Lecture 11

Nervous system

- Reminder on composition of nerve tissue
- Structure of gray matter of spinal cord, cerebellum, and telencephalon (iso- and allocortex)
- Peripheral nervous system - ganglia and peripheral nerves
- Earliest phases of development of nervous system
- Histogenesis of neural tube
- Development of brain and spinal cord

Brno, November 2021

Nervous system - Histologically

Made of 3 structurally different components:

The nerve tissue

Blood vessels

capillaries, arterioles and venules that densely penetrate the nerve tissue

The connective tissue

- **provides protection of both previous components is organized into:**

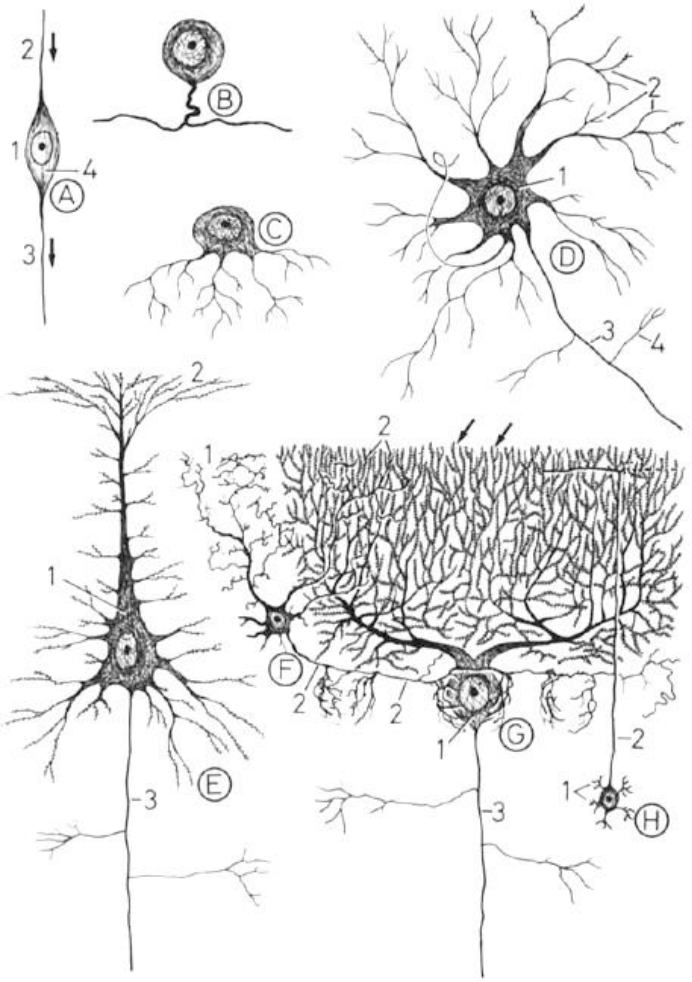
- **meninges - envelope the brain and spinal medulla**
- **epi-, peri- and endoneurium - connective tissue within nerves or on their surfaces**
- **thin capsules - surround the cerebrospinal and autonomic ganglia**

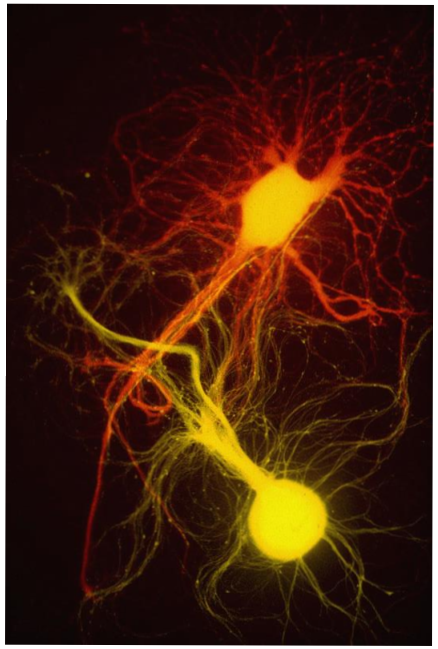
Nerve tissue – General features

Nervous tissue is made up of just 2 types of cells:

