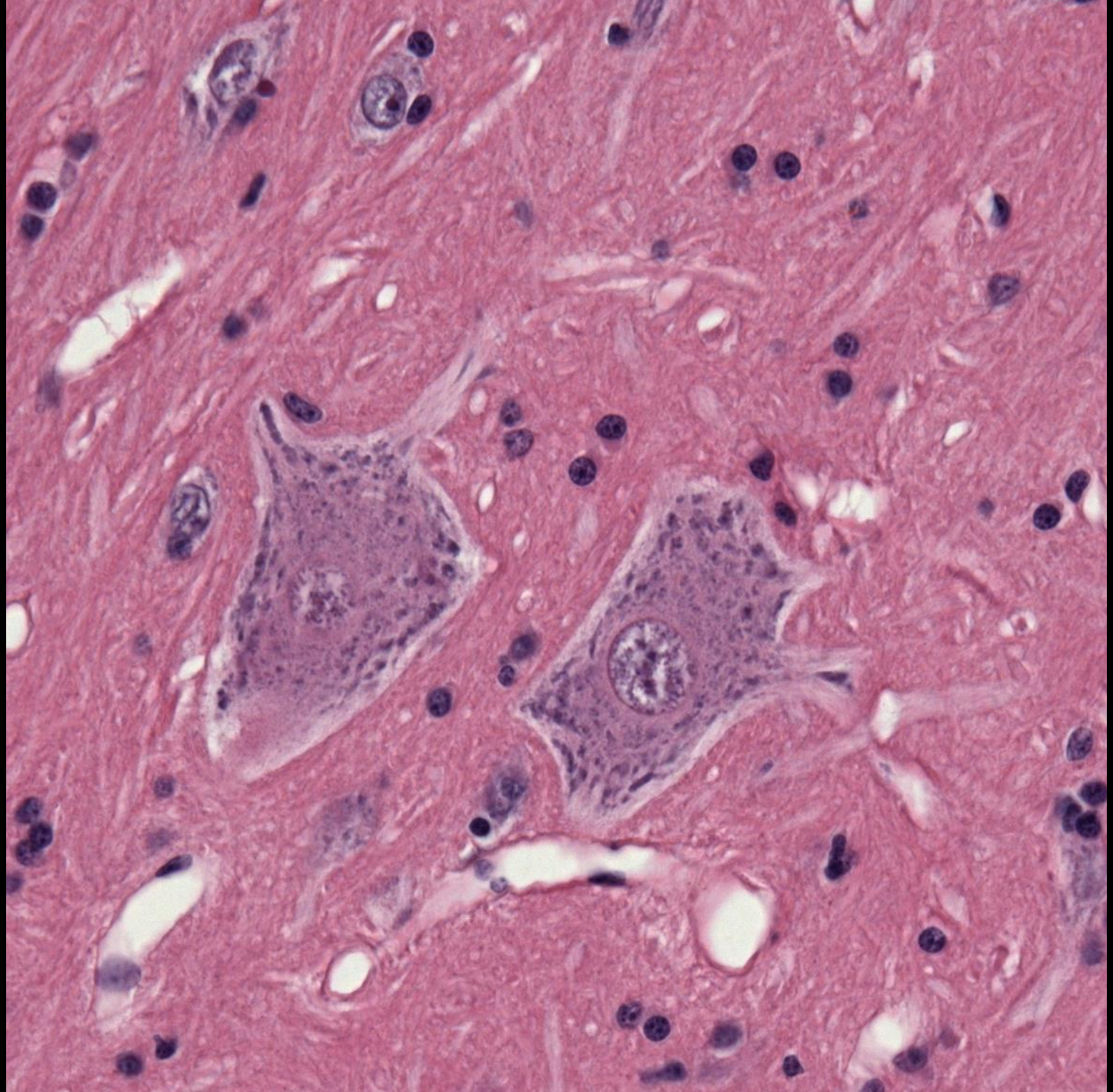


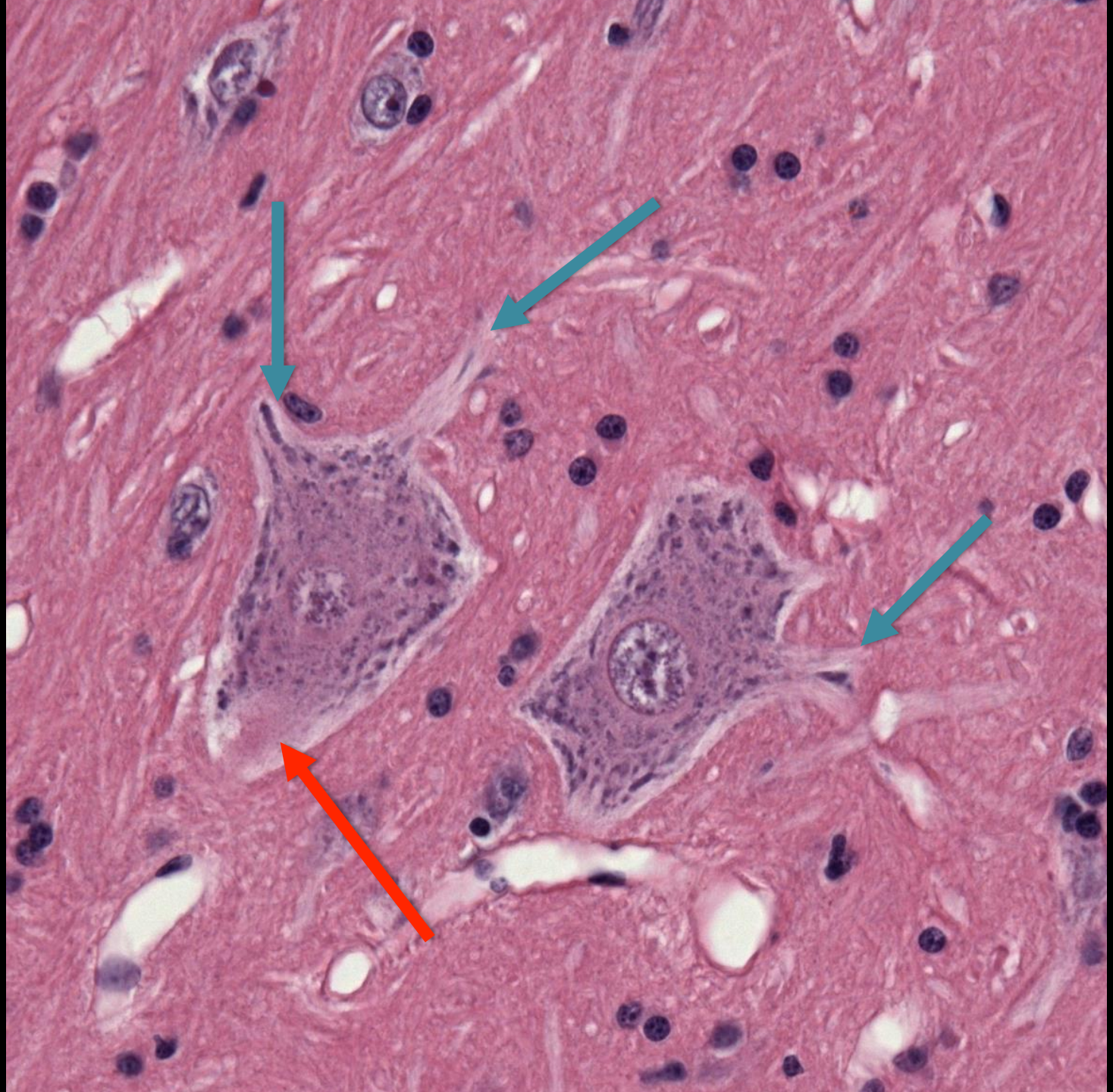
# DENDRITES

**shorther processes**
**MAP 2, MAP 1**

**- branching**
**- contain RER**
**- conduct signals to the body of neurons**

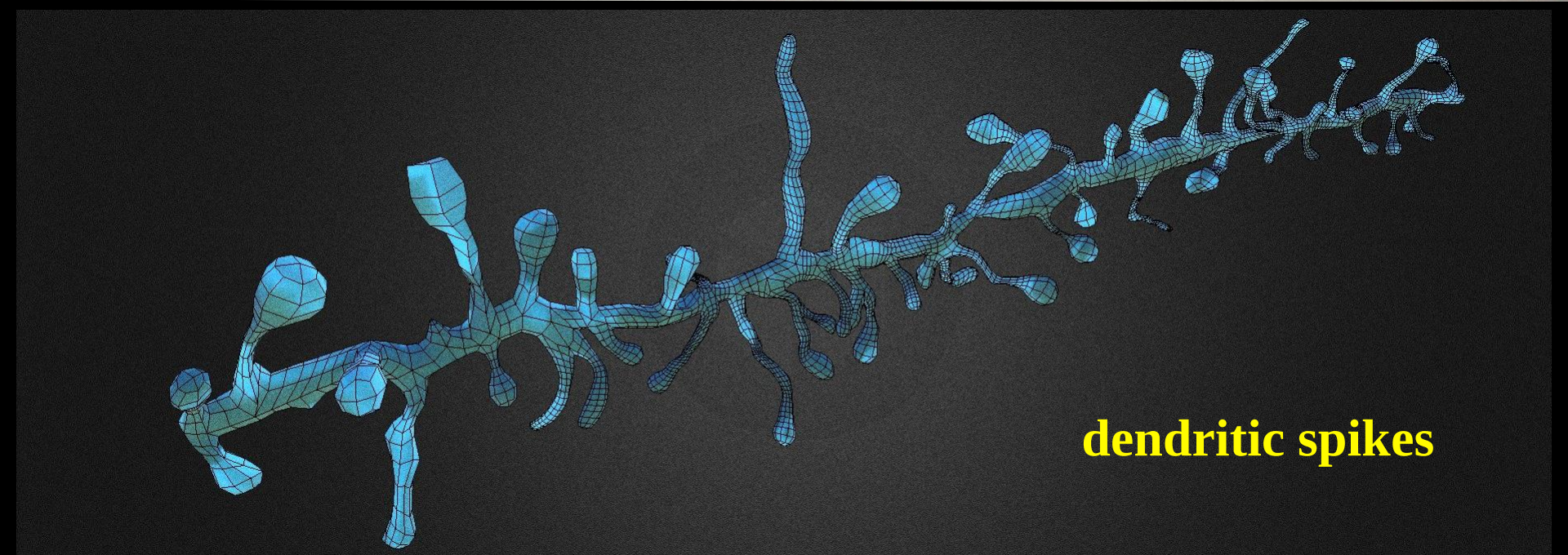

axon
axon hillock
(lighter staining area)
soma
dendrites

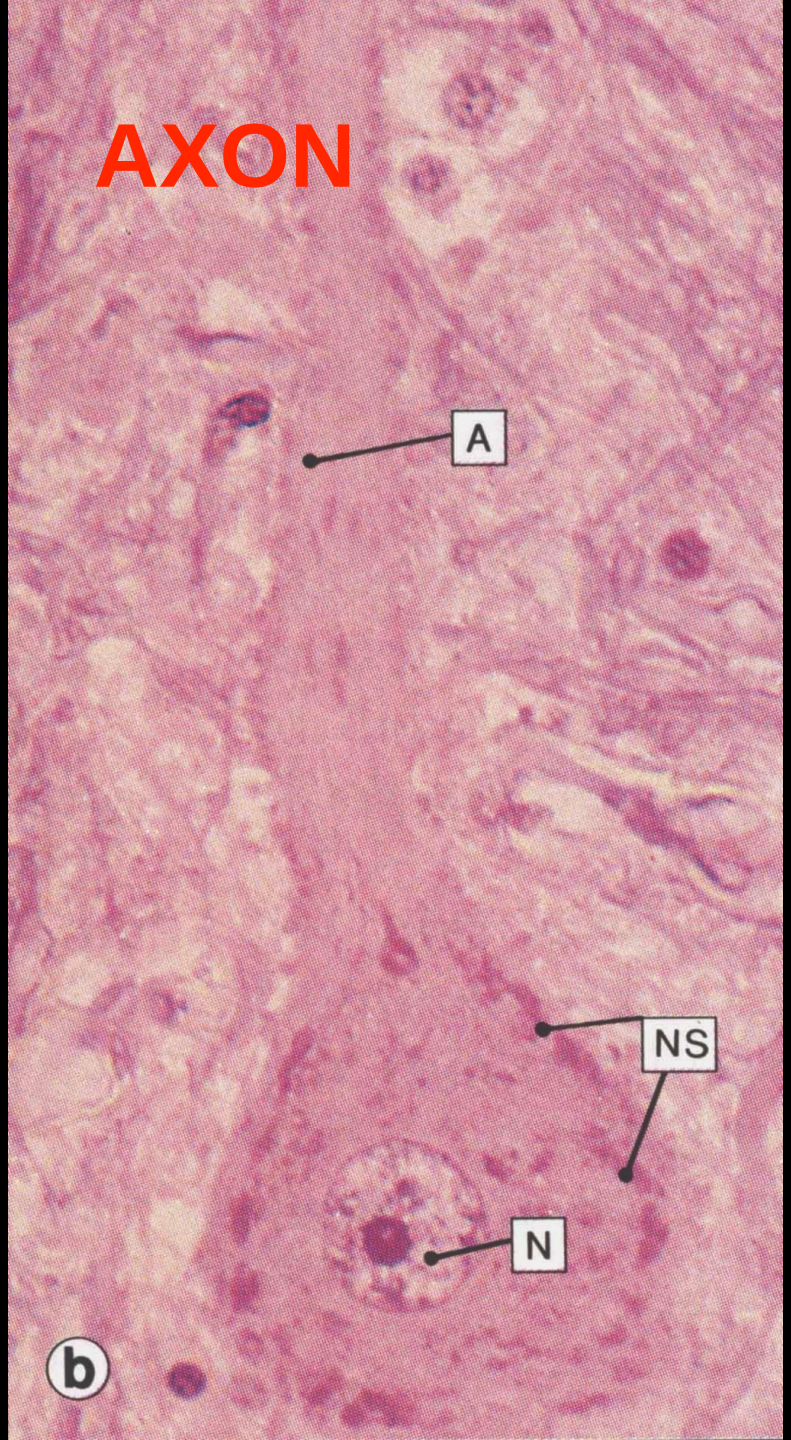





Dendrite
Axon
Spine
Synapse
Spine
Axon
Dendrite
Synapse
Spine


a
b
axon
dendrite


dendritic spikes

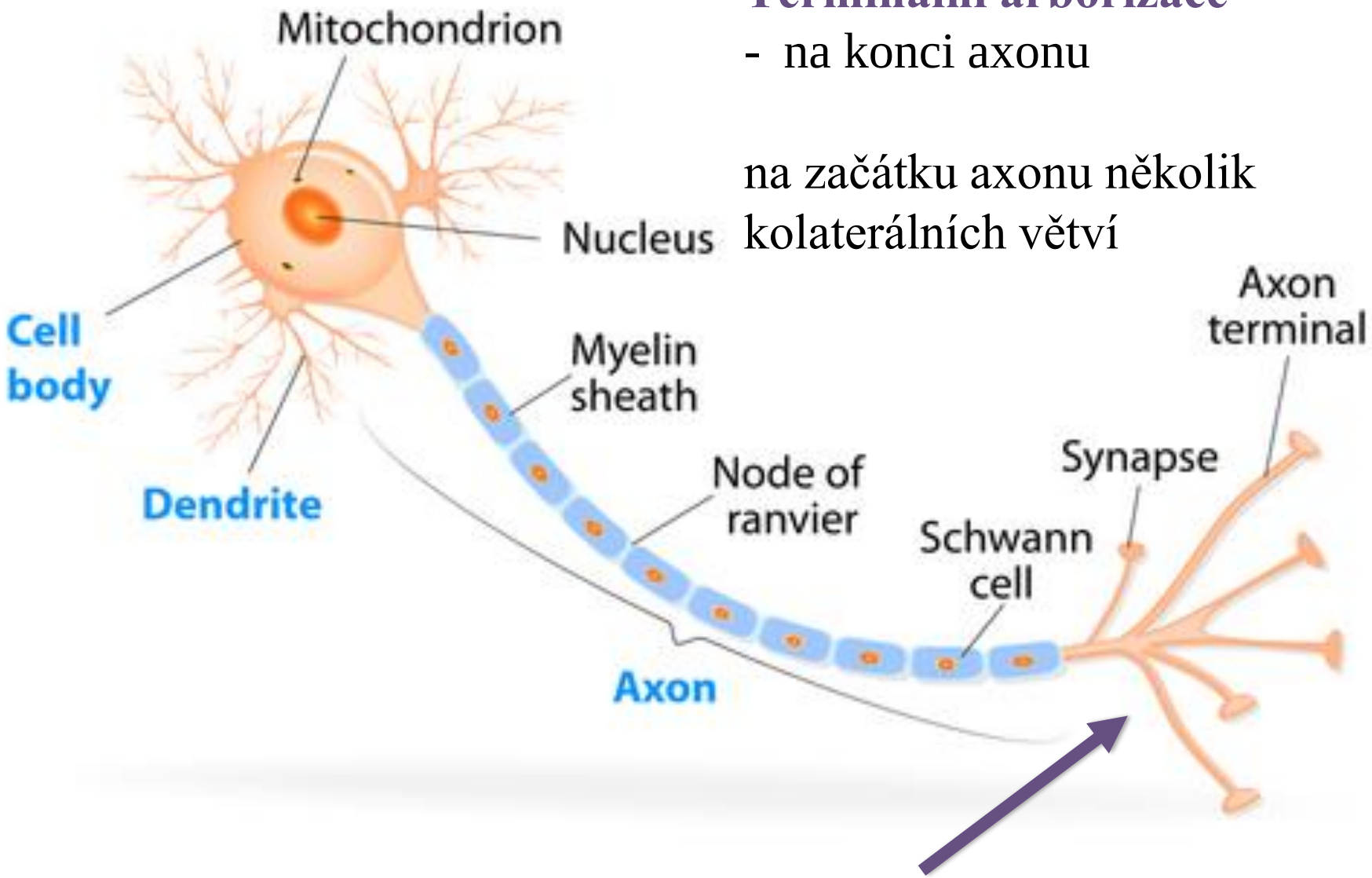

AXON
A
NS
N
b


Axon hillock
axon hillock
MT
initial segment
Initial segment
axon
AE

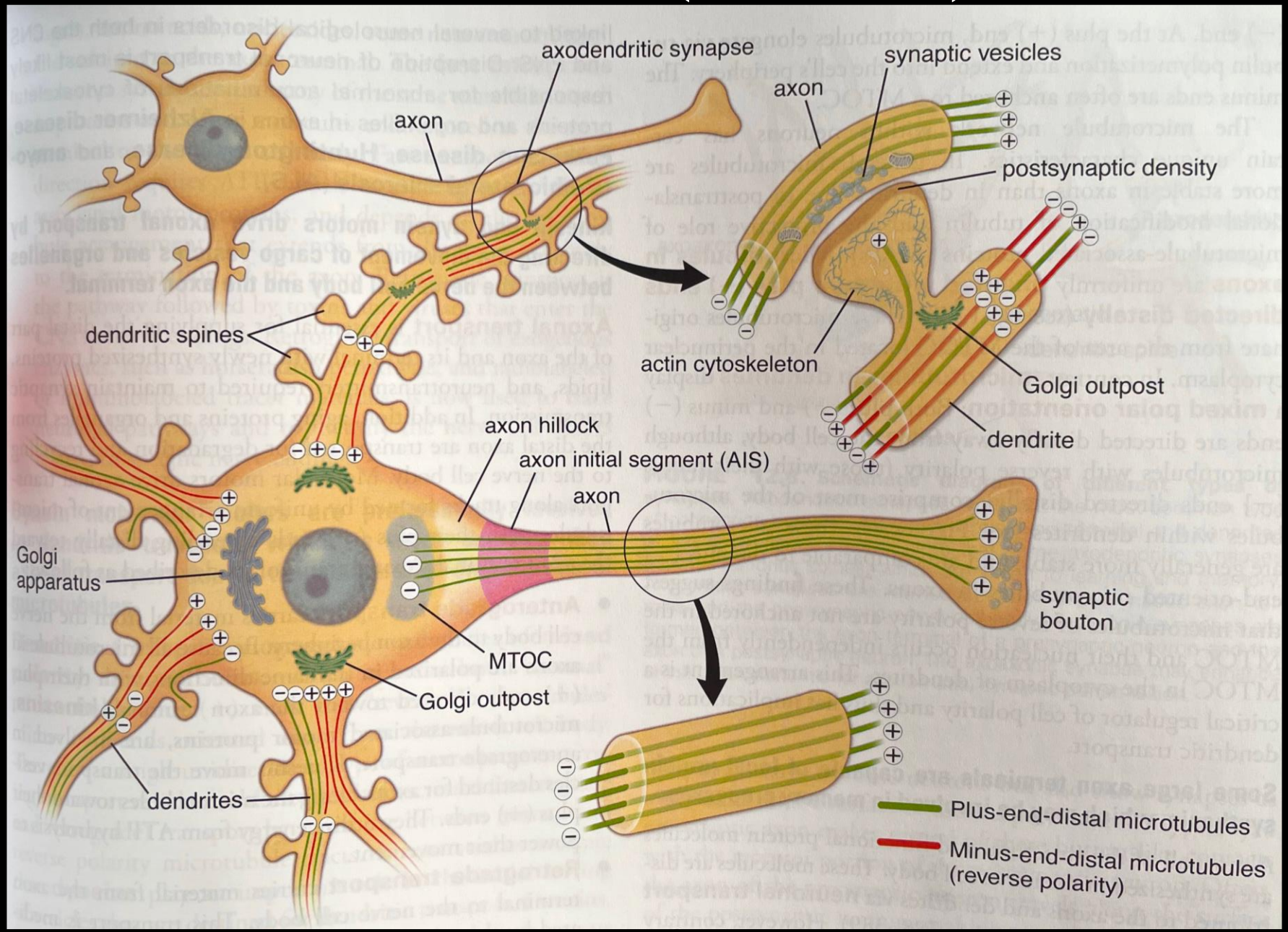
## Terminální arborizace

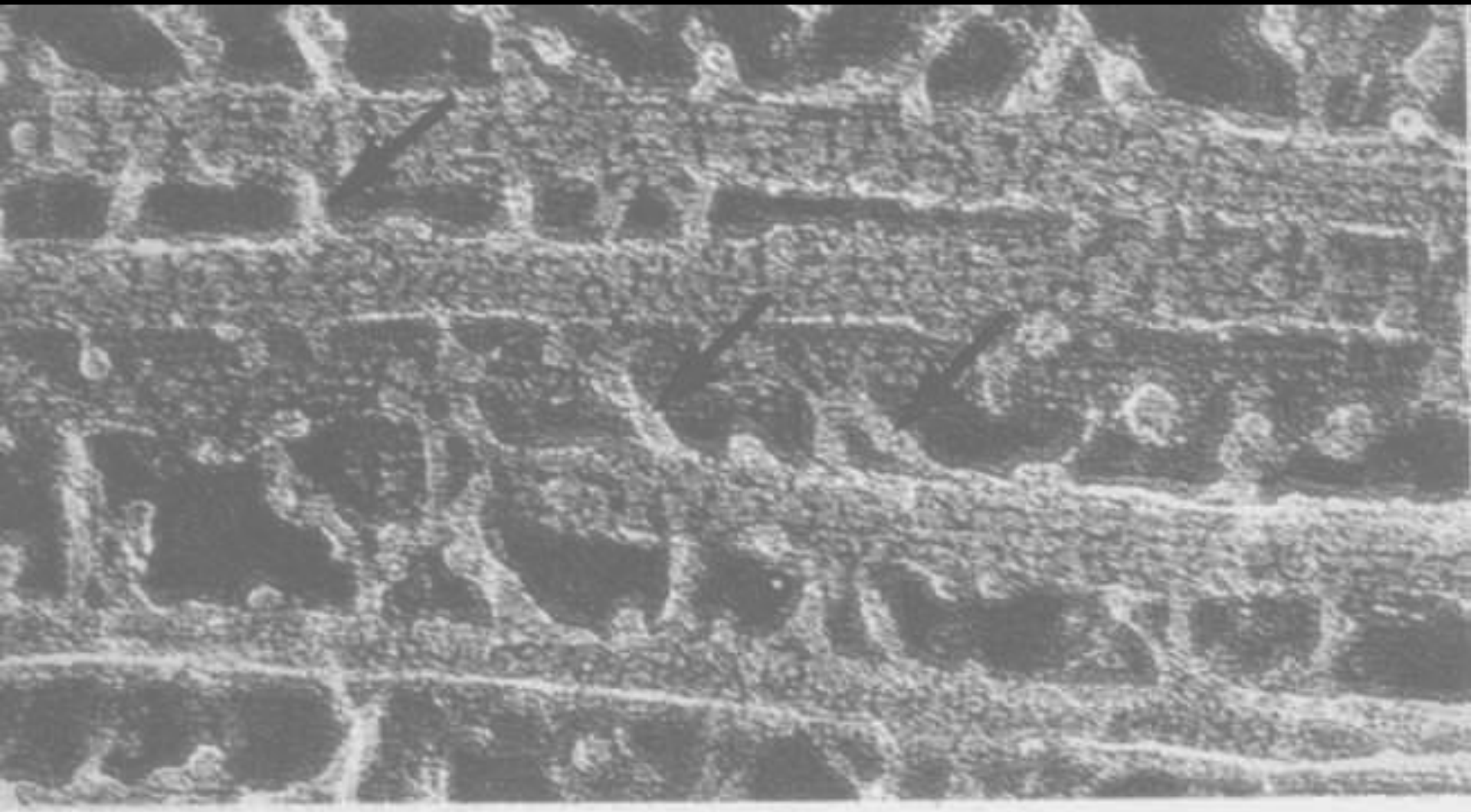
- na konci axonu

na začátku axonu několik kolaterálních větví



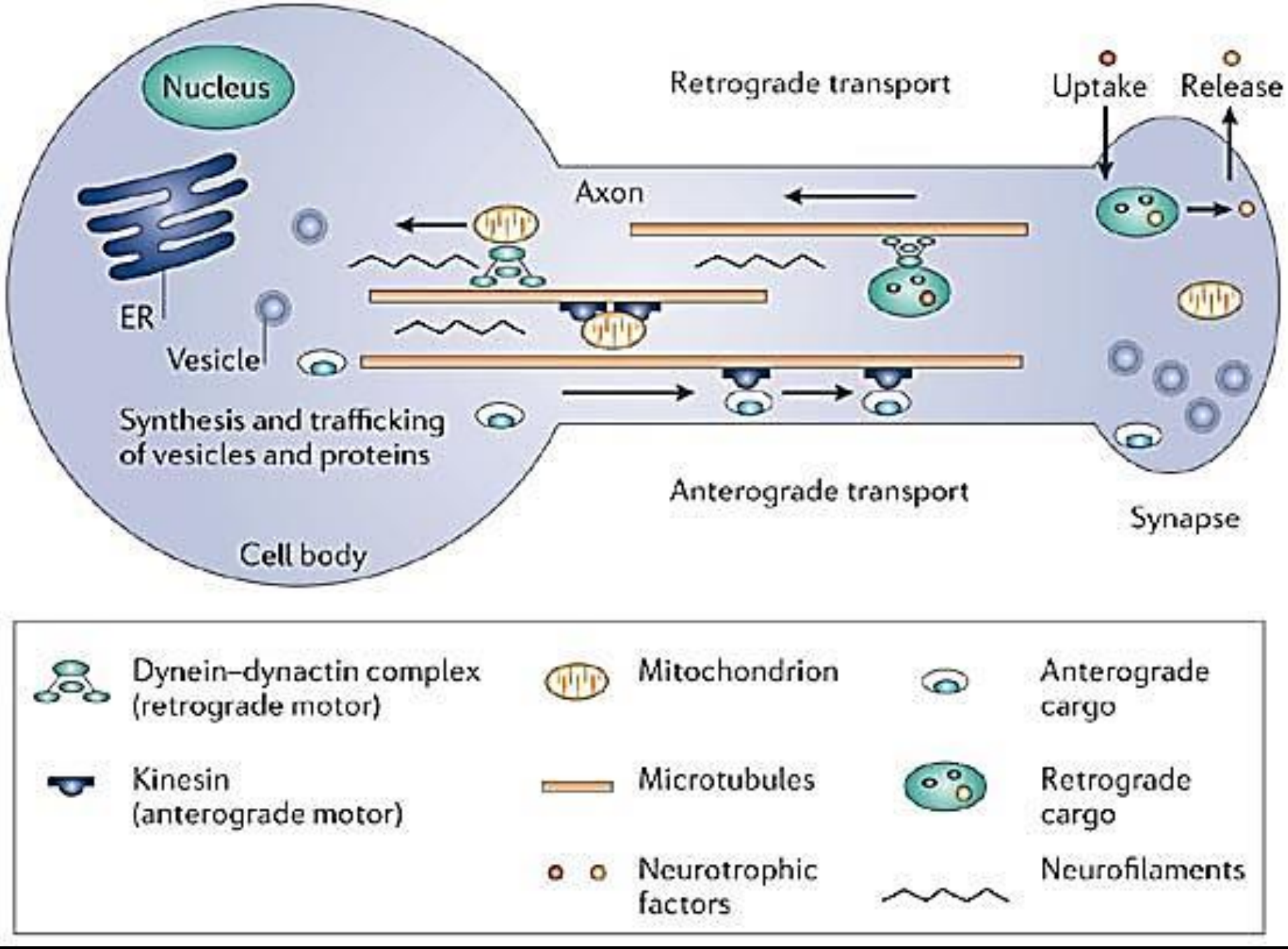
# Neurotubules (microtubules)



