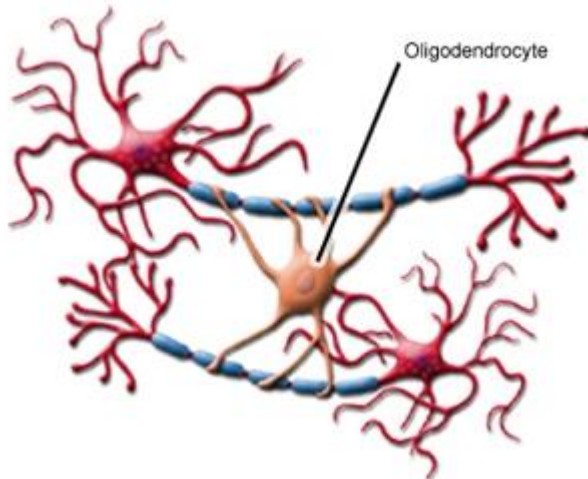


# NERVE SYSTEM

## Nerve tissue

### Neurons



### Glial cells

#### central

- astrocytes (protoplasmic and fibrous)
- oligodendrocytes
- microglia
- ependyma

#### peripheral

- Schwann cells
- satellite cells

# Neurons

## Function in neural network

Efferent  
Sensor  
Interneurons

Sensitive  
Motor  
Associative

## Mediator

Dopaminergic  
Cholinergic  
Serotonergic  
Aminergic  
GABAergic  
nitriergic,  
peptidergic, ...

## Morphology

Unipolar  
Bipolar  
Multipolar  
Pseudounipolar

## Axon

Golgi type I (long)  
Golgi type II (short)

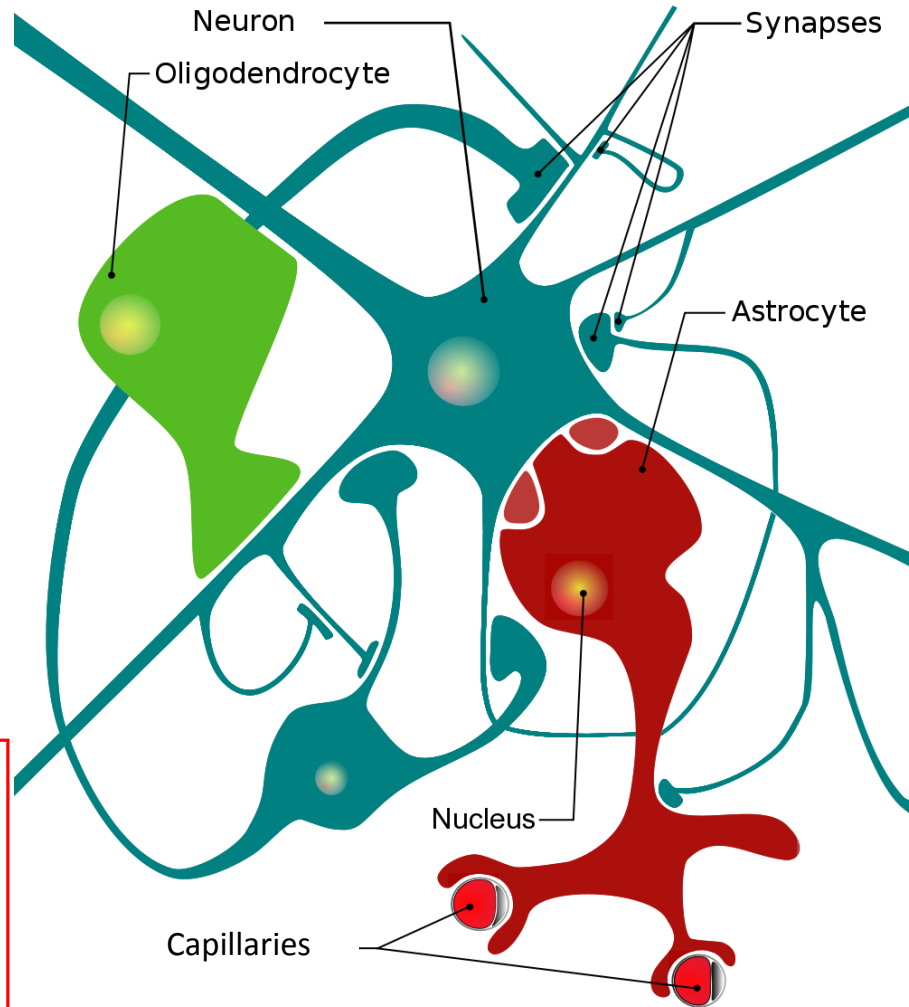
# Glial cells

## CNS

Astrocytes  
- fibrous (grey matter)  
- protoplasmic (white matter)  
Oligodendrocytes  
Microglia  
Ependyme cells

## Periphery

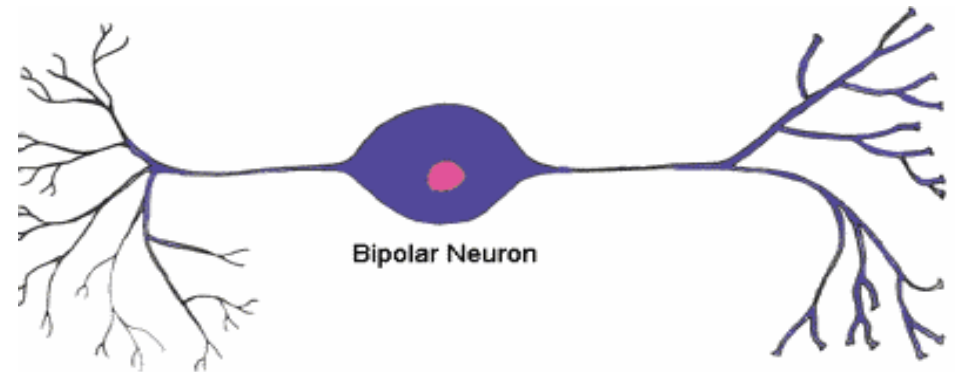
Schwann cells  
Sattelite cells (amphicytes)



# Classification of neurons

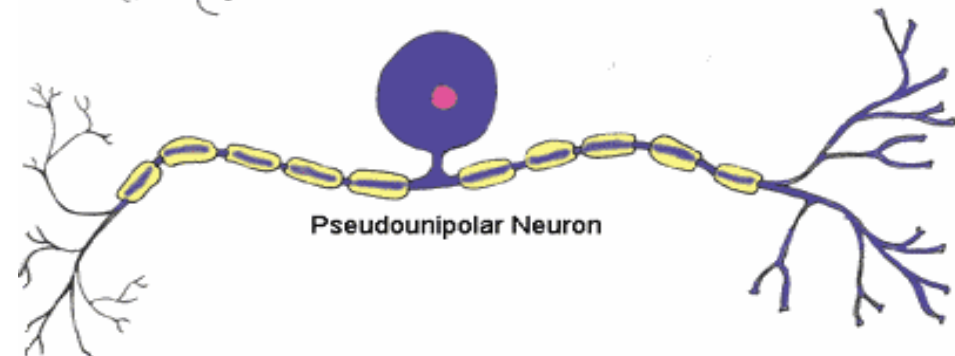
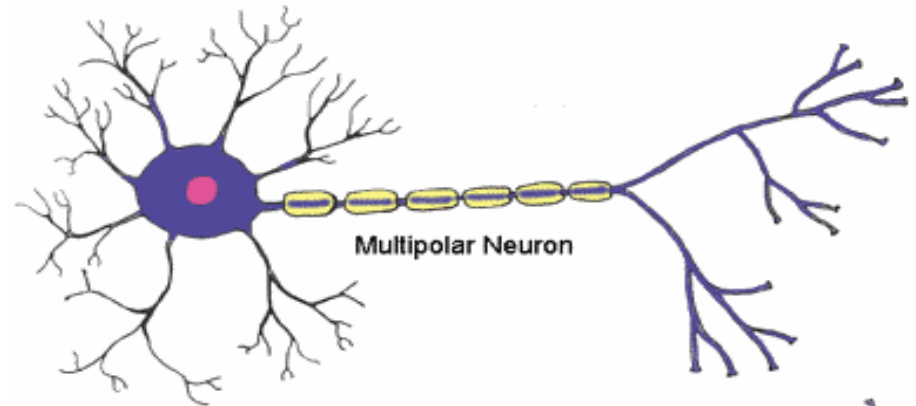
According to the **number of processes**

- Apolar
- Unipolar
- Pseudounipolar
- Bipolar
- Multipolar

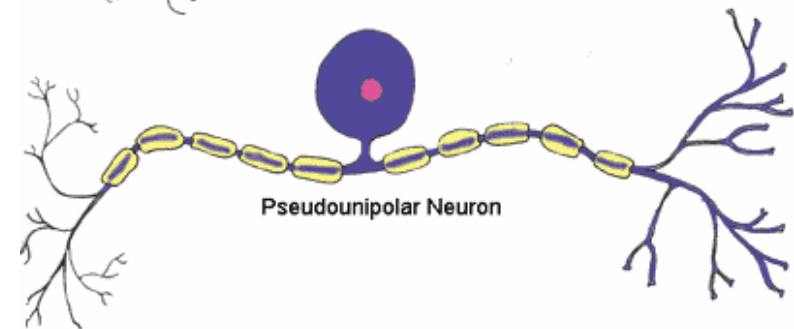
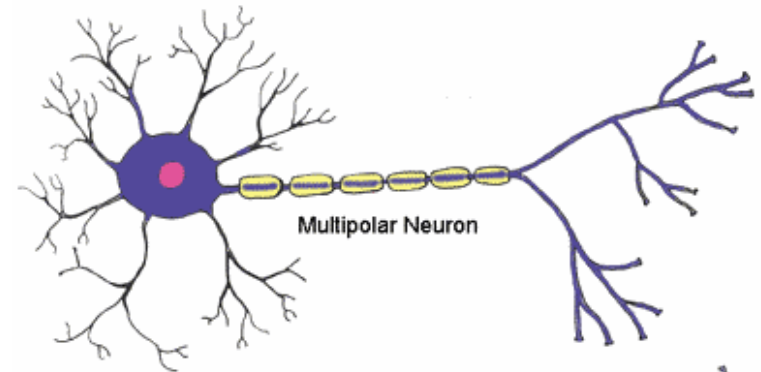
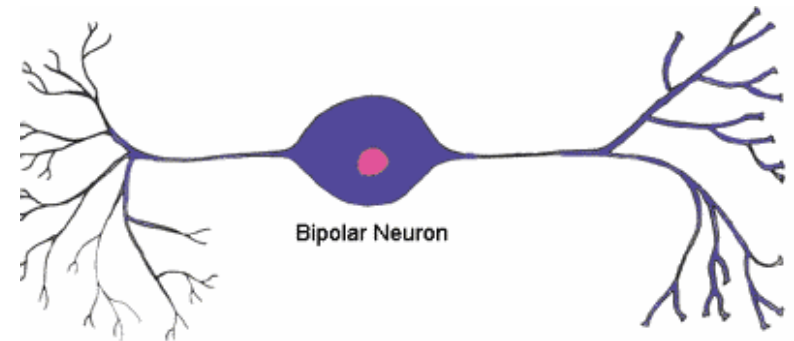


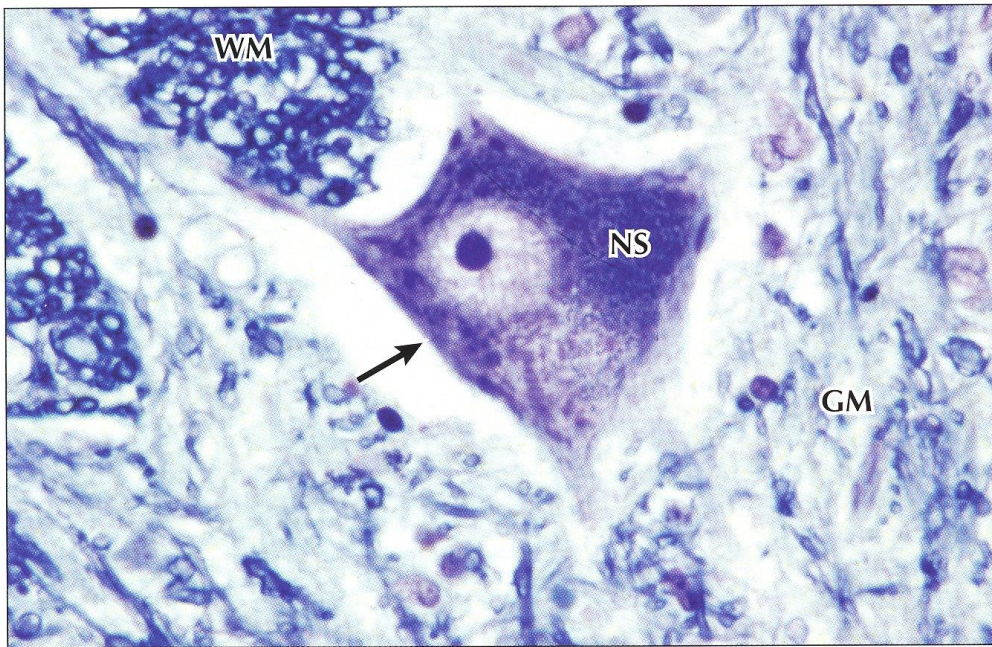
According to the **length of axon**

- Golgi I /long axon – 1 m/
- Golgi II /short axon -  $\mu\text{m}$ /



- **Apolar** – hairy cells in inner ear
- **Unipolar** – primary sensory cells /rods, cones/
- **Bipolar** – the 2nd neuron in the retina, ganglion vestibulocochleare
- **Pseudounipolar** –
  - T-shaped process.
  - **branches of the neurite** connecting the ganglion cell with the CNS (central branch) and the periphery (peripheral branch).
  - function as one actively conducting axon, which transmits information from the periphery to the CNS – dorsal root ganglia, some cranial nerves
- **Multipolar** - the most frequent – CNS, the autonomic ganglia





## Spinal multipolar neuroal

10-100 $\mu$ m

### Perikaryon

- round nucleus, dominant nucleolus
- basophilic cytoplasm – rod-like mitochondria, GA, Nissl substance

### GER

- neurofilaments, neurotubules
- lipofuscin

### Dendrites, dendritic spines

### Axon

- odstupový konus
- initial segment
- axolemma

### Synapse

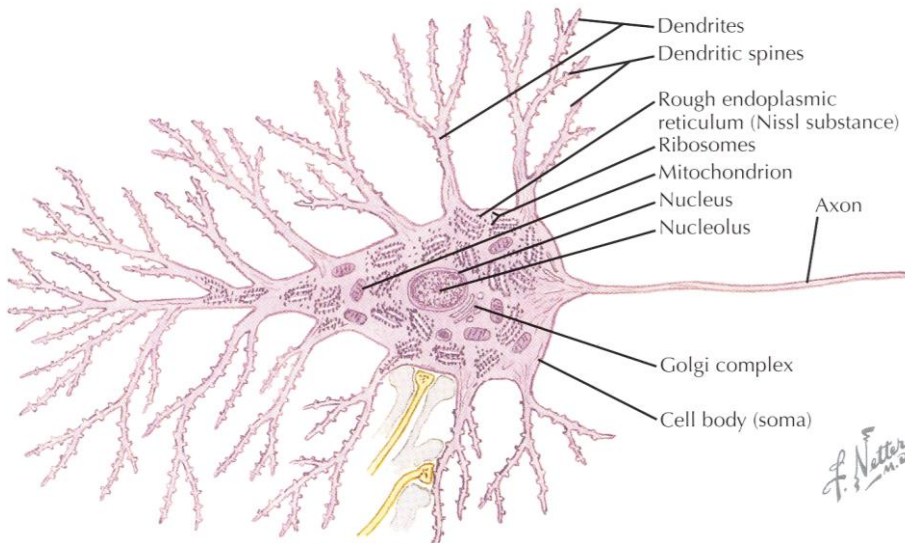
- presynaptic end (terminal arborization)
- synaptic cleft
- postsynaptic membrane

### Motori plate

- large cholinergic synapse

## Pyramidal neuron of cerebral cortex

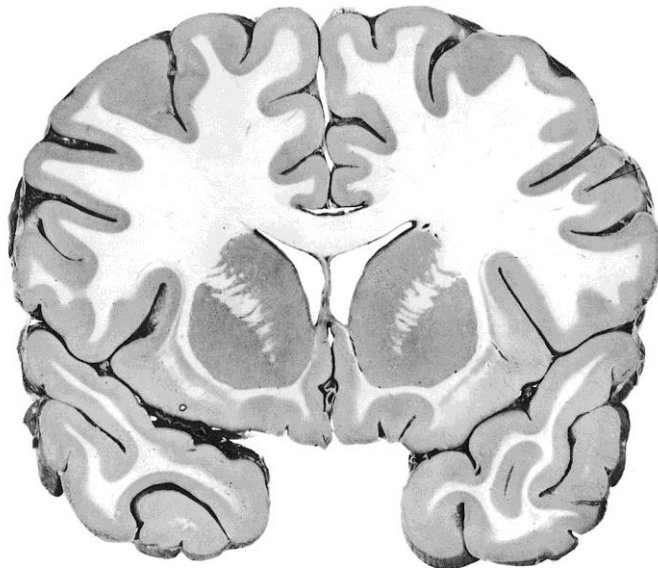
(inner pyramidal layer, „motorcortex“)



# CNS

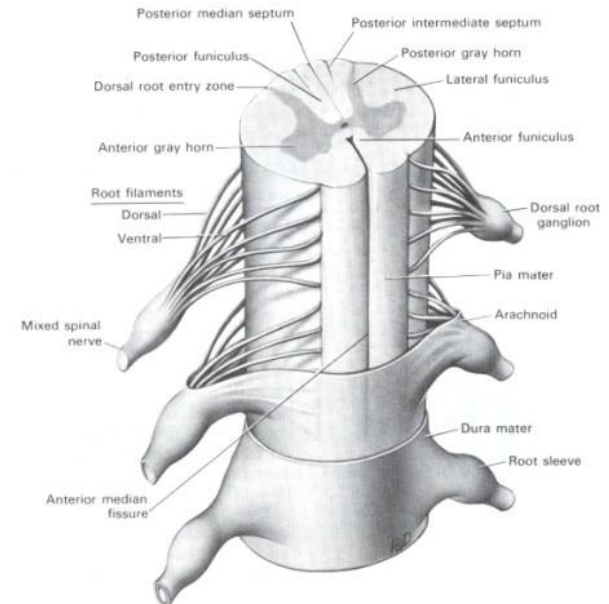
- **Gray matter**

- cell bodies
- nonmyelinated fibers
- associated neuroglial cells
- very dense capillary network



- **White matter**

- only myelinated axons of neurons
- neuroglial cells (oligodendrocytes)
- blood capillaries (lesser than in gray matter)



# Telencephalon

## Grey matter

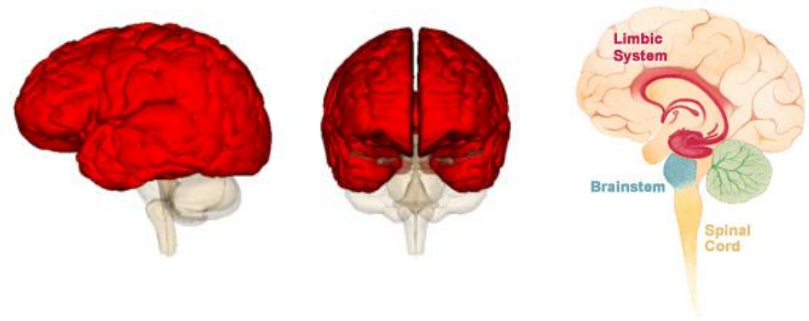
1.5-5mm, 0.2-0.25m<sup>2</sup>

**Surface** (*cortex cerebri*) + **regions under the cortex**  
(*ncl. caudatus, lentiformis, claustrum, amygdale*)

## Isocortex

- 11/12 of surface
- 8-9×10<sup>9</sup> neurons
  
- 6 layers
  - homotypic isocortex
  - heterotypic isocortex

Allocortex 1/12 of surface, rhinencephalon



## Neurons

Pyramidal (motorneurons)  
Granular (stellate)  
Fusiform (spindle)  
Cells of Cajal (horizontal)  
Cells of Martinotti (vertical)