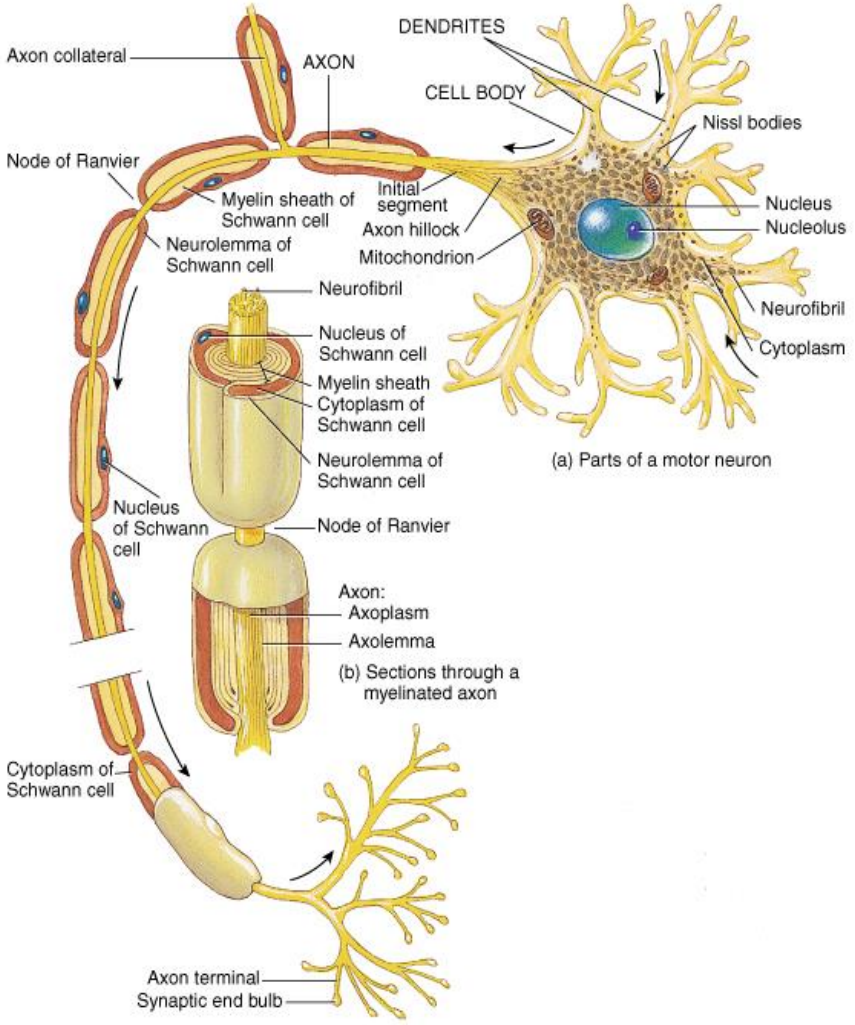
- **Neurons**
- **Neuroglia - glial cells** (supporting cells)

- Neurons are the basic functional units of nervous tissue.
- They are highly specialized to transmit nerve impulses.





Neuron



1. **Perikaryon (neurocyte)**

2. **Processes:**

   (one-way signal conduction)

- axon

(always only one; centrifugal conduction)

- dendrit(es)

(centripetal conduction)

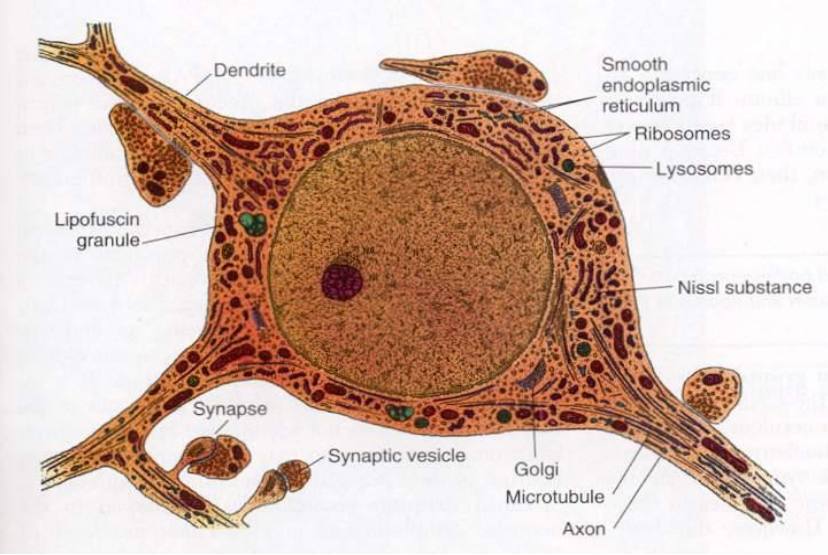
Neuron - Perikaryon

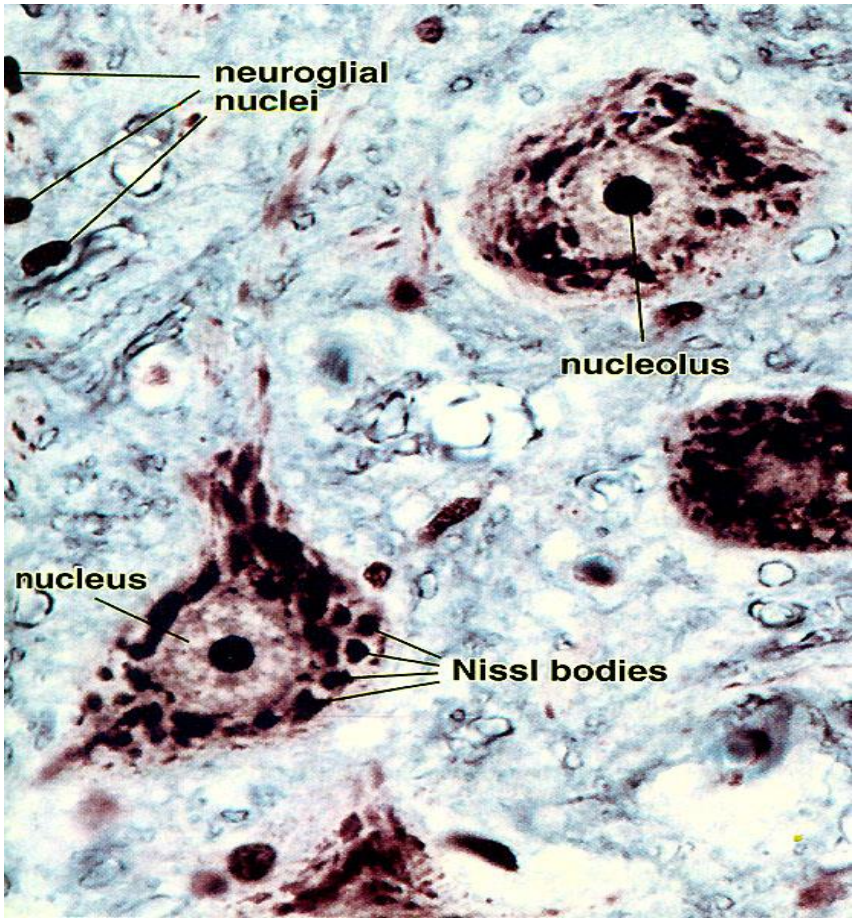
Position:
CNS – grey matter
PNS – ganglia