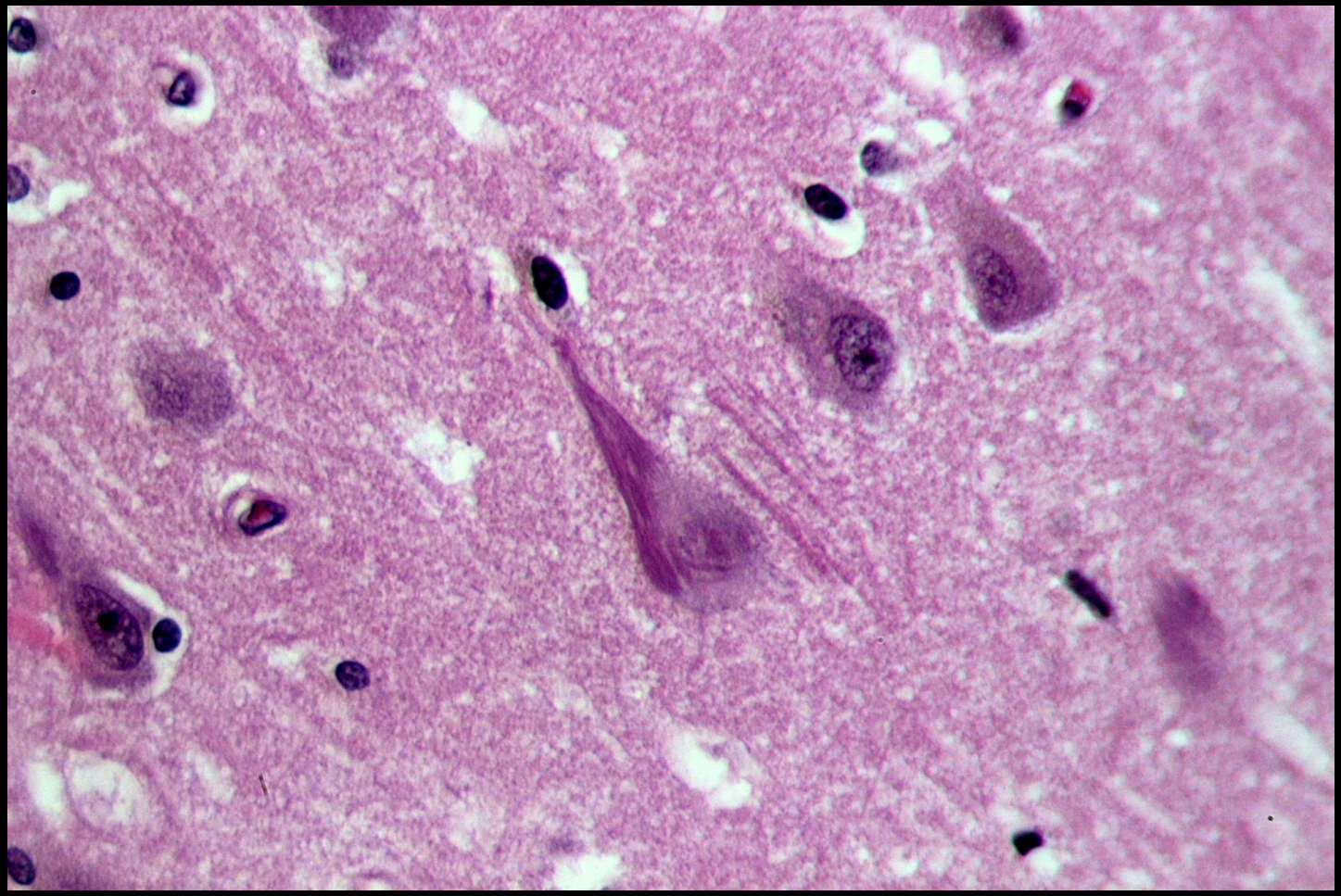


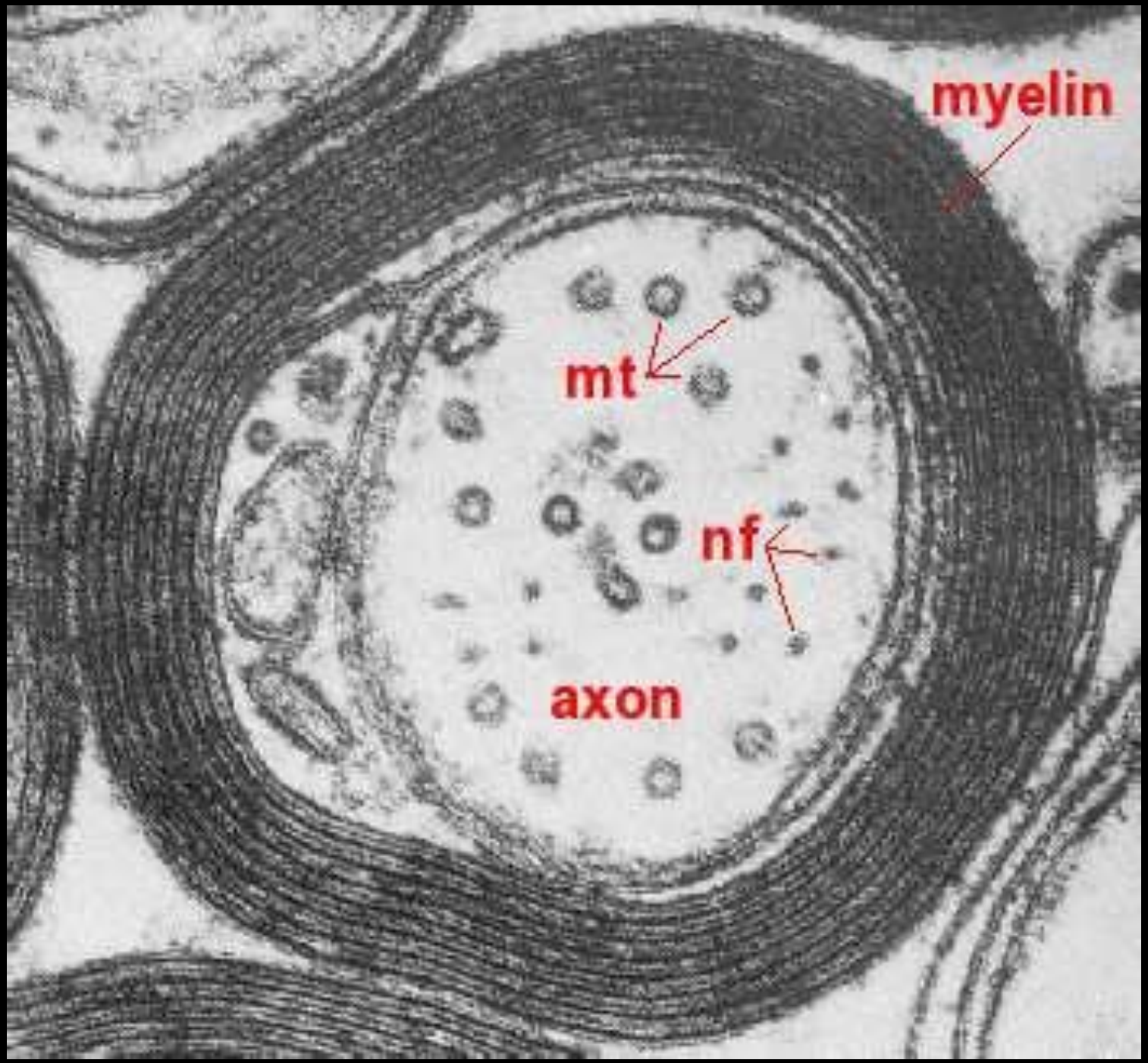

**MAP 1** **MAP $\tau$**

**kinesin (anterograde flow)** **dynein (retrograde flow)**

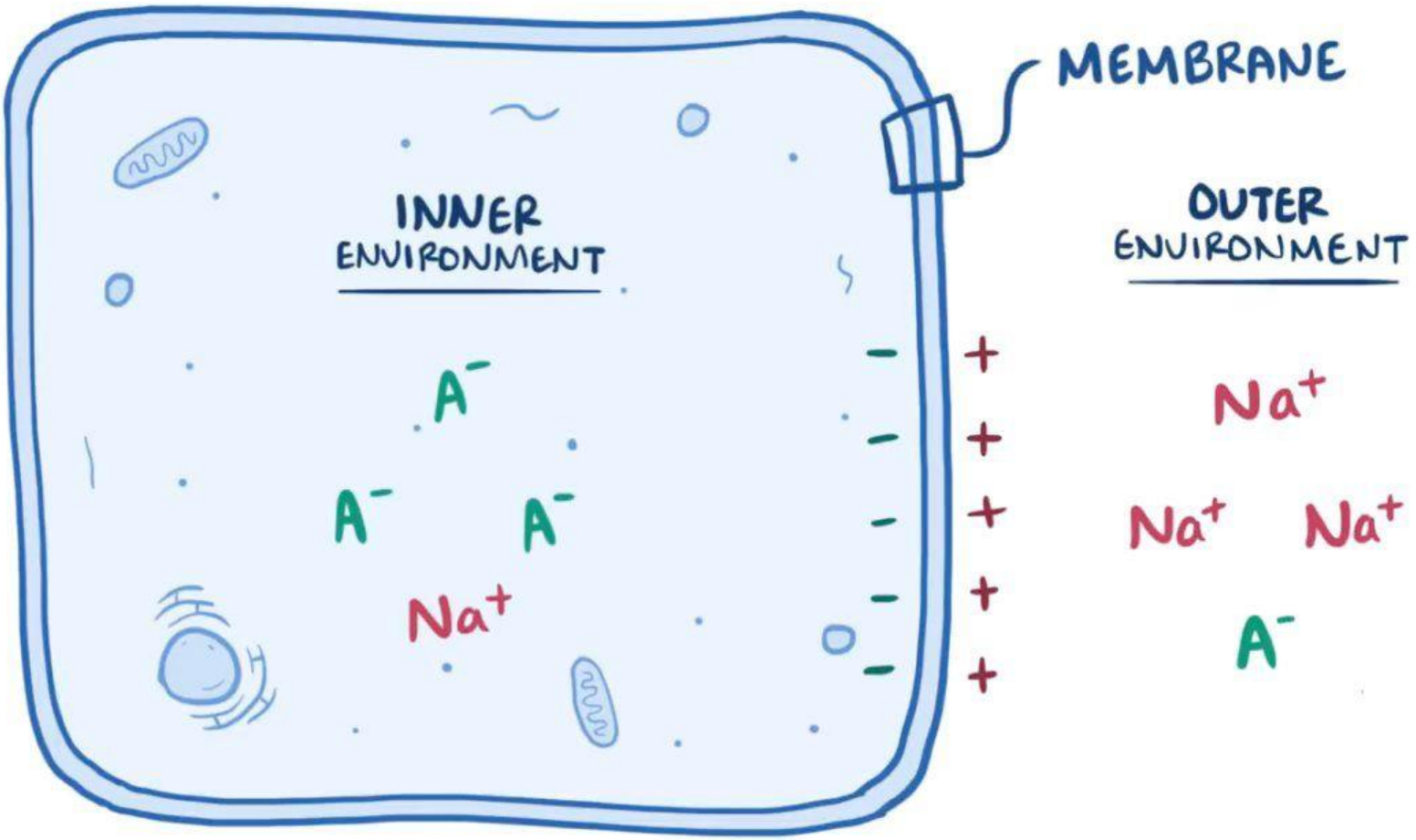

Nucleus
Retrograde transport
Uptake
Release
Axon
ER
Vesicle
Synthesis and trafficking
of vesicles and proteins
Anterograde transport
Synapse
Cell body
Dynein–dynactin complex
(retrograde motor)
Kinesin
(anterograde motor)
Mitochondrion
Microtubules
Neurotrophic
factors
Anterograde
cargo
Retrograde
cargo
Neurofilaments

**Tau, the microtubule-associated protein, forms insoluble filaments that accumulate as neurofibrillary tangles in Alzheimer's disease**




myelin
mt
nf
axon

# Membrane potential

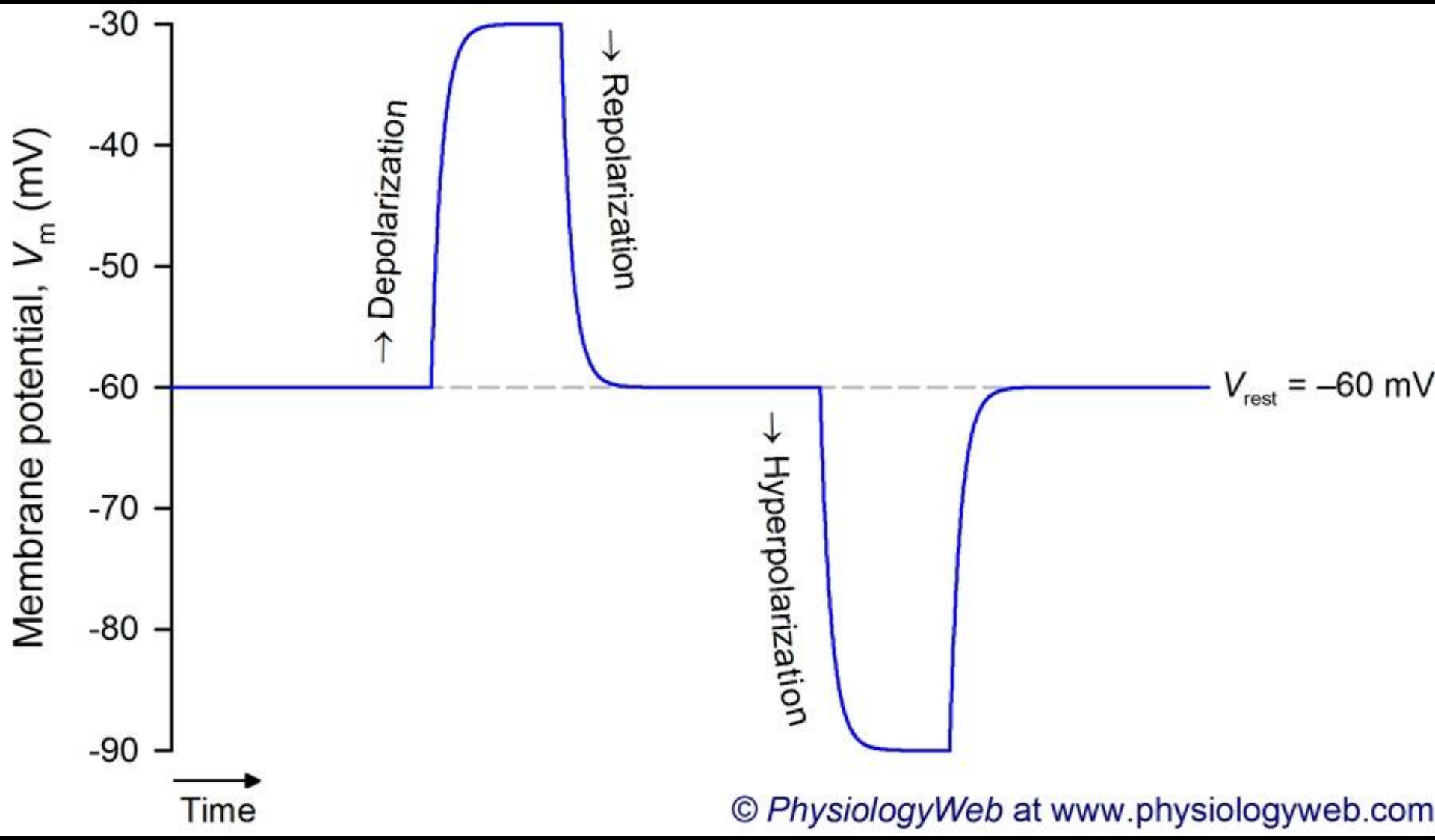


# Membrane potential

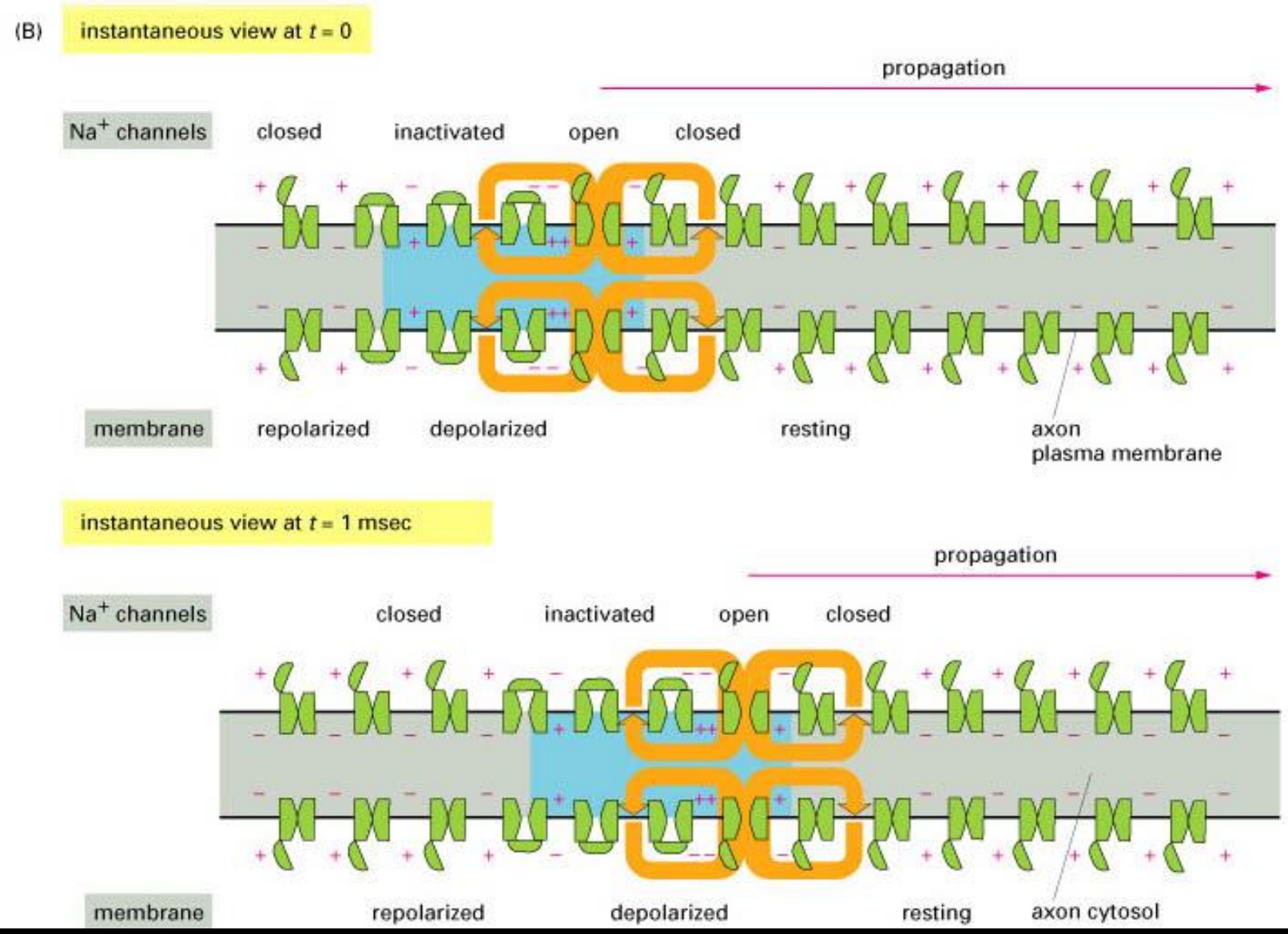
resting membrane potential –65 to –70 mV

depolarization above -50 mV ($Na^+$, $Ca^{++}$ inflow) = excitation
hyperpolarization below -70 mV ($K^+$ outflow, $Cl^-$ inflow) = inhibition

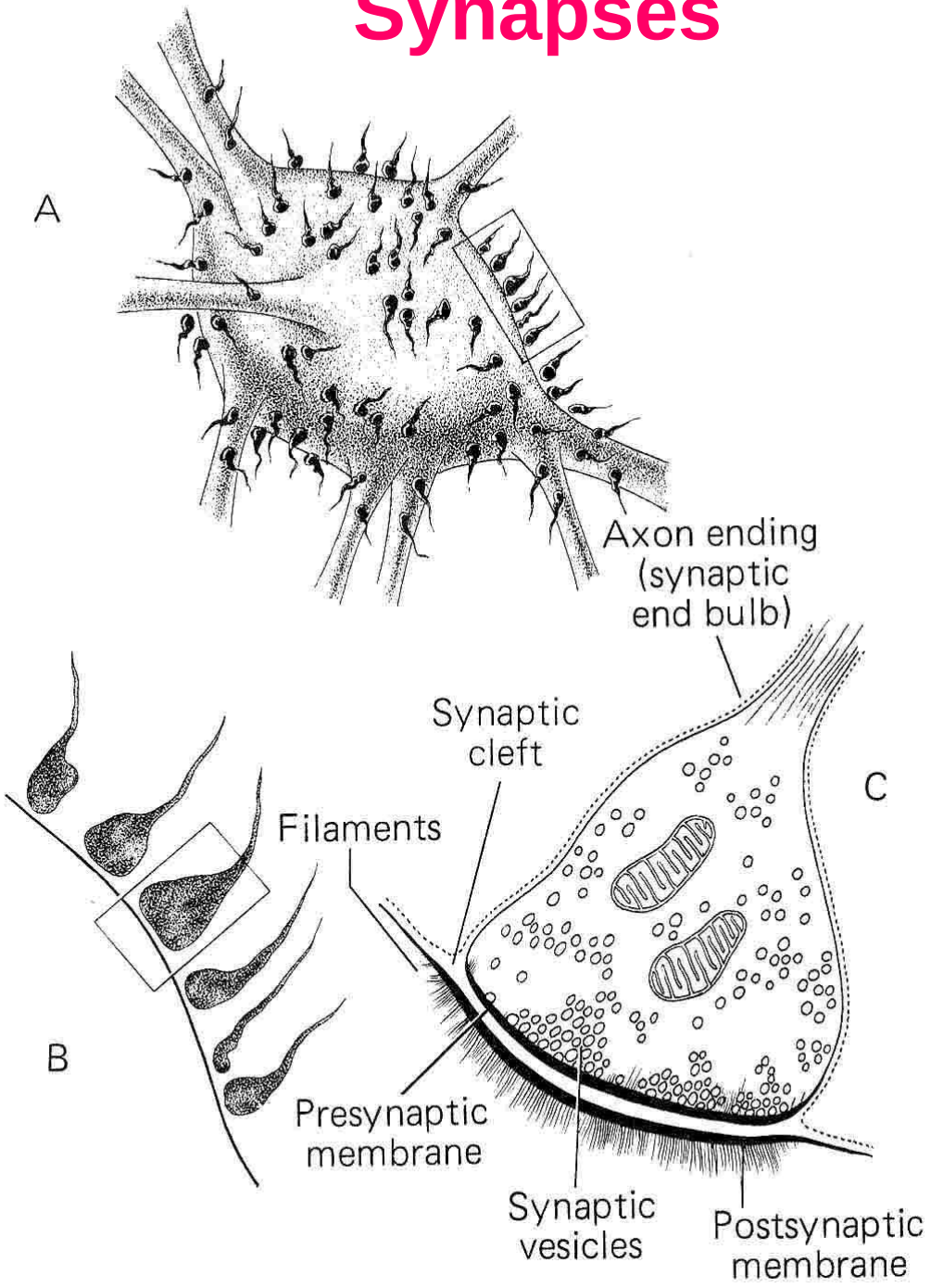
propagation of membrane potential change = impulse
excitation/inhibition potential - on dendrites and cell bodies, spreading with decrement in all directions
action potential - on axons only, spreading without decrement and only cellulifugal, summation of about 200 impulses needed for firing, short depolarization up to +30 - +50 mV