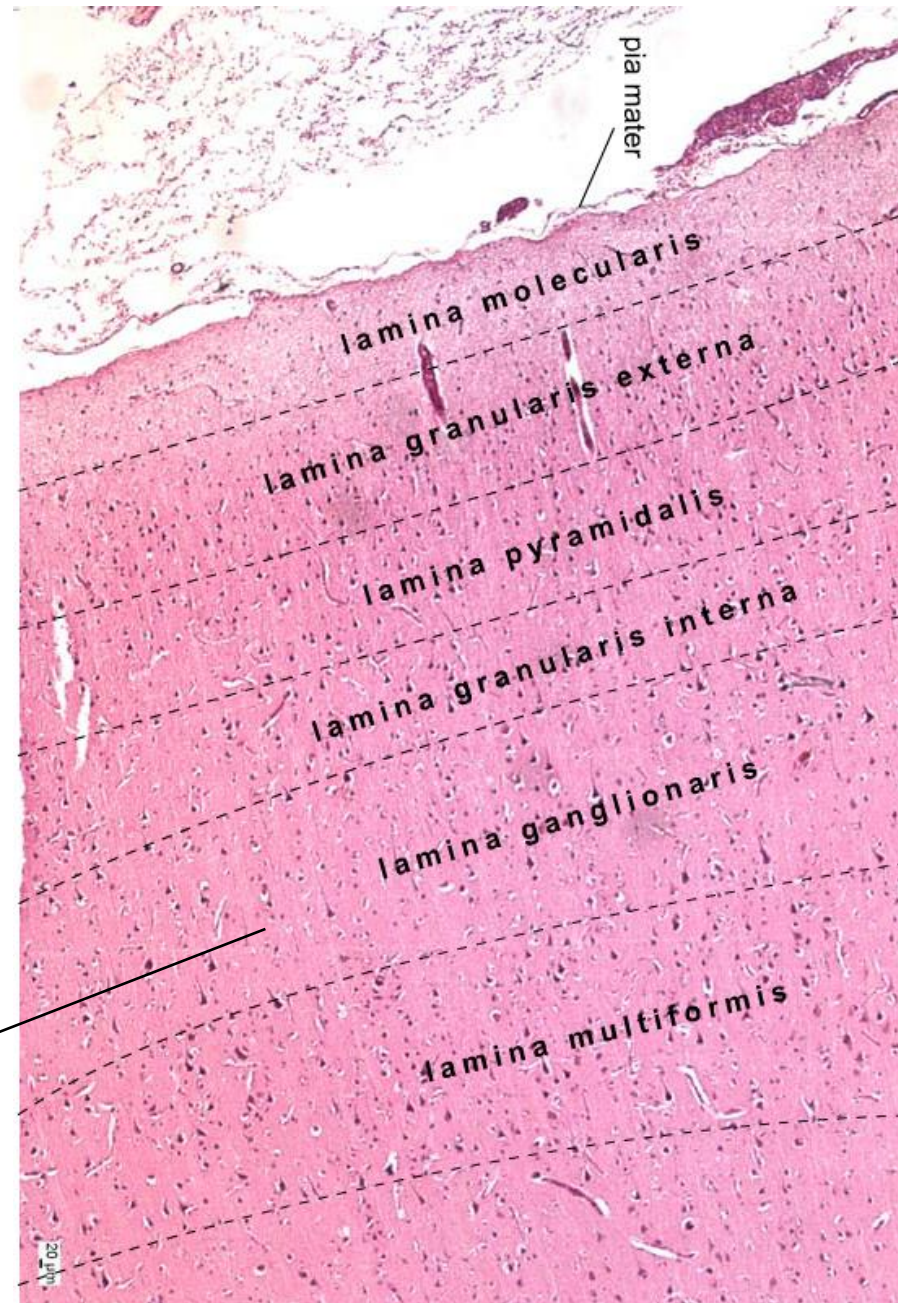
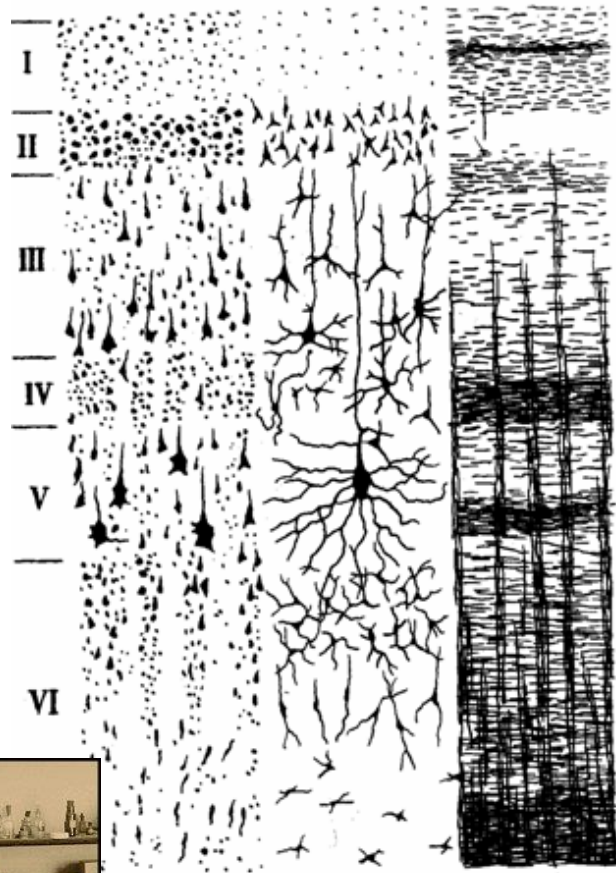
## Neuroglial cells

Plasmatic astrocytes  
Microglia

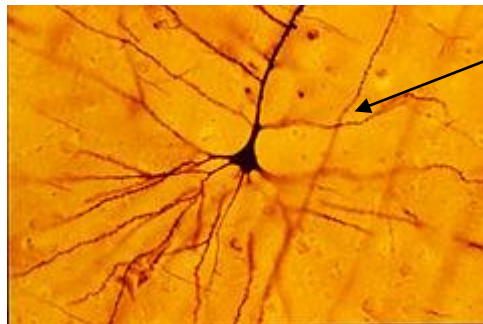
- 
1. **Lamina molecularis**
  2. **Lamina granularis externa**
  3. **Lamina pyramidalis**
  4. **Lamina granularis interna**
  5. **Lamina ganglionaris**
  6. **Lamina multiformis**

## White matter

*Corpus medullare telencephali*



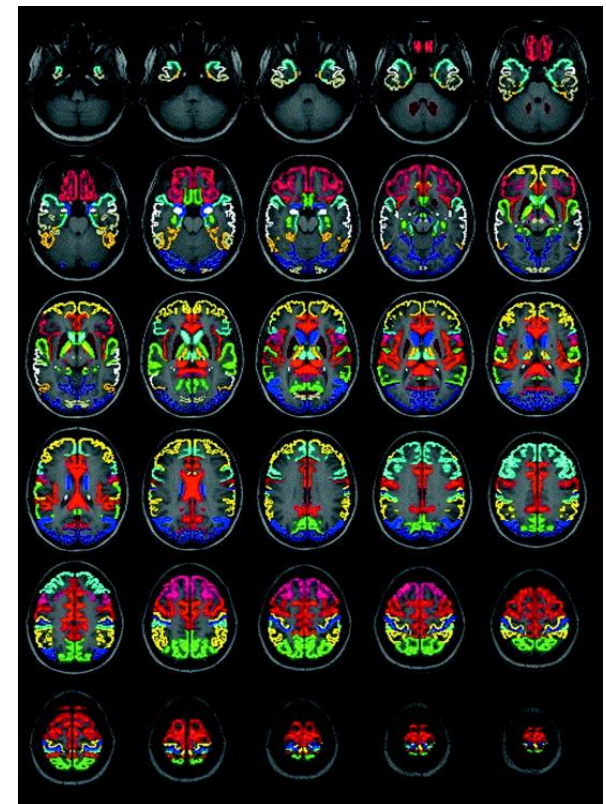
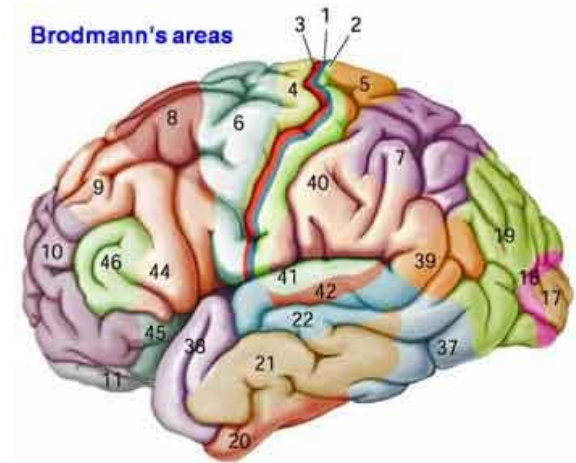
**Santiago R. Cajal**  
Nobel prize 1906



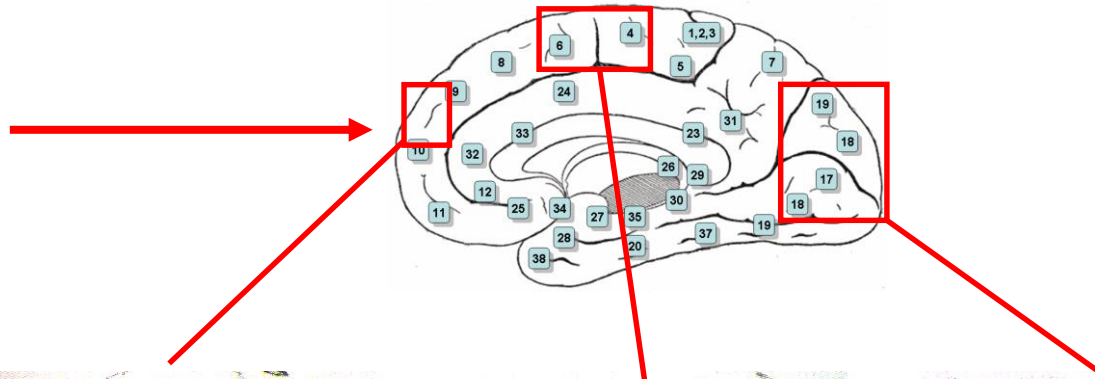


# Brodmann classification of isocortex

REGIO	AREAE	FUNCTION
Postcentralis	1,2,3,43,(2s)	Soamtosensoric, taste
Praecentralis	4,6, (4s)	Motor
Frontalis	8,9,10,11,44, 45,46,47, (8s)	associative
Insularis	13,14,15,16	Integrative
Temporalis	20,21,22,36,37,38,41,42,52	Hearing
Parietalis	5,7,39,40	Associative
Occipitalis	17,18,19,(19s)	Vision
Cingularis	23,24,31,32,33	Spontaneous
Retrosplenialis	26,29,30	Spontaneous
Hippocampica	27,28,34,35,48,51	Smell,
Olfactoria	area olfactoria trigonum olfactorium	Smell



REGIO	AREAE	FUNKCE	POZNÁMKA
Postcentralis	1,2,3,43,(2s)	somatosenzorická, chuťová	zakončení thalamokortikálních vláken
Praecentralis	4,6, (4s)	motorická	Betzovy pyramidové buňky
Frontalis	8,9,10,11,44, 45,46,47, (8s)	asociační	volní úkony, vliv na mimovolní oblast
Insularis	13,14,15,16	integrační	
Temporalis	20,21,22,36,37,38,41,42,52	sluchová	rozdílly mezi druhy
Parietalis	5,7,39,40	asociační	vztah k somestézii
Occipitalis	17,18,19,(19s)	zraková	k zrakové kůře patří i další oblasti
Cingularis	23,24,31,32,33	mimovolní	limbický systém
Retrospenialis	26,29,30	mimovolní	limbická, atokortex
Hippocampica	27,28,34,35,48,51	čich (34),mimovolní paměť	
Olfactoria	area olfactoria trigonum olfactorium	čichová	tzv. bazální čichová kůra



I. Lamina molecularis

II. Lamina granularis externa

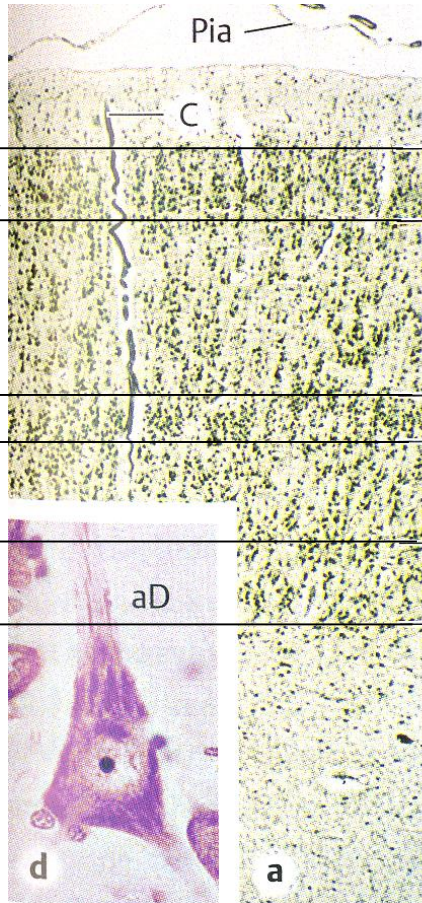
III. Lamina pyramidalis

IV. Lamina granularis interna

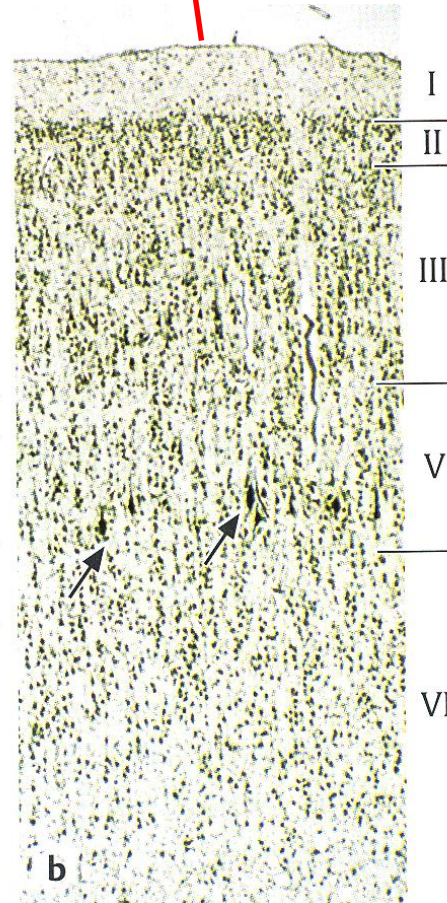
V. Lamina ganglionaris

VI. Lamina multiformis

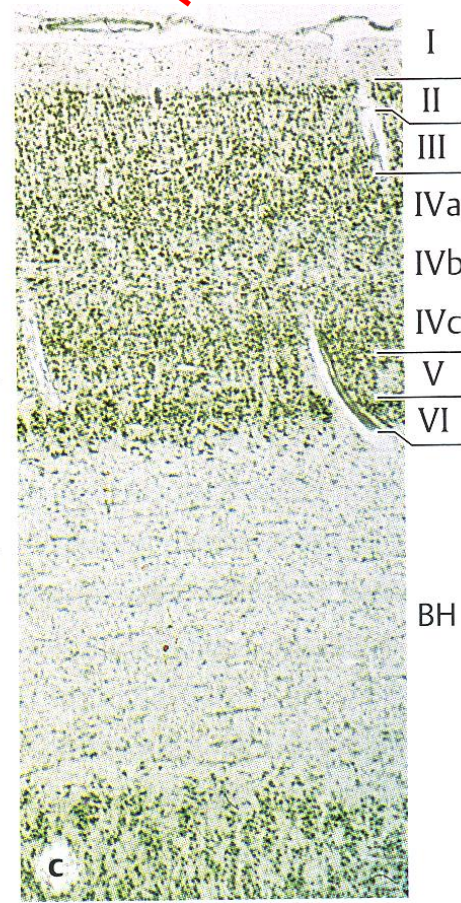
White matter



Homotypical isocortex



Primary motor cortex



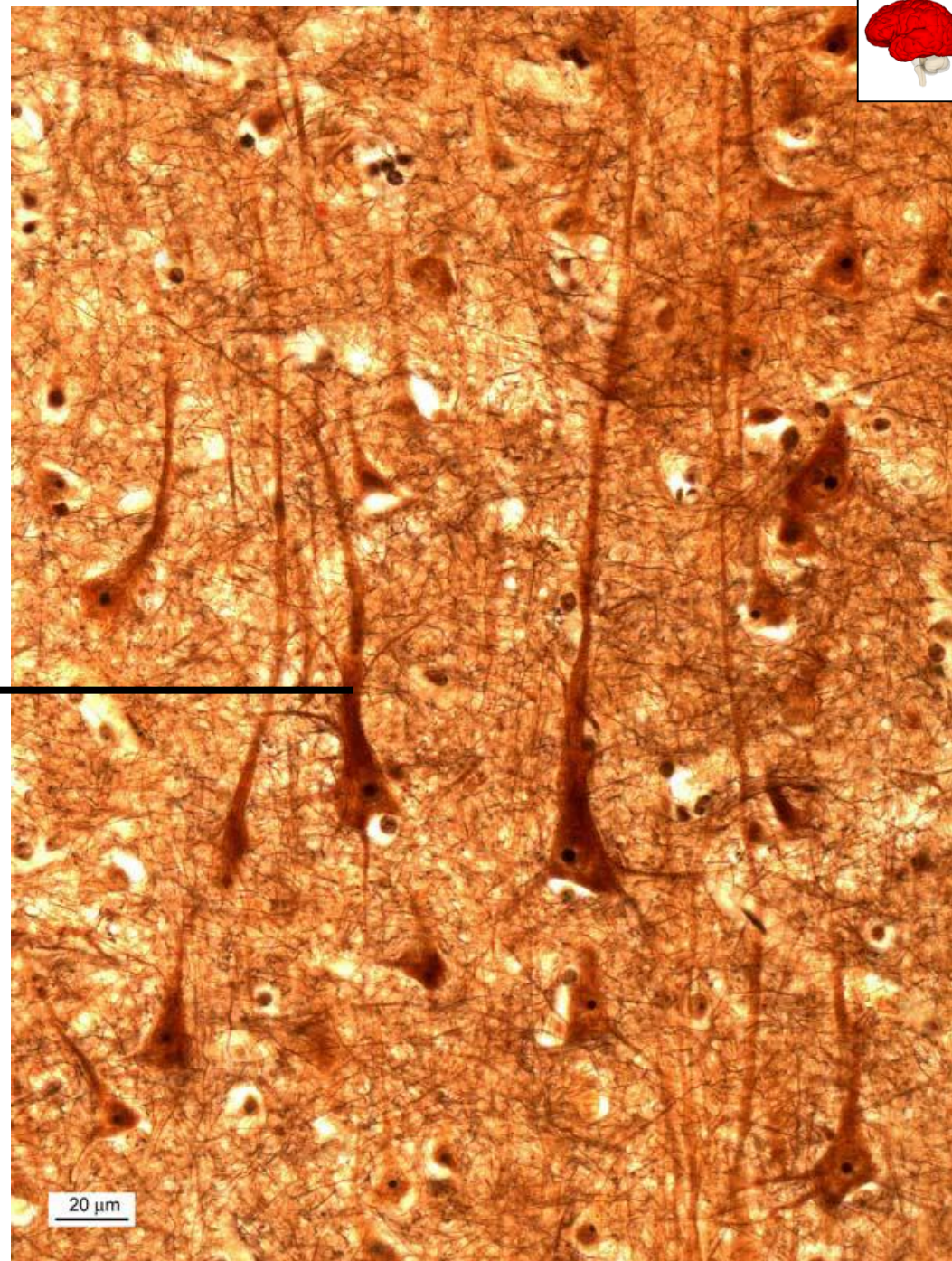
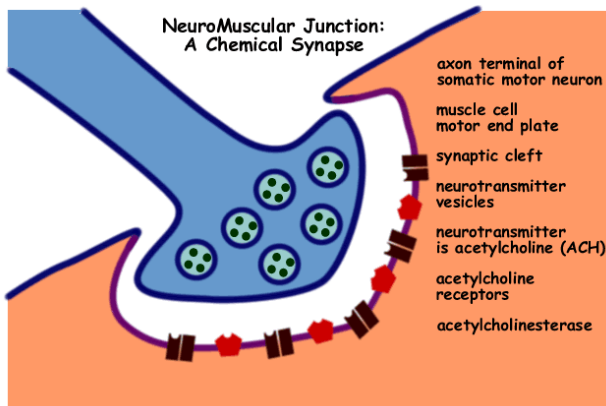
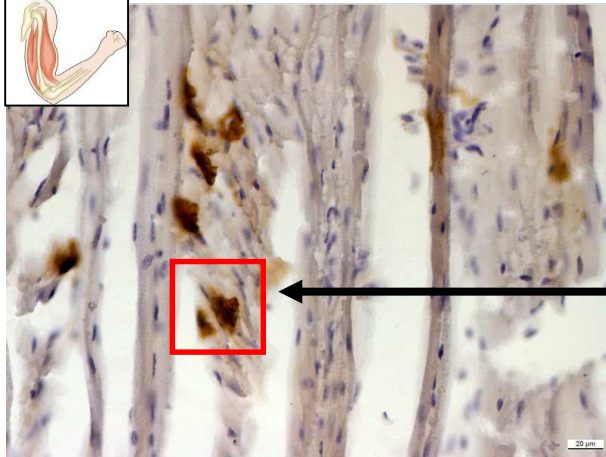
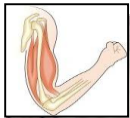
Primary visual cortex

# Motor neurons (motoneurons)

Lamina ganglionaris (V) – Betz cells

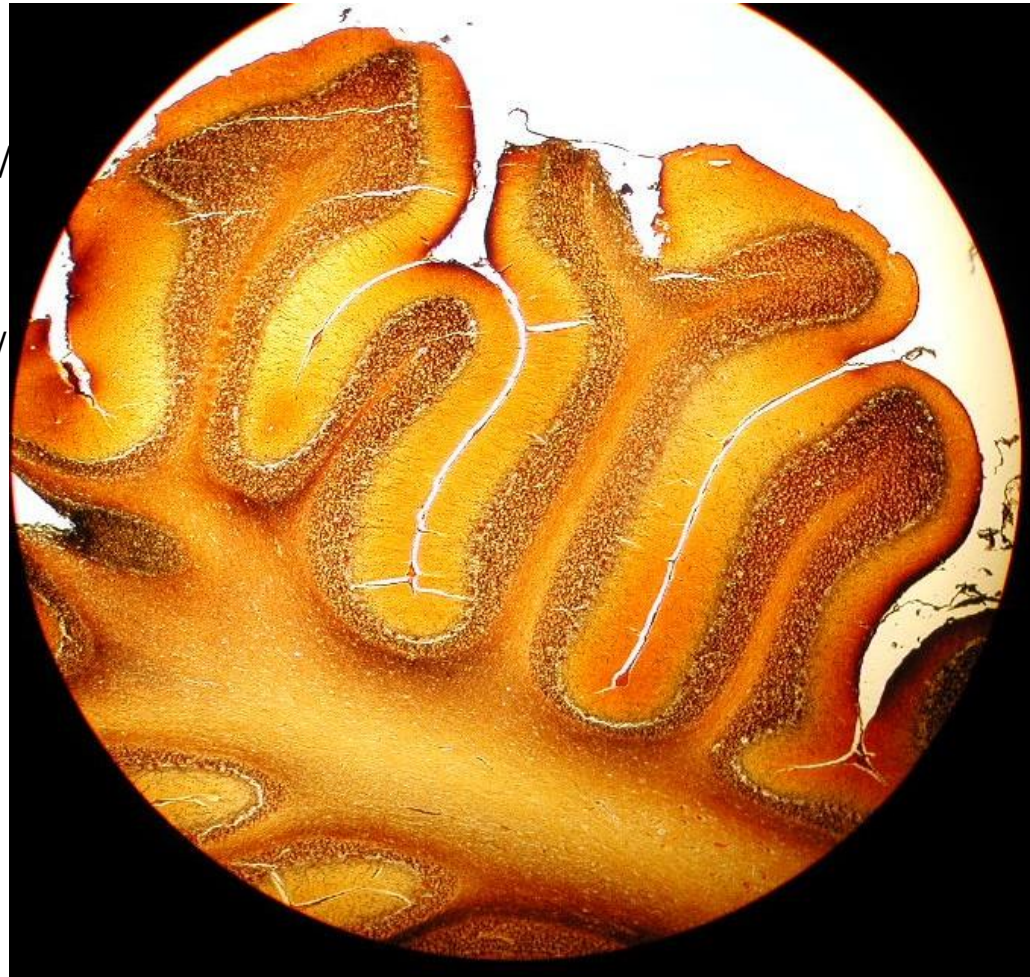
Send axons outside CNS and control muscles  
(directly or indirectly)

Always cholinergic  
– utilize neurotransmitter **acetylcholin**



# Cerebellum

- **Gray matter /cortex cerebelli/**
  - ca 1mm
  - 3 distinct layers
    - Molecular layer /stratum moleculare/
    - Purkinje cell layer /stratum gangliosum/
    - Granular layer /stratum granulosum/
- **White matter**
  - Efferent fibers
  - Afferent fibers
- Nuclei of cerebellum