Shape:
pyramidal, shpherical, ovoid, peer-shaped

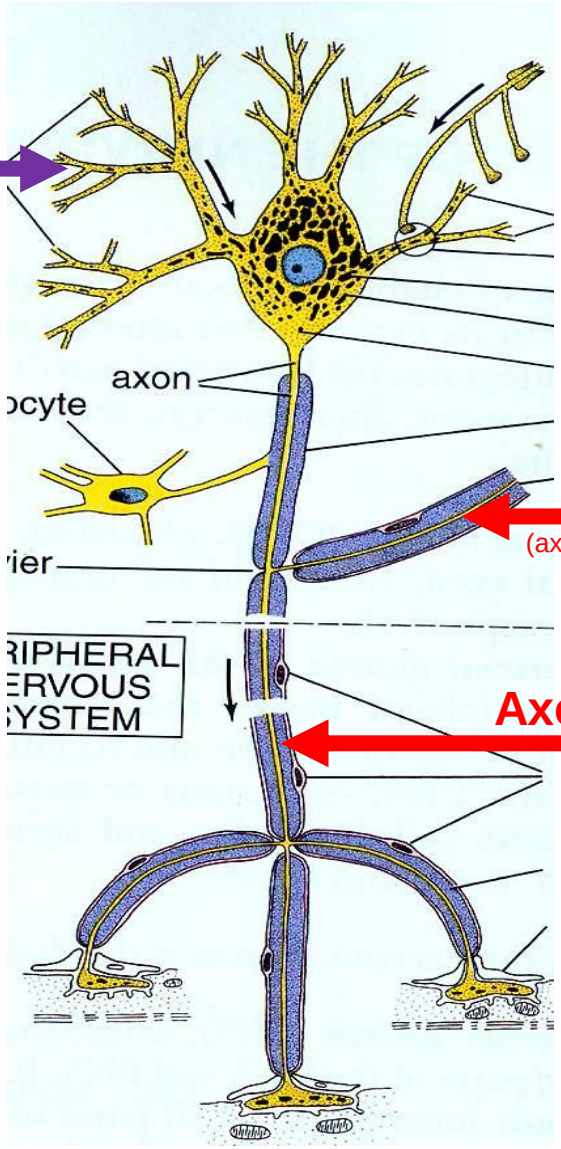
Size:
5 to 150 μm

Organelles:
- Nuclues – large + pale + prominent nucleoli
- Nissl substance – rough ER
- Neurofibrils (neurofilaments + neurotubules + actin)
- Lipofuscin pigment clumps





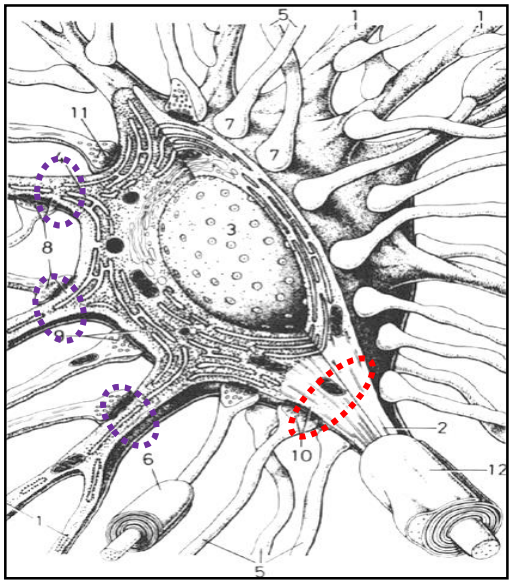
Neuron – Neurites / Processes



Neuron – Neurites / Processes

Dendrites

- Conducts impulses **towards the cell body**
- Typically **short, highly branched & unmyelinated**
- Surfaces specialized for contact with other neurons
- Contains **neurofibrils & Nissl bodies**
- Receptive surface for synaptic junctions
- Contain **MAP-2** (distinction from axon)
- Tens of thousands of synapses on large dendrites
- **Dendritic spines** located on surface of some dendrites
- Spines diminish with age and poor nutrition



Axon (nerve fiber)