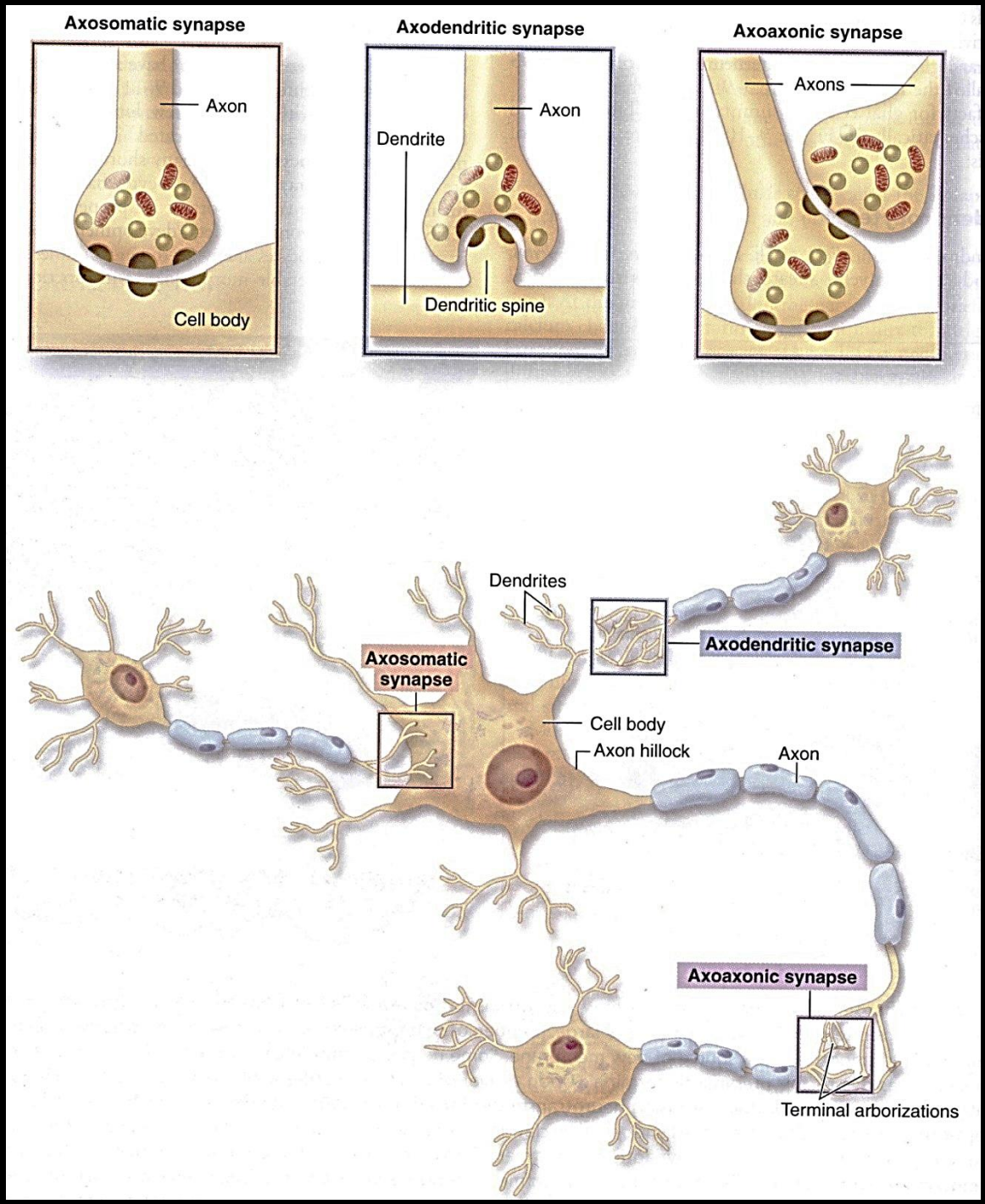

-30
-40
-50
-60
-70
-80
-90
Membrane potential, $V_m$ (mV)
→ Depolarization
→ Repolarization
→ Hyperpolarization
$V_{rest}$ = –60 mV
Time
© PhysiologyWeb at www.physiologyweb.com

# Action potential



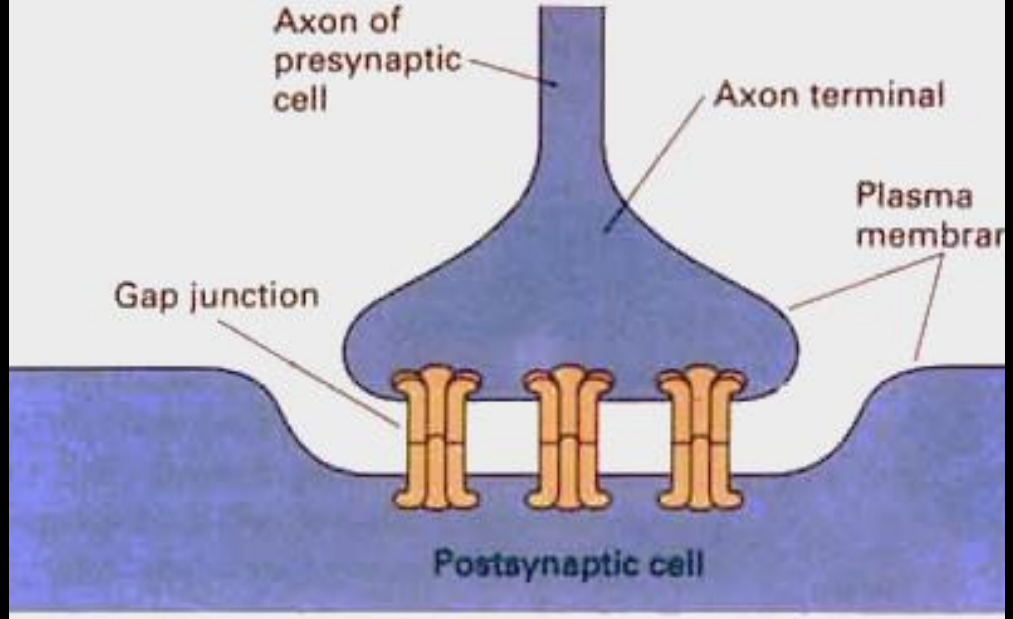
# Synapses

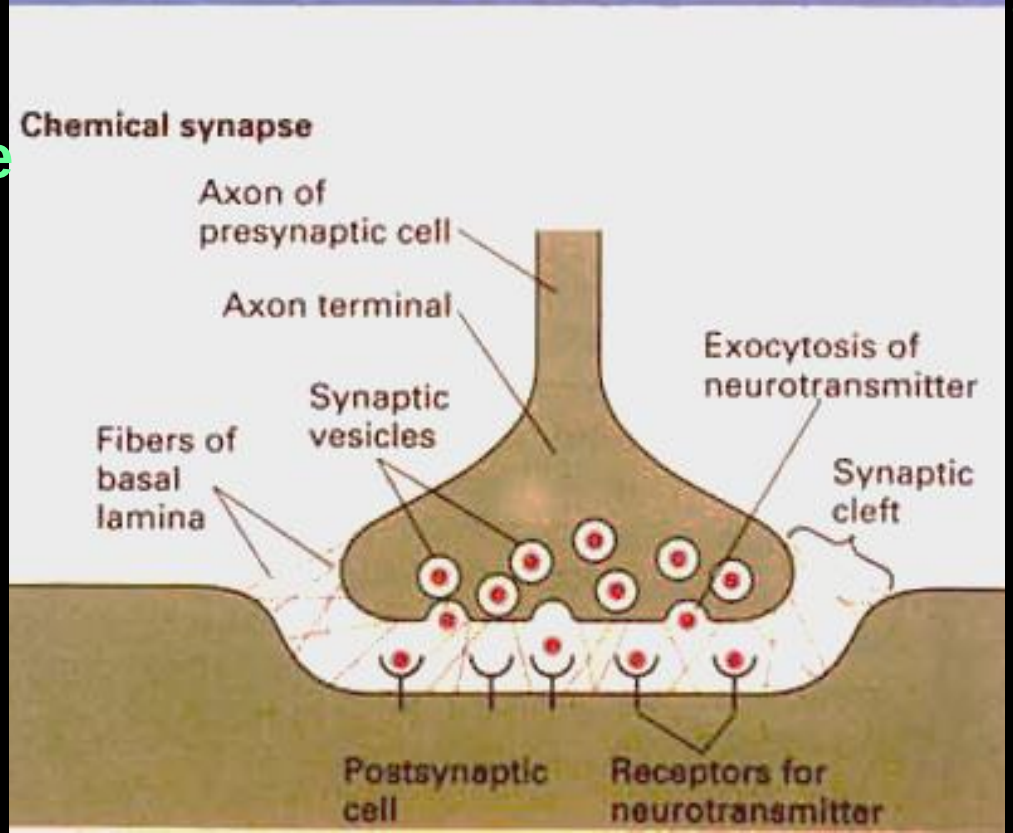

A
Axon ending
(synaptic
end bulb)
Synaptic
cleft
C
Filaments
B
Presynaptic
membrane
Synaptic
vesicles
Postsynaptic
membrane


Axosomatic synapse
Axon
Cell body
Axodendritic synapse
Axon
Dendrite
Dendritic spine
Axoaxonic synapse
Axons
Dendrites
Axodendritic synapse
Axosomatic synapse
Cell body
Axon hillock
Axon
Axoaxonic synapse
Terminal arborizations

**mediators in CNS**

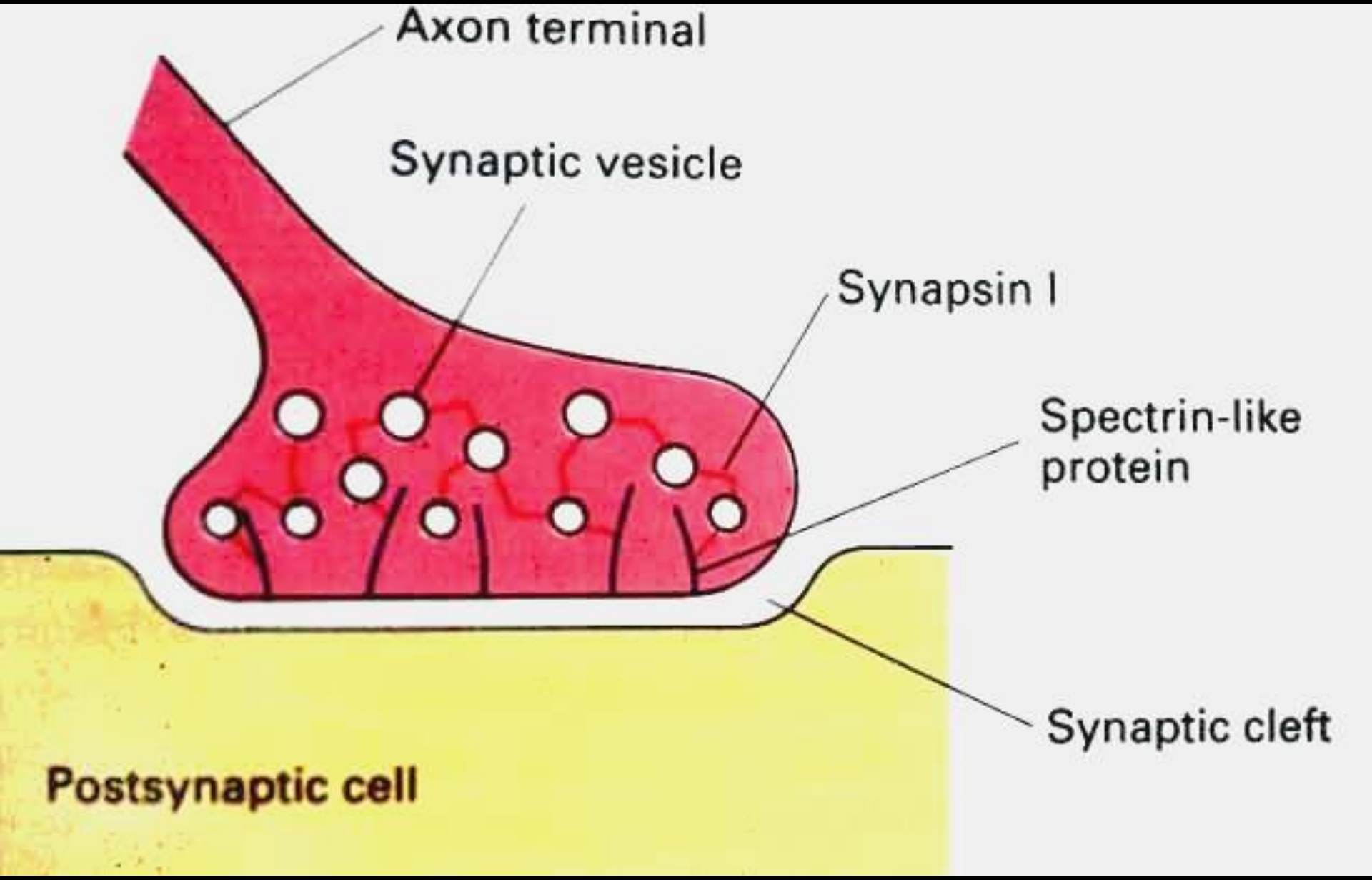
**acetylcholine**
**epinephrine**
**norepinephrine**
**serotonin**
**glutamate**
**dopamine**
**glycine**
**γABA**
**histamine**

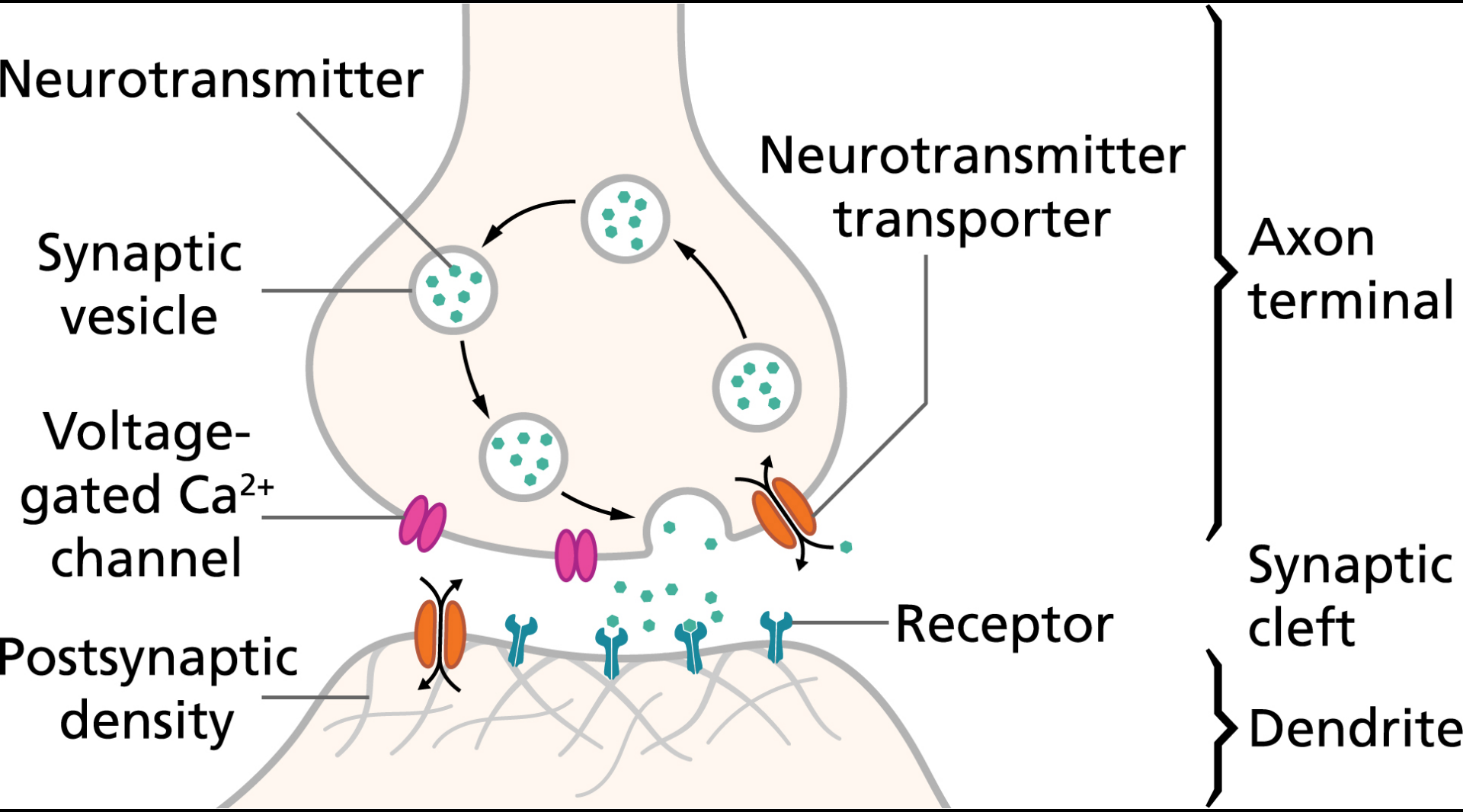


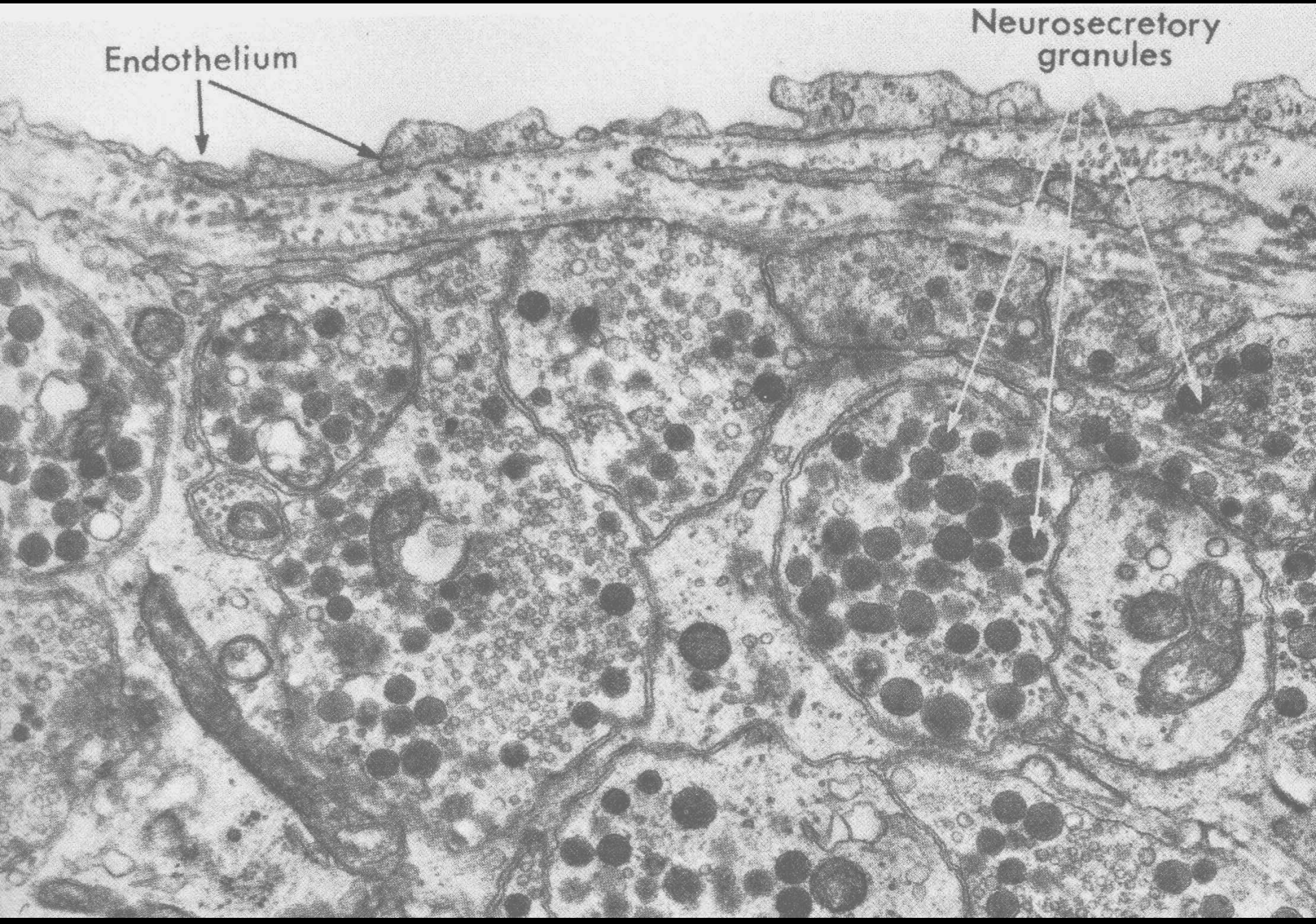

**mediators in PNS**

**acetylcholine**
**norepinephrine**
**histamine**
**dopamine**
**serotonin**


Axon terminal
Synaptic vesicle
Synapsin I
Spectrin-like protein
Synaptic cleft
Postsynaptic cell


Neurotransmitter
Synaptic vesicle
Voltage-gated $Ca^{2+}$ channel
Postsynaptic density
Neurotransmitter transporter
Receptor
Axon terminal
Synaptic cleft
Dendrite

# Neurosecretory granules (neurohypophysis)



## EXAMPLES OF MEDIATOR INACTIVATION AND RELEASE FROM THE RECEPTOR

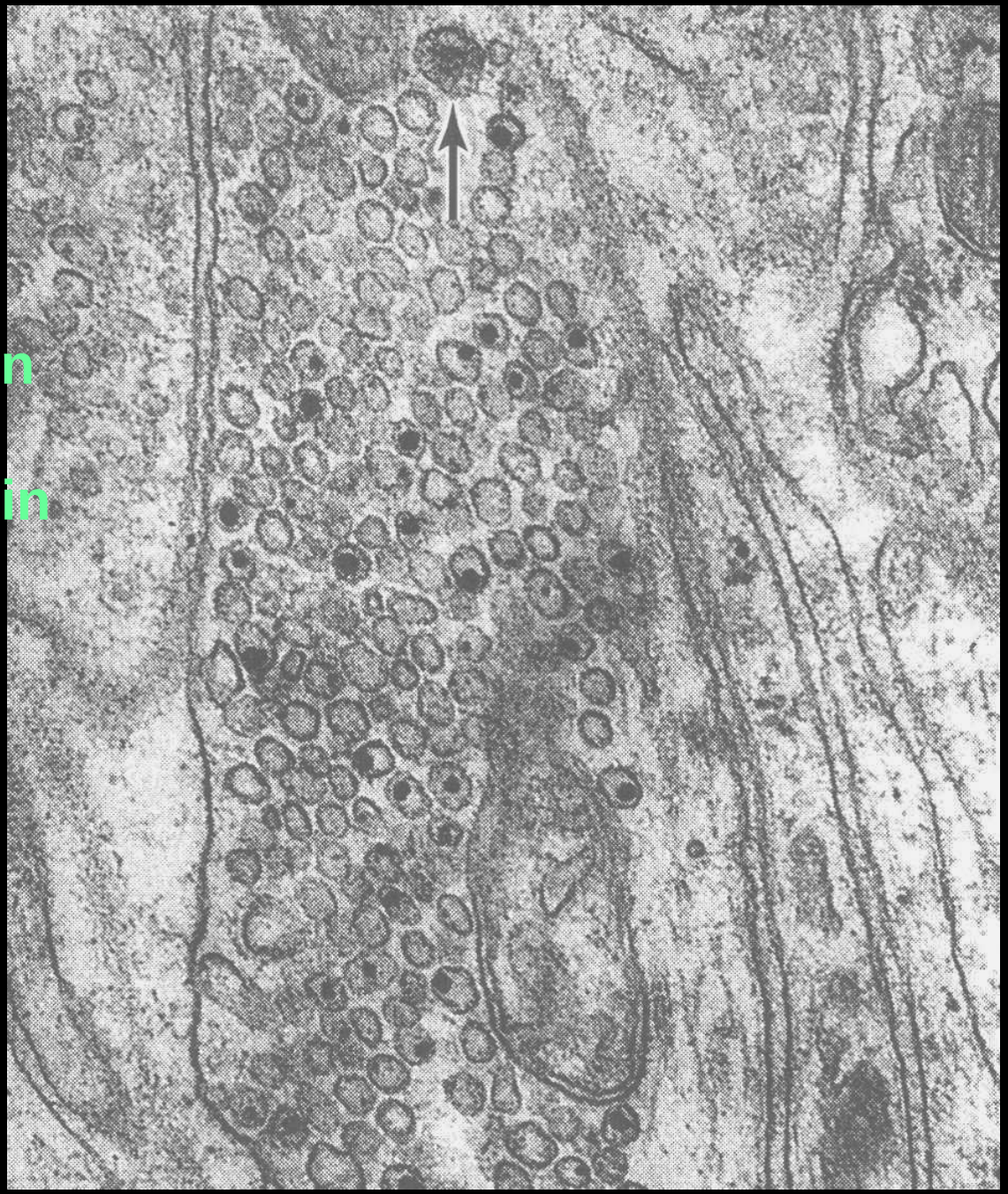
-acetylcholinesterase in synaptic cleft

-reuptake of catecholamines ba presynaptic membrane and deactivation by monoaminooxidase (MAO)