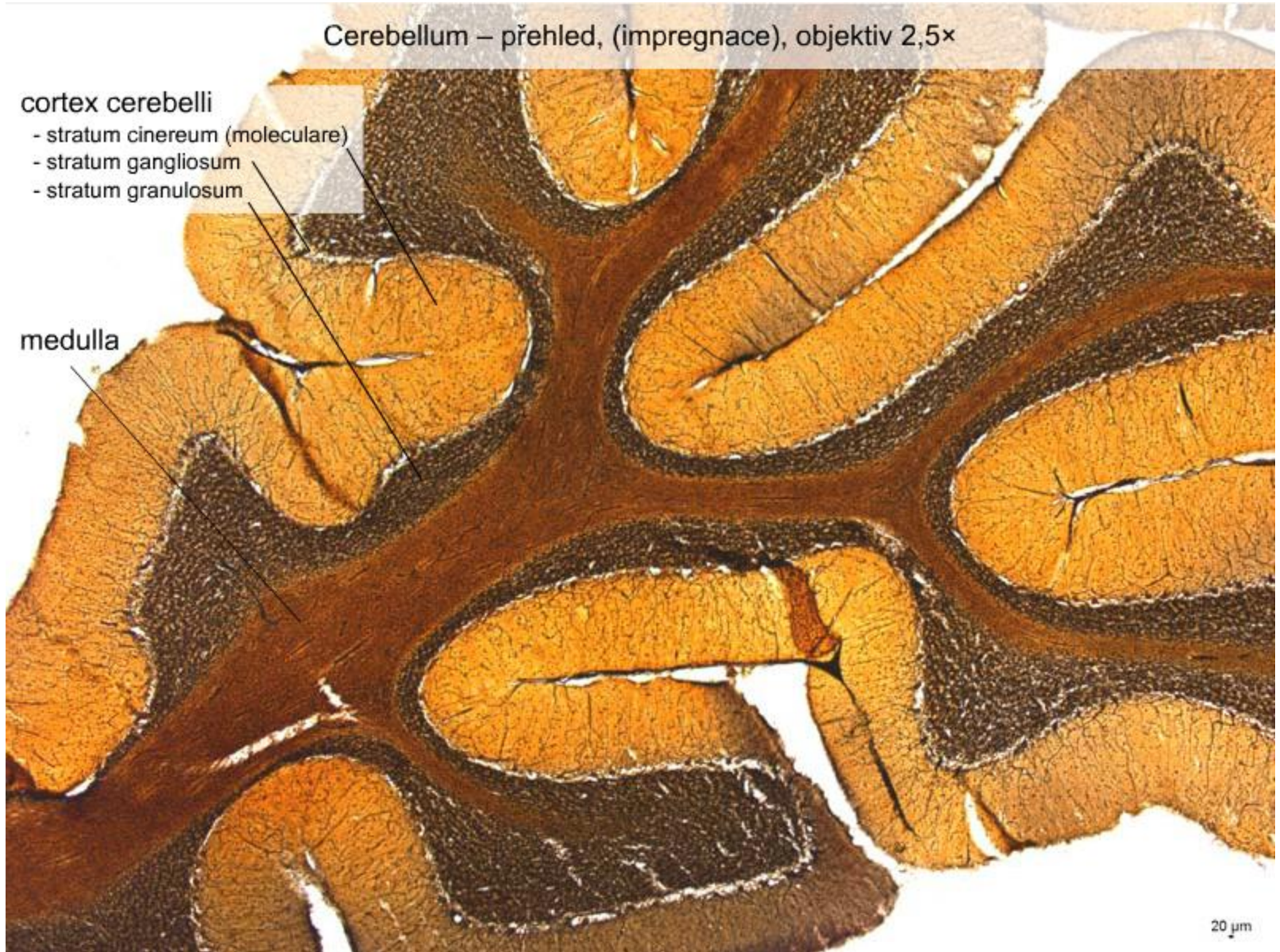


Cerebellum – přehled, (impregnace), objektiv 2,5×

cortex cerebelli

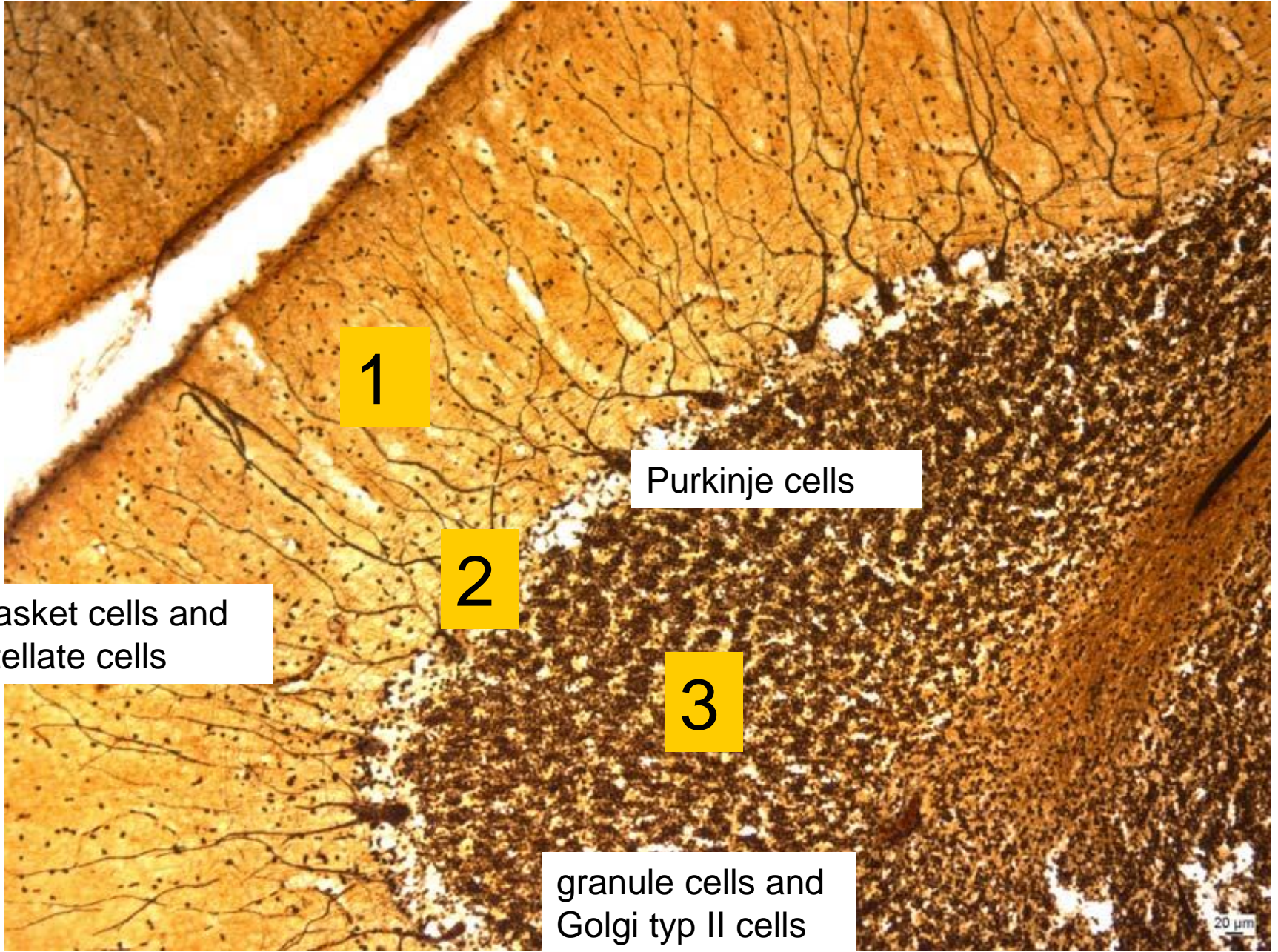
- stratum cinereum (moleculare)
- stratum gangliosum
- stratum granulosum

medulla



20 μm

# Cerebellum



1

Purkinje cells

2

basket cells and stellate cells

3

granule cells and Golgi typ II cells

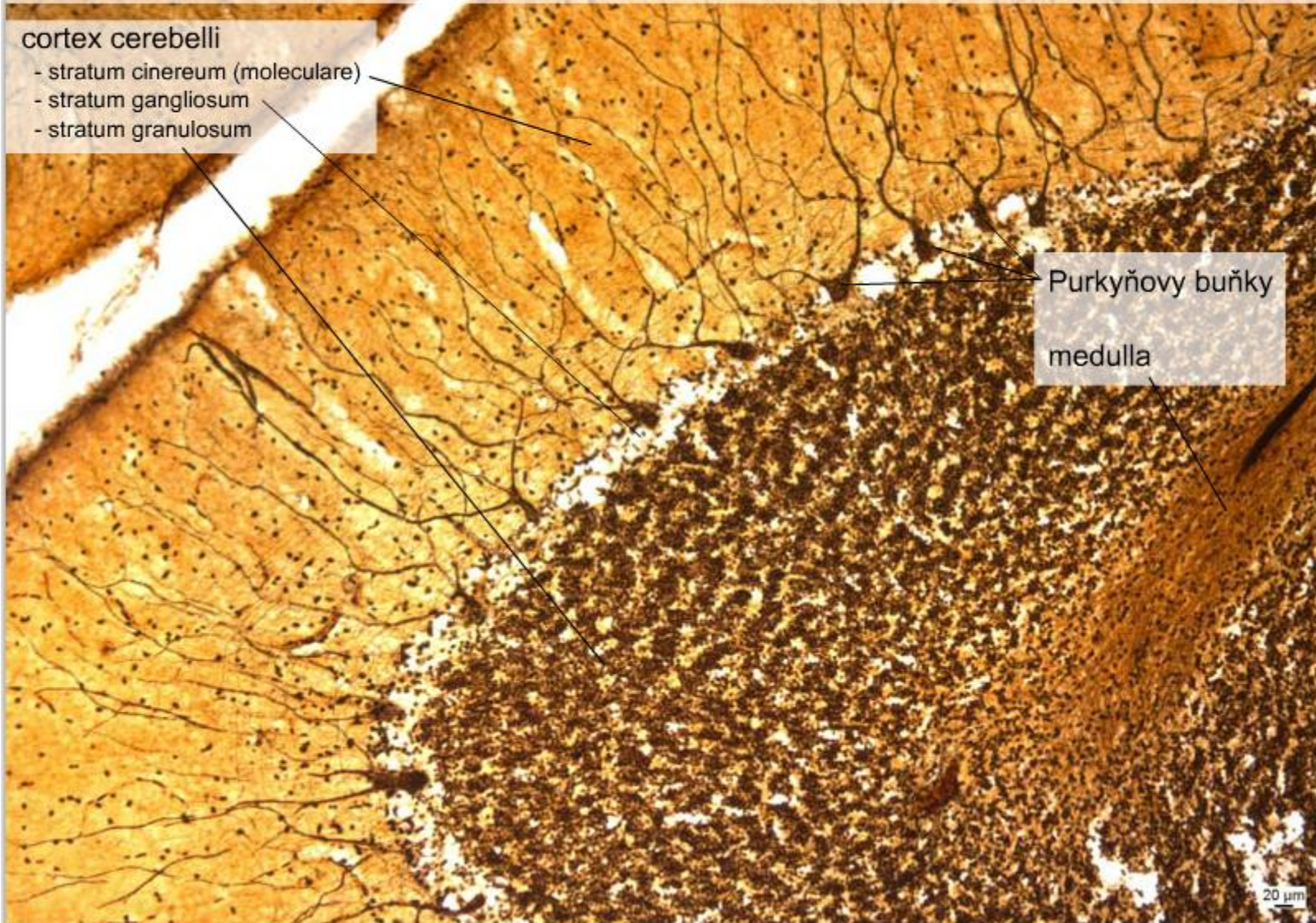
Cerebellum – cortex I, (impregnance), objektiv 10×

cortex cerebelli

- stratum cinereum (moleculare)
- stratum gangliosum
- stratum granulosum

Purkyňovy buňky  
medulla

20 μm



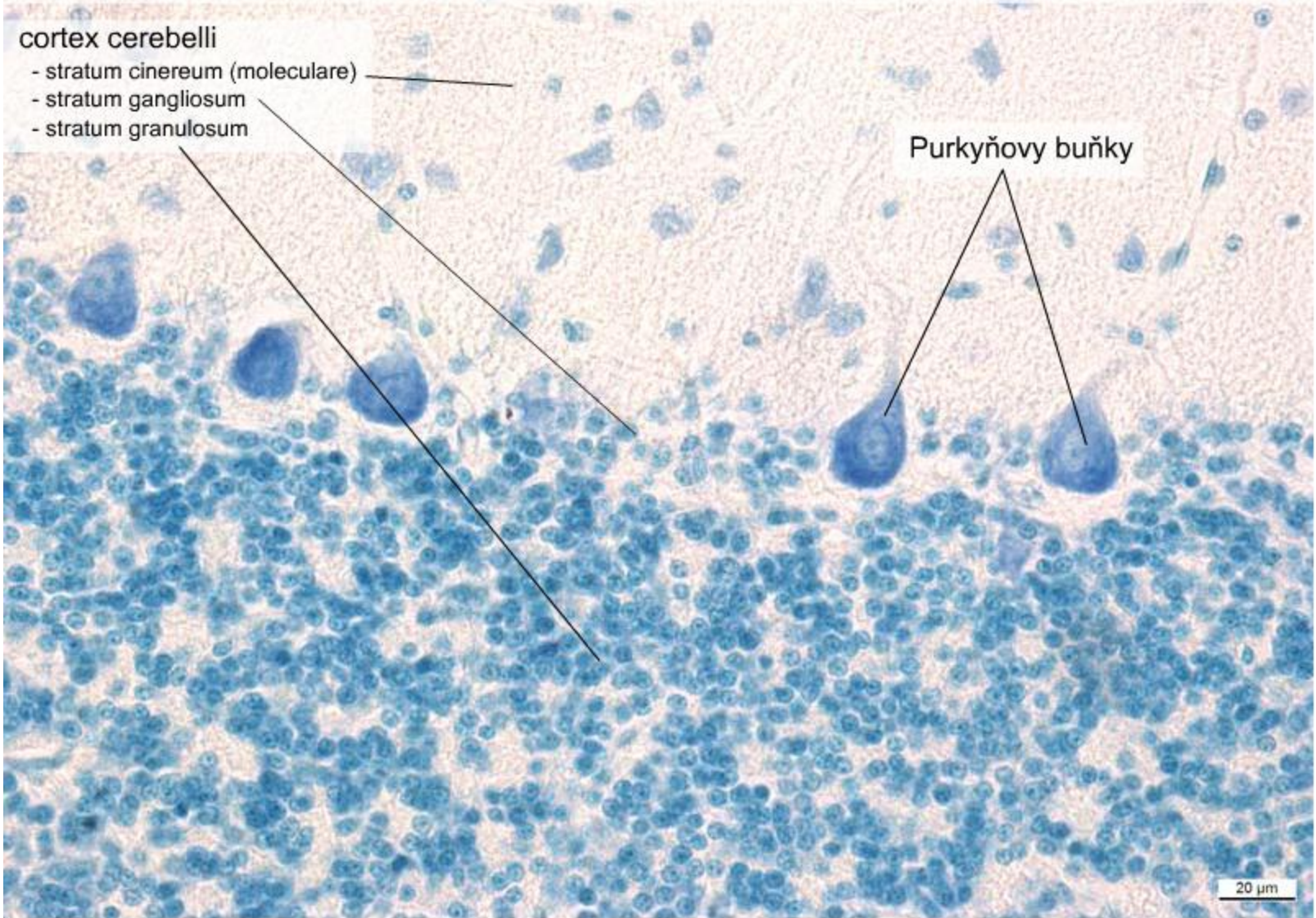
Cerebellum – cortex II, (Nissl), objektiv 40×