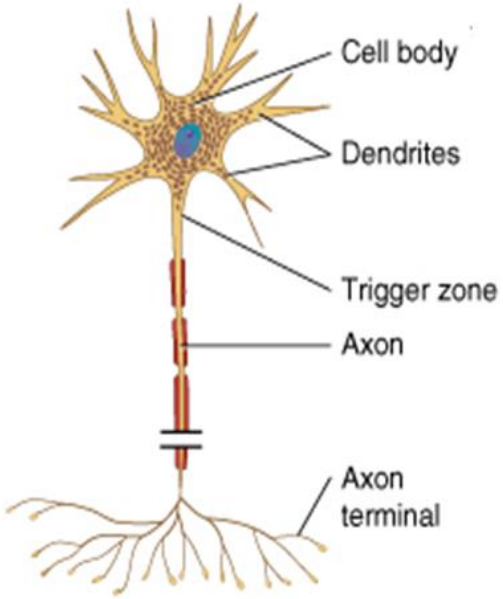
- 1 axon projects from cell body at axon hillock
- **Axon hillock** - pyramid shaped region of the soma that is **devoid of RER**
- Some axons are up to **100 cm**
- **Initial segment** = **Spike trigger zone** (a portion of axon from its origin to the beginning of myelin sheath)
- **At spike trigger zone** trigger zone summation of excitatory and inhibitory impulses occurred
- Collateral branches, Terminal arbor
- **Myelinated** or **Unmyelinated**
- Conduct impulses **away from cell body**
- Swollen tips called **synaptic knob (terminal button)** contain **synaptic vesicles** filled with neurotransmitters
- Cell membrane = **axolemma**
- Cytoplasm = **axoplasm**

White matter: areas of myelinated axons
Gray matter: areas of unmyelinated axons, cell bodies, and dendrites

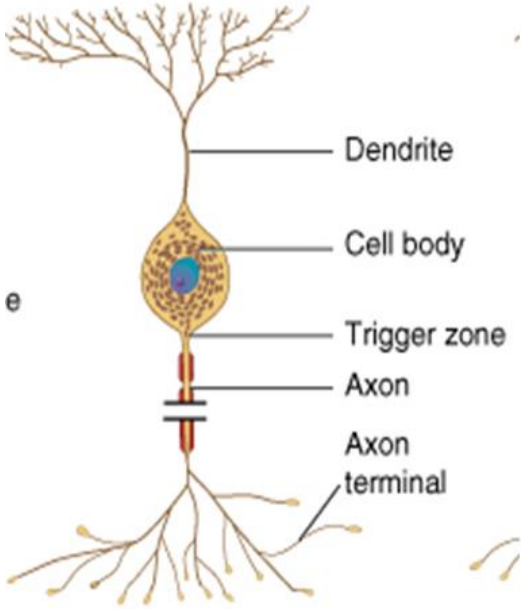
Neuron – Classification 1

According to the number of the processes

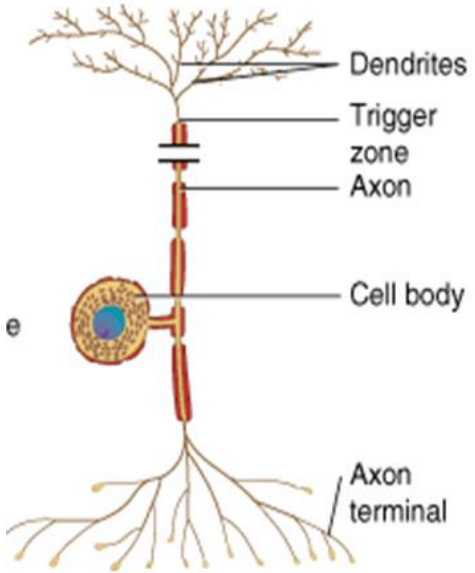
Multipolar
several dendrites & one axon
(most common cell type)



Bipolar
one main dendrite & one axon
(in retina, vestibular and cochlear ganglion)

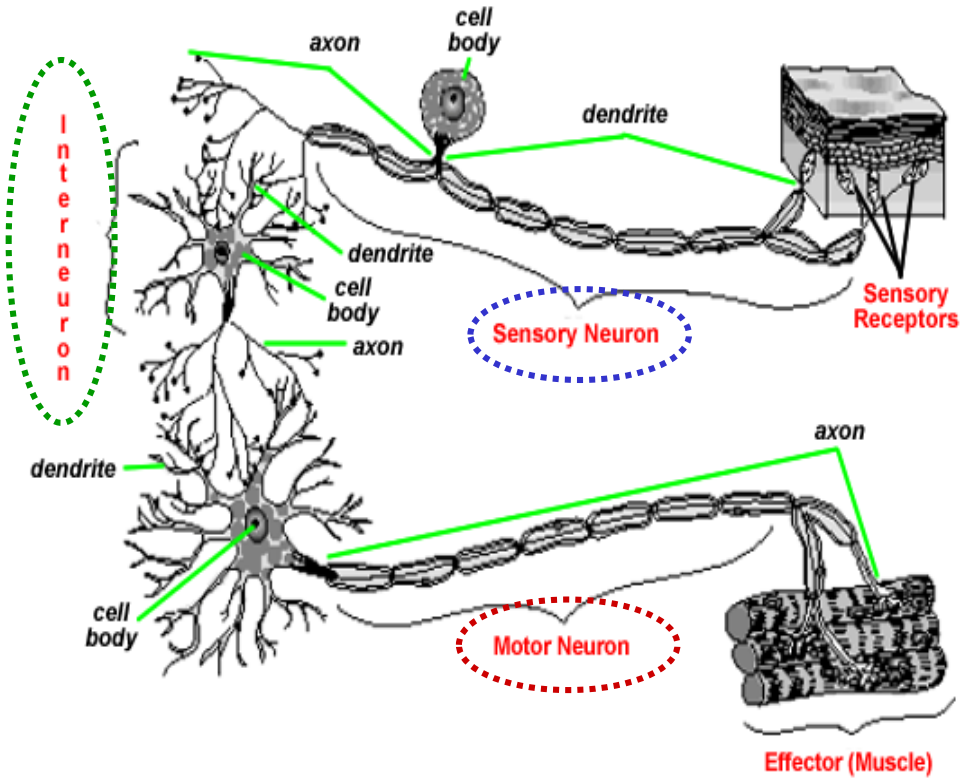


Unipolar (pseudounipolar)
one process only
(develop from a bipolar)
(always sensory, in spinal ganglia)