-COMT (catechol-O-methyltransferase) in postsynaptic neuron

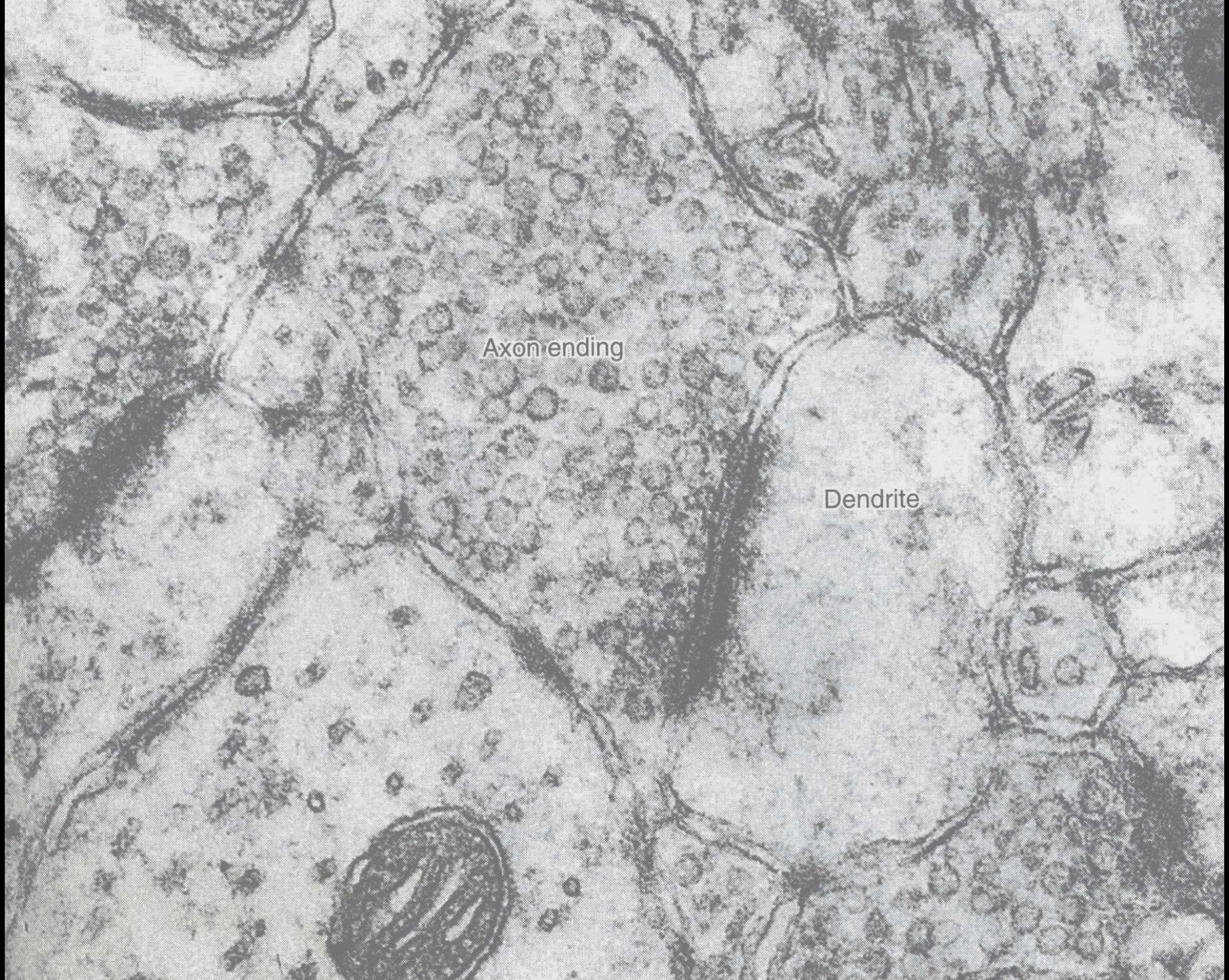
**mediátory v CNS**

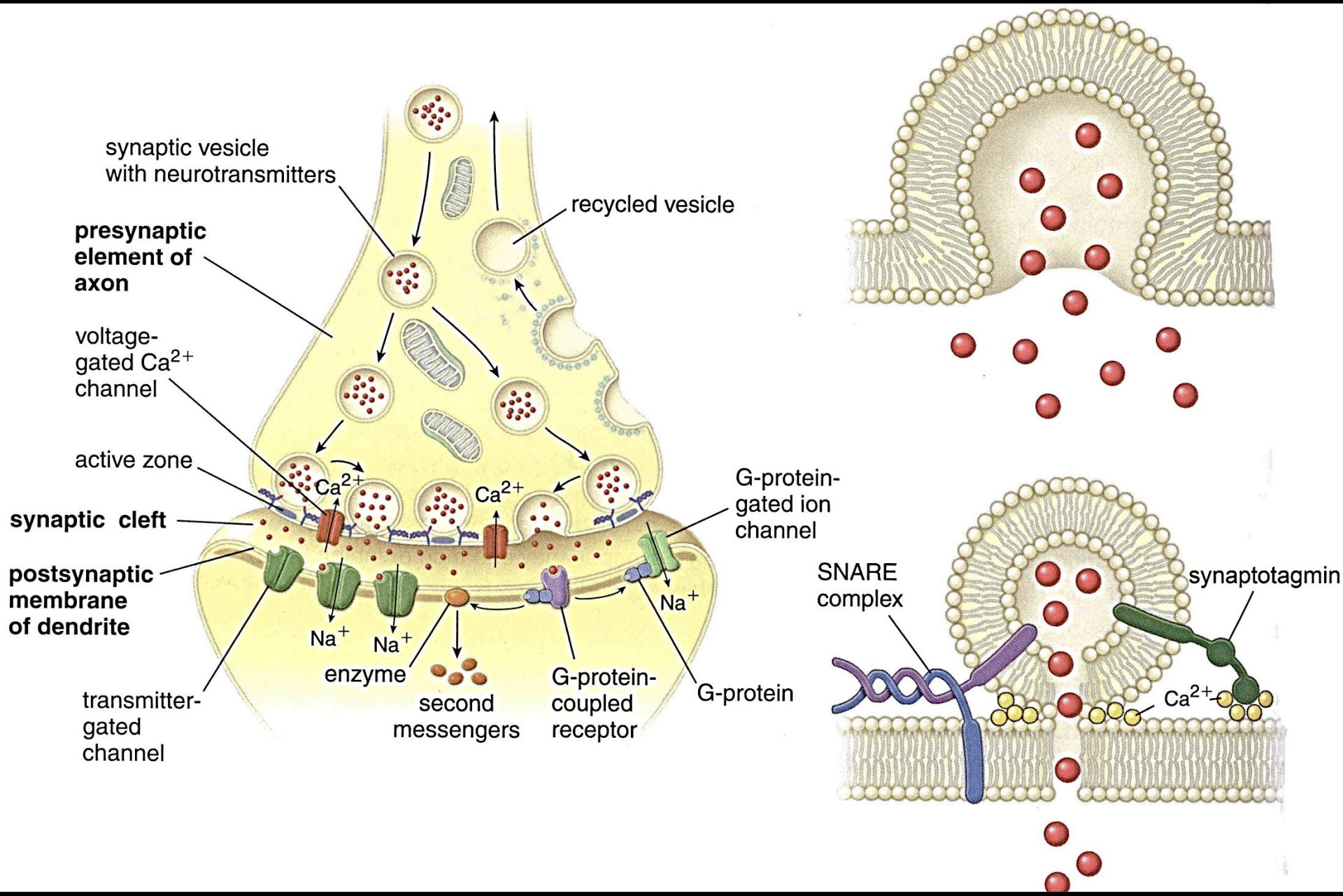
**acetylcholin**
**adrenalin**
**noradrenalin**
**serotonin**
**glutamát**
**dopamin**
**glycin**
**GABA**
**histamin**

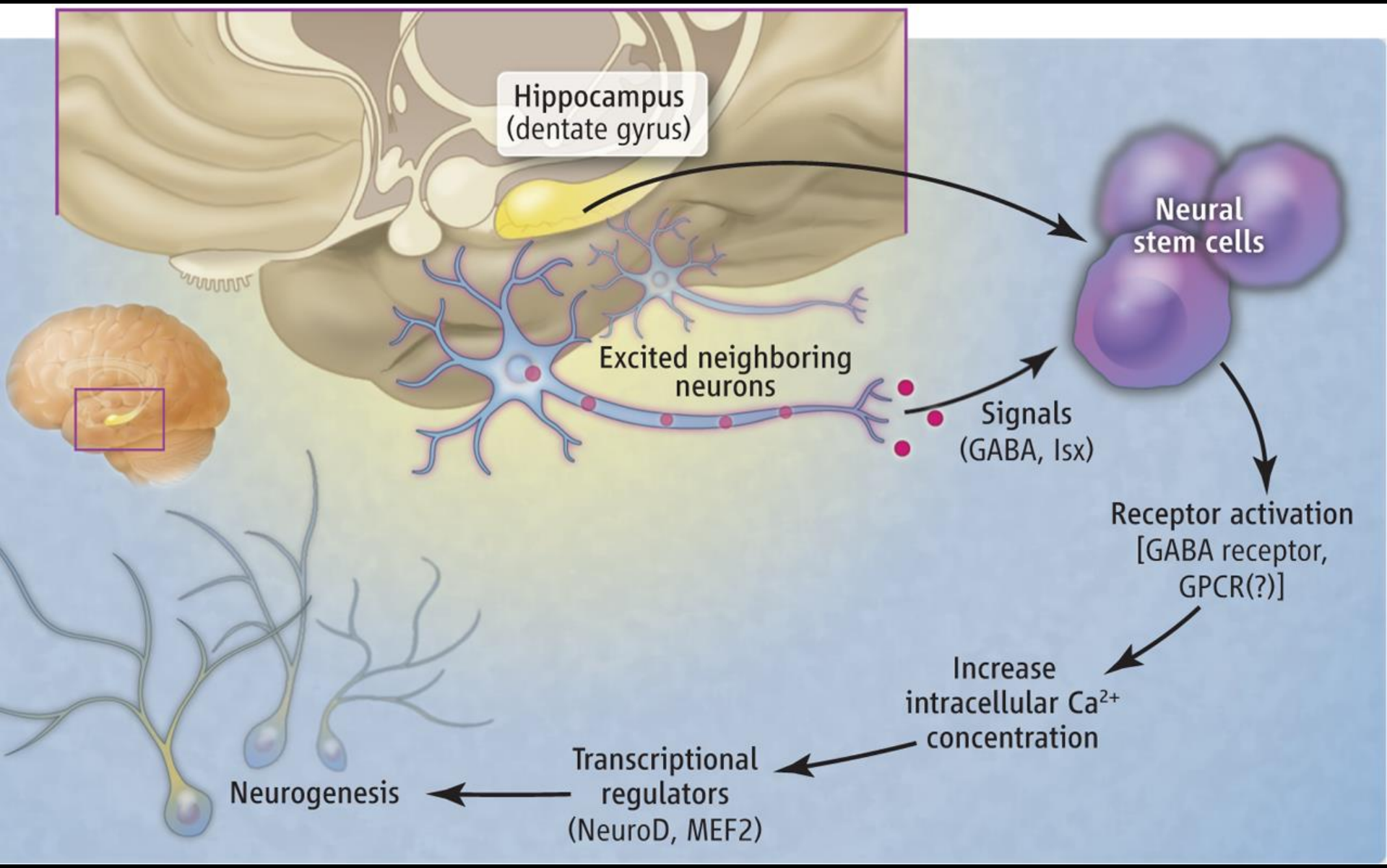


**mediátory v PNS**

**acetylcholin**
**noradrenalin**
**histamin**
**dopamin**
**serotonin**


Axon ending
Dendrite


synaptic vesicle
with neurotransmitters
recycled vesicle
presynaptic
element of
axon
voltage-
gated Ca2+
channel
active zone
synaptic cleft
postsynaptic
membrane
of dendrite
Ca2+
Ca2+
Na+
Na+
Na+
enzyme
second
messengers
G-protein-
coupled
receptor
G-protein
G-protein-
gated ion
channel
transmitter-
gated
channel
SNARE
complex
synaptotagmin
Ca2+


Hippocampus
(dentate gyrus)
Neural
stem cells
Excited neighboring
neurons
Signals
(GABA, Isx)
Receptor activation
[GABA receptor,
GPCR(?)]
Increase
intracellular $Ca^{2+}$
concentration
Transcriptional
regulators
(NeuroD, MEF2)
Neurogenesis

# Glial cells, neuroglia

provide neurons with

- trophic support (storage of energy)
- mechanical and insulation (barrier) support
- support in formation and maintenance of synapses
- so-called second key for the synaptic transduction (e.g. D-serine)
- tissue integrity surveillance
- production of ECM and immunity

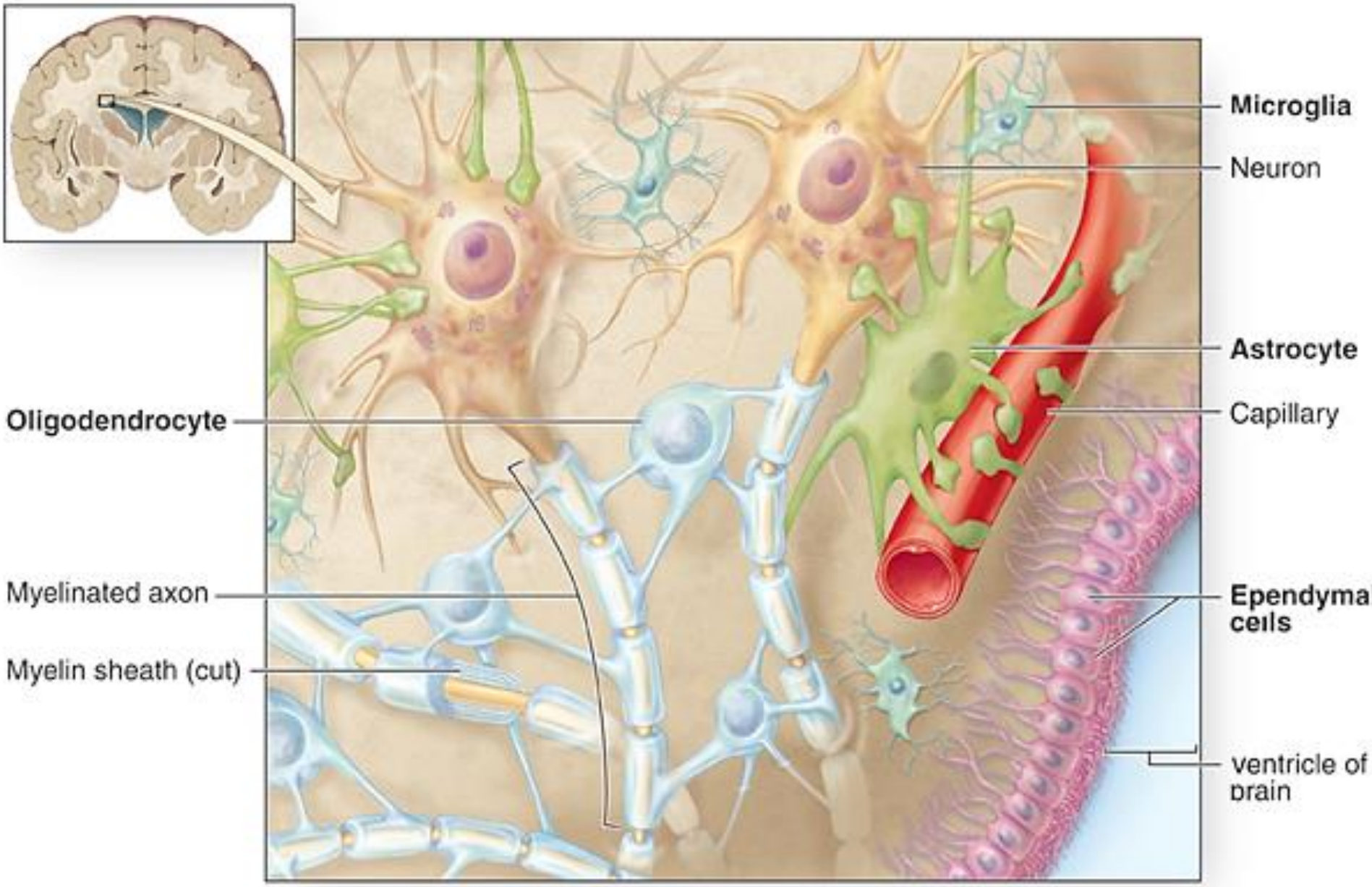
# NEUROGLIA

**1. Neuroglia in CNS**

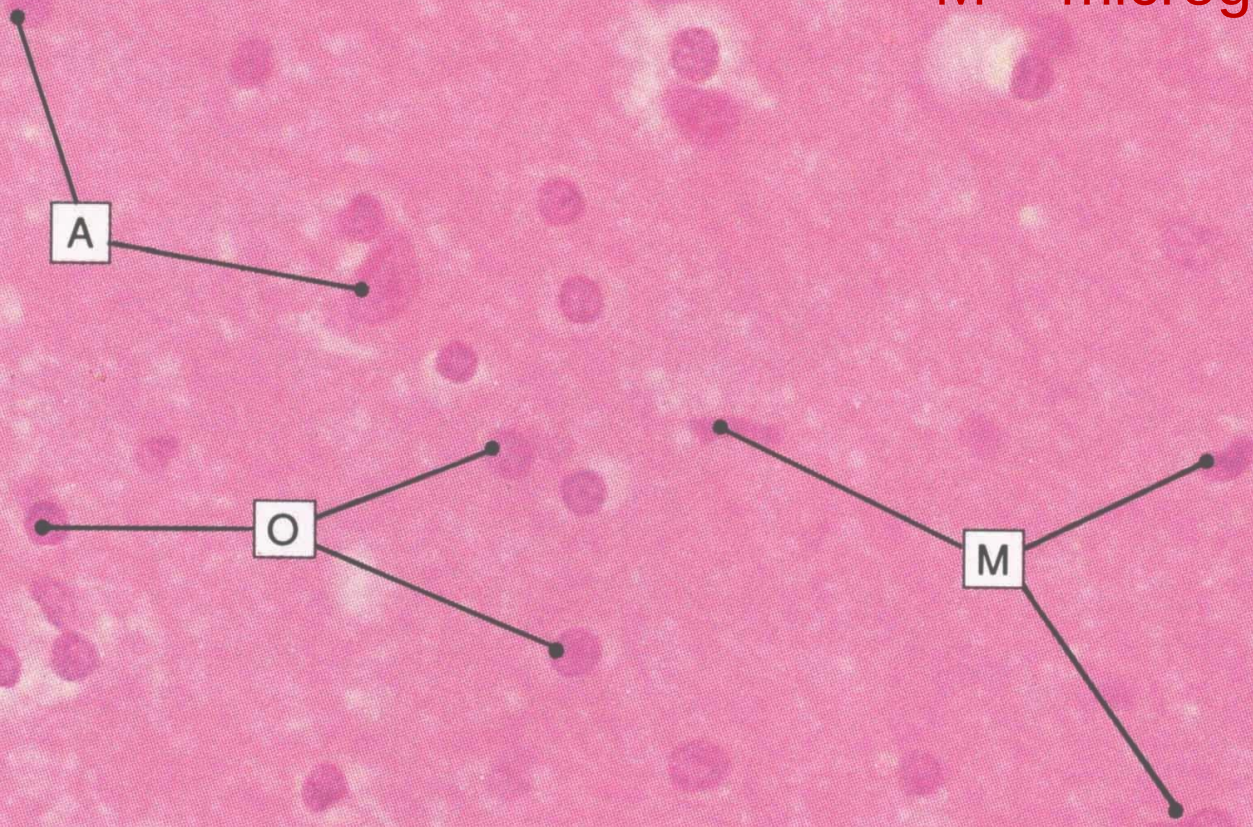
- **1. ependyma**
- **2. astrocytes**
  - **1. protoplasmic (grey matter)**
  - **2. fibrous (white matter)**
- **3. oligodendrocytes (axon myelination)**
- **4. microglia**

**2. Neuroglia in PNS**

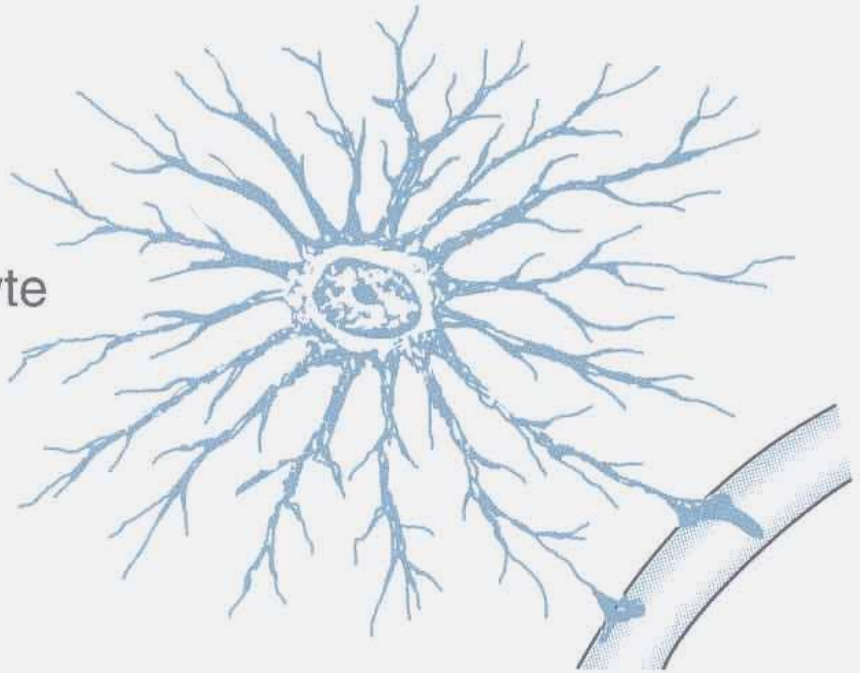
- **1. Schwann cells (axon myelination)**
- **2. satellite cells (cerebrospinal and vegetative ganglia)**