cortex cerebelli

- stratum cinereum (moleculare)
- stratum gangliosum
- stratum granulosum

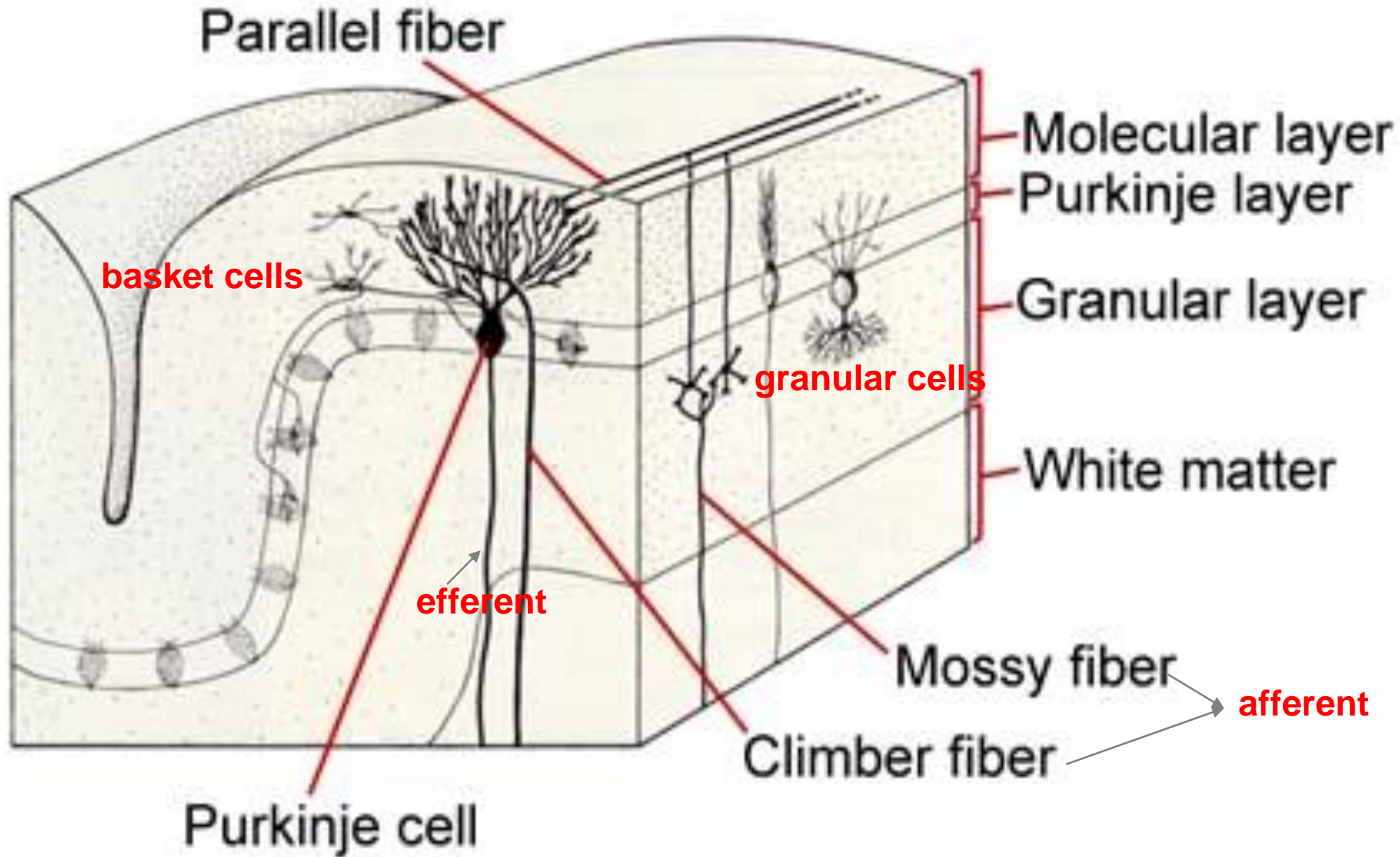
Purkyňovy buňky

20 μm

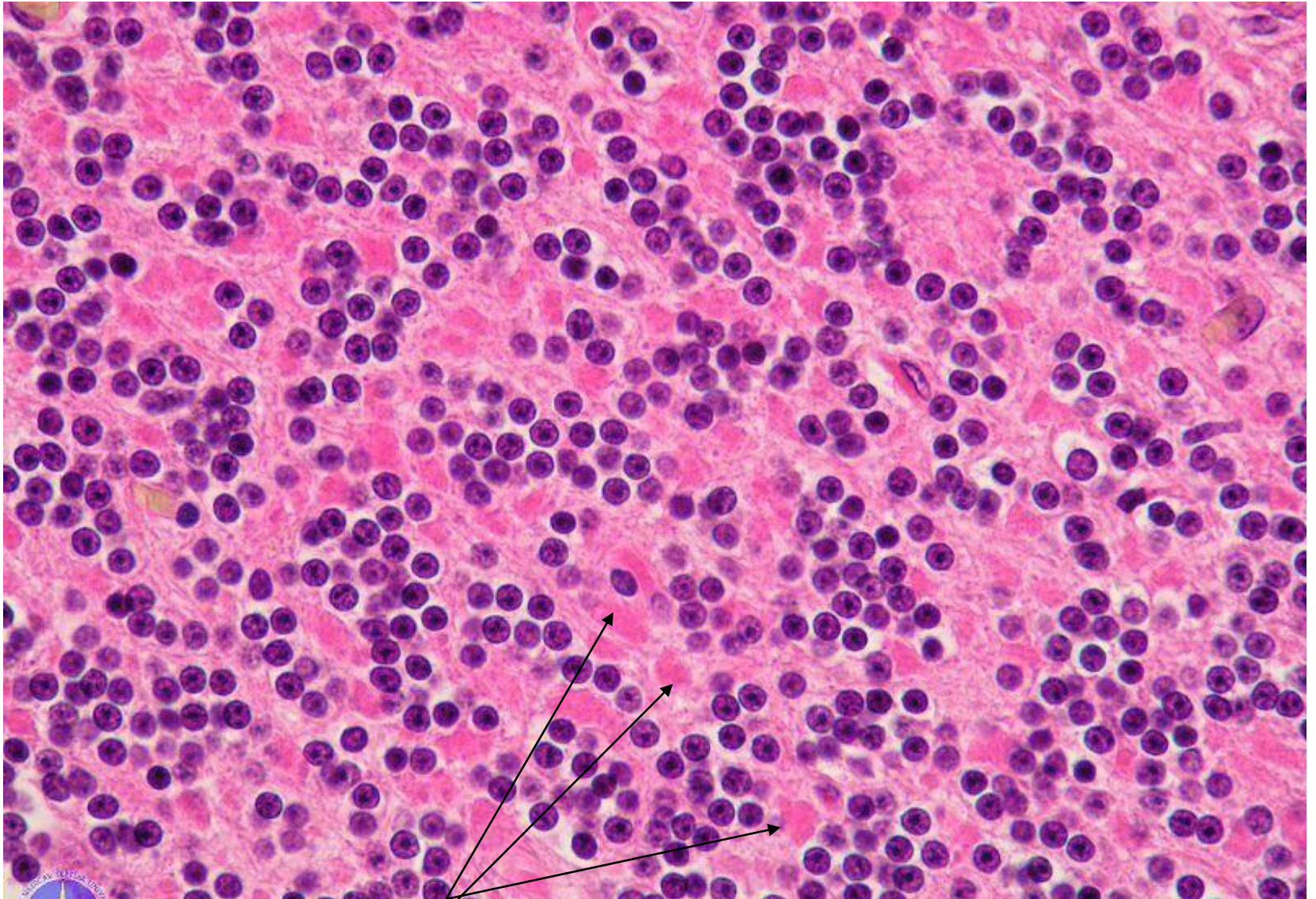




# Cerebellum – white matter

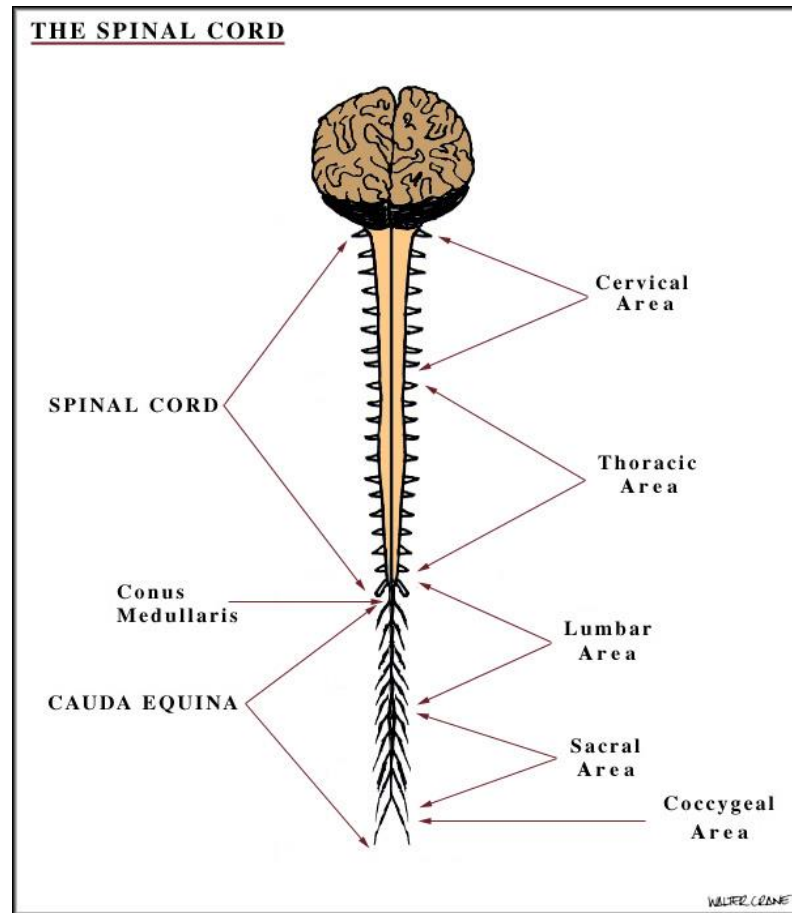


# Cerebellum – stratum granulare

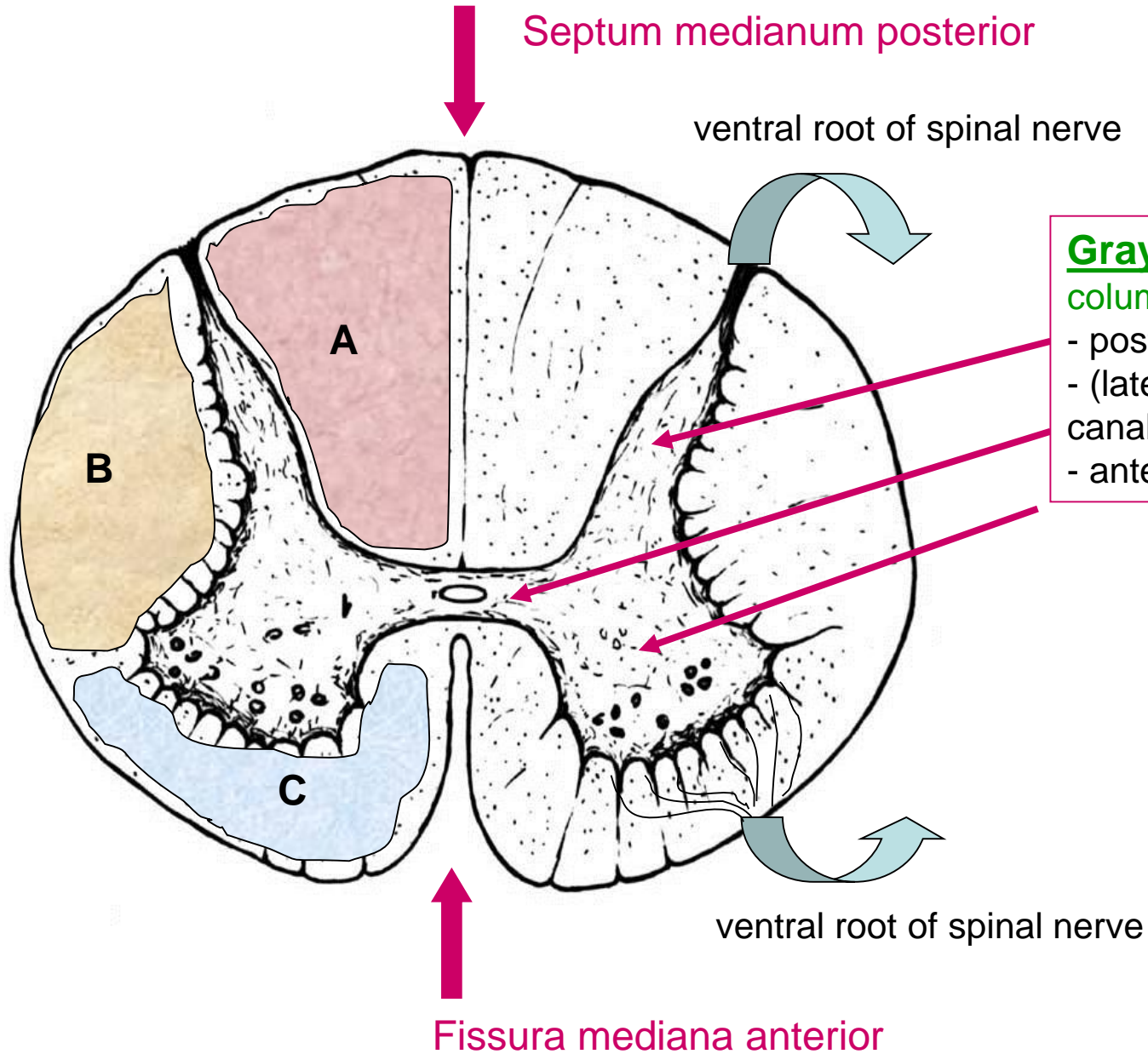
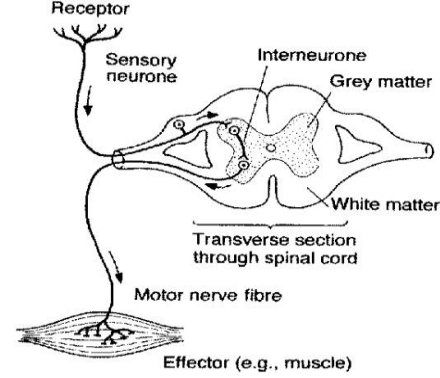


glomeruli /cerebellar islands/ - synapses between dendrites of granular cells and mossy fibers

# Medulla spinalis



# Spinal cord (medulla spinalis)



**Gray matter**  
columns (horns)  
- posterior  
- (lateral)  
canalis centralis  
- anterior

**White matter**  
Funiculi:  
A – dorsal  
B – lateral  
C – ventral

Medulla spinalis – přehled, (HE), objektiv 2,5×

šedá hmota

- dorzální roh
- ventrální roh

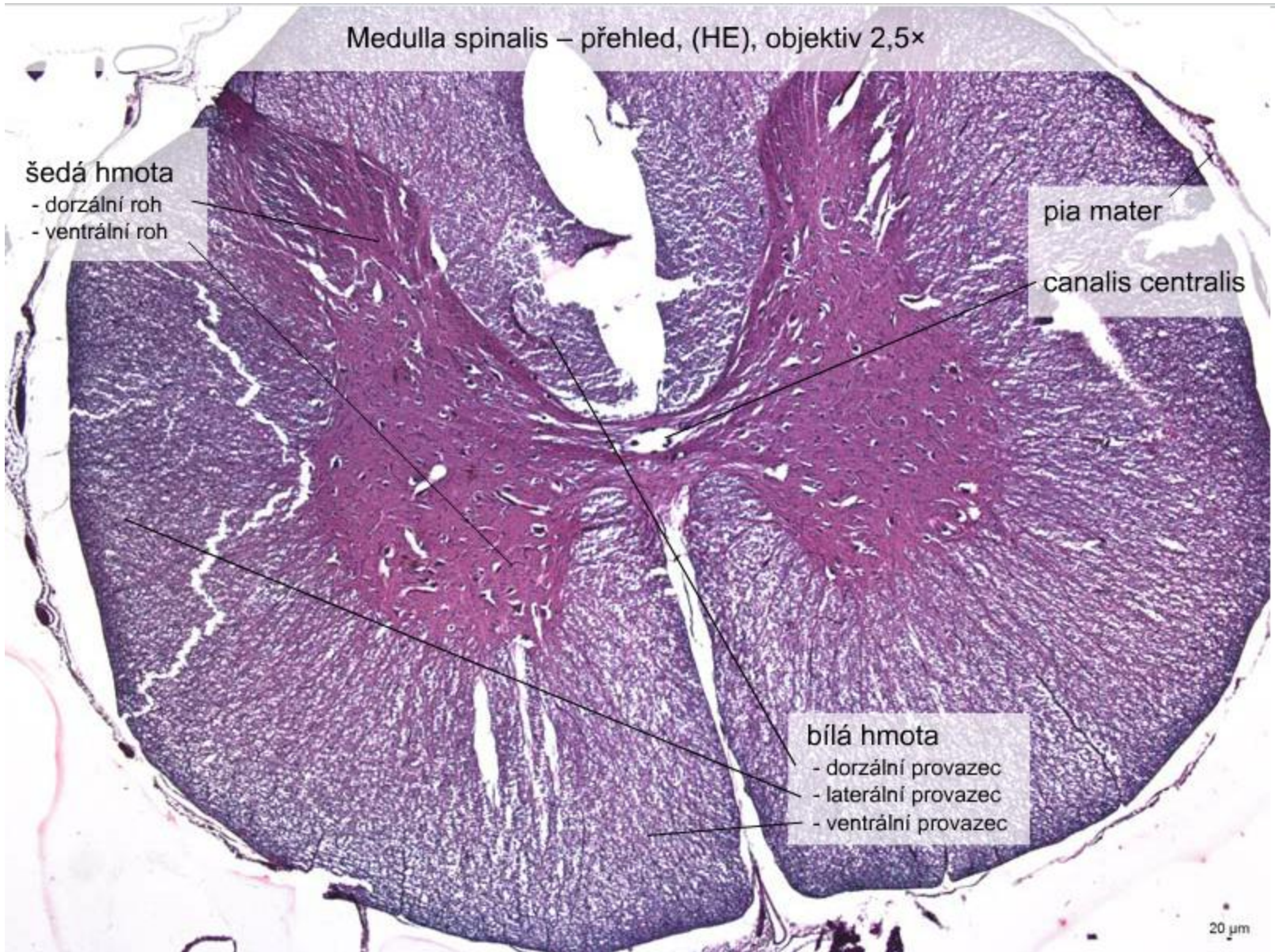
pia mater

canalis centralis

bílá hmota

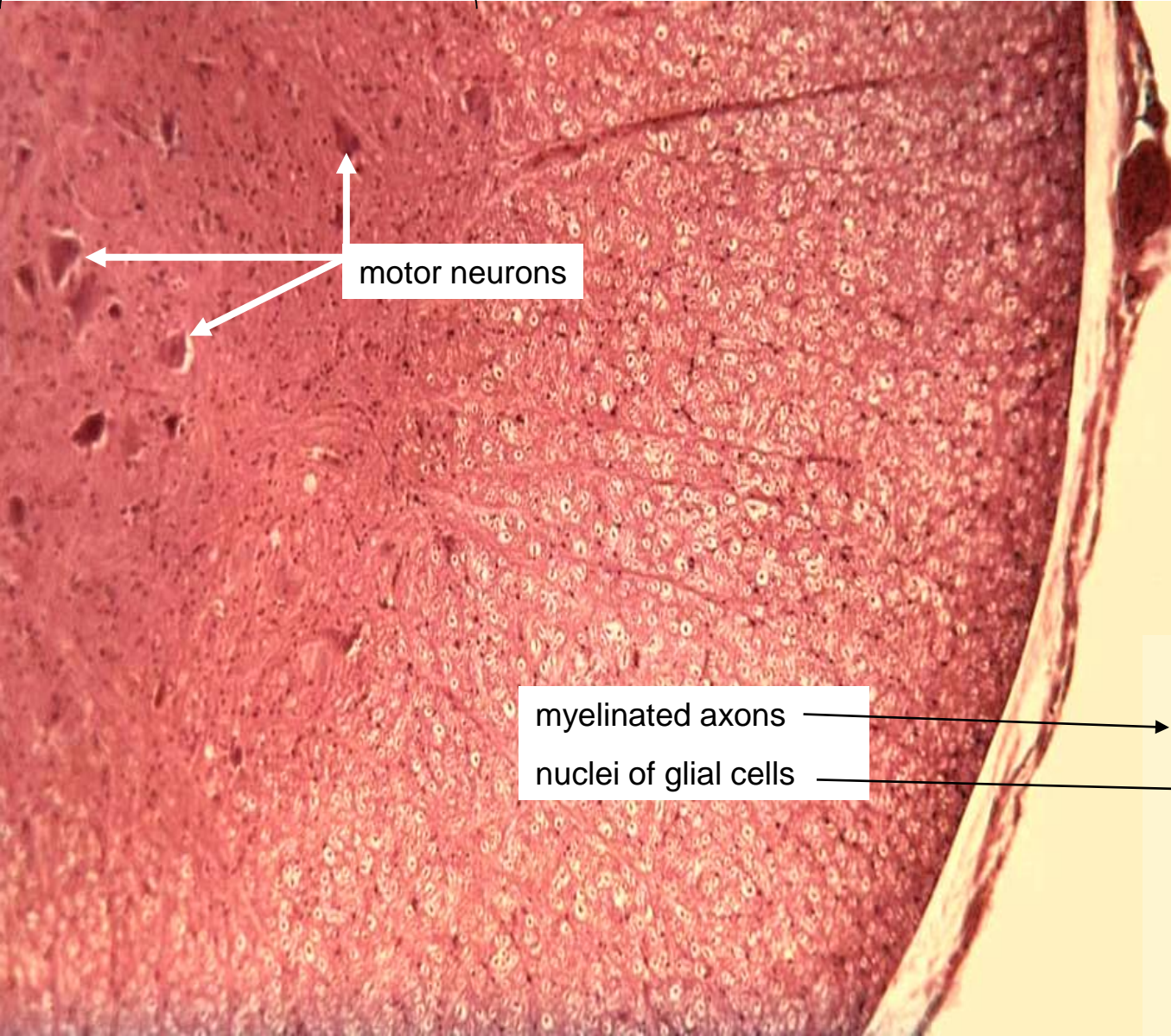
- dorzální provazec
- laterální provazec
- ventrální provazec

20 μm



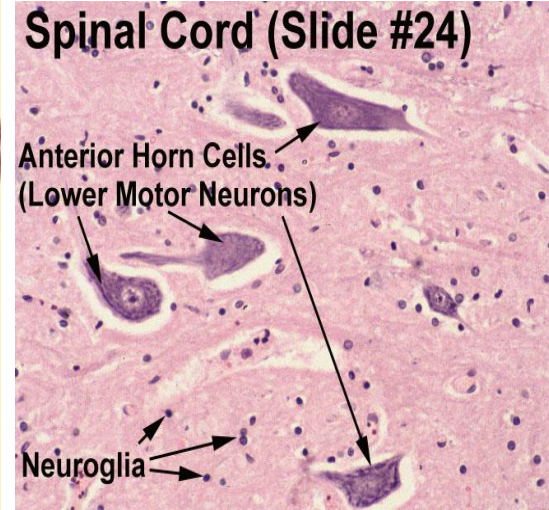
# Medulla spinalis (HE) – anterior horn and funiculus

pia mater



motor neurons

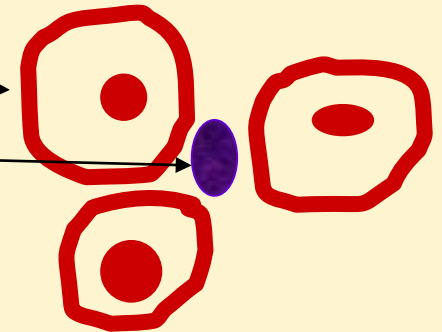
myelinated axons  
nuclei of glial cells



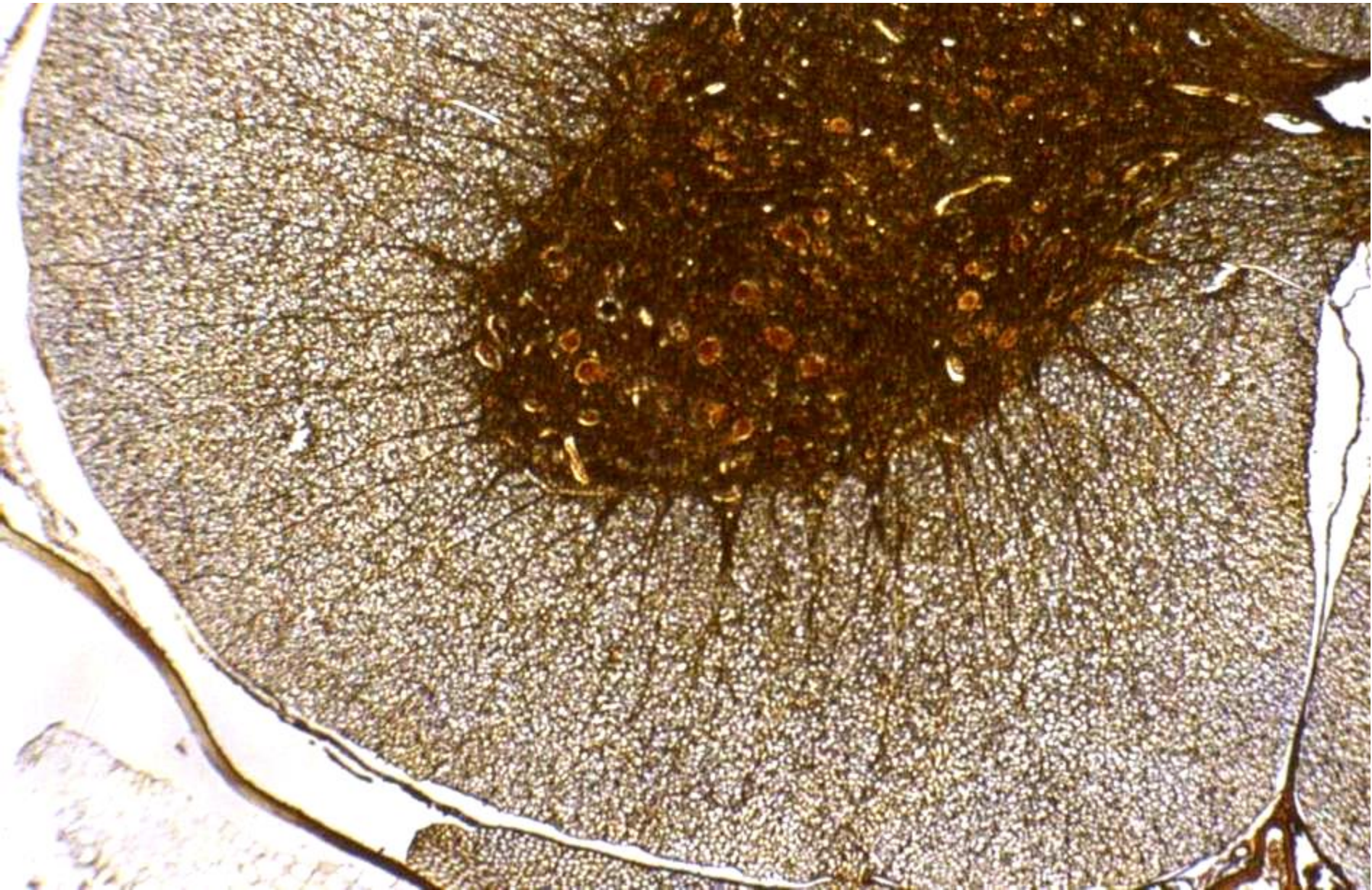
## Spinal Cord (Slide #24)

Anterior Horn Cells  
(Lower Motor Neurons)