Neuron – Classification 2

According to the function



Motor (efferent) neurons:
- conduct impulses to muscles, neurons, glands

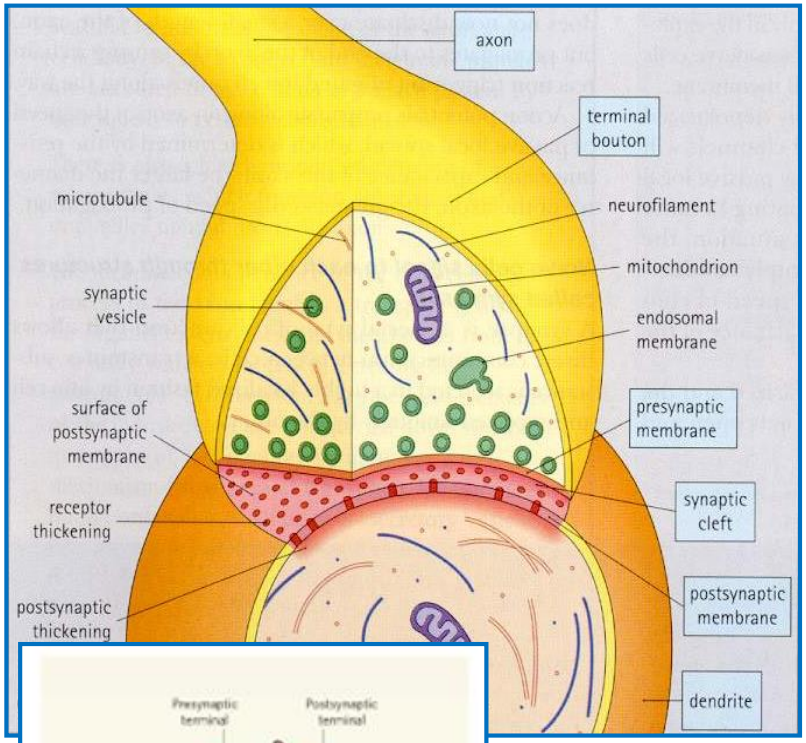
Sensory (afferent) neurons:
- receive sensation

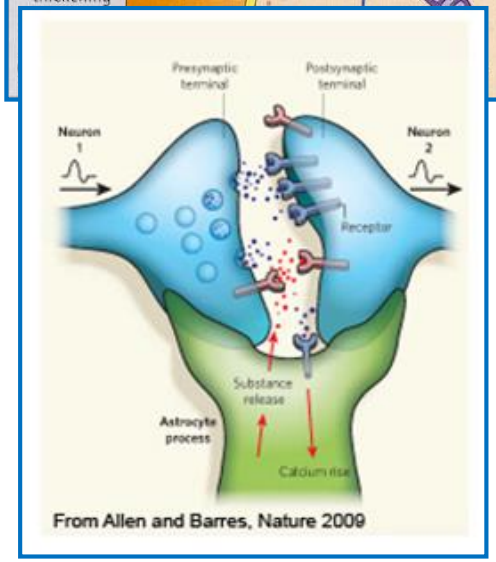
Interneurons:
- local circuit neurons

Synapse

Definition

Synapses are highly specialized intercellular junctions, which link the neurons of each nervous pathway