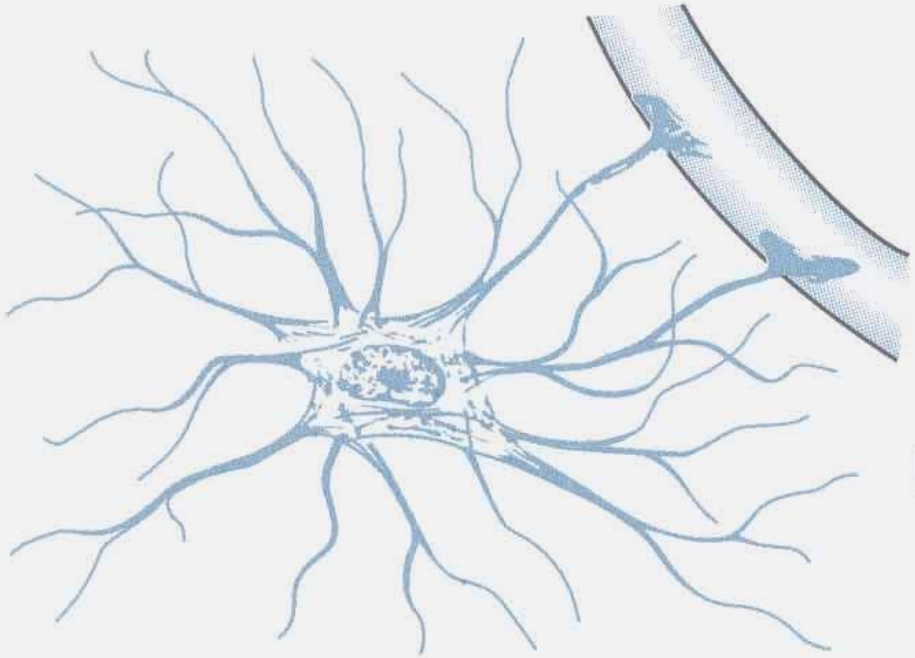


A = fibrous astrocytes
O = oligodendrocytes
M = microglia



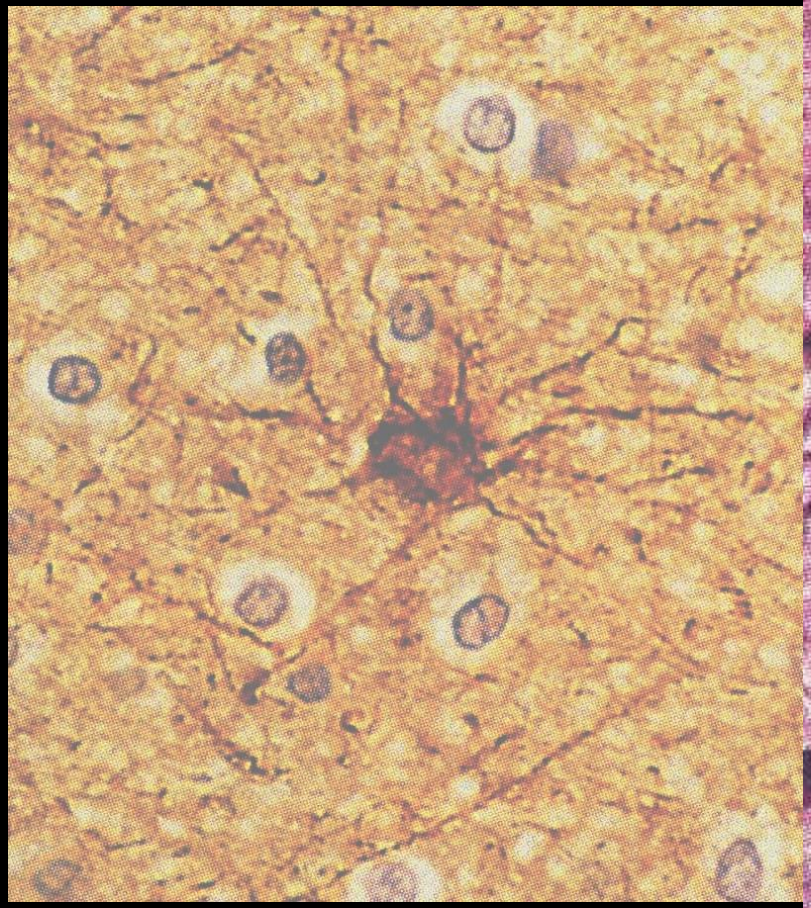
Protoplasmic astrocyte

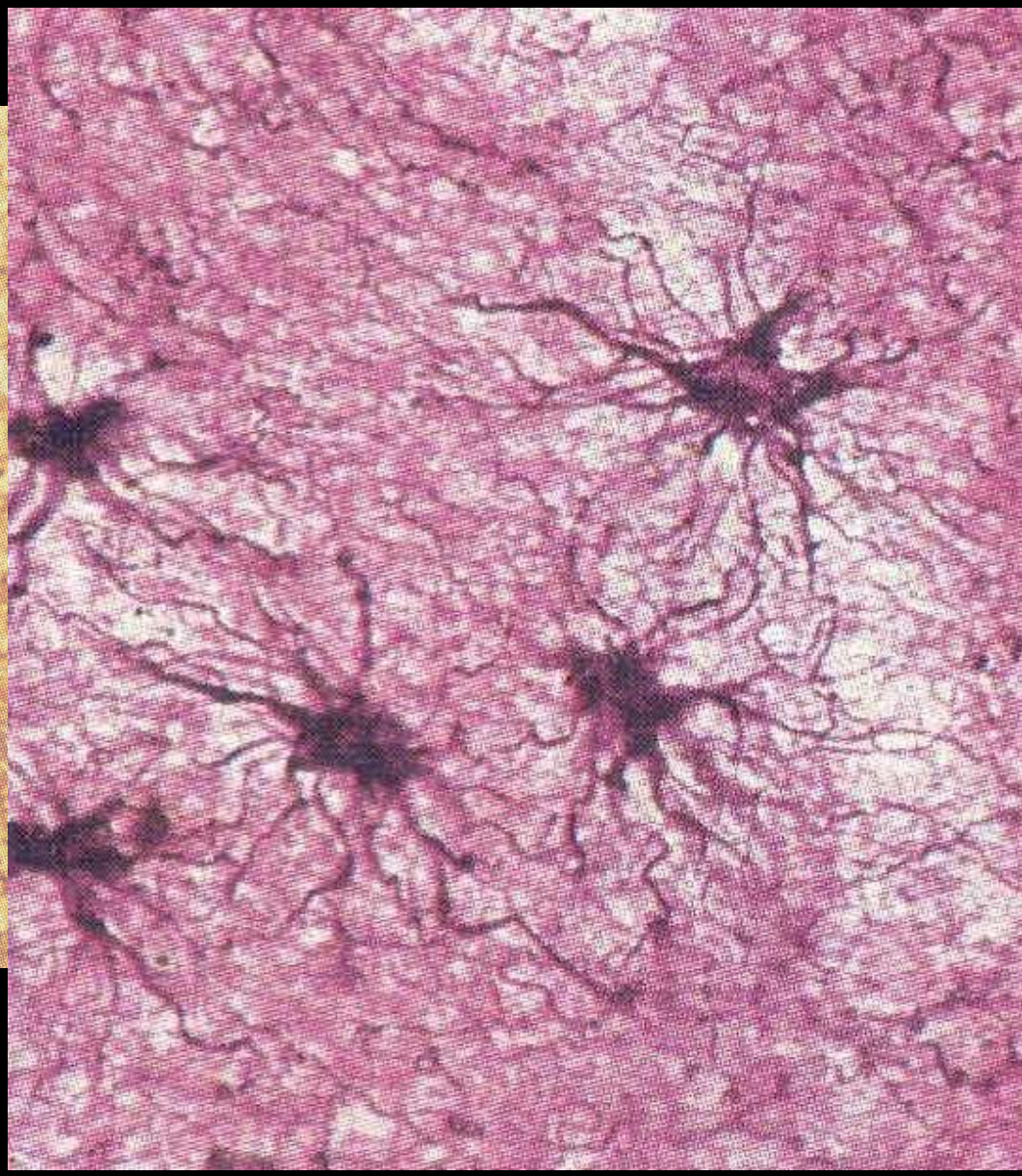


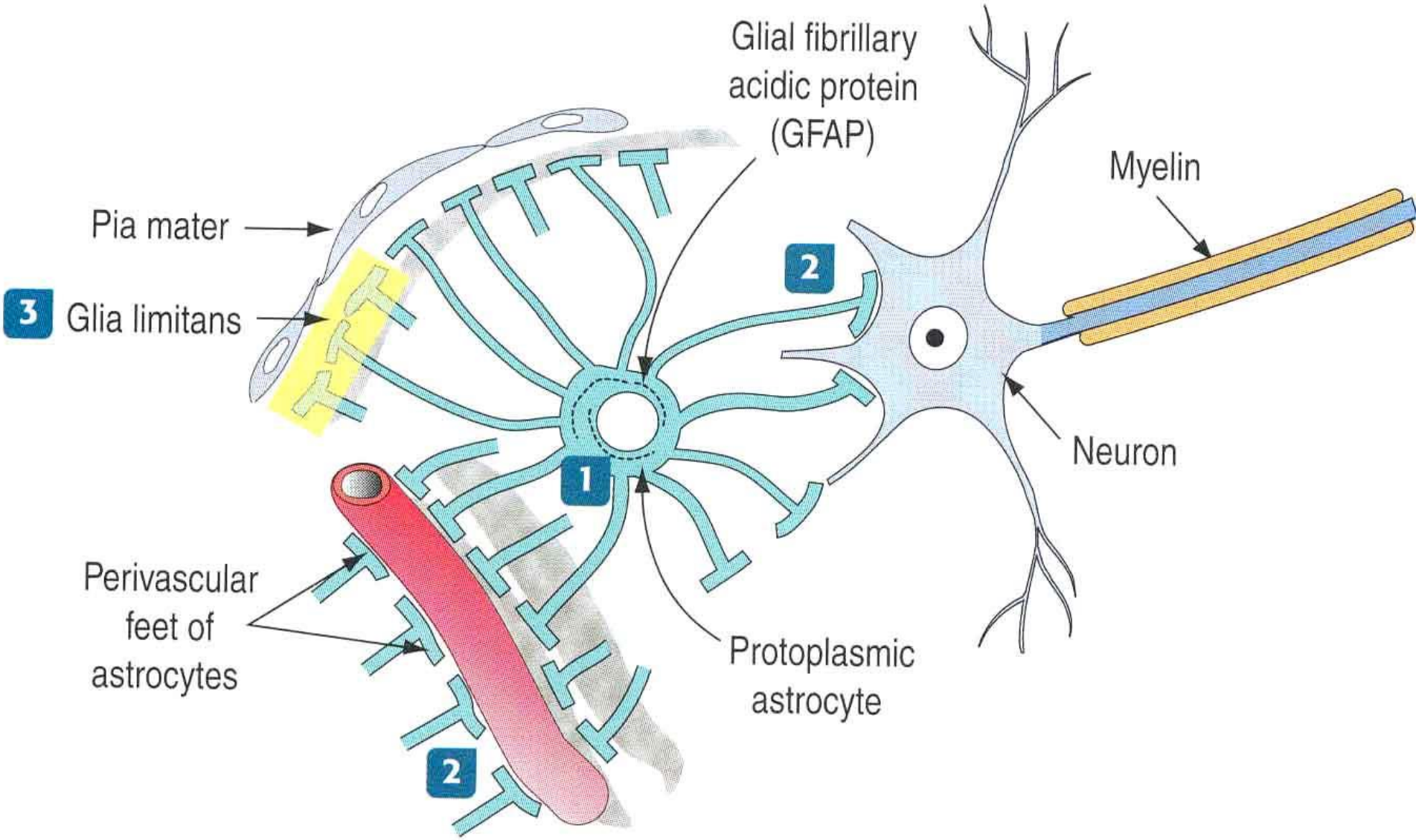


Fibrous astrocyte

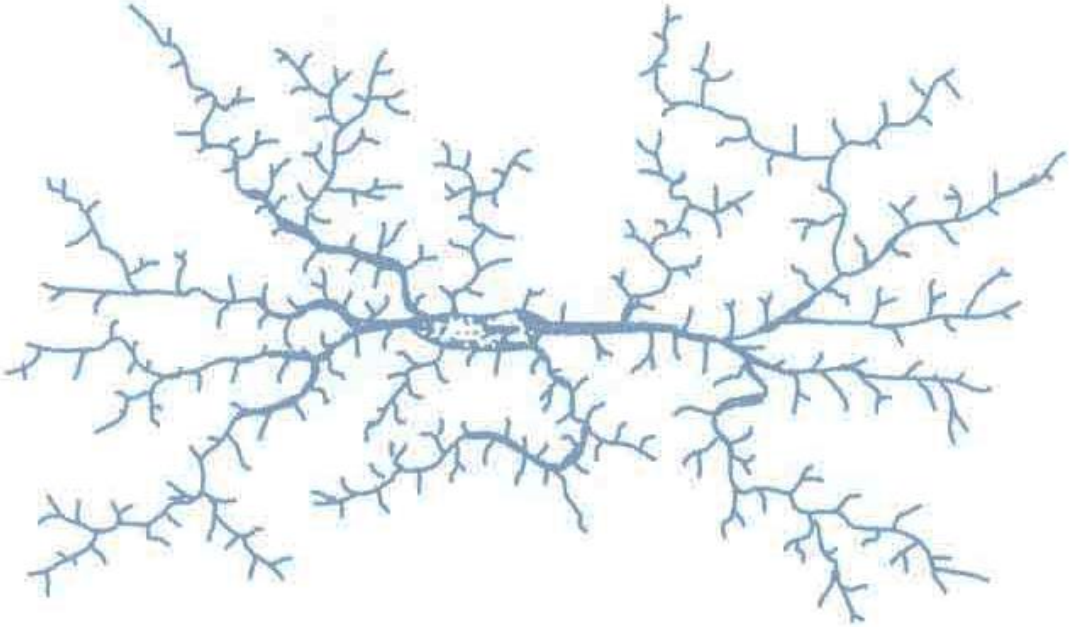
# Protoplasmic astrocytes (GFAP immunohistochemistry and impr

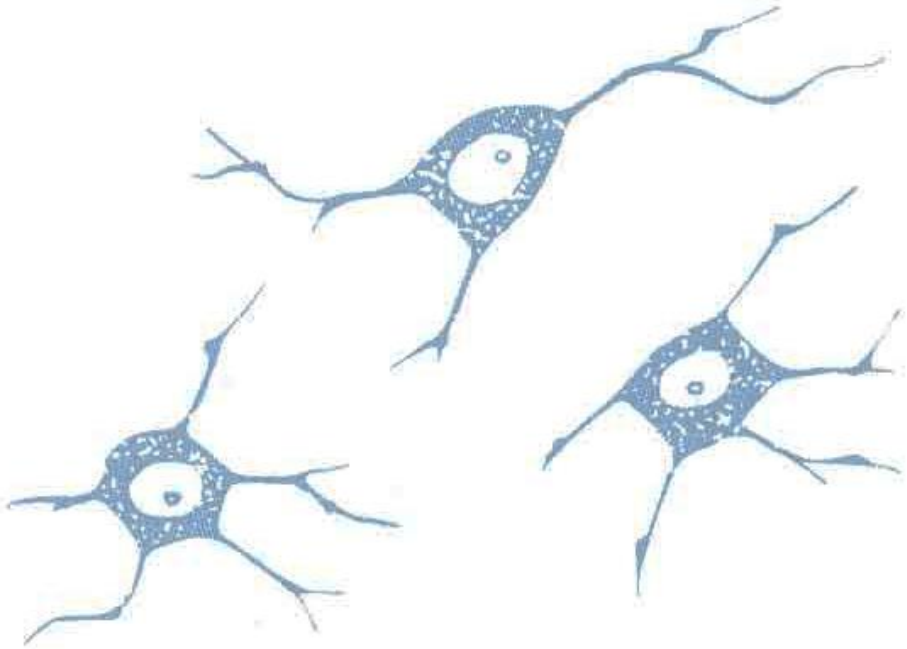





Glial fibrillary acidic protein (GFAP)
Myelin
Pia mater
3
Glia limitans
2
1
Neuron
Perivascular feet of astrocytes
Protoplasmic astrocyte
2