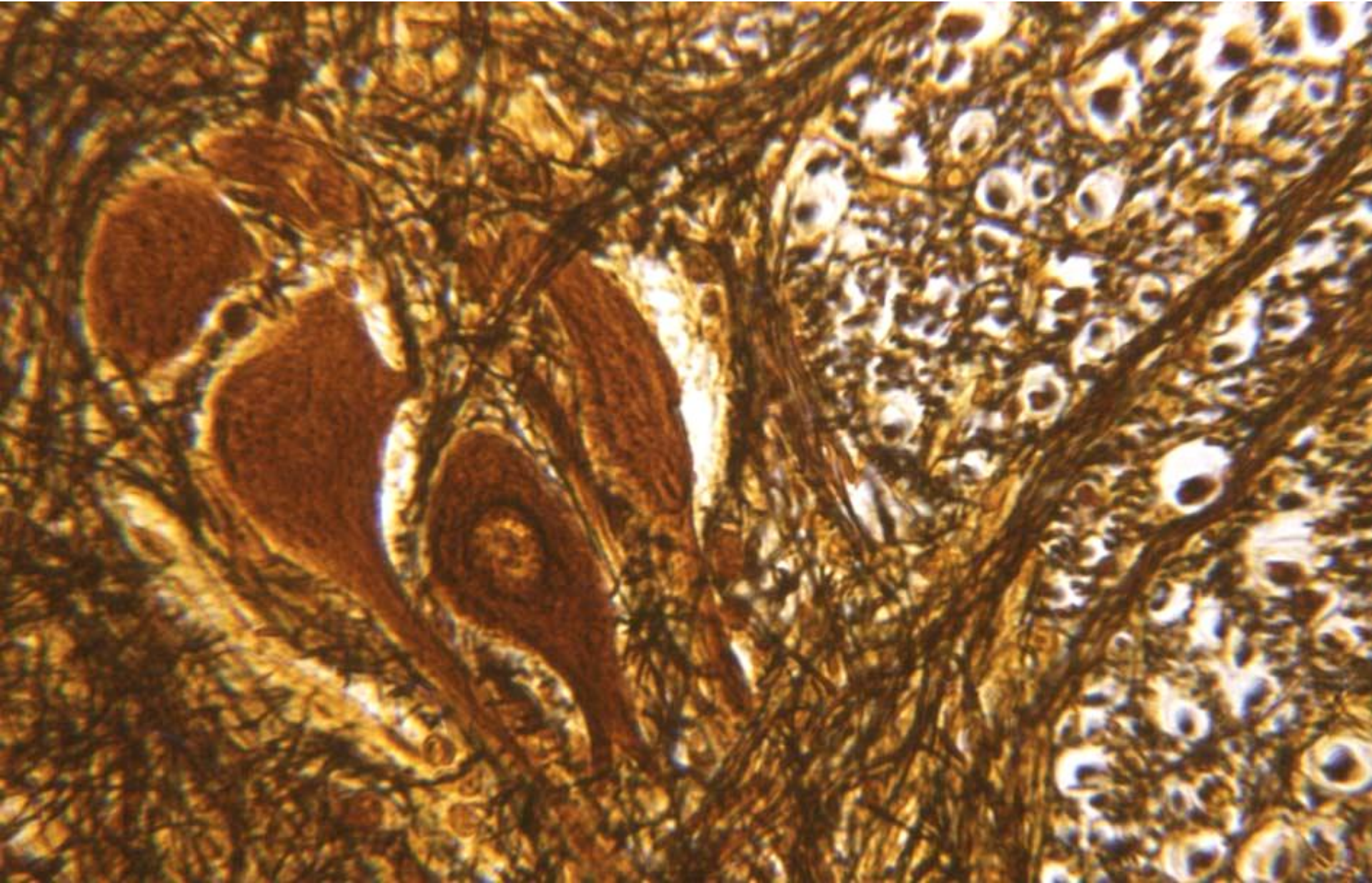
Neuroglia



# Medulla spinalis (impregnation) – ventral horn



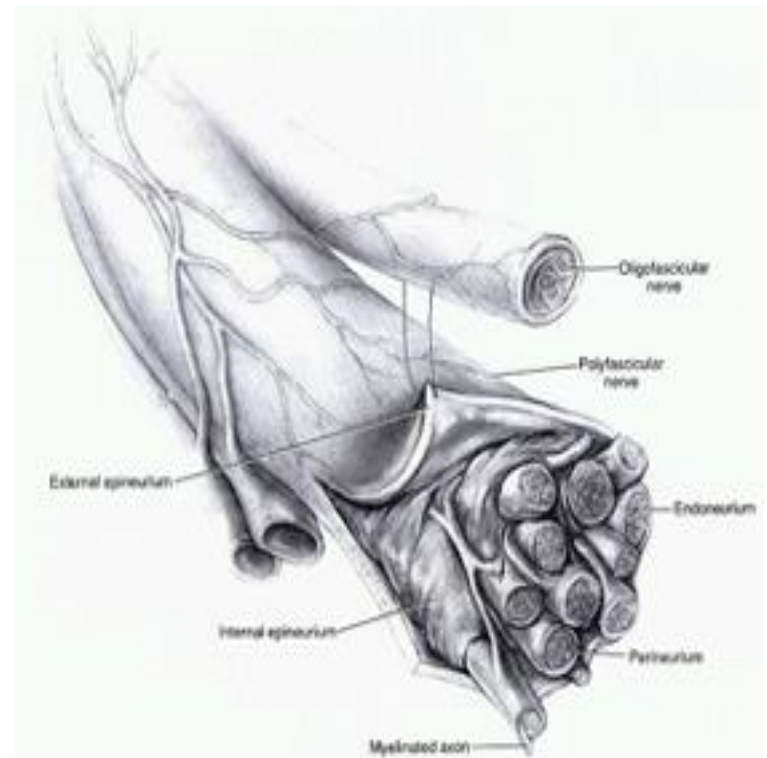
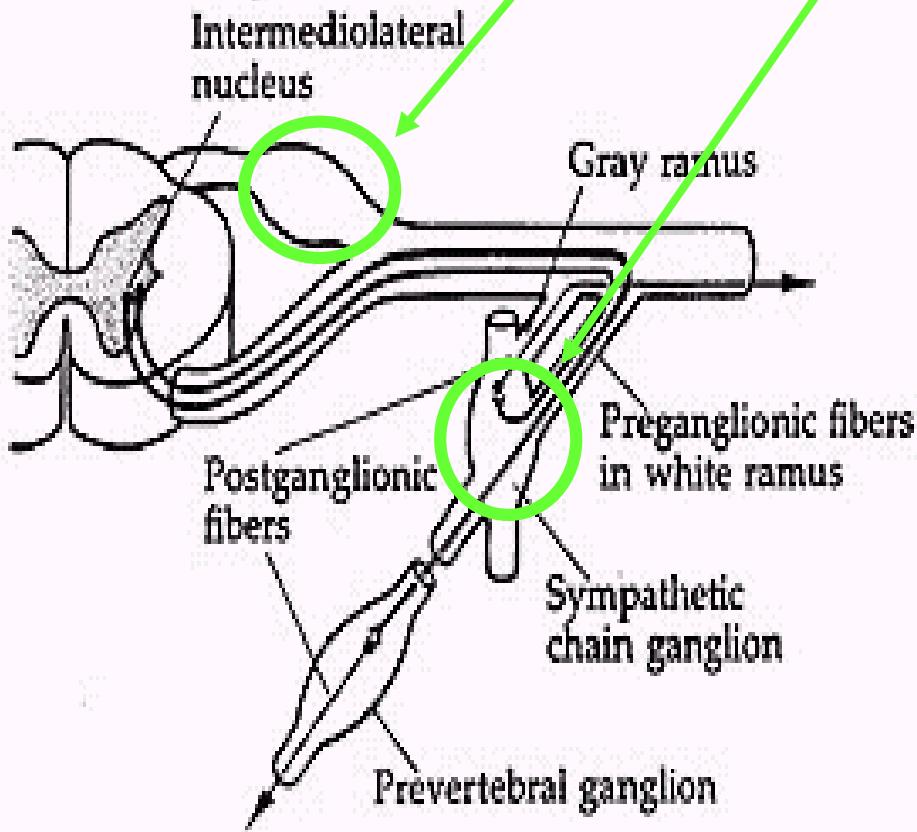
# Medulla spinalis (impregnation) – ventral horn: motor neurons





# PNS ganglia and nerves

spinal      autonomic



**Spinal ganglion (HE)**

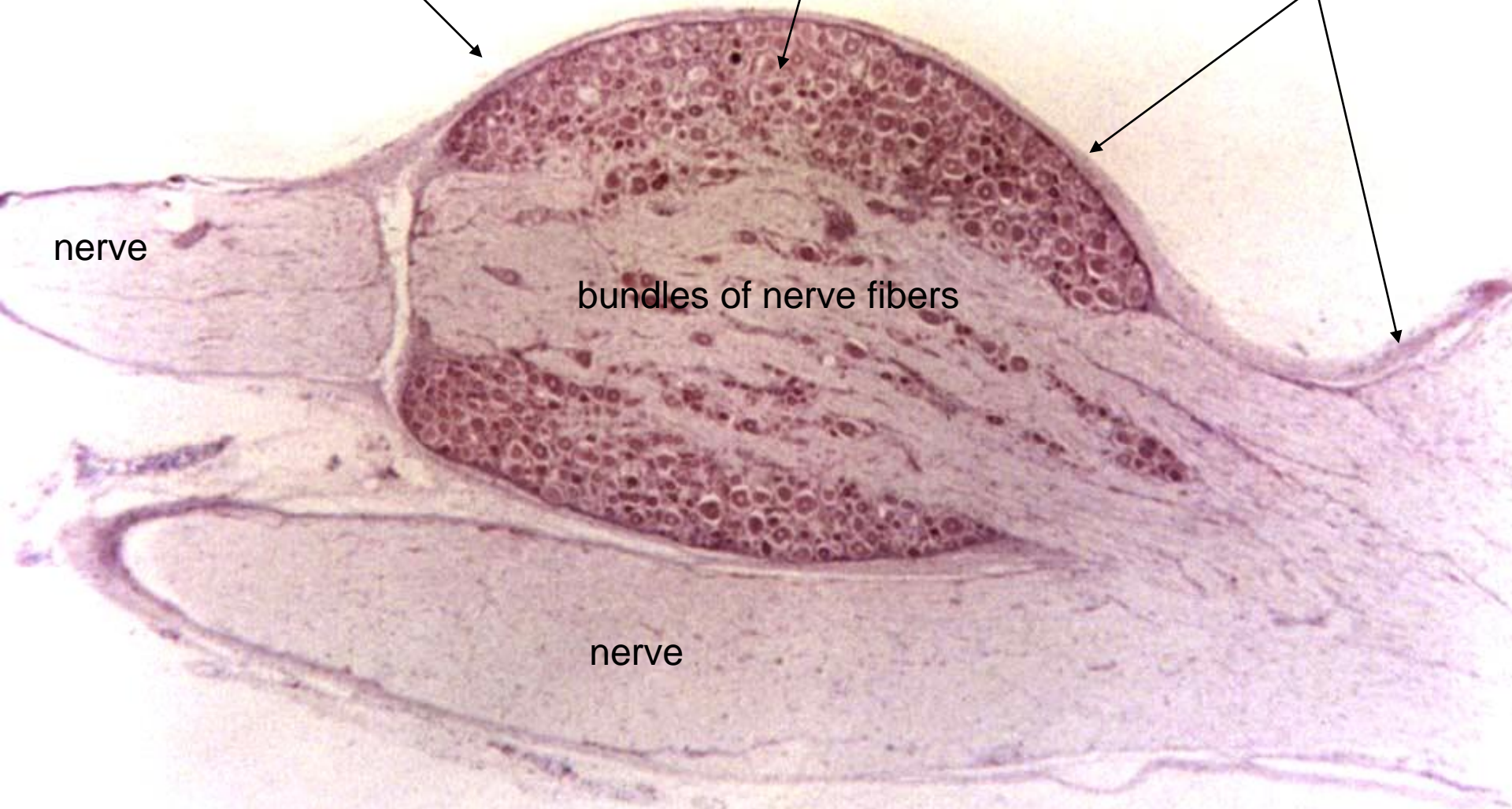
pseudounipolar neurons

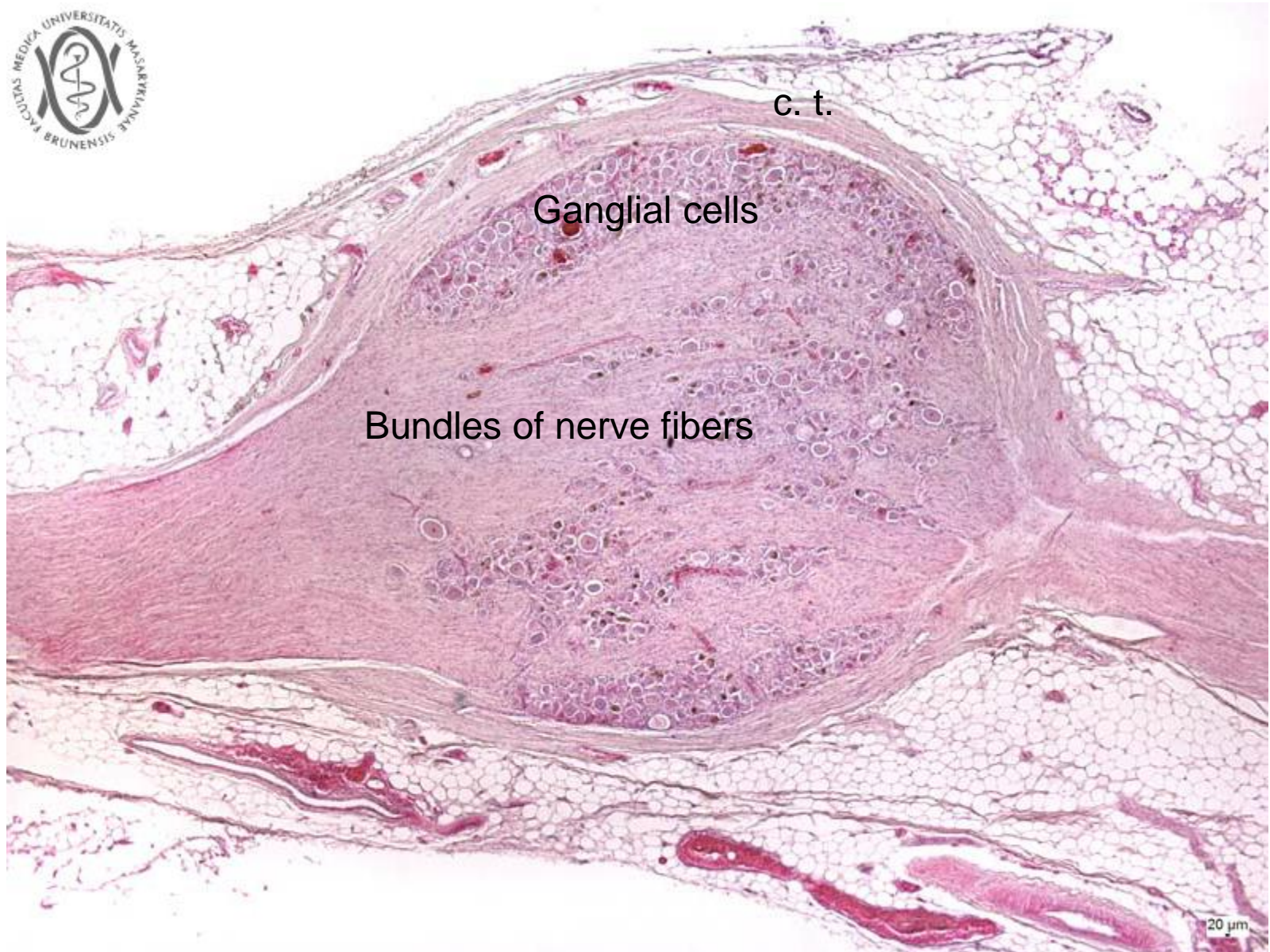
epineurium

nerve

bundles of nerve fibers

nerve





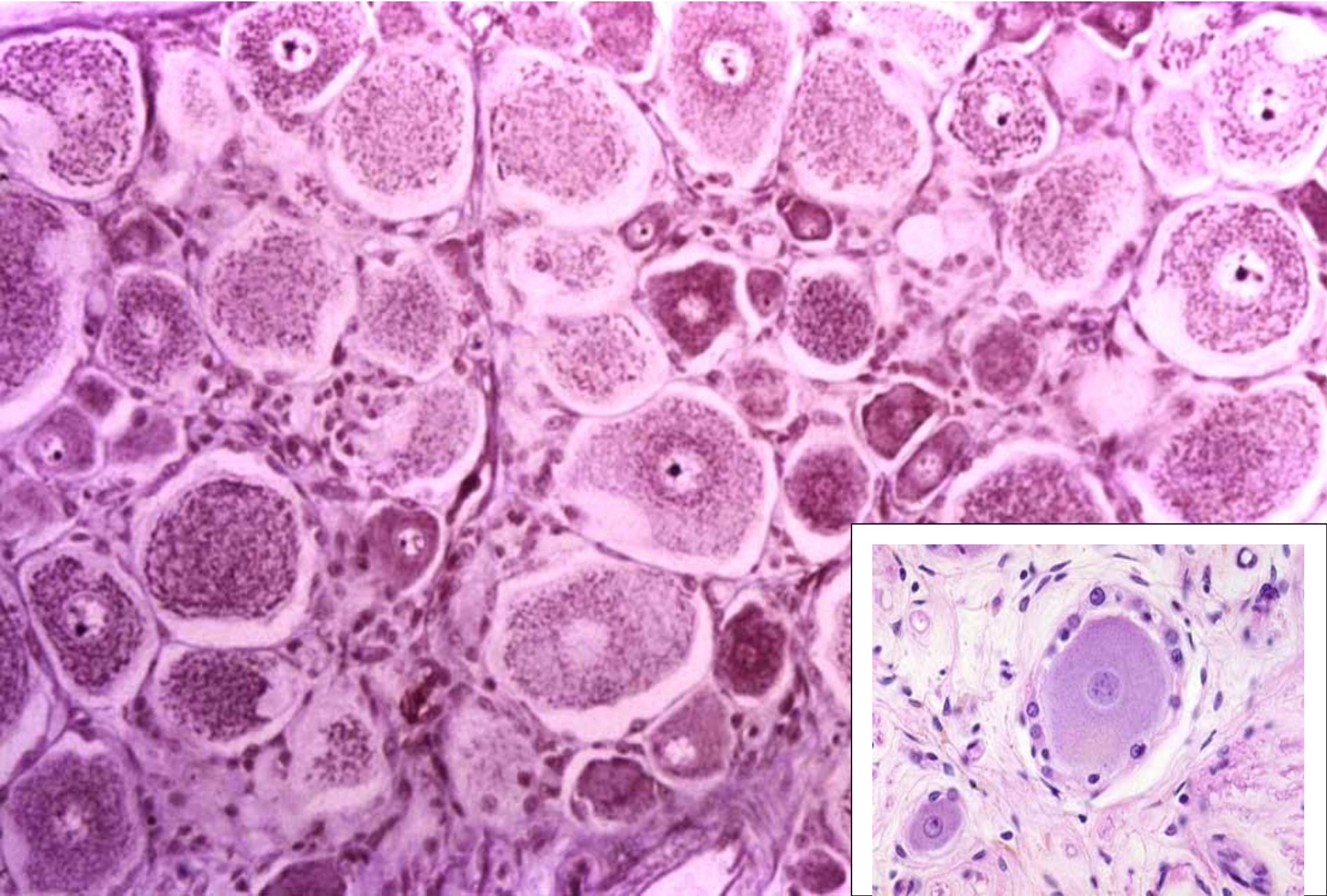
C. t.