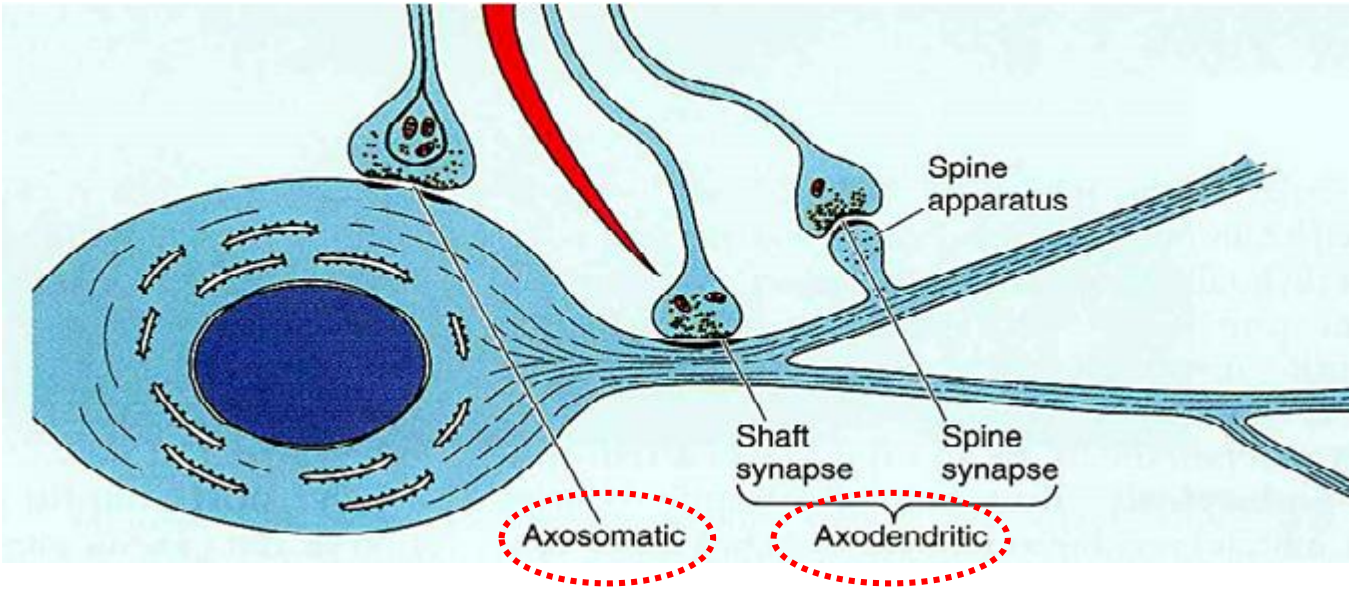




- **Axon terminal** forms **bouton terminal**
- **Presynaptic membrane -** contains mitochondria, and an abundance of **synaptic vesicles with neurotransmitter**
- **Presynaptic dense projections -** are associated with synaptic vesicles form active sites of synapse
- **Synaptic vesicles** (smaller + larger – storage)
- **Postsynaptic membrane -** contains receptors and some dense materials
- **Synaptic cleft -** 20-30 nm width, occupied by fine filaments
- **Glial cells** increase synaptic efficacy
- **Asymmetric synapses are excitatory** (a thick postsynaptic membrane and a 30 nm synaptic cleft)
- **Symmetric synapses are inhibitory** (thin postsynaptic membrane and a 20 nm synaptic cleft)
- Need **special staining** to see by light microscopy

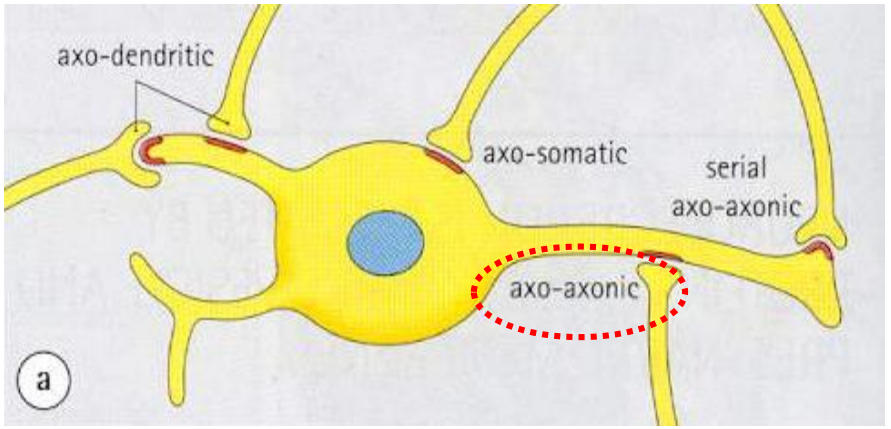
Synapse

Classification according to the constitution



Axodendritic
Axosomatic
Axoaxonic

Note:
Neuromuscular junction – synapse between neuron and effector muscle fibre



Neuroglia

General features

- **non-neuronal** cells of several types
- support and protect the neurons
- bind neurons together and **form framework for nervous tissue**
- in fetus, **guide migrating neurons** to their destination
- if mature neuron is not in synaptic contact with another neuron, it is covered by glial cells
- prevents neurons from touching each other
- gives **precision to conduction pathways**
- only nuclei visible by light microscopy without special staining
- there are several glial cells for each neuron

Number of **neurons**: about **100 billions to 1 trillion**
Number of **glial cells: 50x more** then neurons