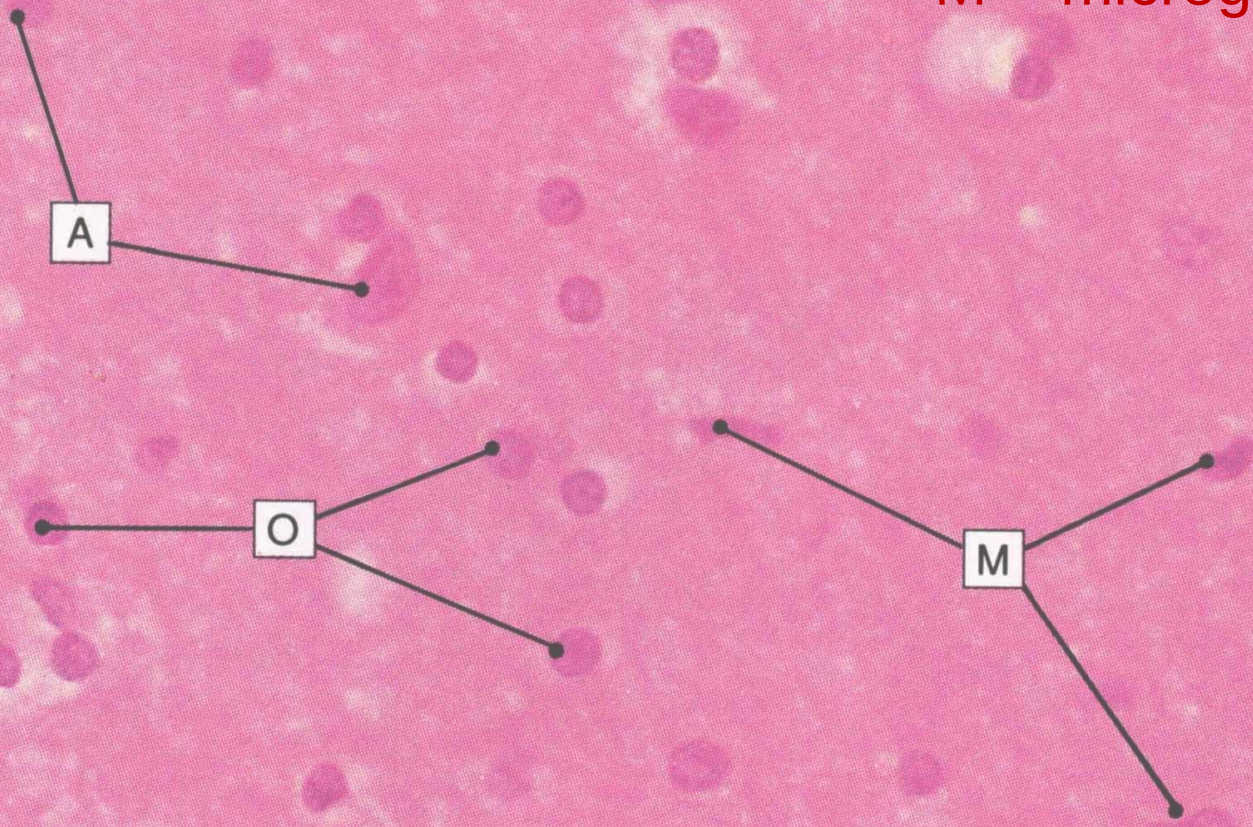
Microglia



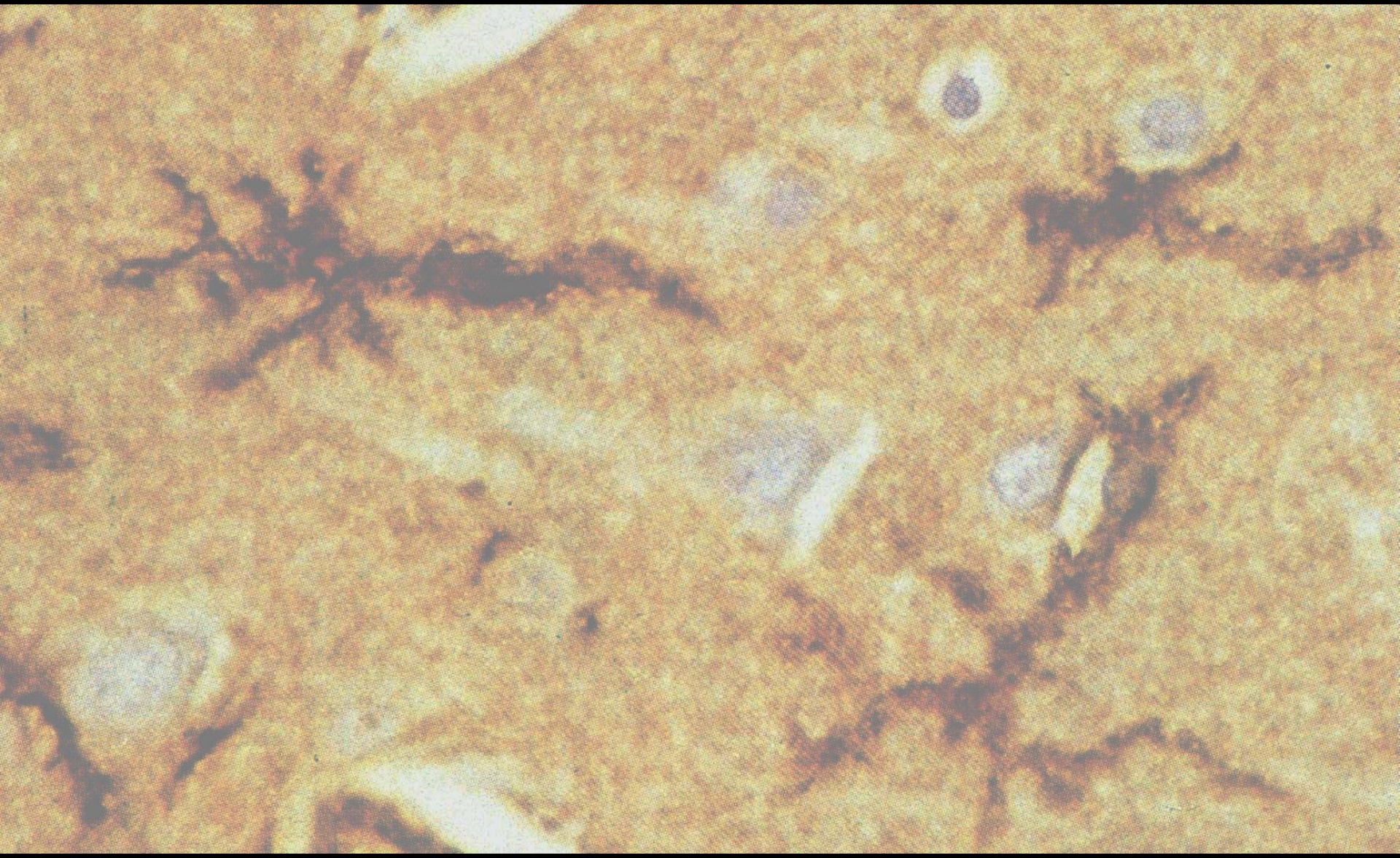


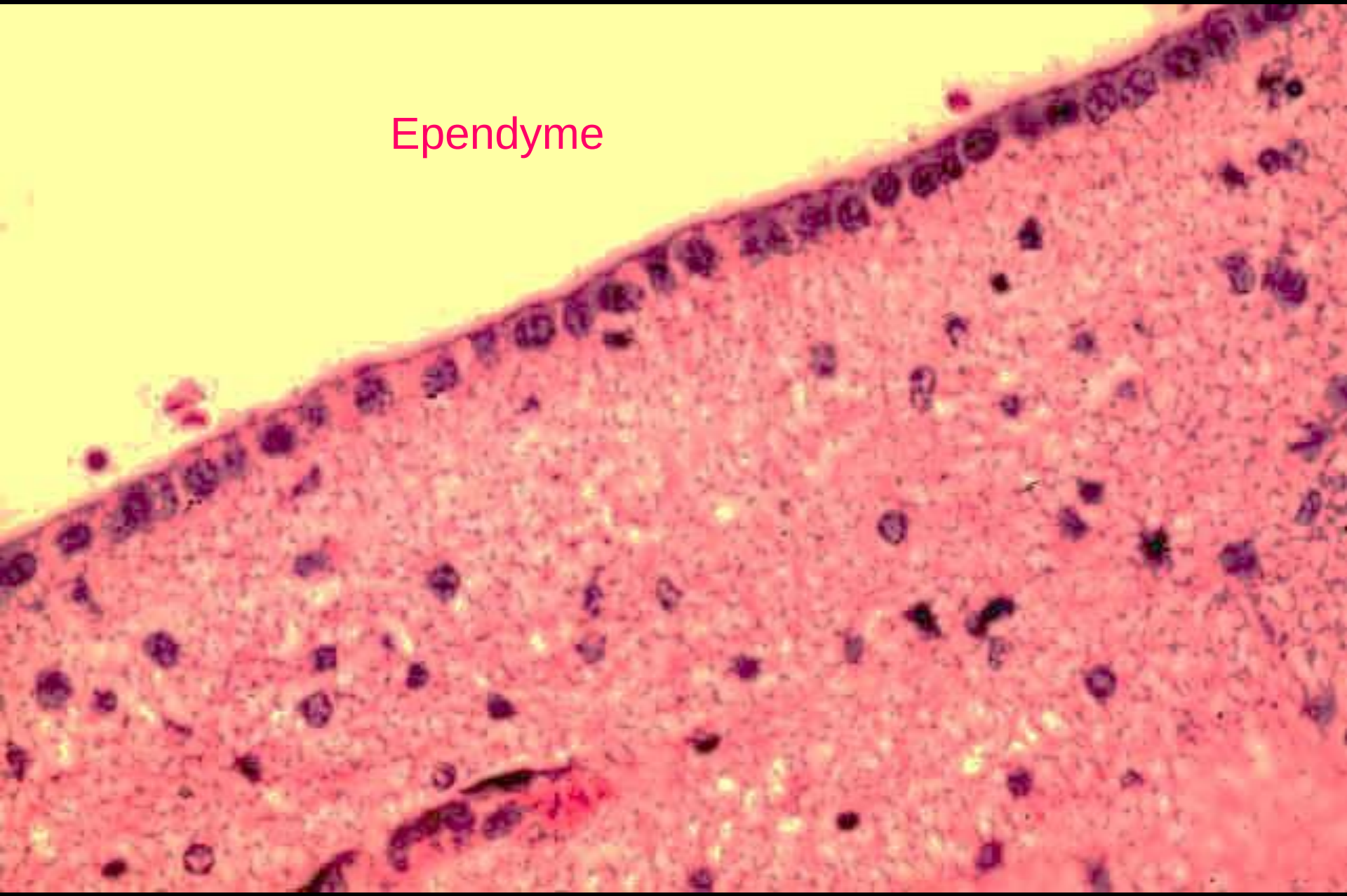
Oligodendrocytes

A = fibrous astrocytes
O = oligodendrocytes
M = microglia

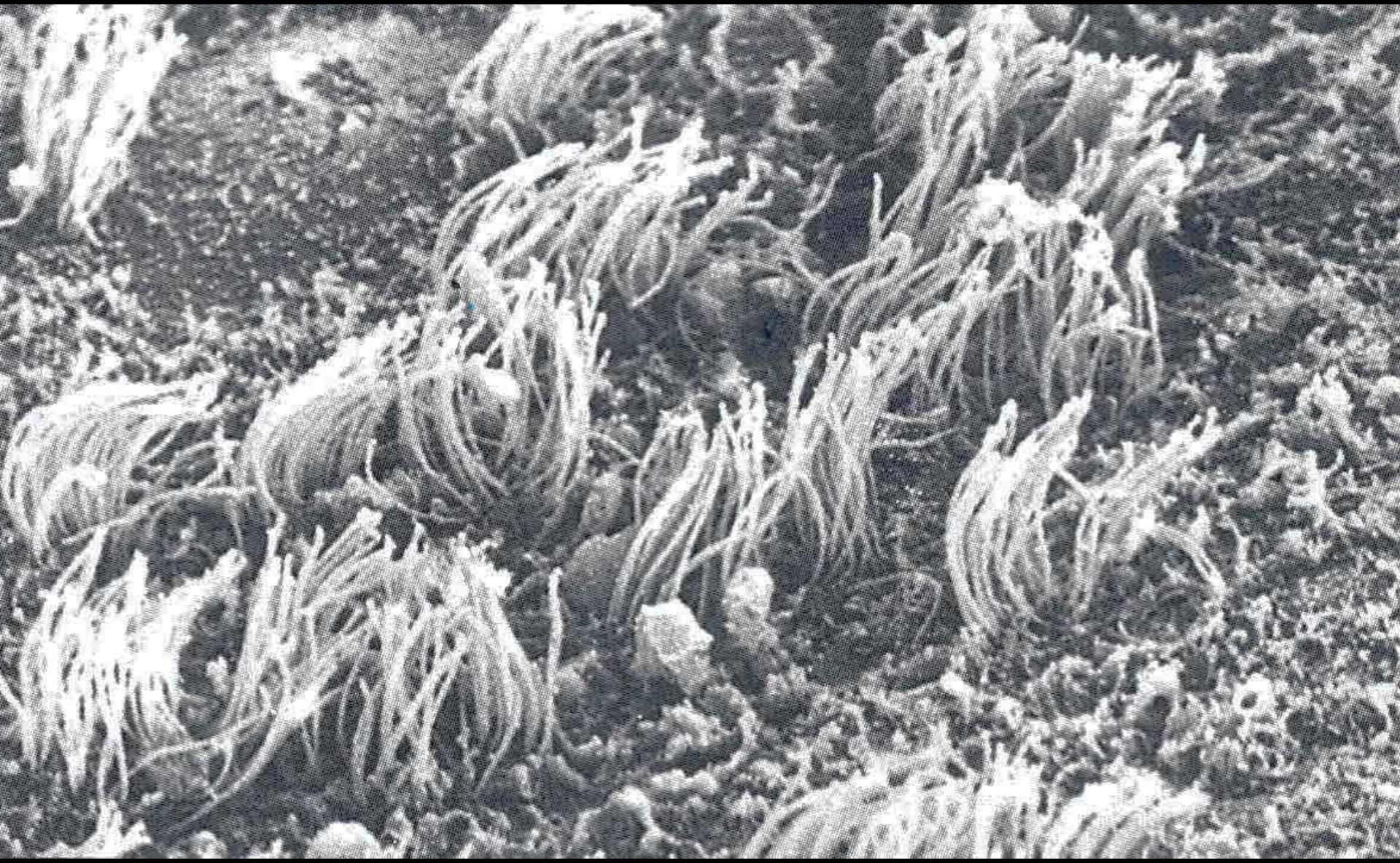


# Microglia (immunohistochemistry)

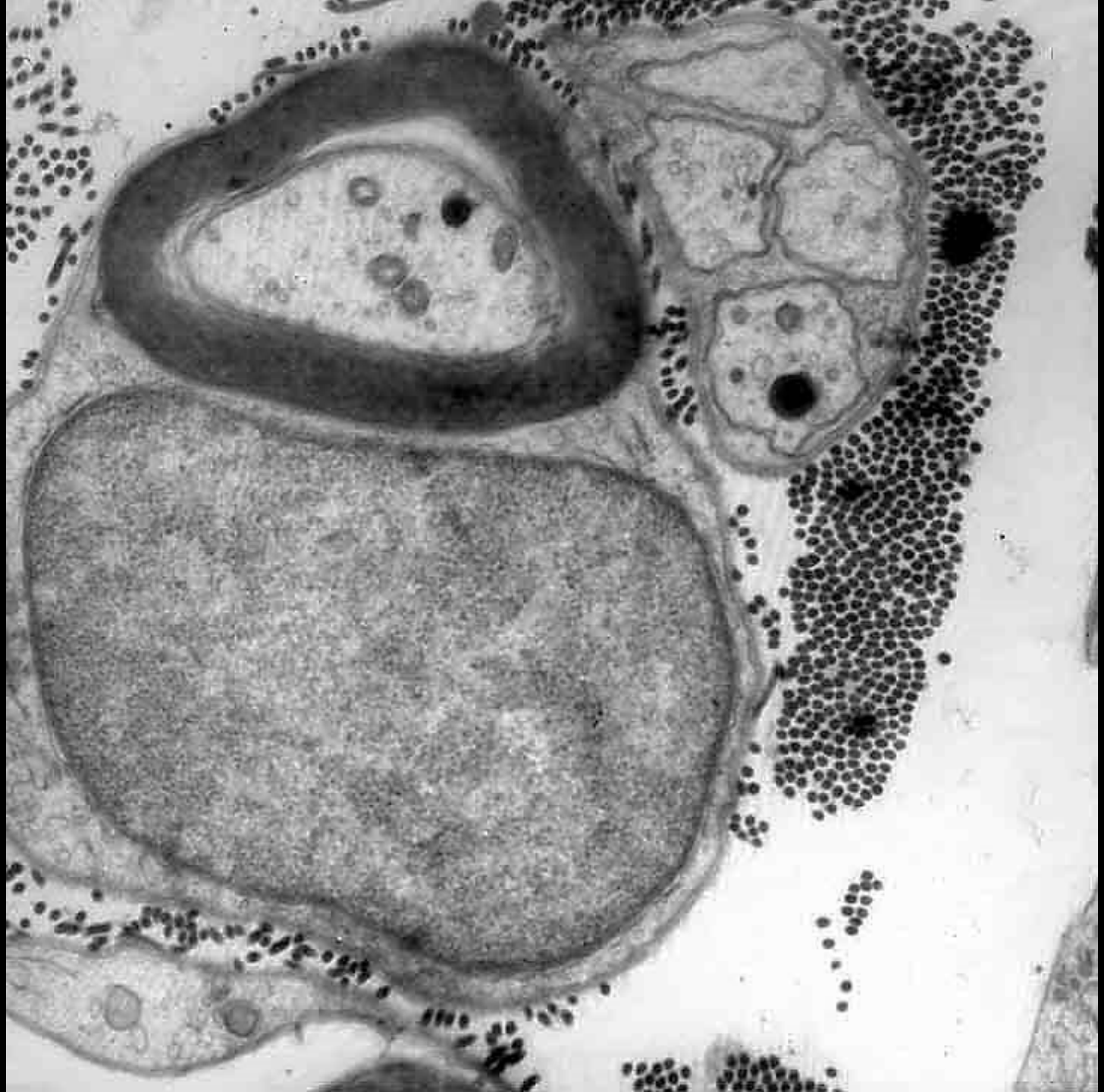



Ependyme

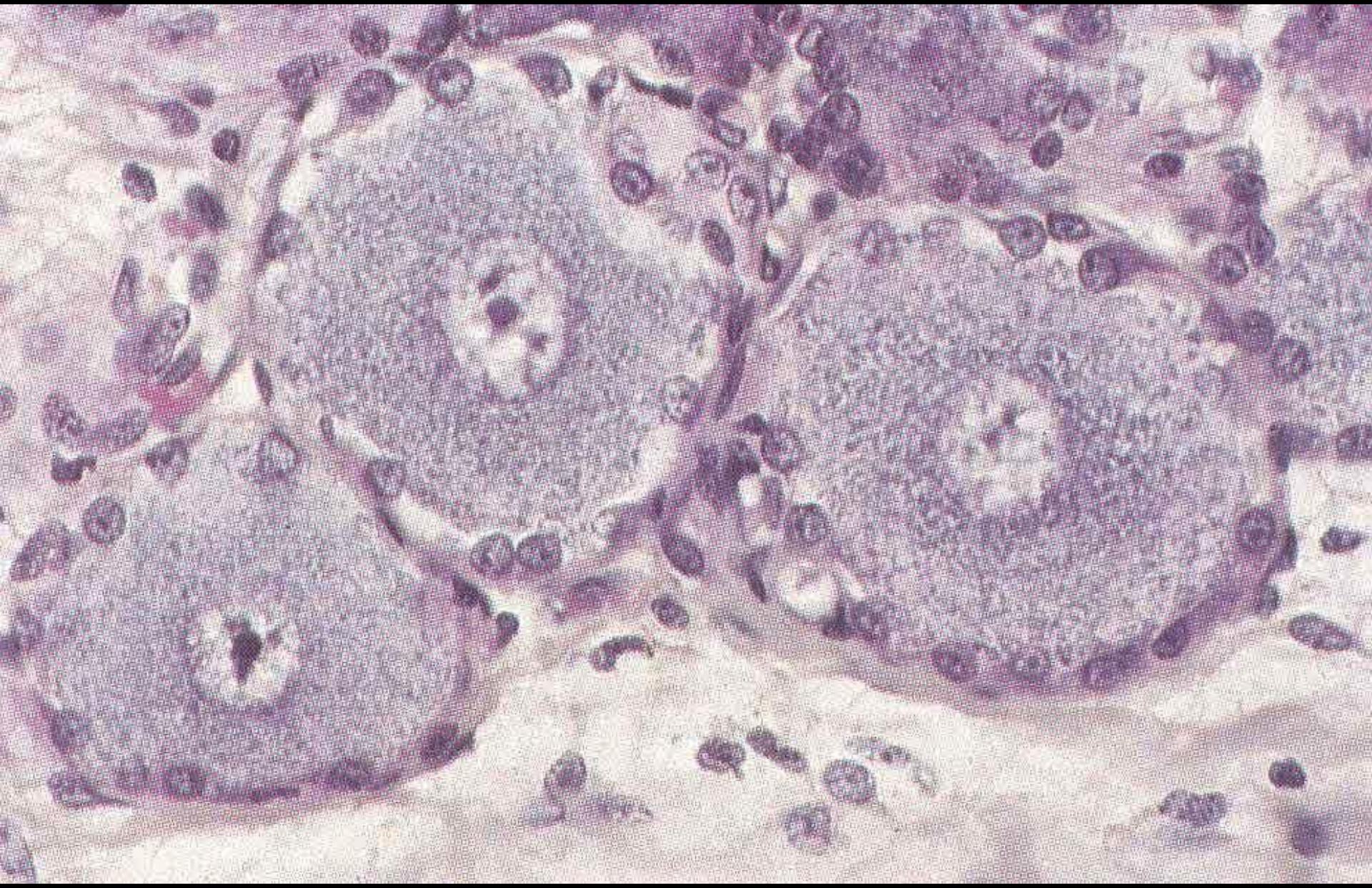

Ependymal cells



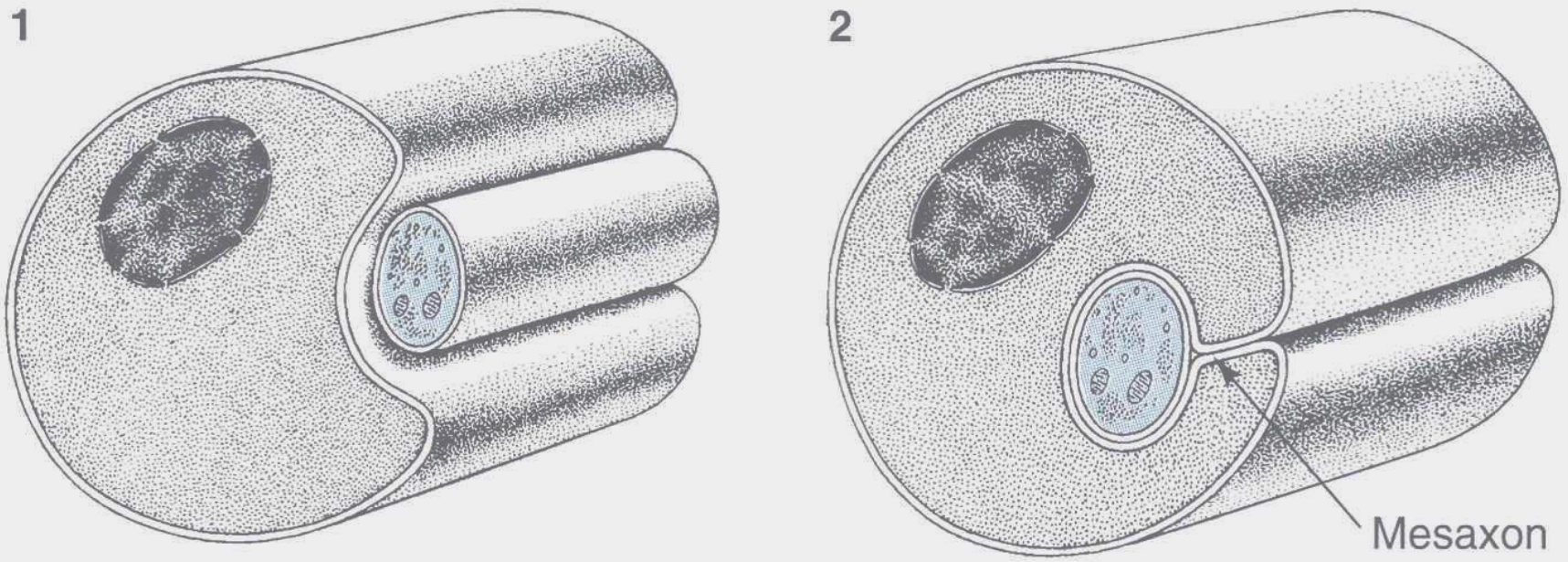
# Schwann cells



# Satelite cells



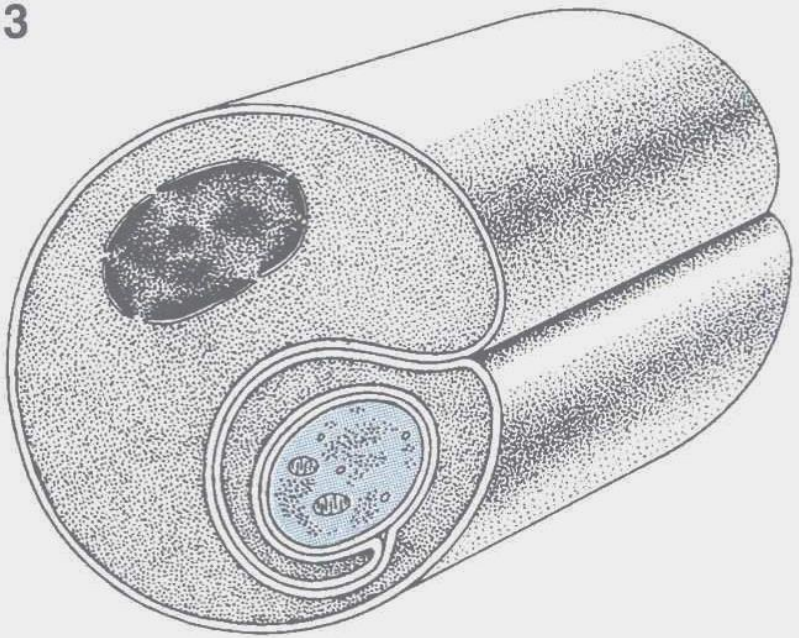
# Myelination



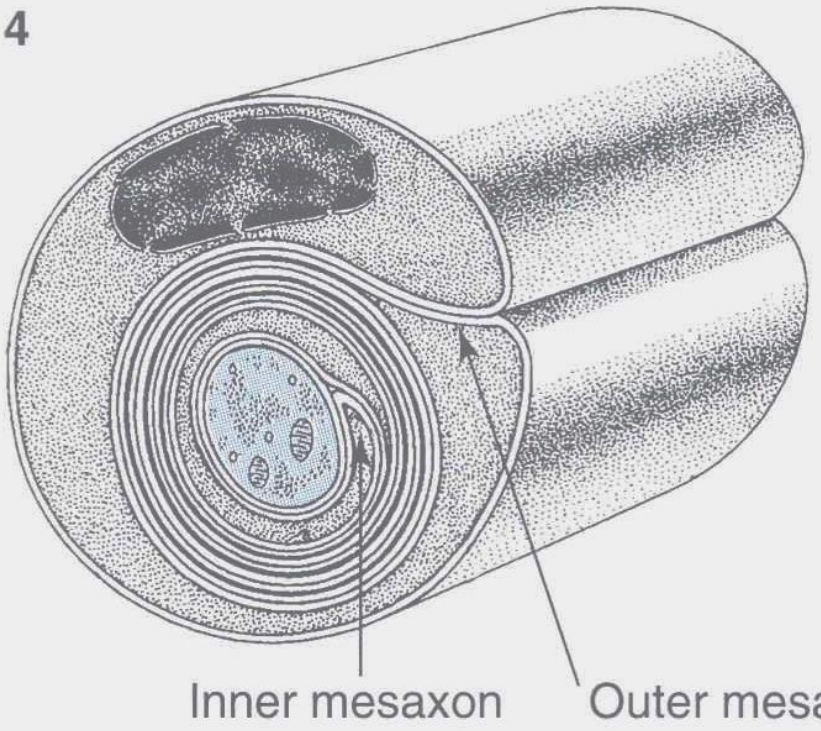

-axon expresses neuregulin-1 in amounts corresponding to its diameter; Schwann cell receives the signal via ErbB-receptor

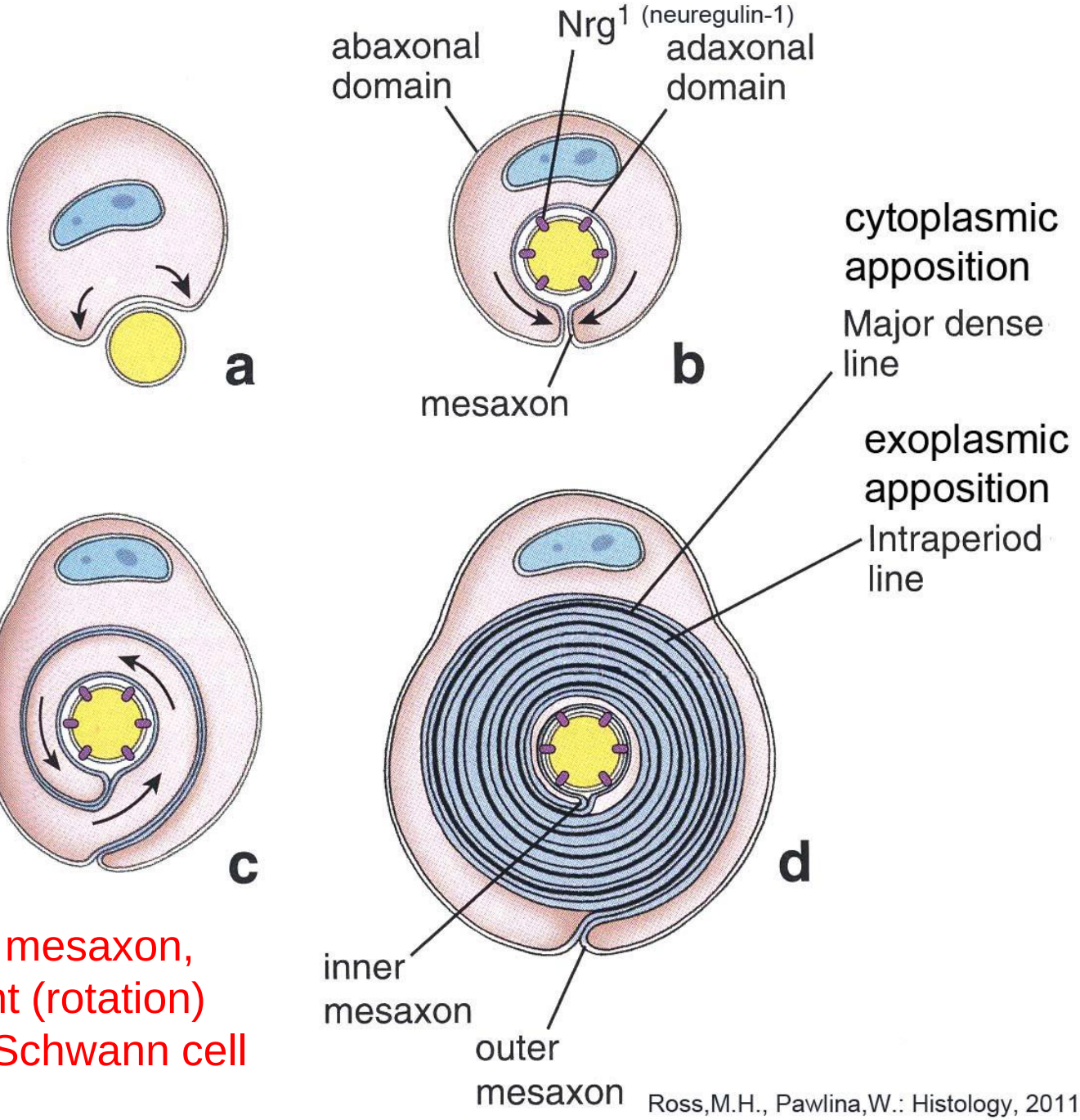
- receptor-mediated adhesion between axon and Schwann cell (NCAM)

3



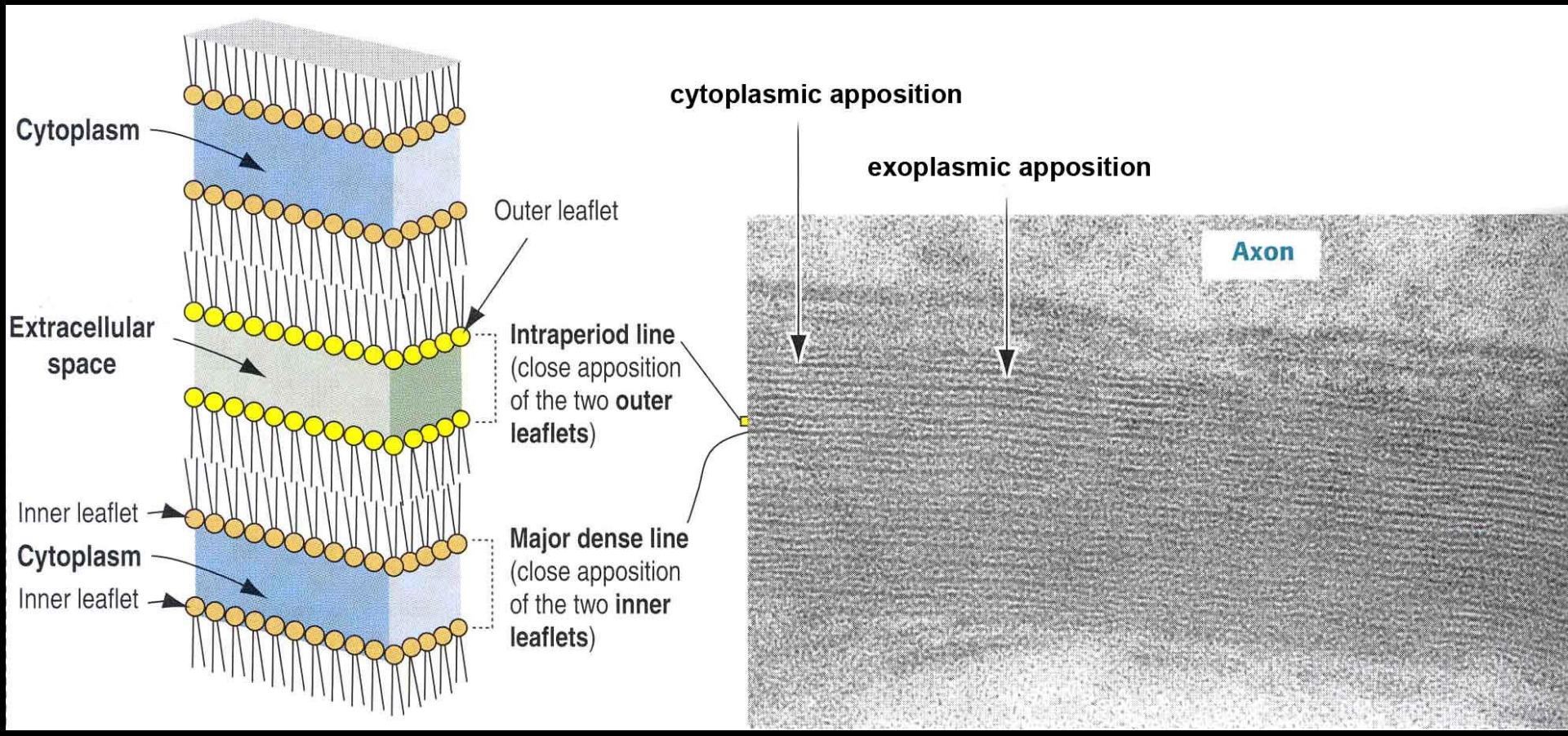
4



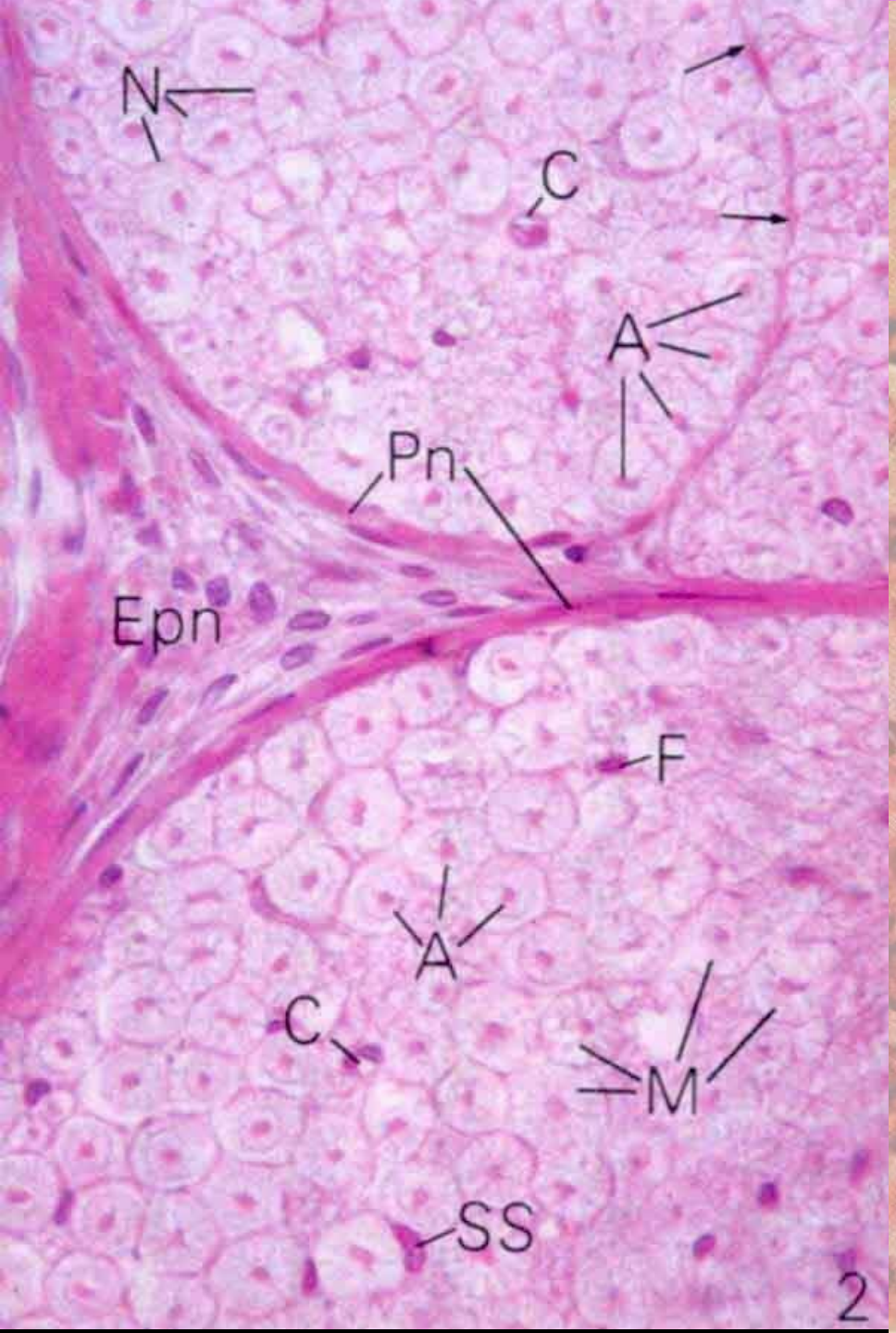


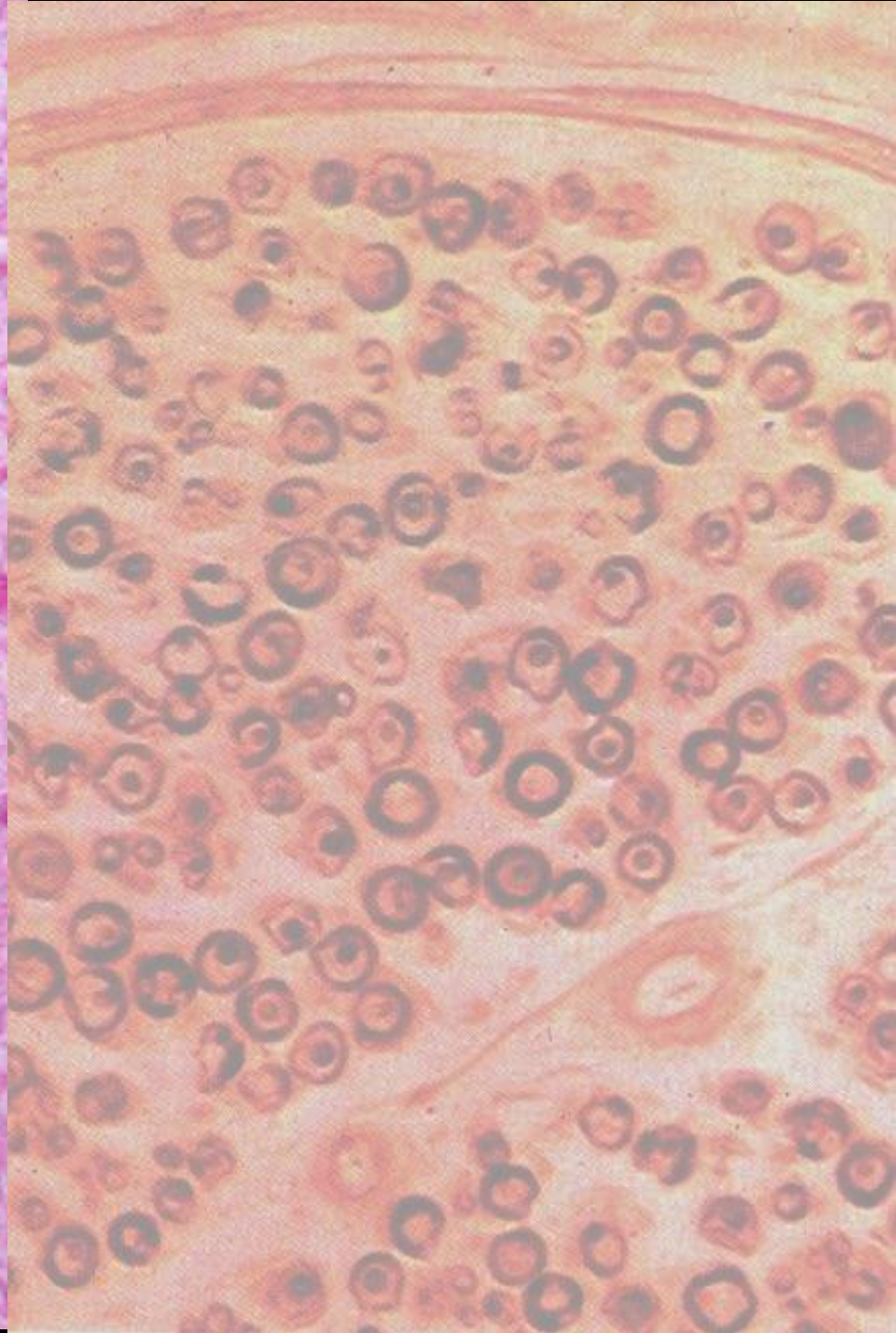

Ross,M.H., Pawlina,W.: Histology, 2011

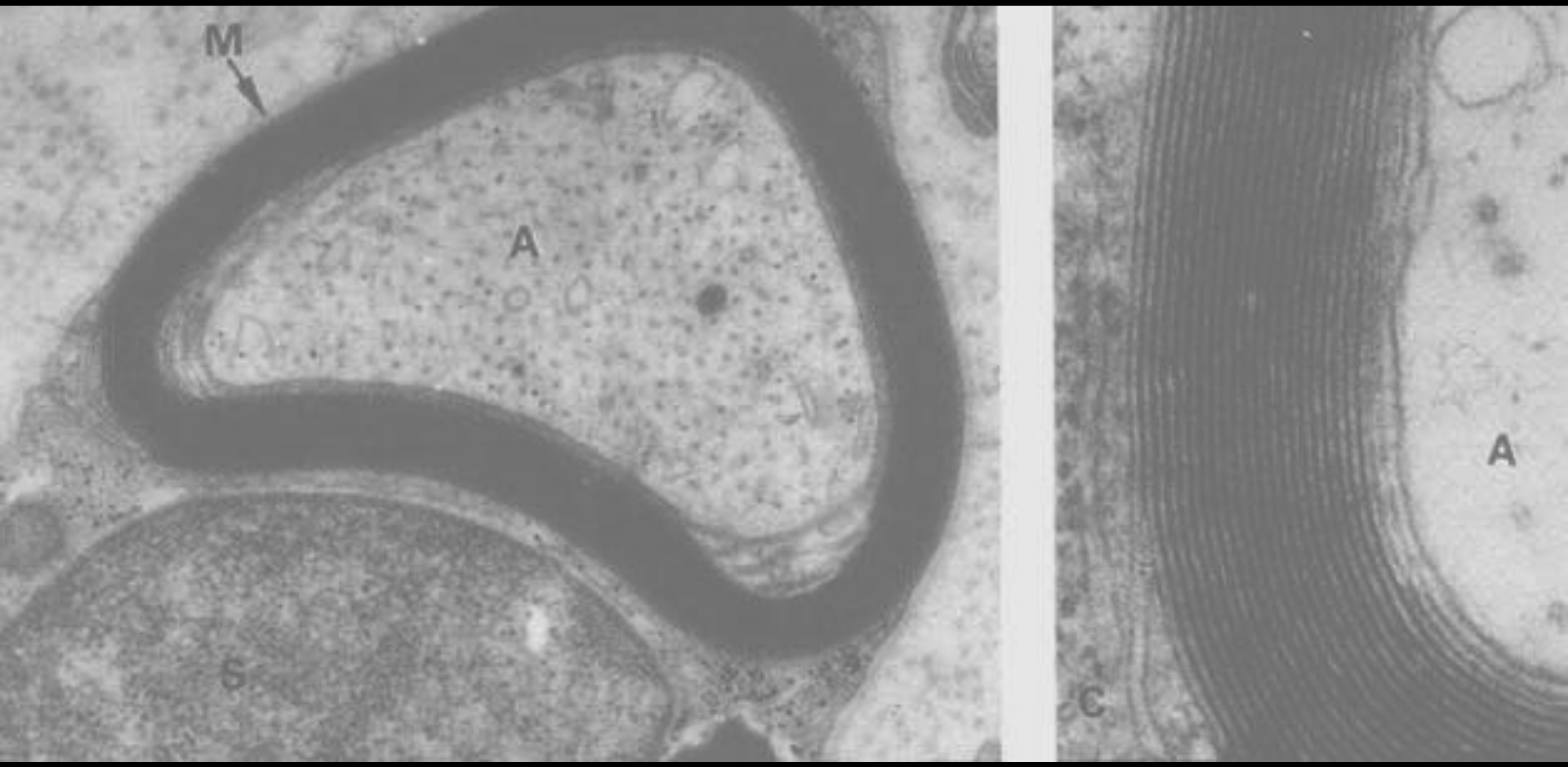
elongation of mesaxon,
not movement (rotation)
of the whole Schwann cell