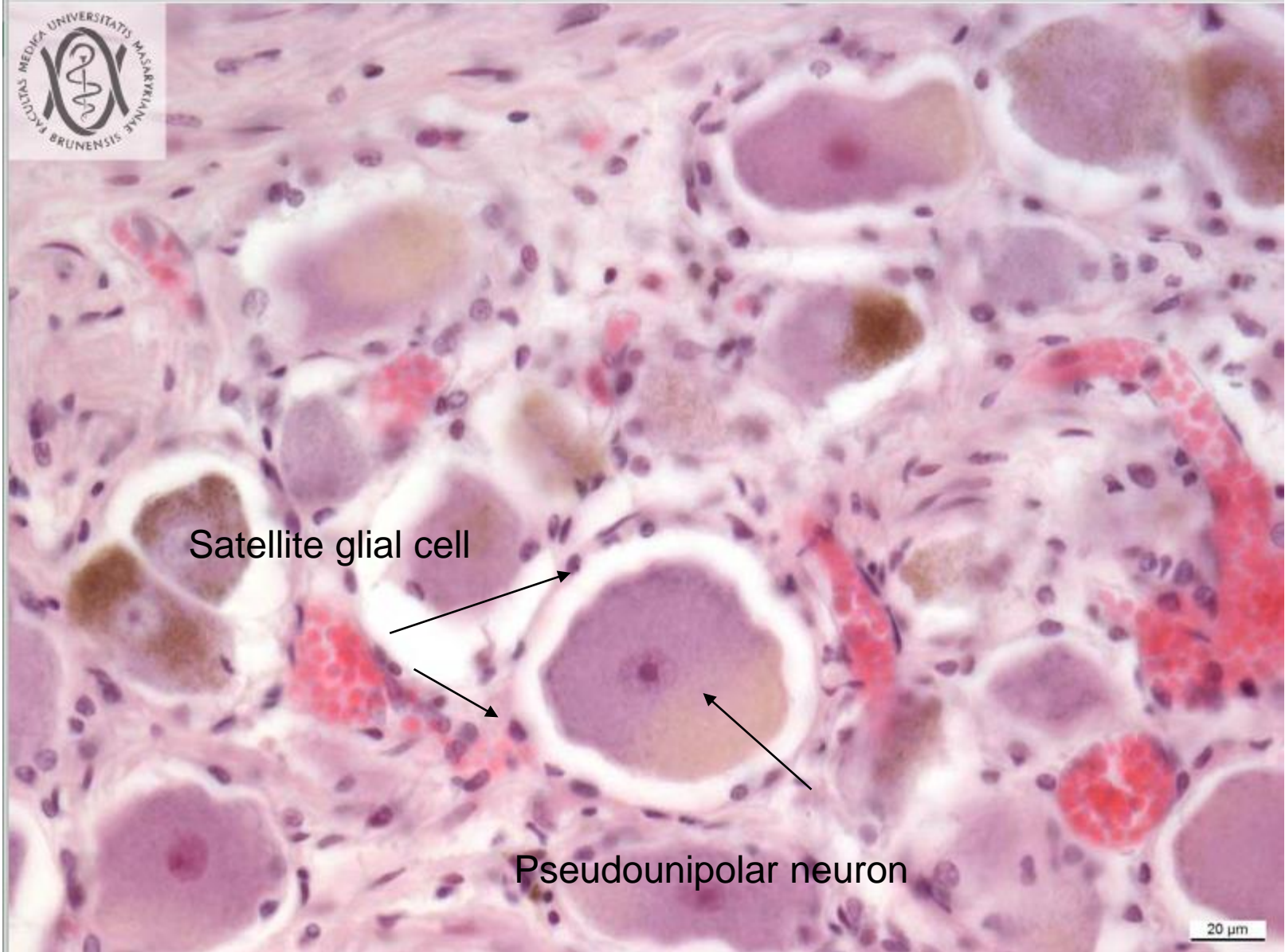
Ganglial cells

Bundles of nerve fibers

20 μm

**Spinal ganglion (HE) – pseudounipolar neurons + satellite cells**



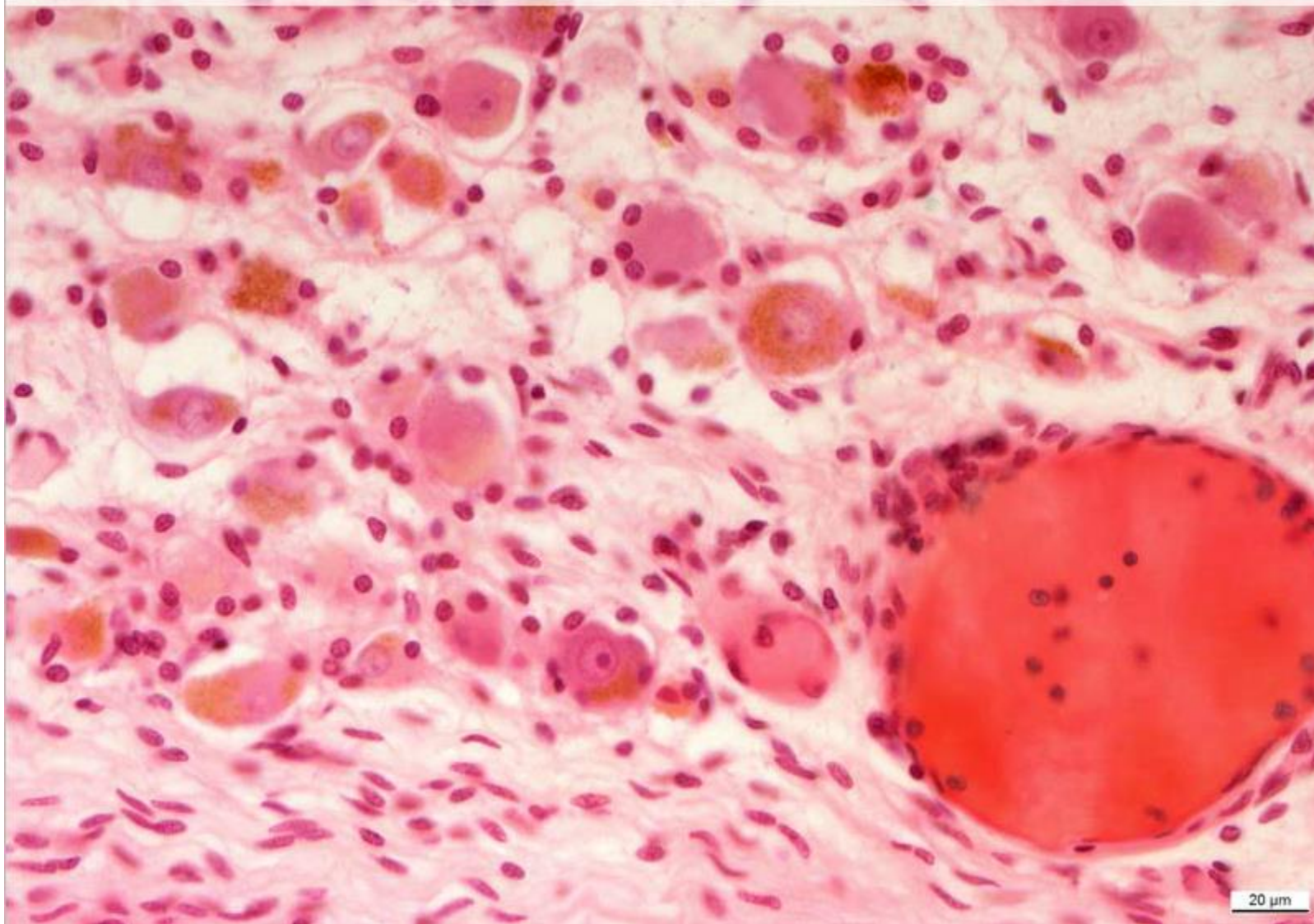


Satellite glial cell

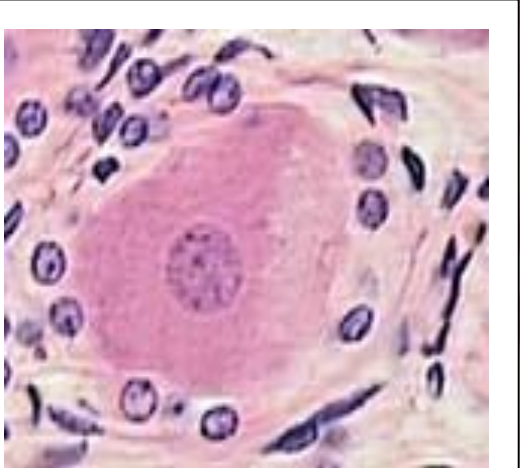
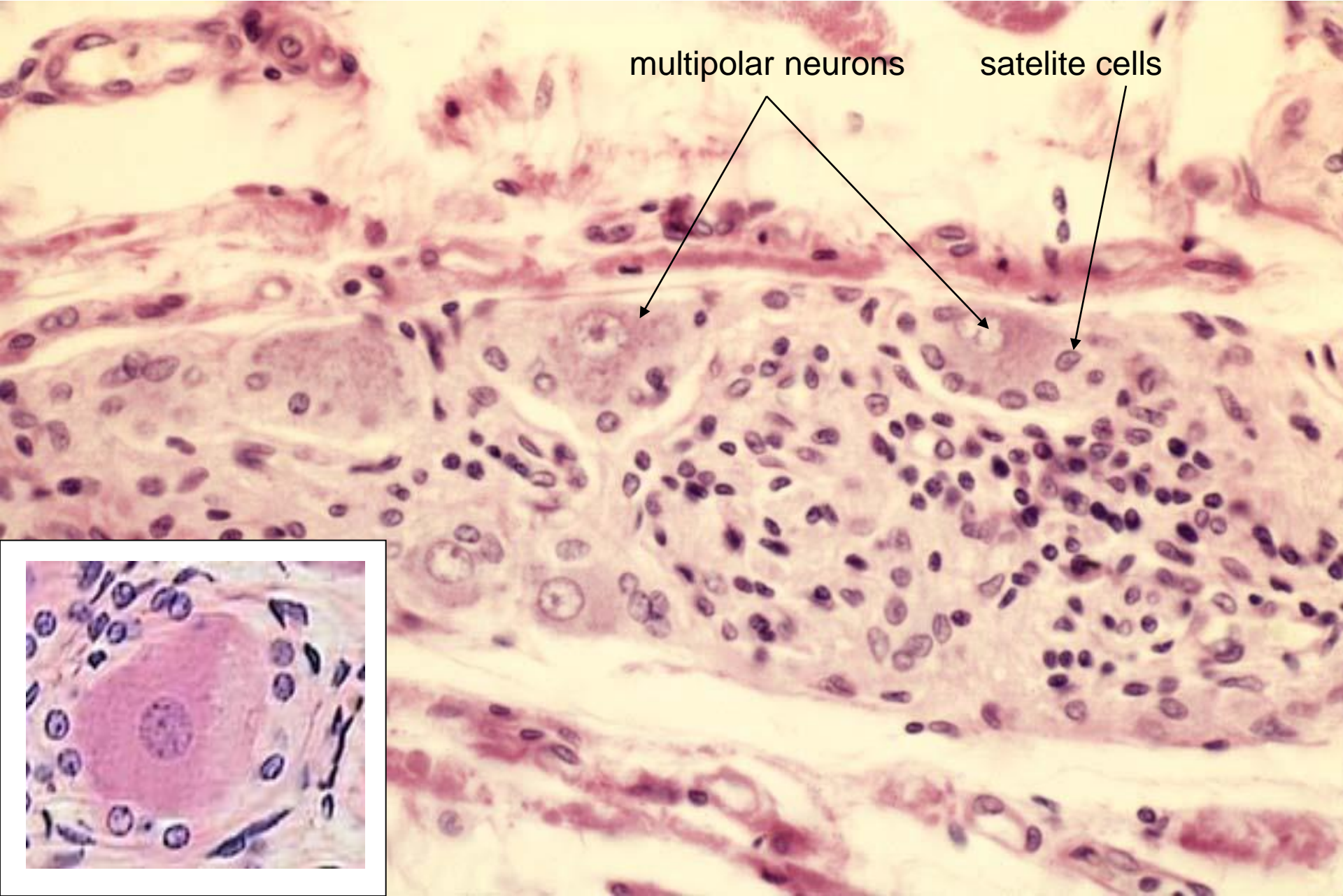
Pseudounipolar neuron

20 μm

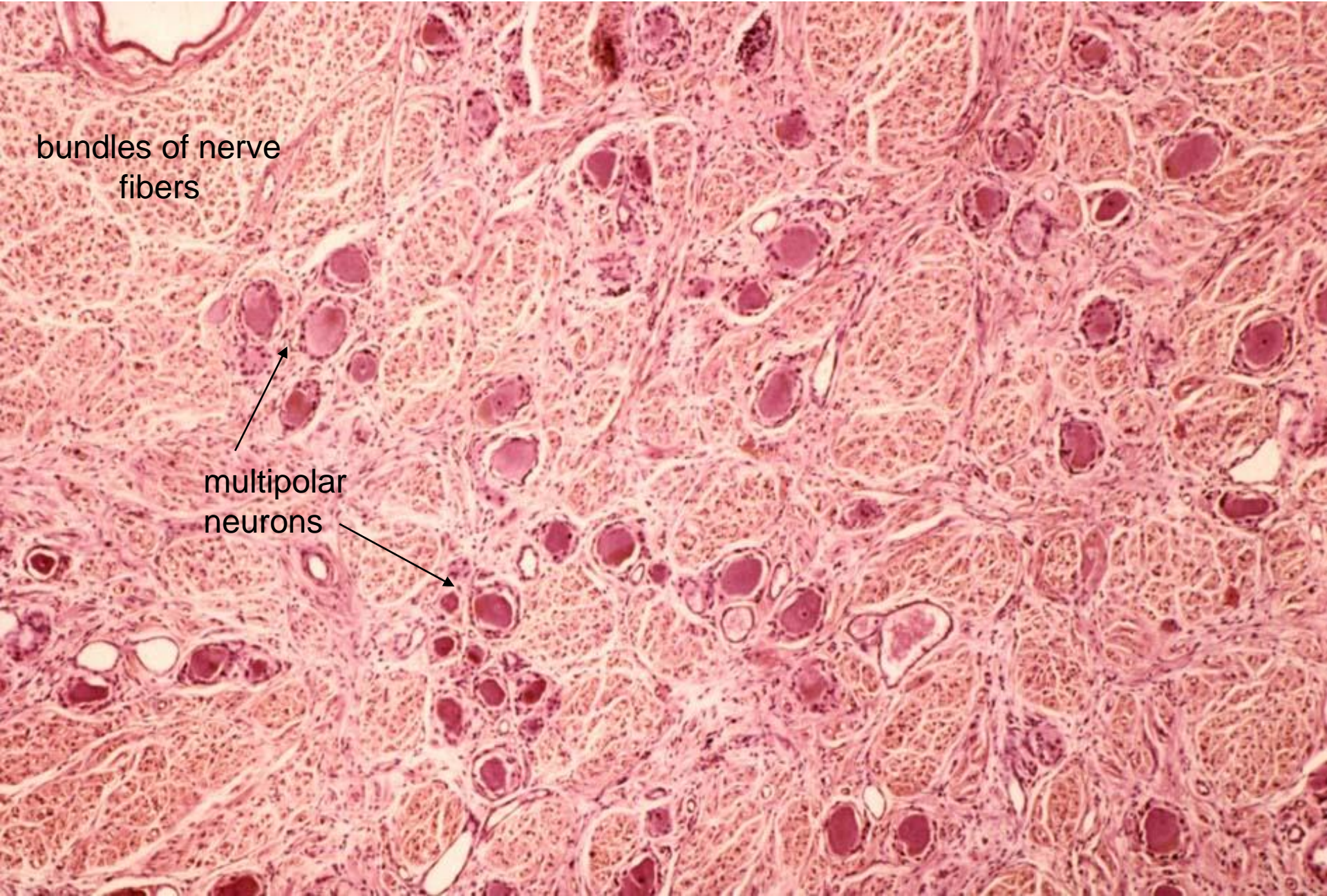
Ganglion spinale – lipofuscin v gangliových buňkách, (HE), objektiv 40×



# Autonomic ganglion (HE)



# Autonomic ganglion (HE)

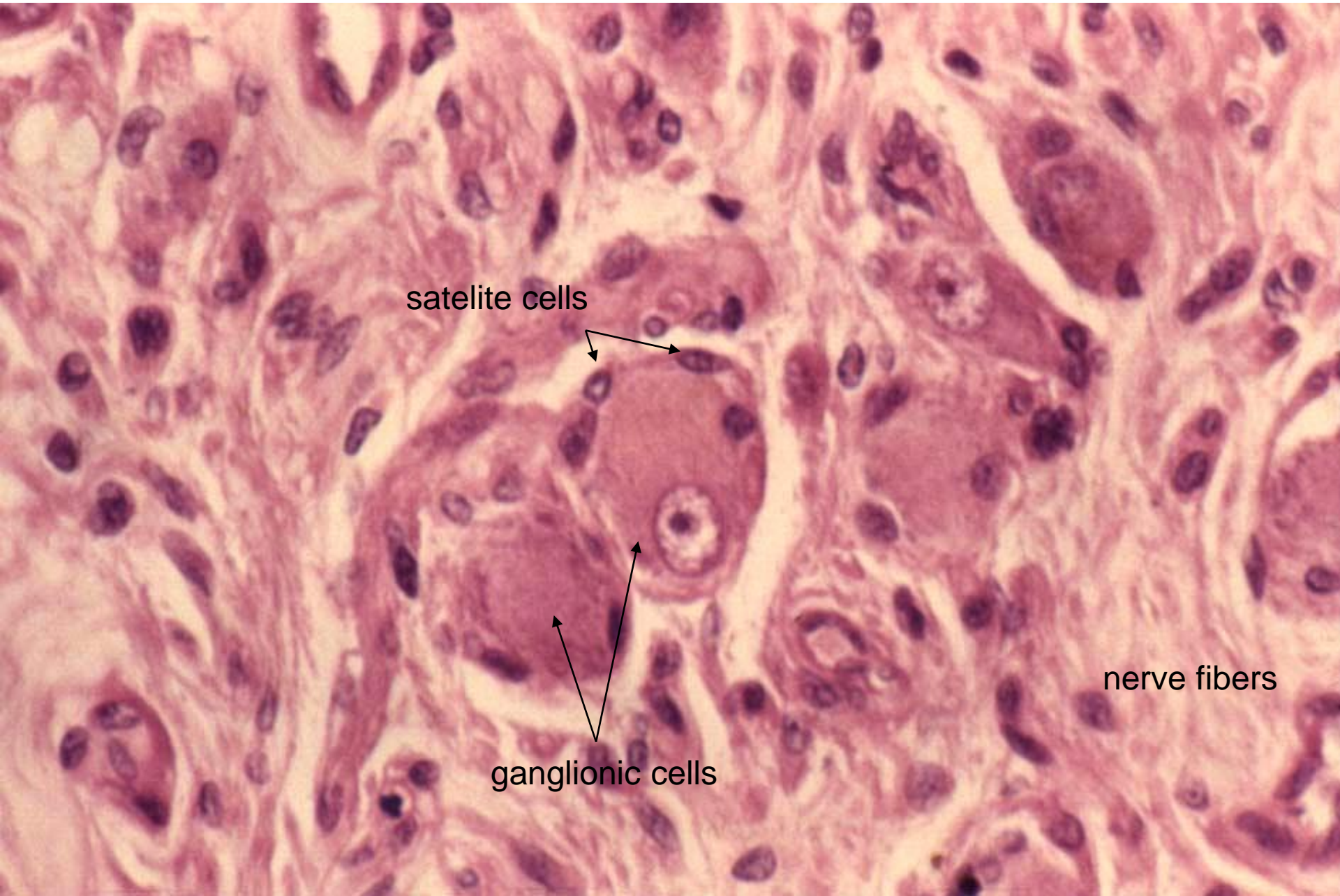


bundles of nerve fibers

multipolar neurons



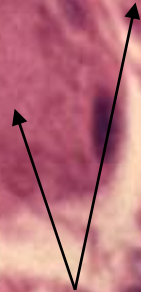
# Autonomic ganglion (HE)



satelite cells

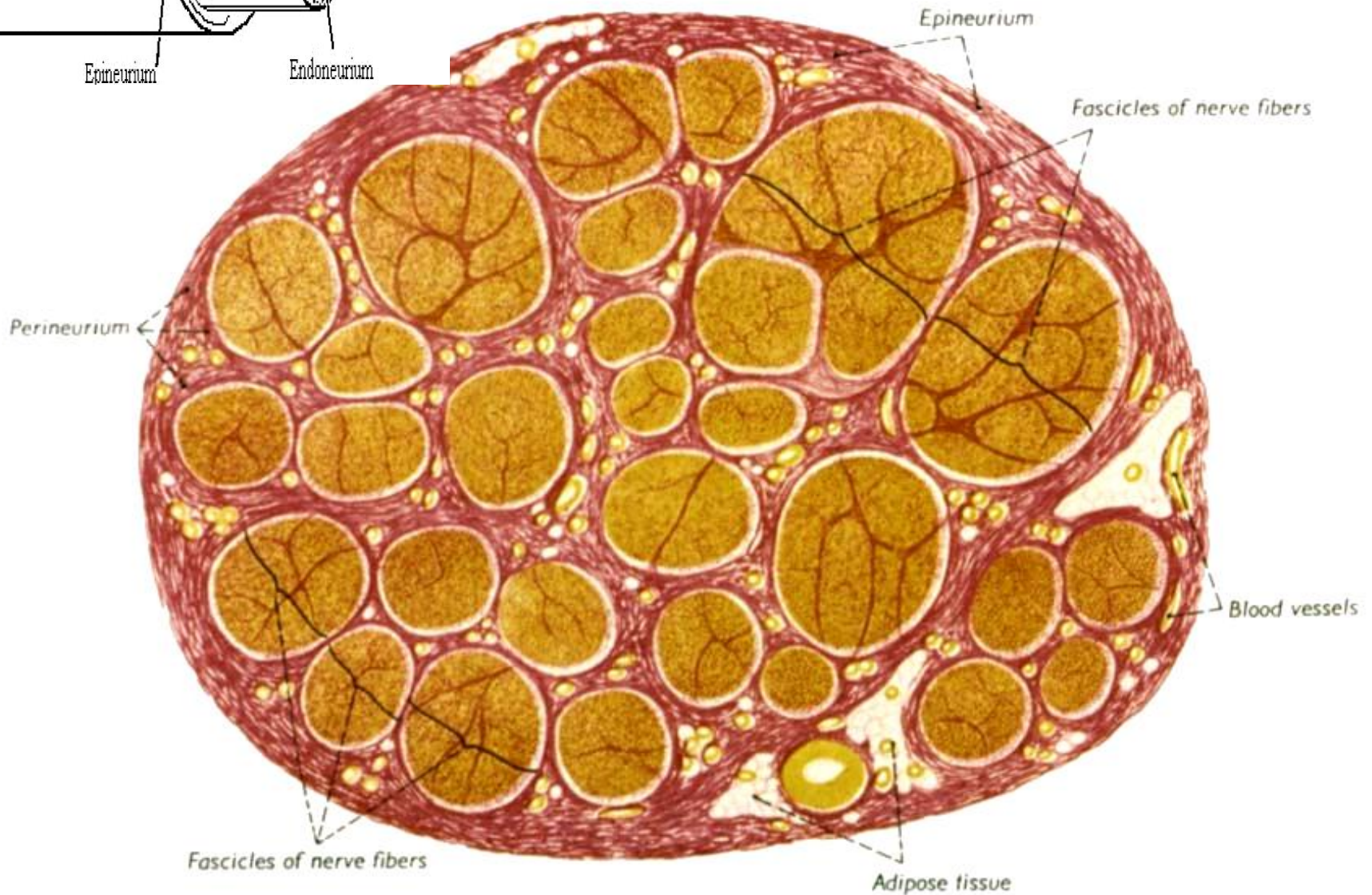
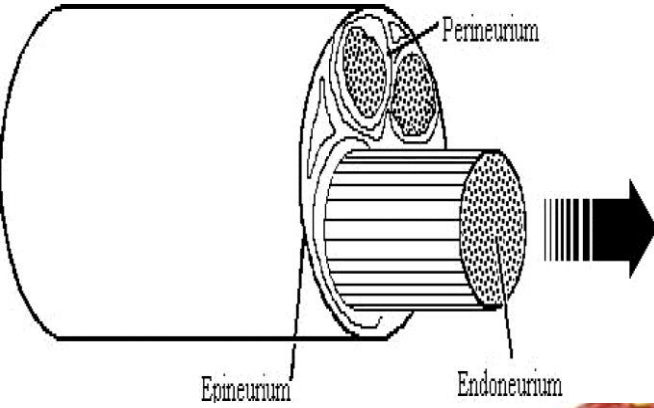