Central neuroglia

- Astrocytes
- Oligodendrocytes
- Microglia
- Ependymal cells

Peripheral neuroglia

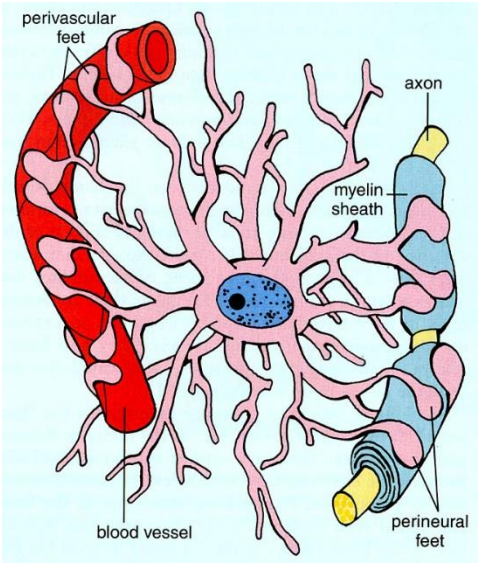
- Schwann cels
- Satellite cells

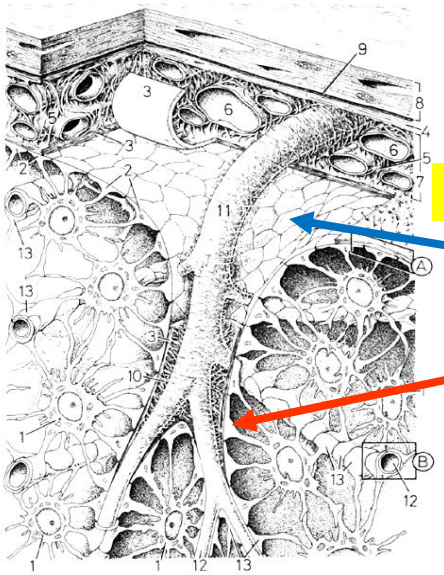
Neuroglia - Astrocytes

- **most abundant glial cell in CNS**
- **covers entire brain surface and most non-synaptic regions of the neurons in the gray matter of the CNS**

- **diverse functions:**

✓ form a **supportive framework** of nervous tissue
✓ have extensions (**perivascular feet**) that contact blood capillaries that stimulate them to form a tight seal called the **blood-brain barrier**
✓ convert blood glucose to **lactate** and supply this to the neurons for nourishment
✓ **nerve growth factors** secreted by astrocytes promote neuron growth and synapse formation
✓ communicate electrically with neurons and may **influence synaptic signaling**
✓ regulate chemical composition of tissue fluid by absorbing excess neurotransmitters and ions
✓ **astrocytosis** or **sclerosis** – when neuron is damaged, astrocytes form hardened scar tissue and fill space formerly occupied by the neuron
✓ contains **GFAP**