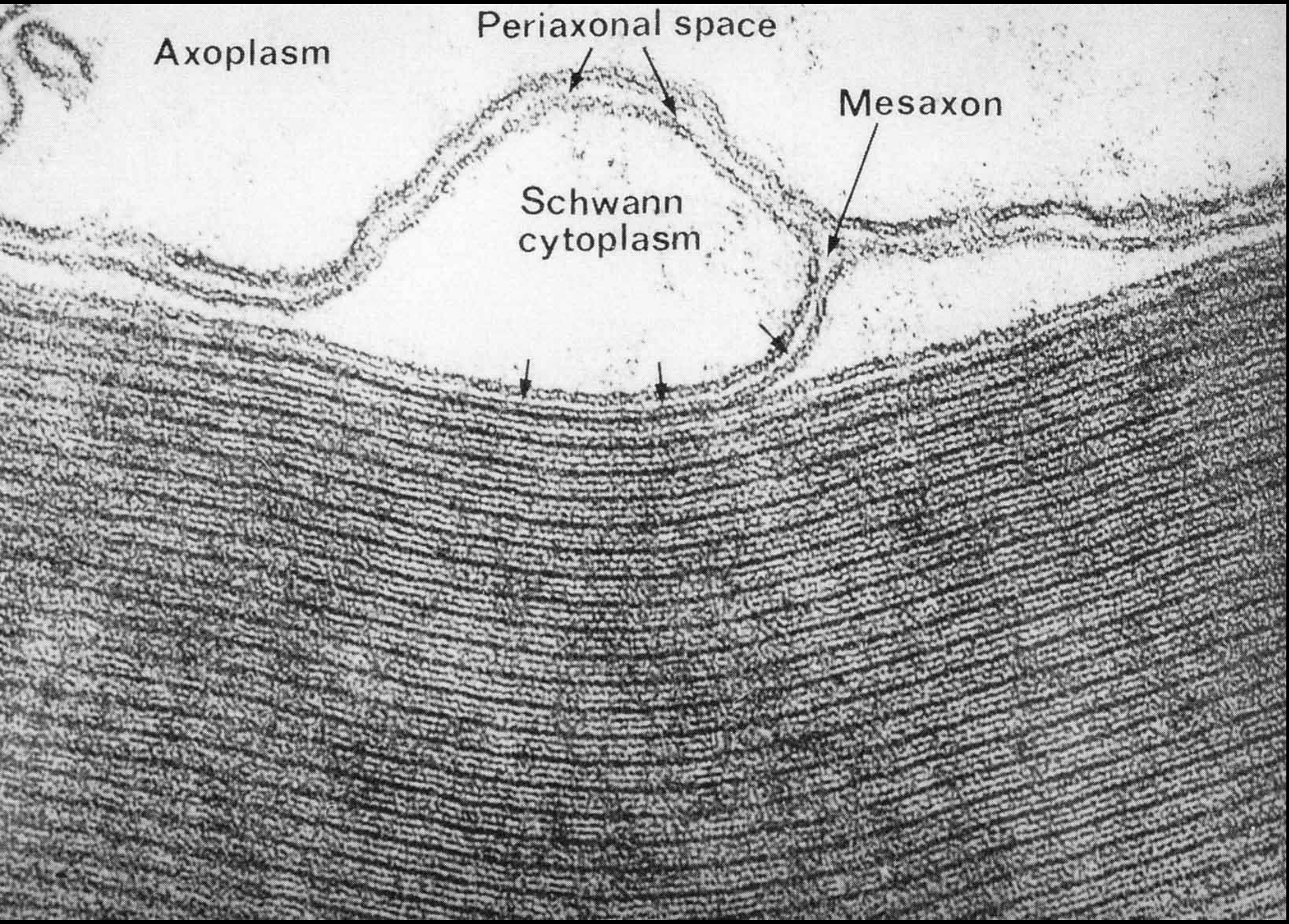



27 % galactocerebroside (galactosylceramide) – outer leaf
16 % plasmalogens – inner leaf

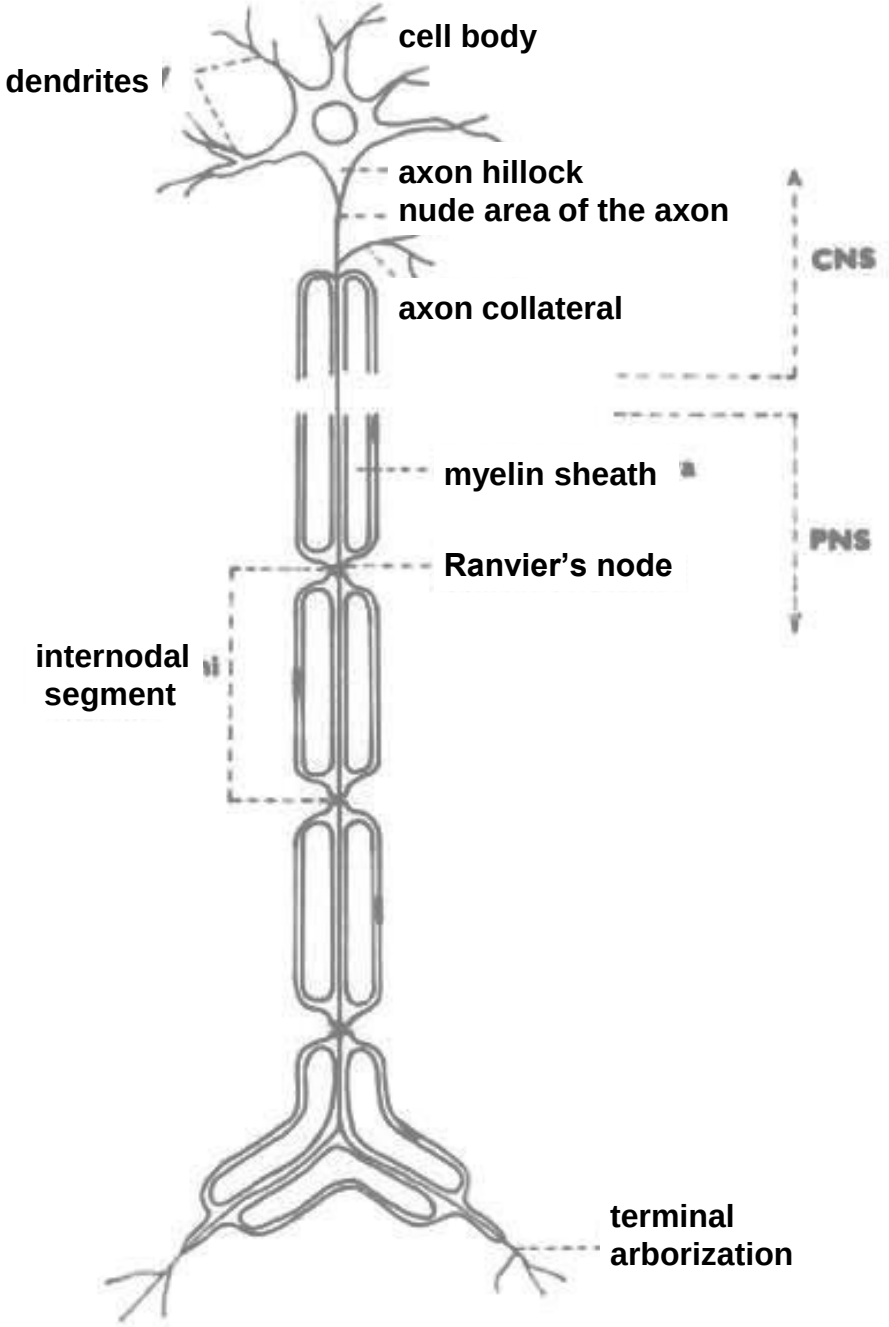

N
C
A
Pn
Epn
F
A
C
M
SS
2

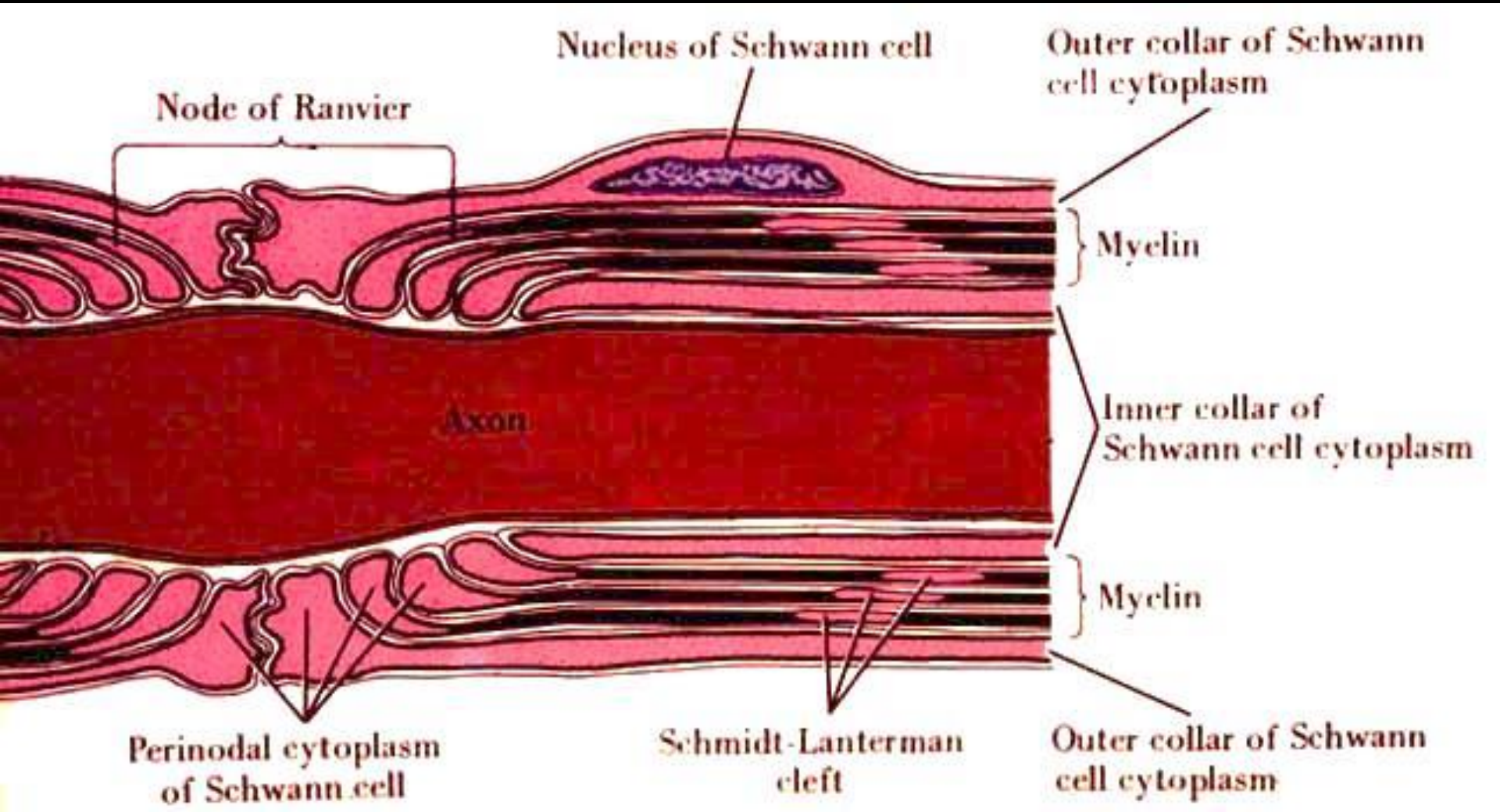


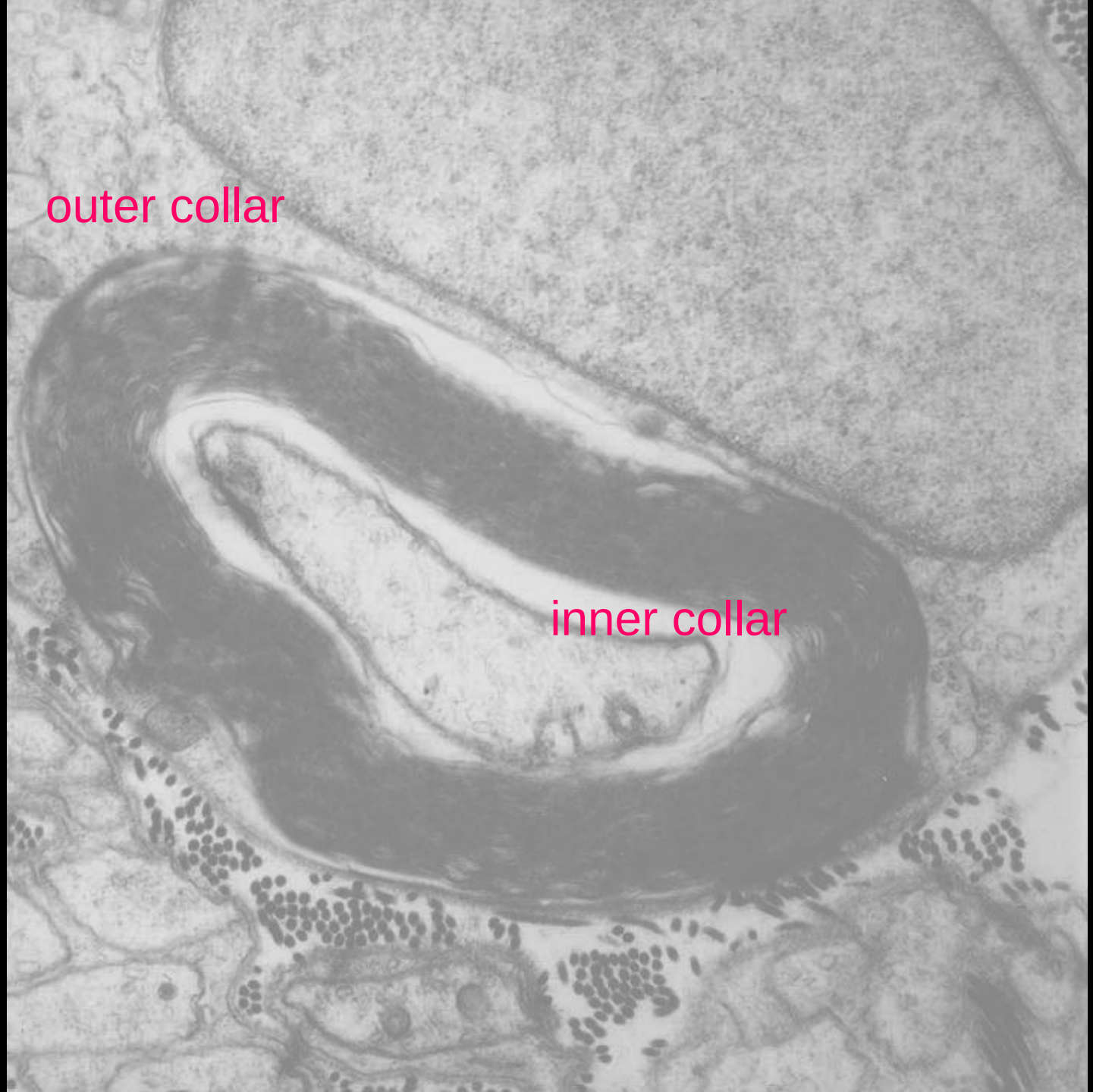

M
A
S
A
C

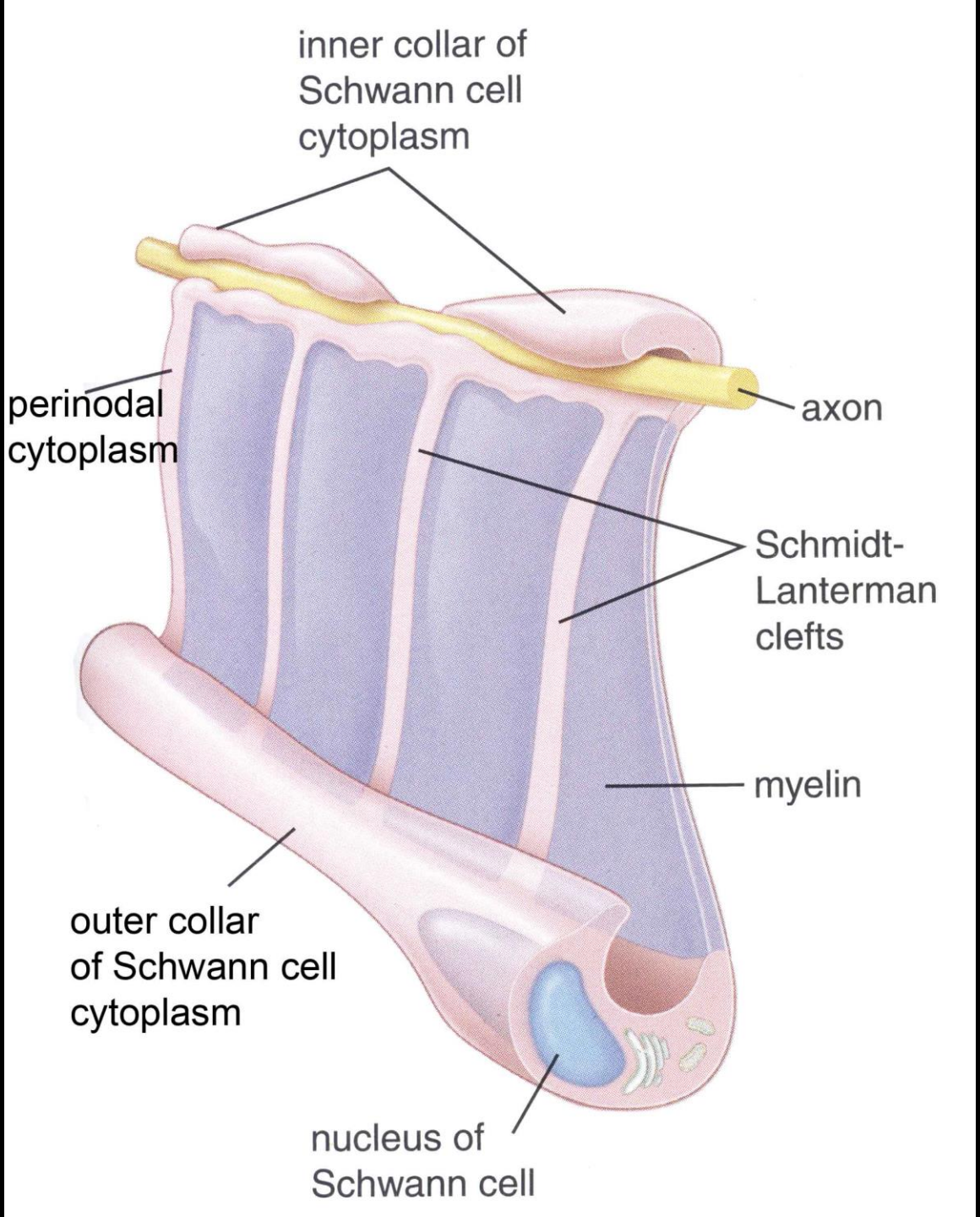

Axoplasm
Periaxonal space
Mesaxon
Schwann
cytoplasm

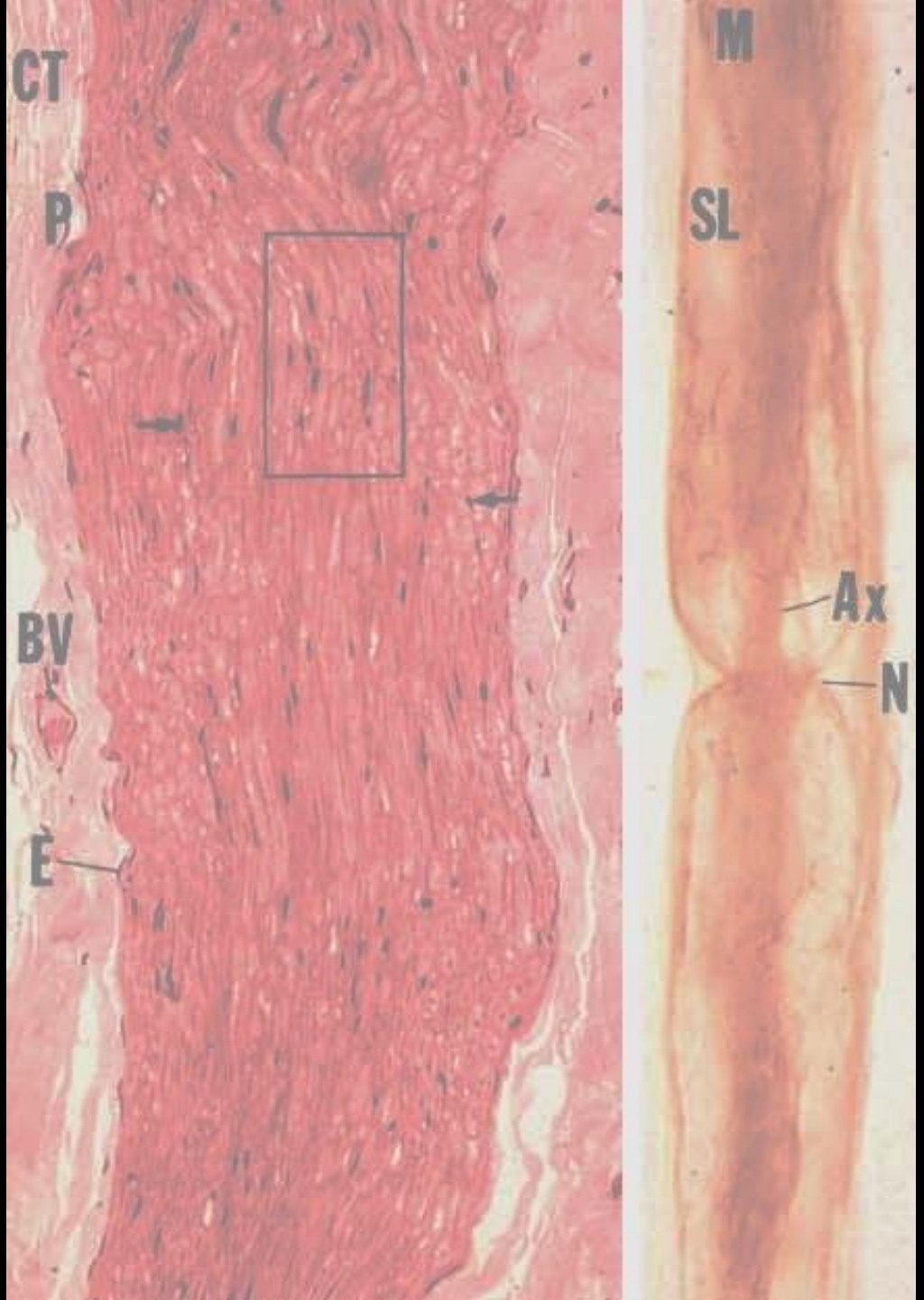
## Multipolar neuron with the long axon

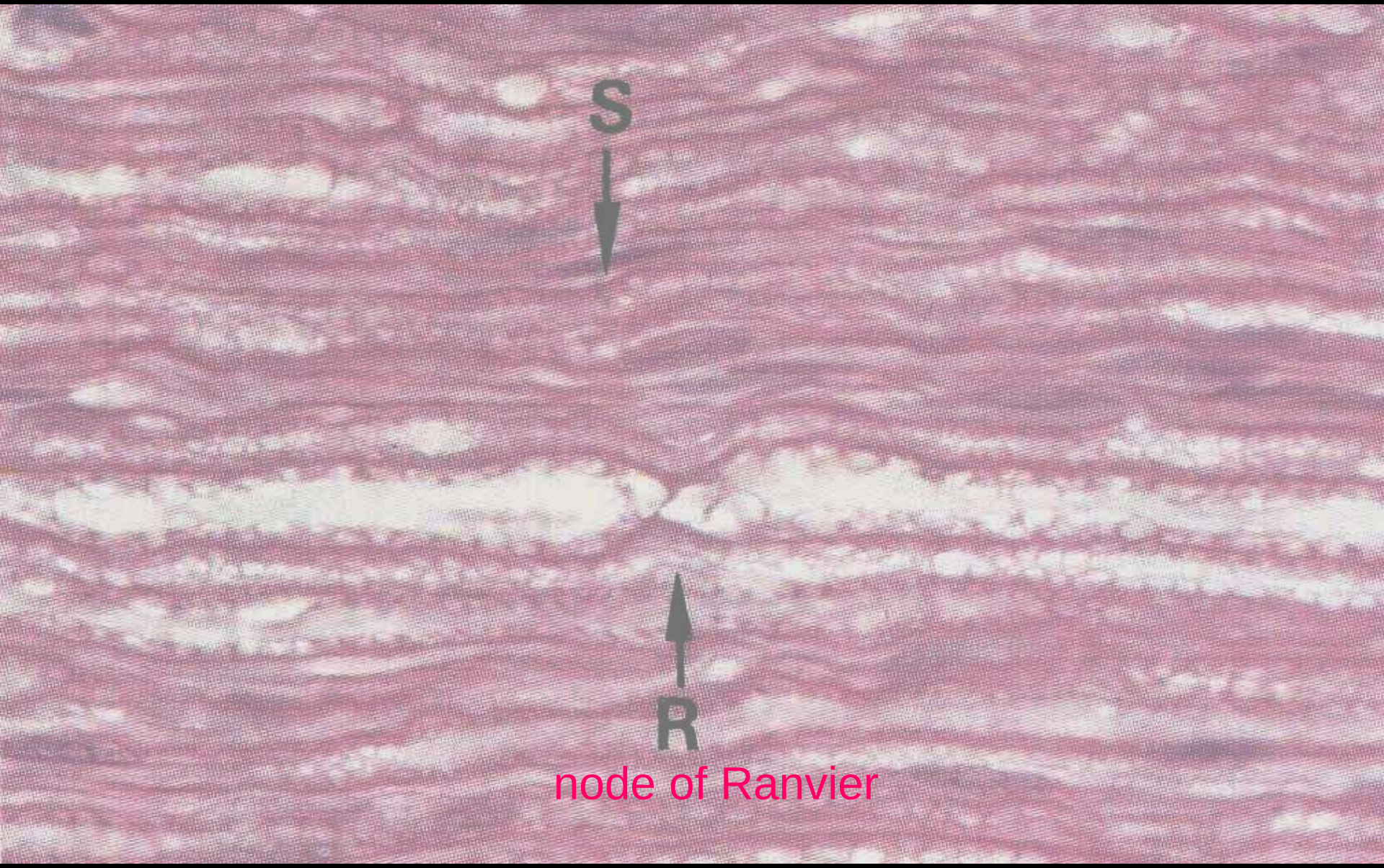



Nucleus of Schwann cell
Outer collar of Schwann cell cytoplasm
Node of Ranvier
Myelin
Axon
Inner collar of Schwann cell cytoplasm
Myelin
Perinodal cytoplasm of Schwann cell
Schmidt-Lanterman cleft
Outer collar of Schwann cell cytoplasm