ganglionic cells

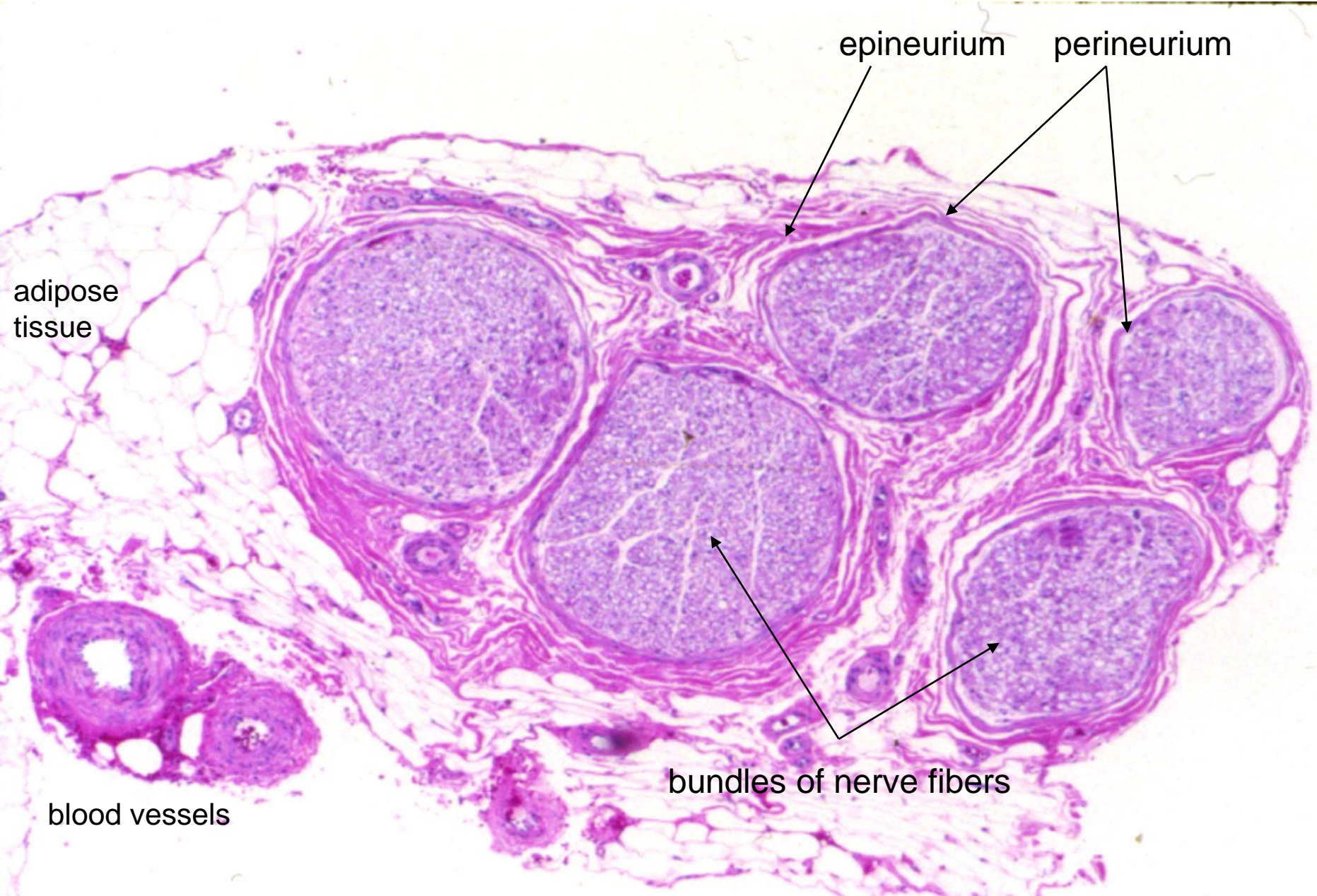


nerve fibers

# Peripheral nerve



**Peripheral nerve (HE) – cross section**



epineurium

perineurium

adipose tissue

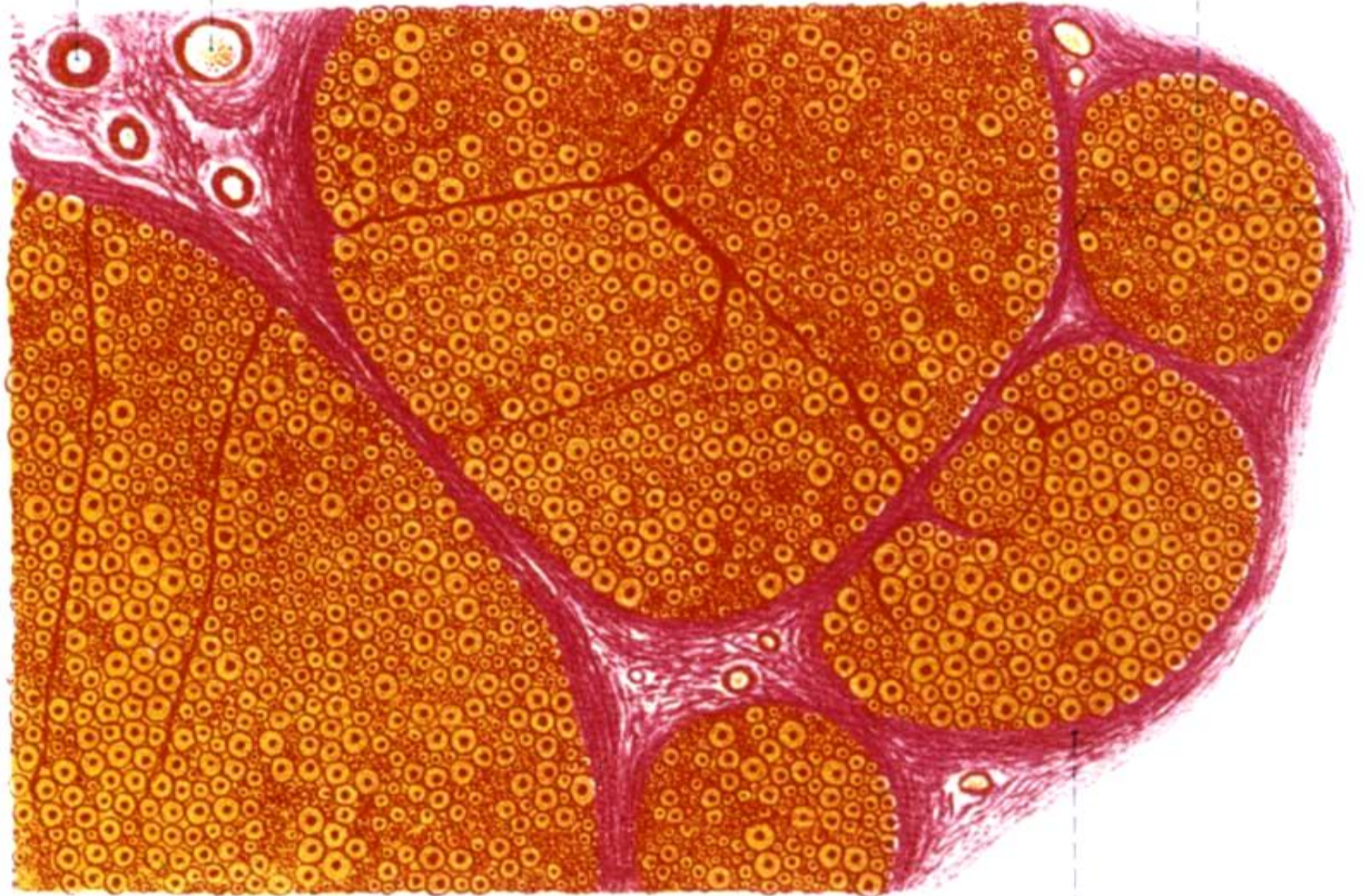
bundles of nerve fibers

blood vessels

Fascicles of nerve fibers

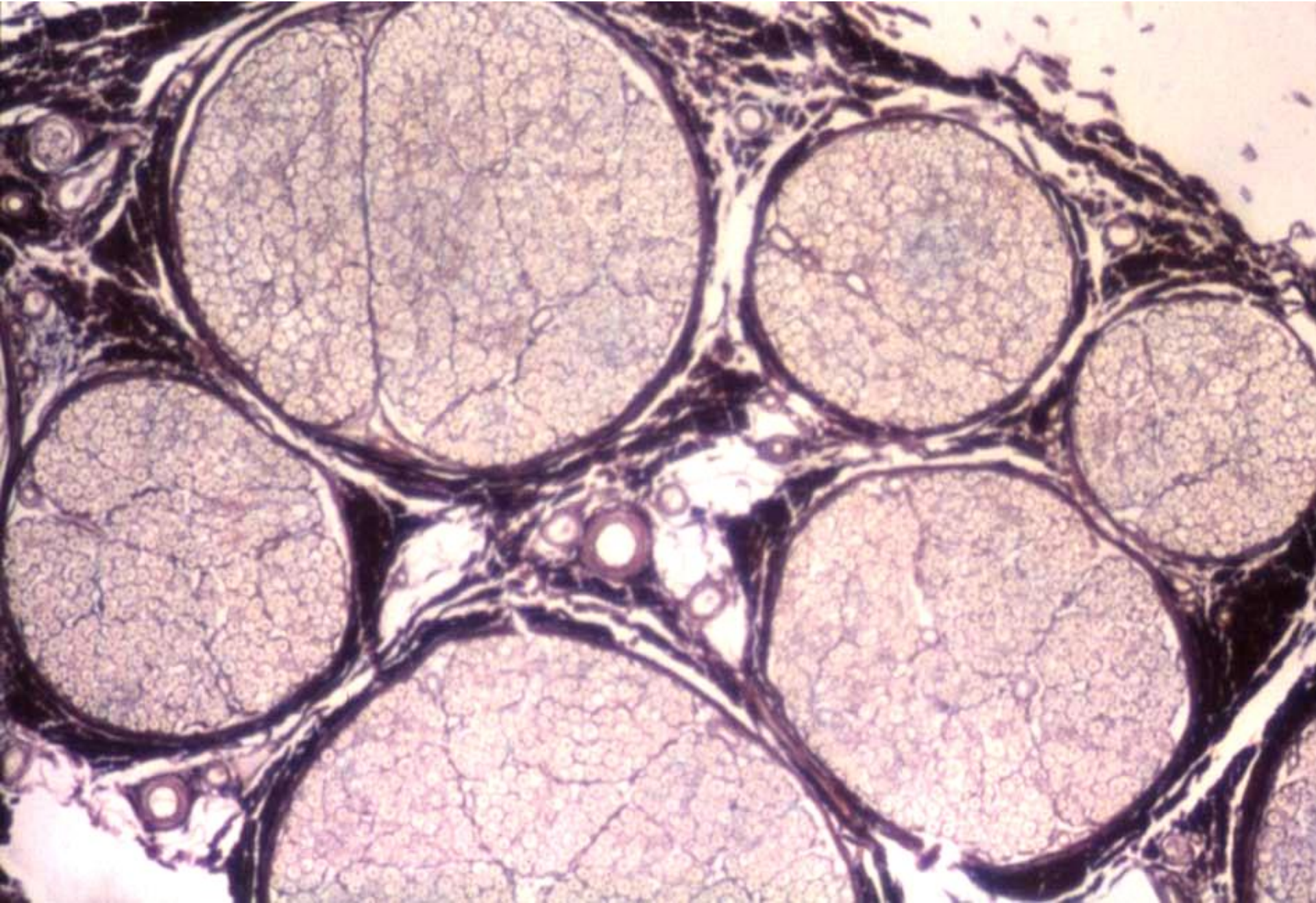
Artery

Vein

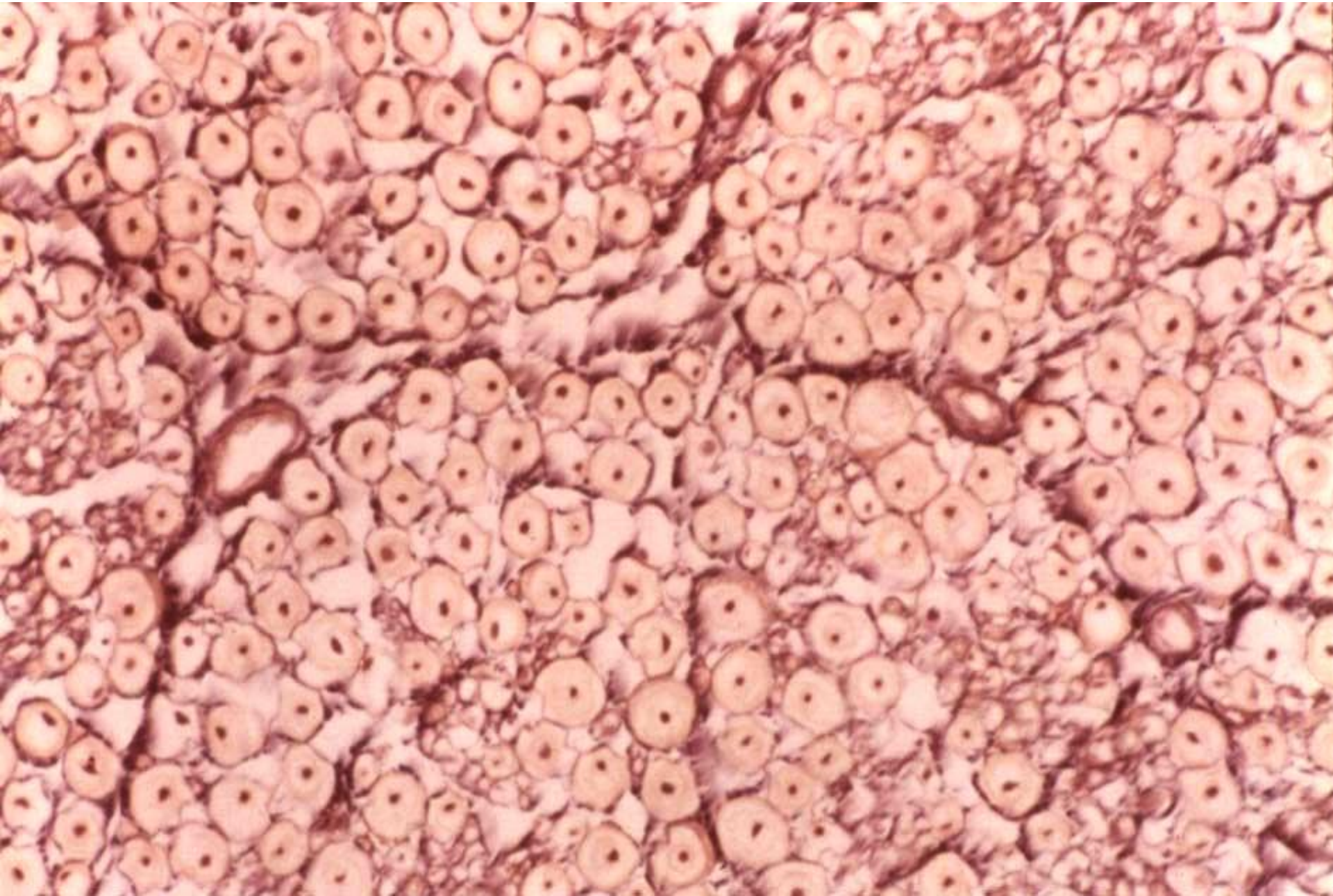


Perineurium

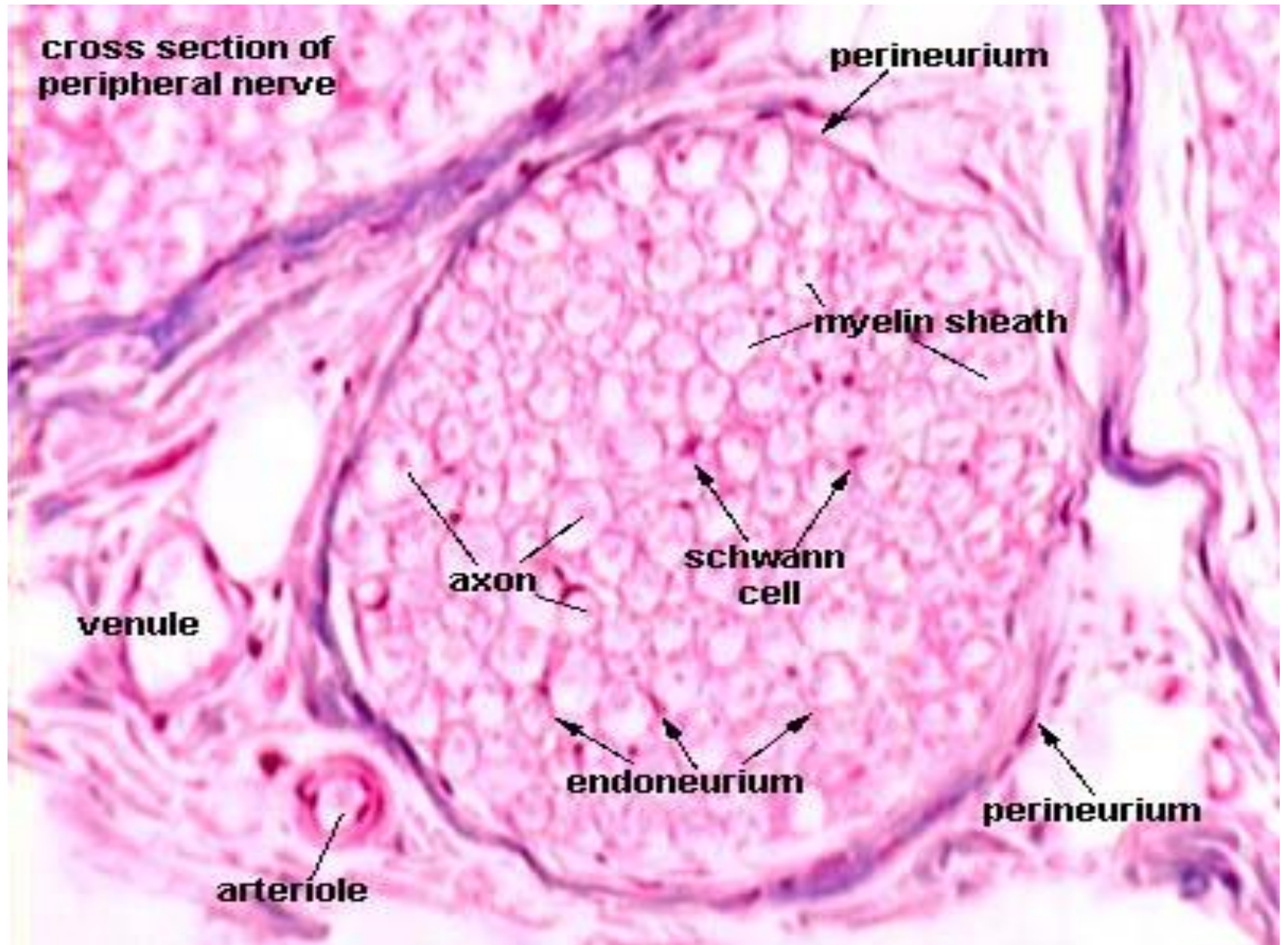
Peripheral nerve (myelin) – cross section