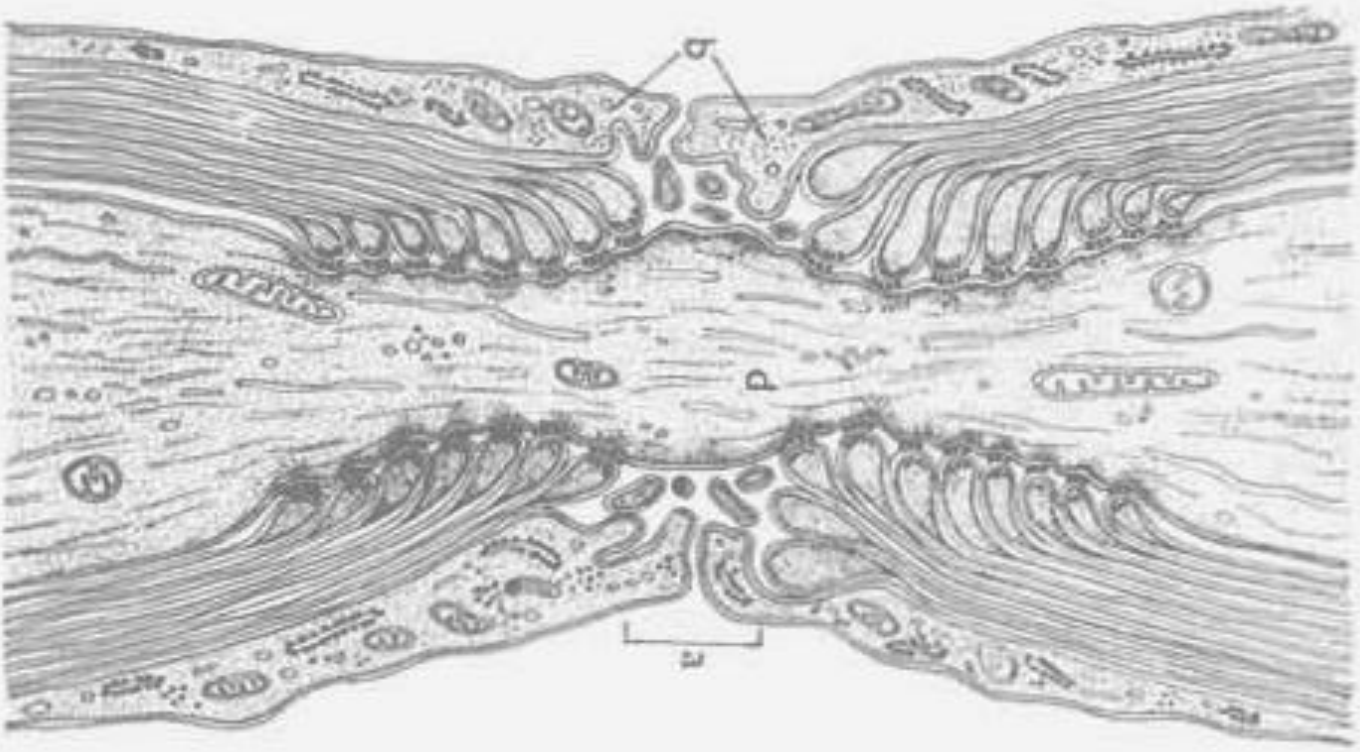

outer collar
inner collar


inner collar of Schwann cell cytoplasm
perinodal cytoplasm
axon
Schmidt-Lanterman clefts
myelin
outer collar of Schwann cell cytoplasm
nucleus of Schwann cell

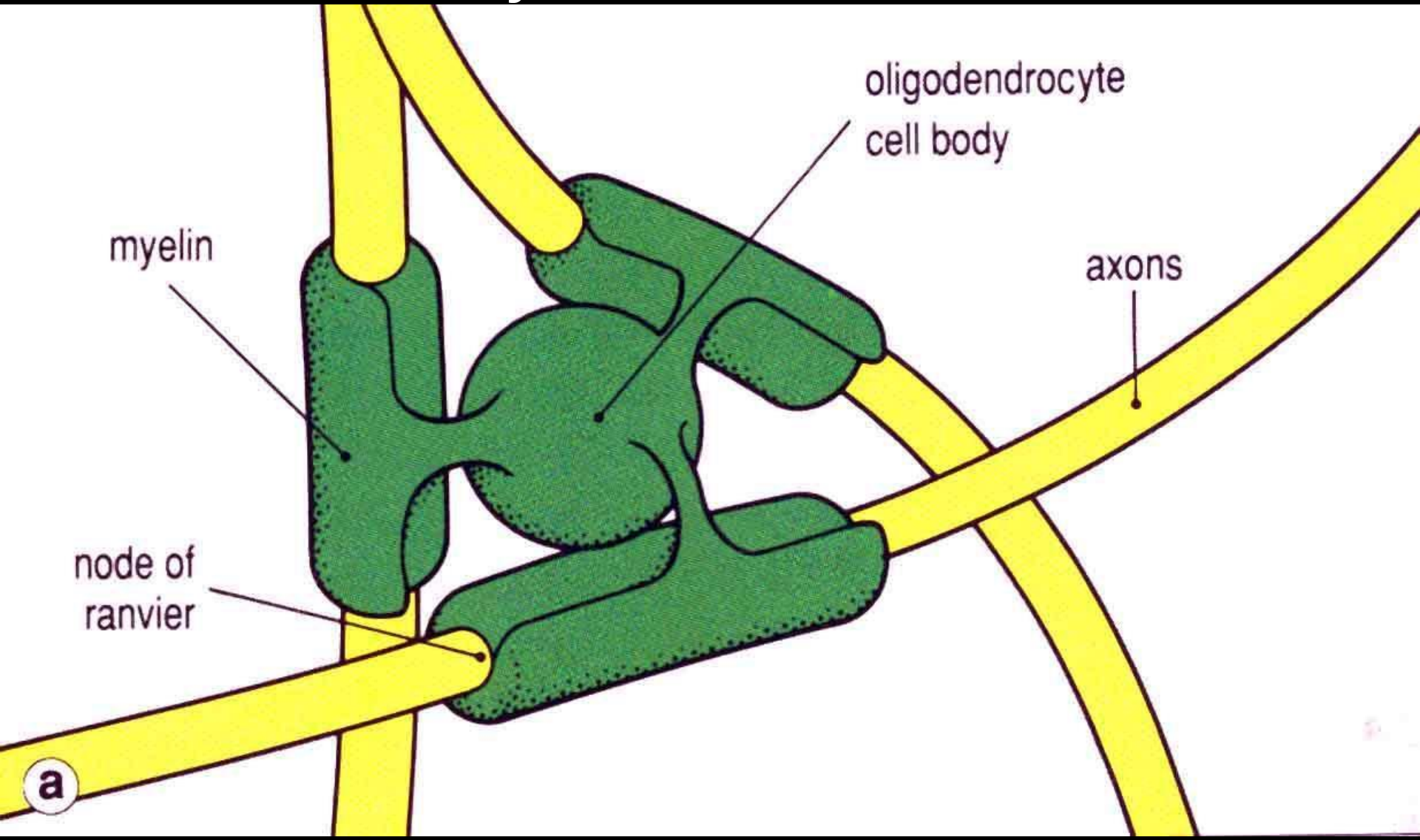

CT
P
BV
E
M
SL
Ax
N



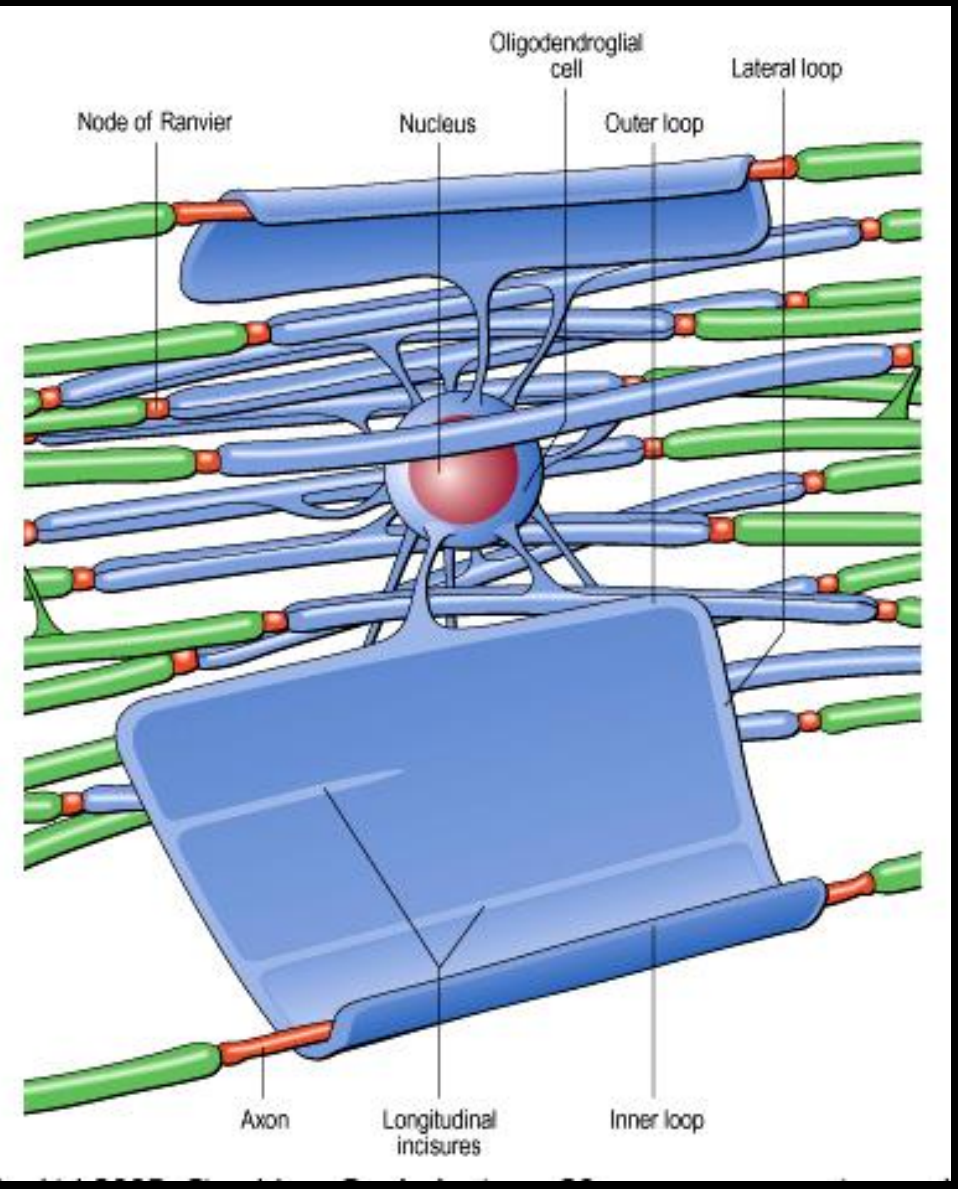

node of Ranvier

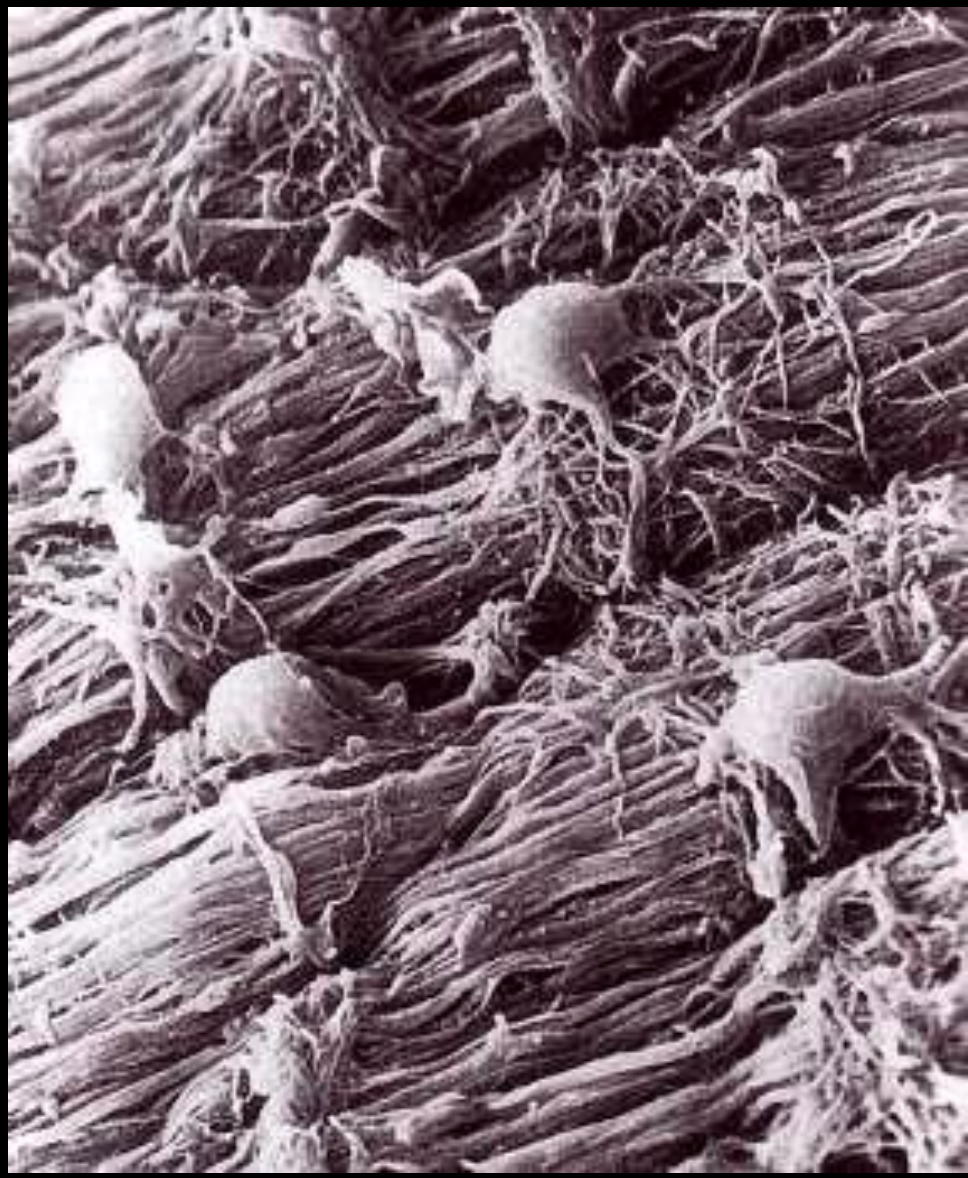

a
p
a

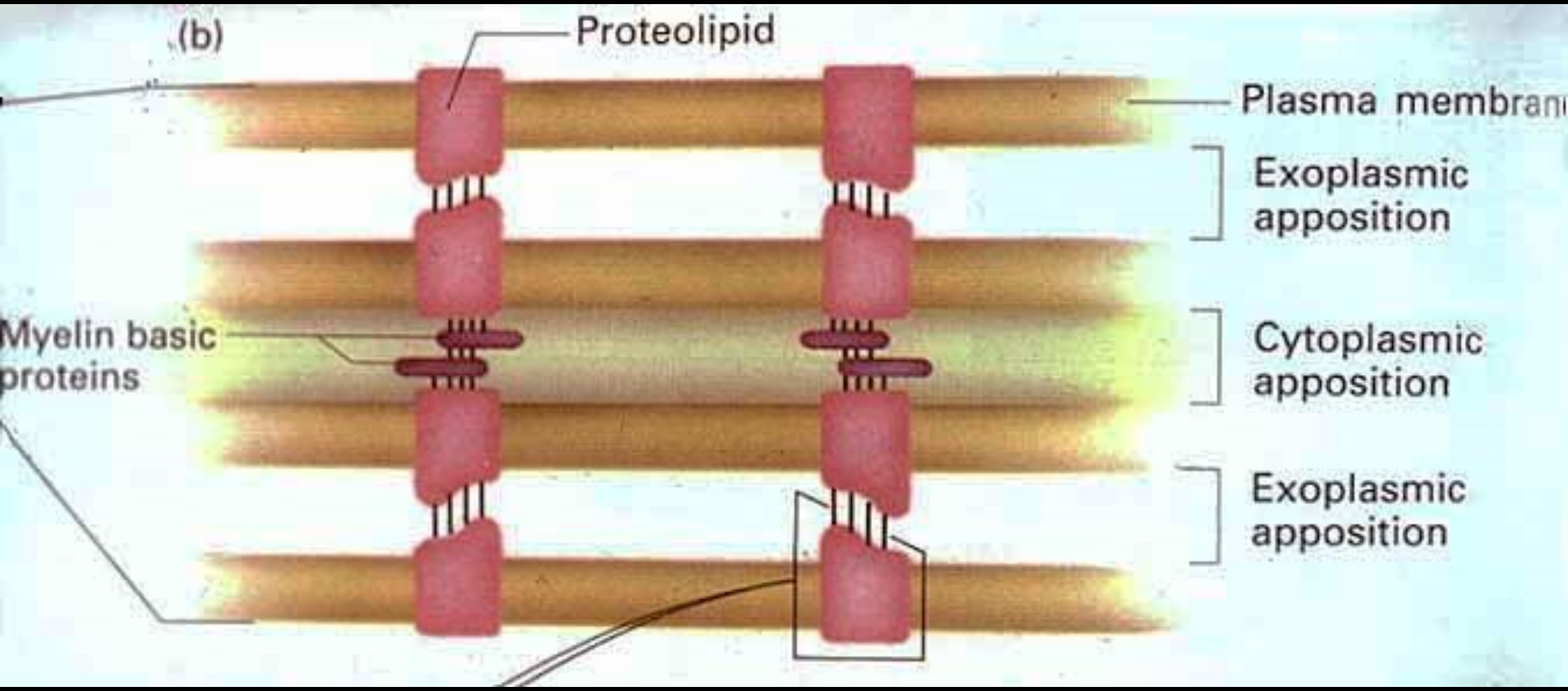
# Myelination in CNS




neuronal regulator that turns on myelination has not been identified in CNS


Oligodendroglial cell
Lateral loop
Node of Ranvier
Nucleus
Outer loop
Axon
Longitudinal incisures
Inner loop



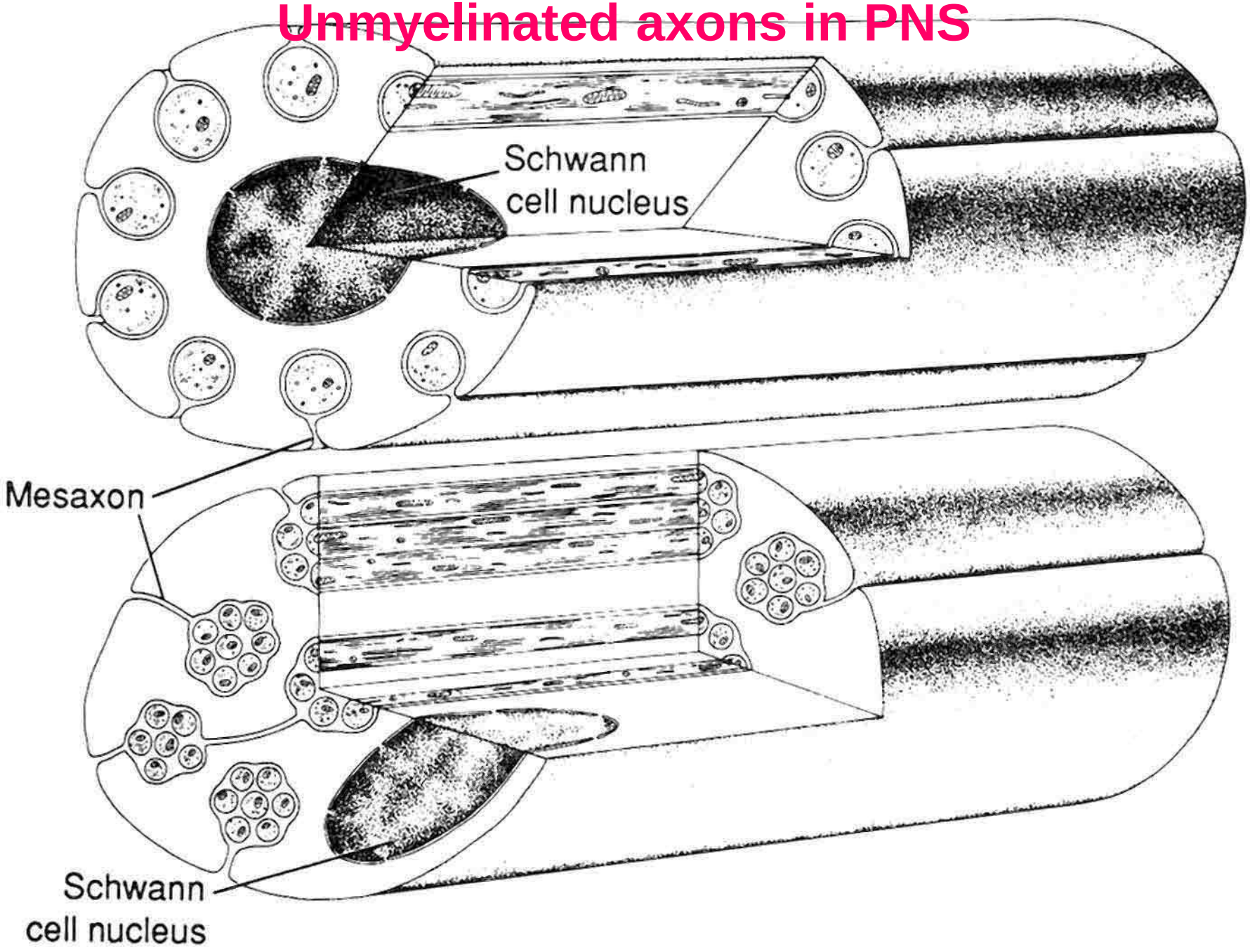


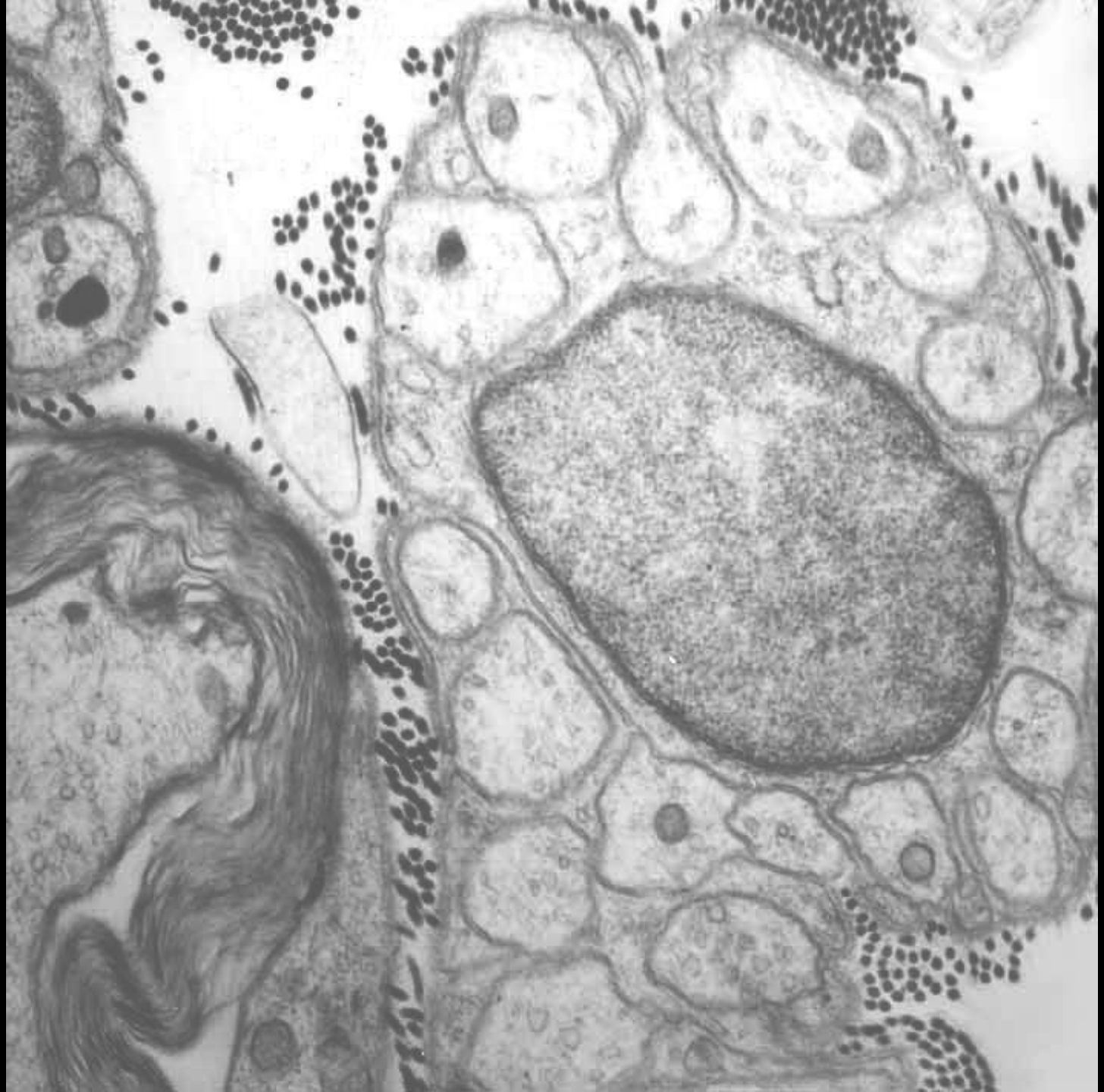

- myelin basic protein or oligodendrocyte myelin glycoprotein (in CNS only) (cytoplasmic apposition)

- proteolipid protein 1 (exoplasmic apposition)

destruction of these structures results in DEMYELINATION

# Unmyelinated axons in PNS





PNS

# Unmyelinated axon in CNS

CNS