Peripheral nerve (HE) – cross section



**cross section of peripheral nerve**



**perineurium**

**myelin sheath**

**schwann cell**

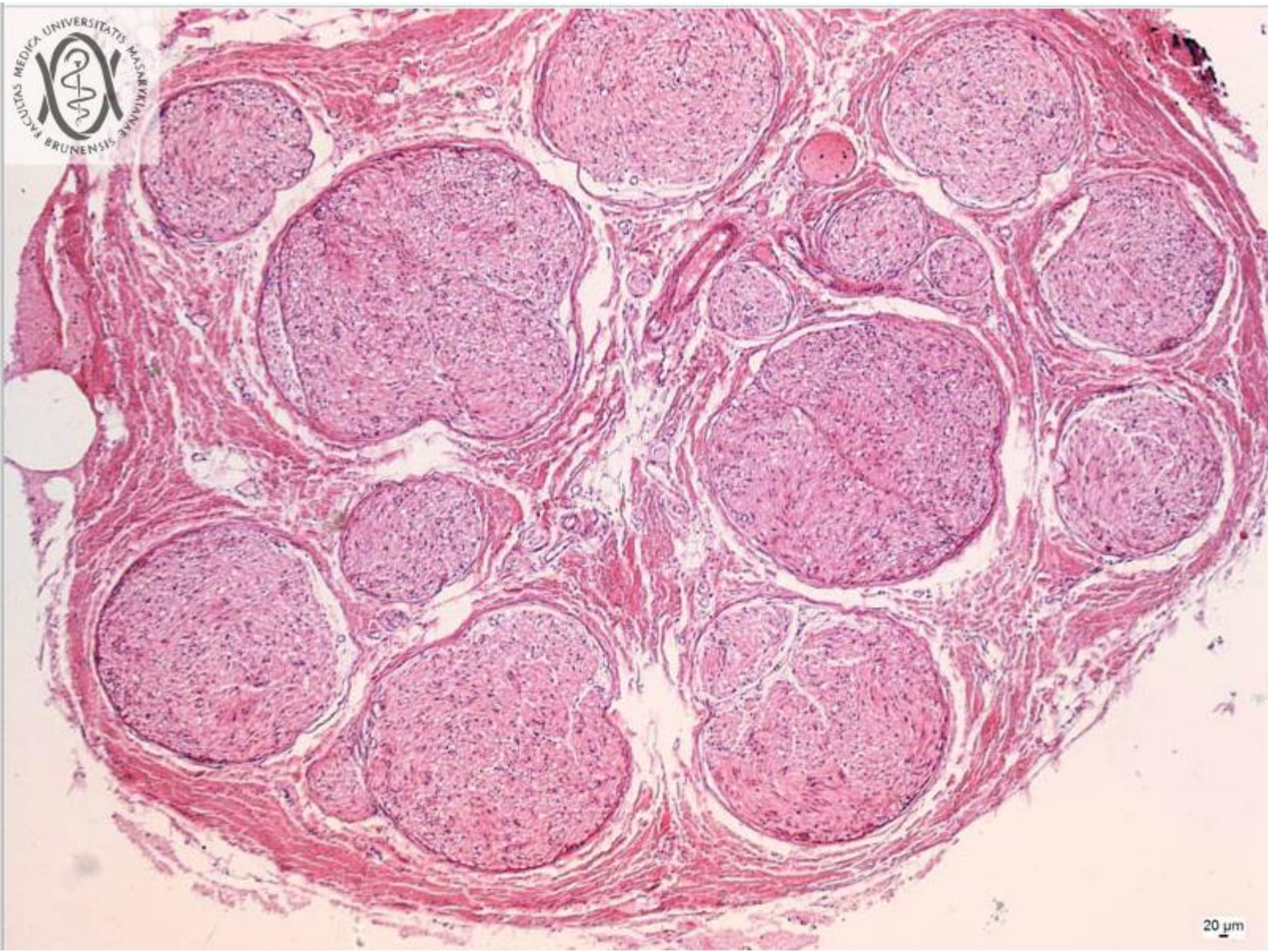
**axon**

**venule**

**endoneurium**

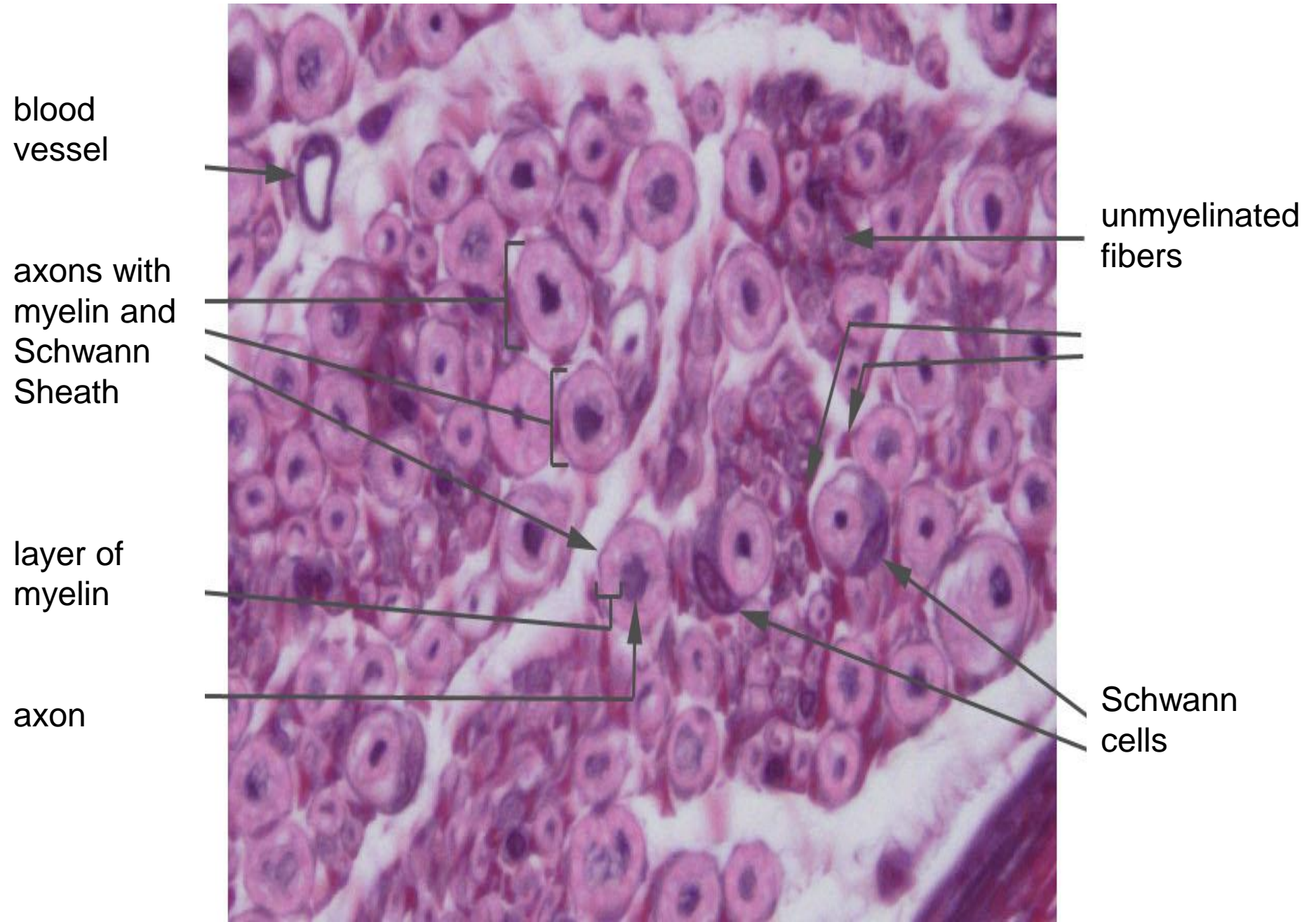
**perineurium**

**arteriole**

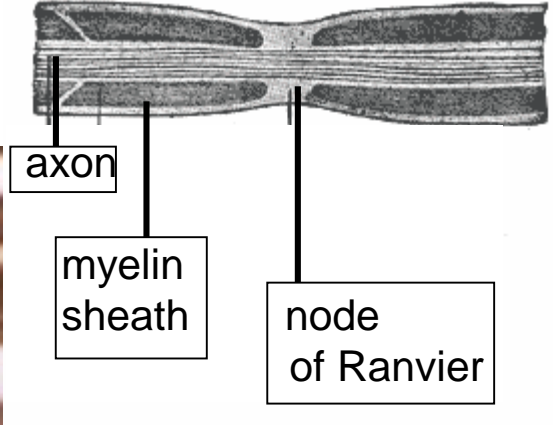




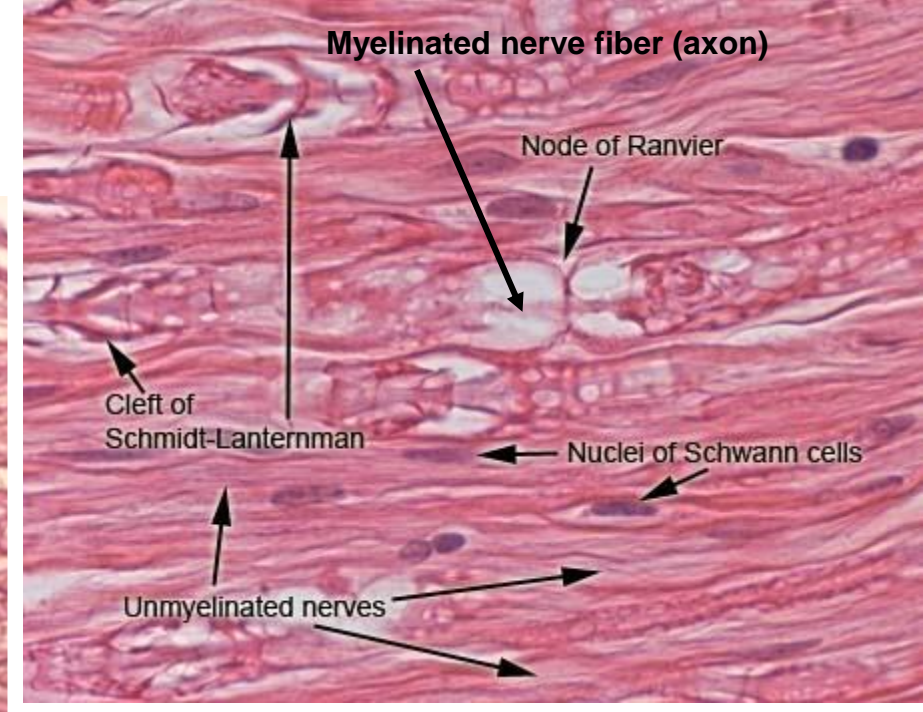
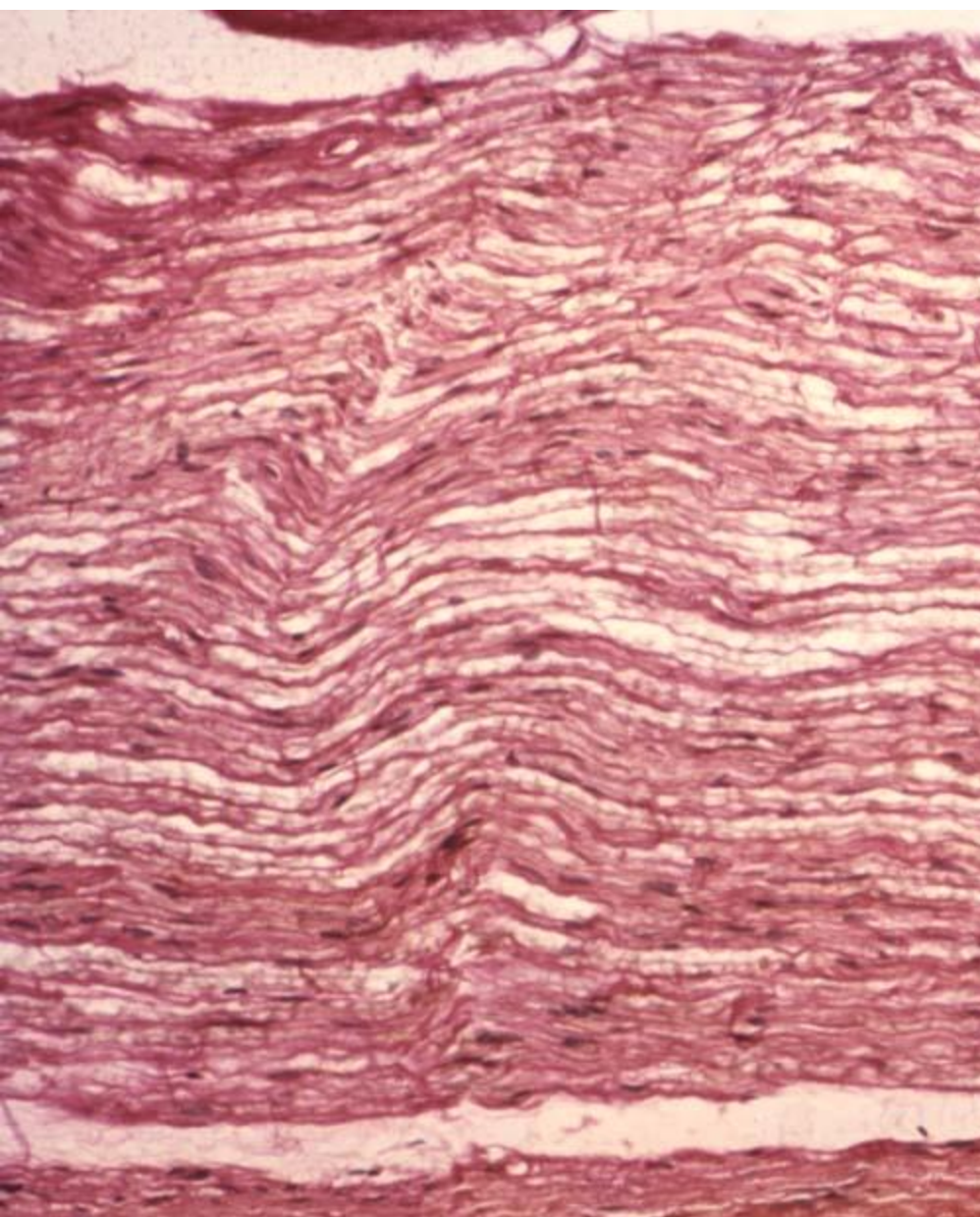
# Peripheral nerve (HE) – detail of cross section



**Peripheral nerve – myelin, longitudinal section**



# Peripheral nerve (HE) longitudinal section



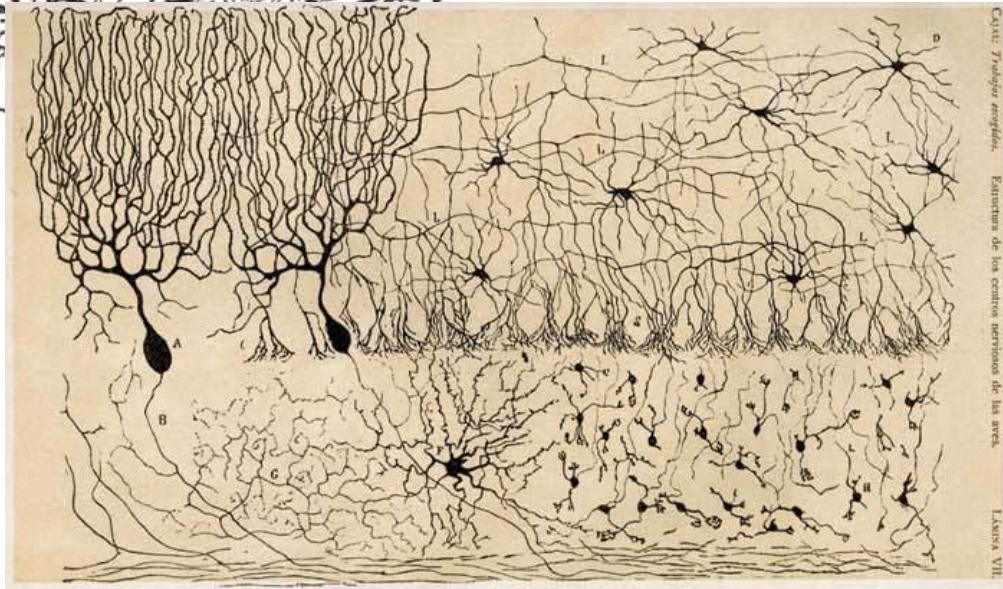
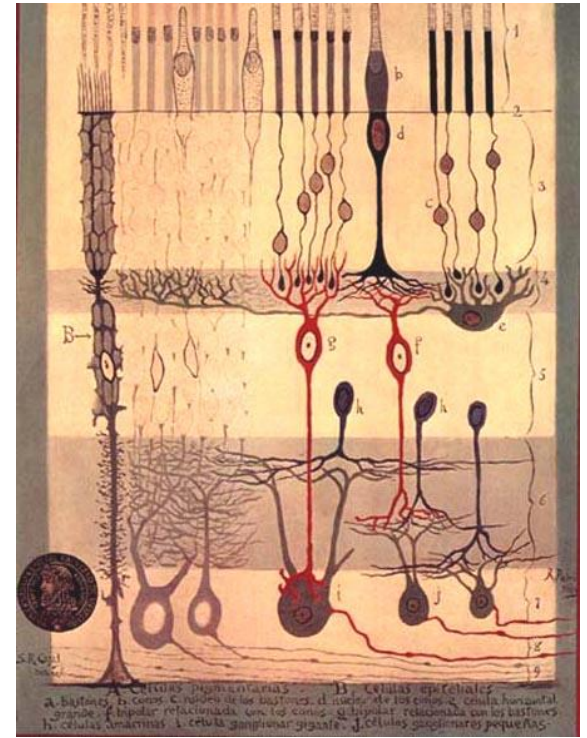
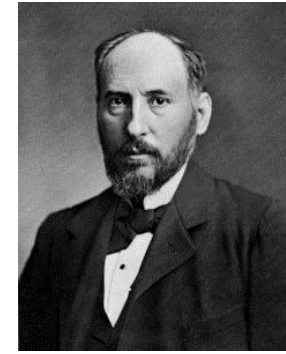
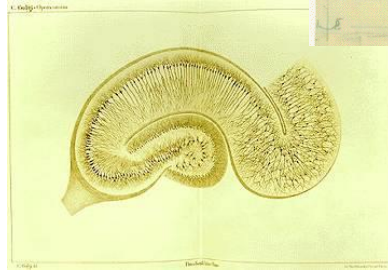
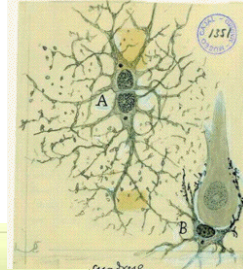
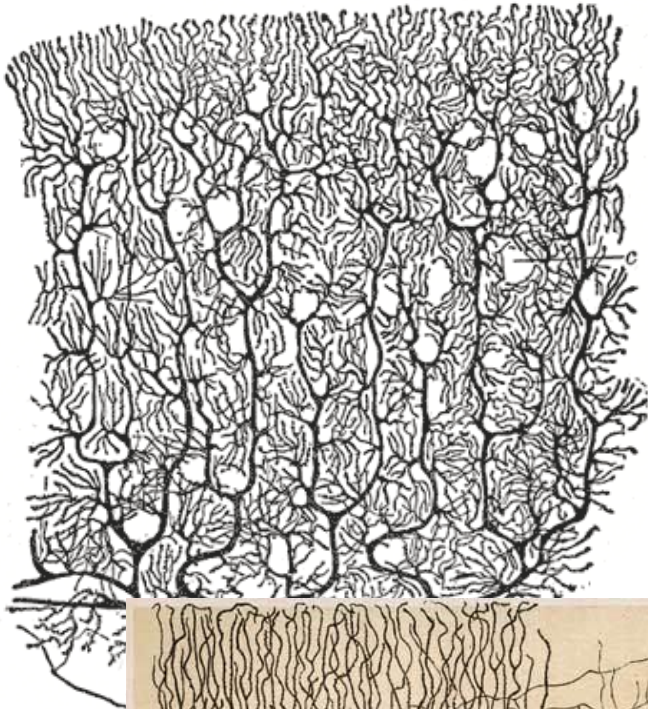
Periferní nerv – podélný řez, (luxolová modř), objektiv 40×

Ranvierův zářez



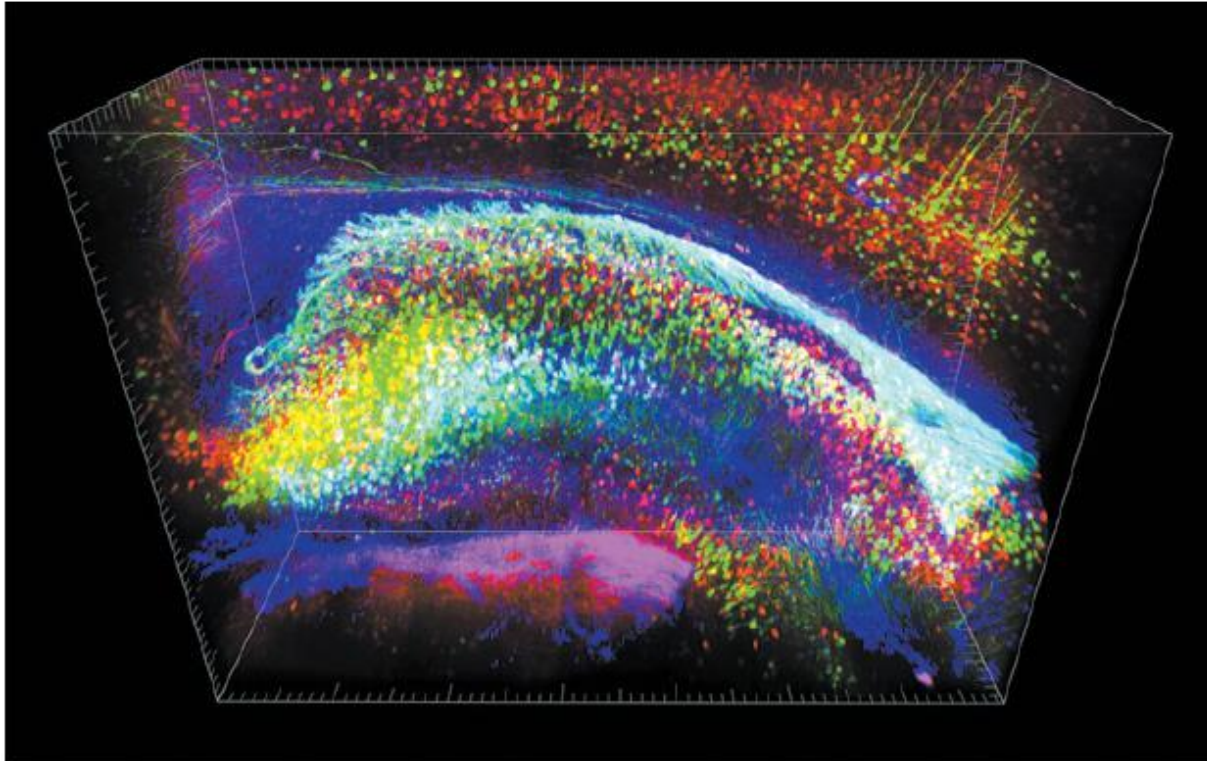
20  $\mu$ m

# This is a view on brain structure as it was developed 100 years ago by Cajal and Golgi

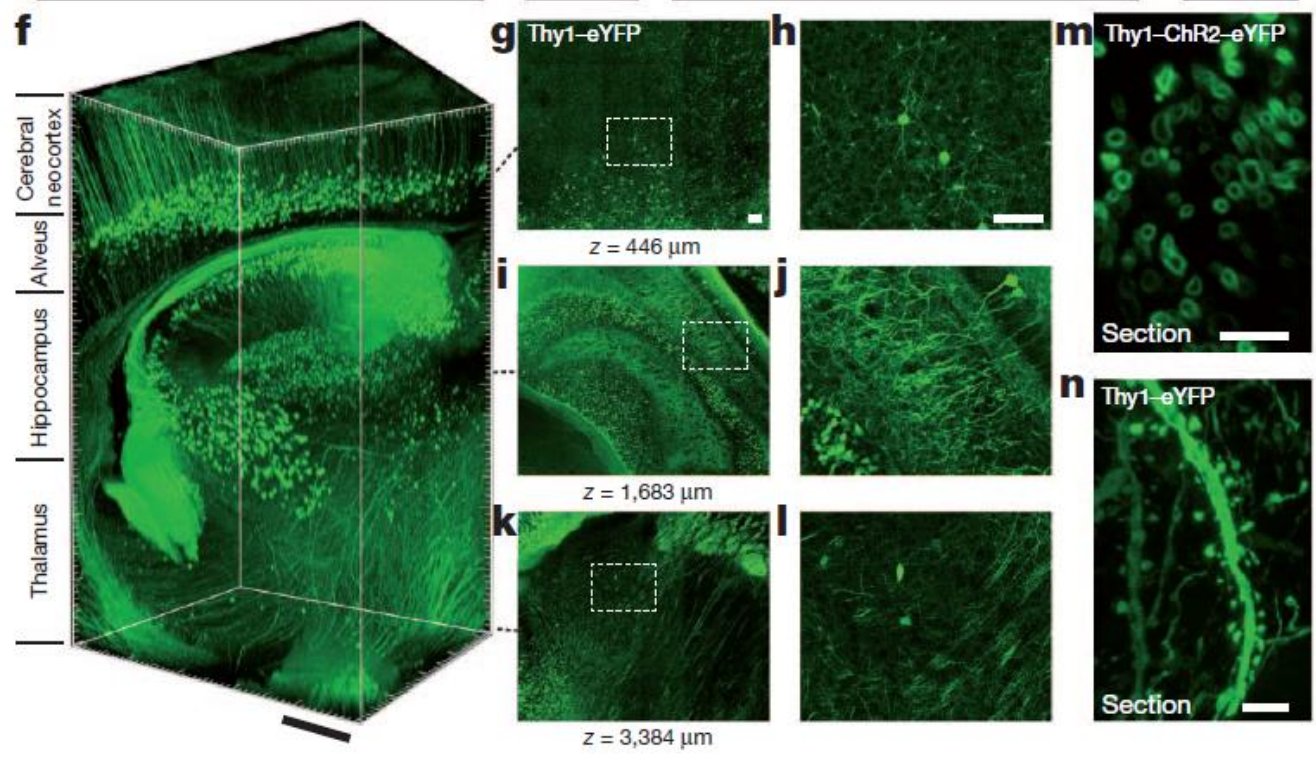
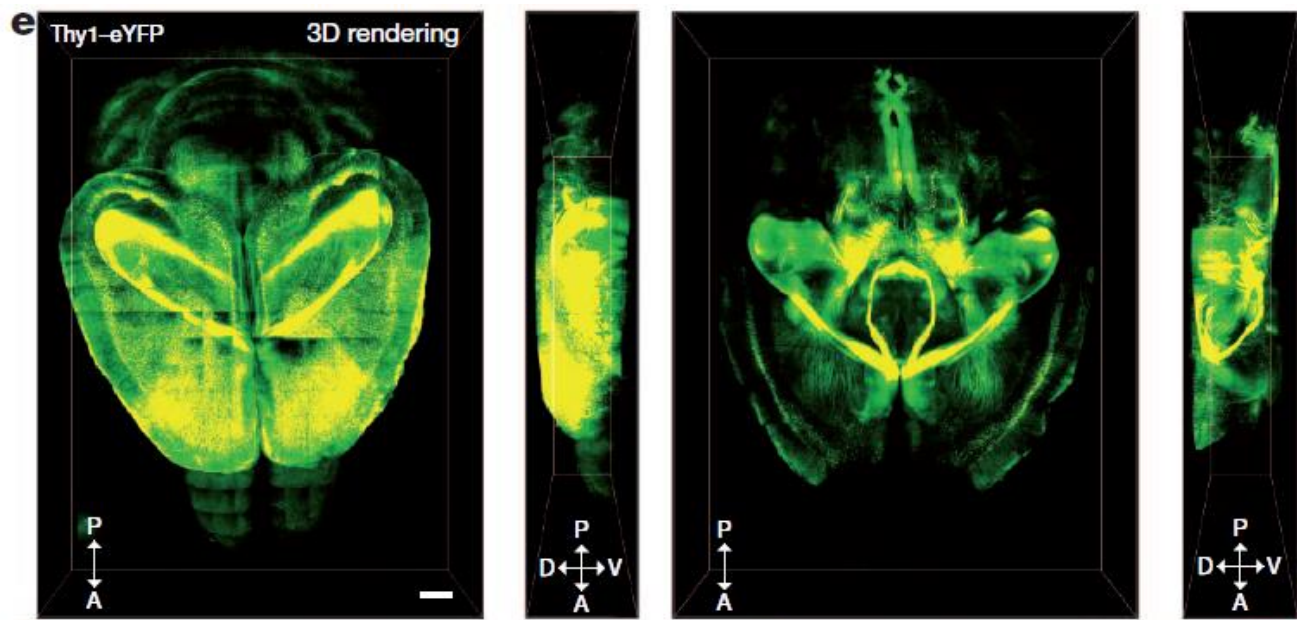


# How can we see brain structure today?

- Not only histological stratification and cell types, but also their connections
- „connectomics“ of large segments of nerve tissue
- Tracing of neuronal fibers through different parts of brain
- Novel techniques of preserving bimolecular composition of nerve tissue while making the brain transparent
- Brain-hydrogel structure allows for application of fluorescent dyes, labels, etc.



Neurons in an intact mouse hippocampus visualized using CLARITY and fluorescent labelling.







# Microscopic structure of the central and peripheral nervous system

- **75. Cortex cerebri**
- **76. Cortex cerebri /impregnation/**
- **77. Cerebellum /impregnation/**
- **78. Cerebellum /Nissl substance/**
- **79. Medulla spinalis**
- 80. Plexus choroideus
- **81. Ganglion spinale**
- **82. Ganglion spinale /impregnation/**
- **83. Ganglion autonomic**
- **84. Peripheral nerve – cross section**
- **85. Peripheral nerve – cross section /myelin/**
- **86. Peripheral nerve – longitudinal section**
- **87. Peripheral nerve – longitudinal section /myelin/**