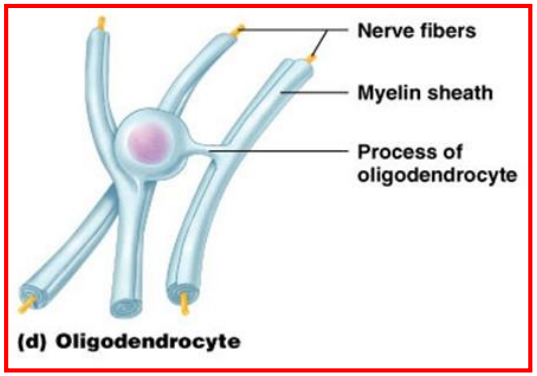
Membrana limitans gliae…

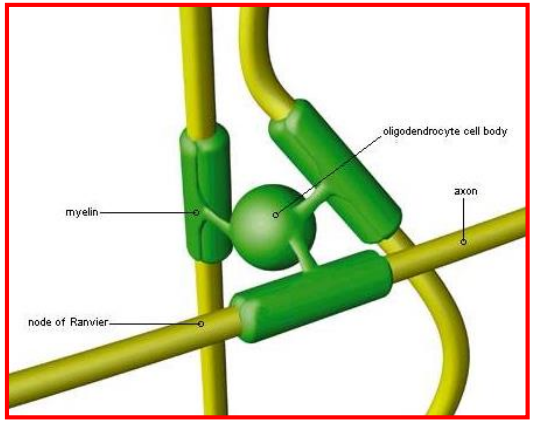
…superficialis

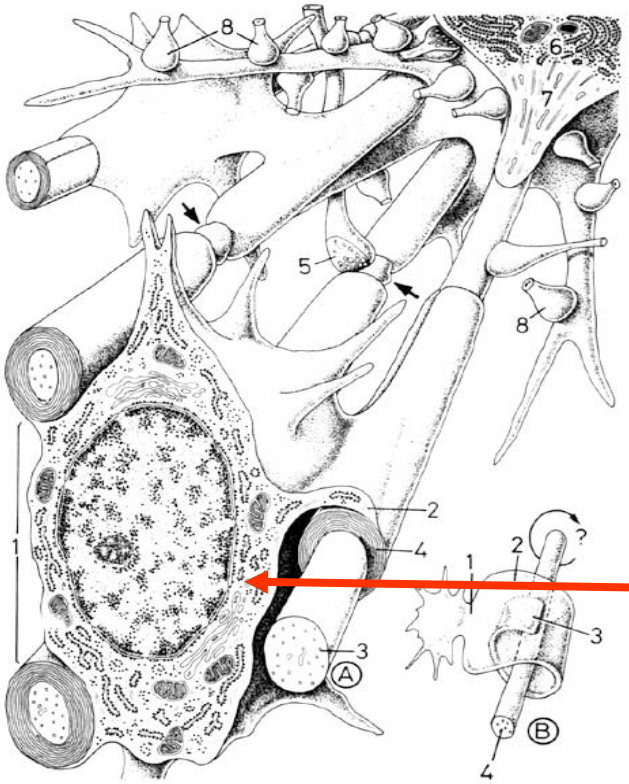
…perivascularis

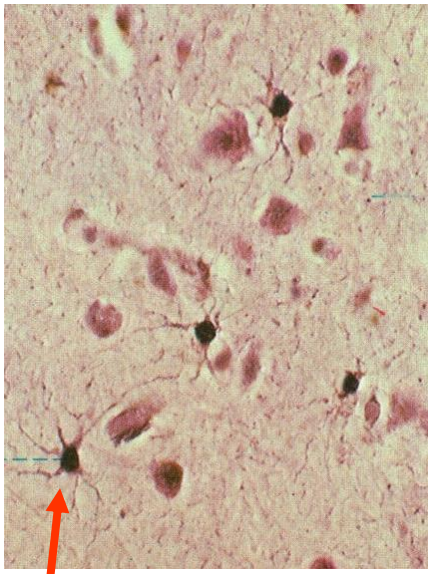
Neuroglia - Oligodendrocytes

- ✓ smaller than astrocytes; darker, round nucleus, abundant RER, well developed golgi apparatus
- ✓ form **myelin sheaths in CNS**
- ✓ one cell **serves more then one axon**
- ✓ **cannot migrate around axons** (unlike Schwann cells) must push newer layers of myelin under the older ones so myelination spirals inward toward nerve fiber
- ✓ nerve fibers in CNS have **no Schwann sheath (neurilemma) or endoneurium**
- ✓ each arm-like process wraps around a nerve fiber forming an **insulating** layer that speeds up signal conduction
- ✓ damaged in **multiple sclerosis**





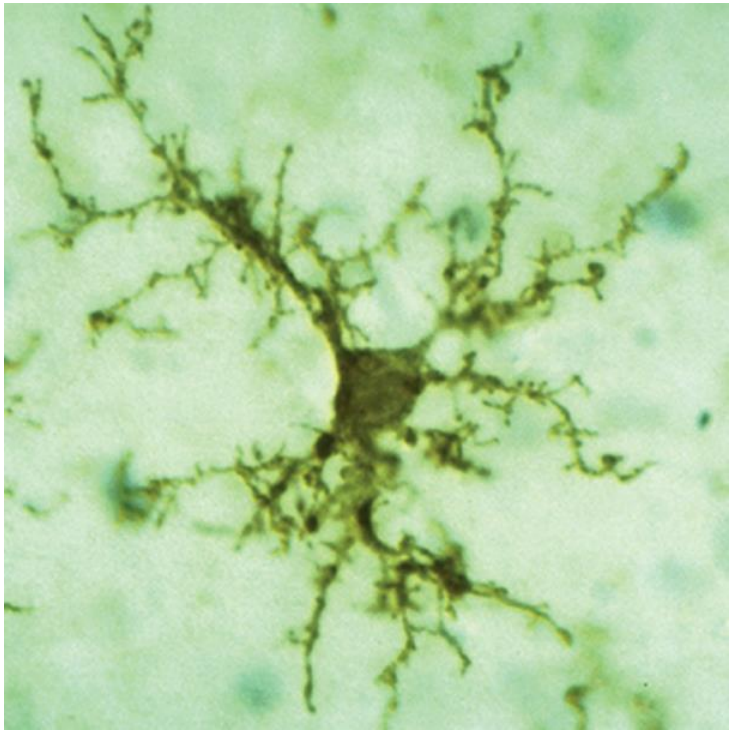


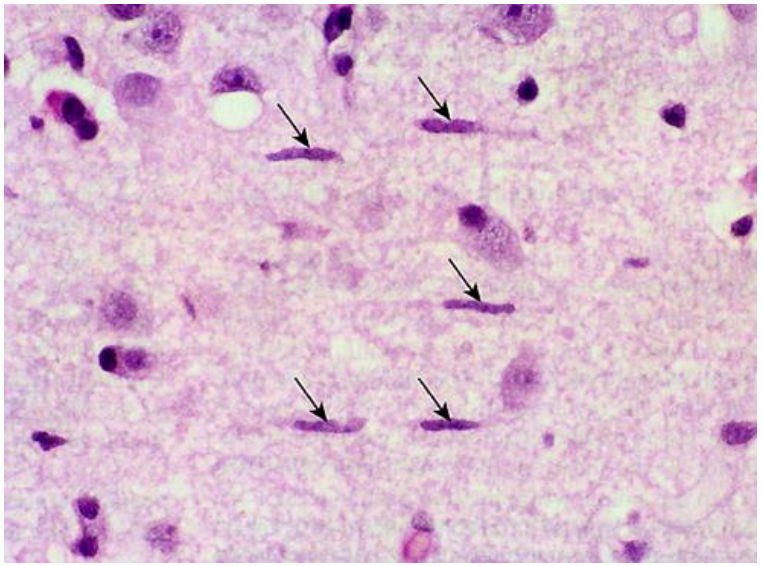


oligodendrocyte

Neuroglia - Microglia

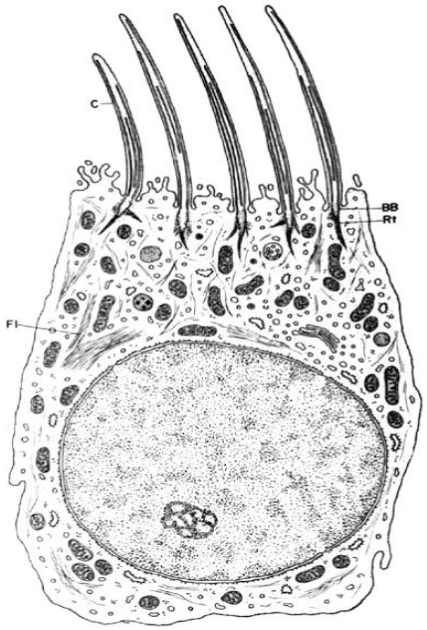
- ✓ **smallest** neuroglial cell
- ✓ small, dark, **elongated nuclei**
- ✓ possess **phagocytotic** properties
- ✓ when activated – **antigen presenting** cell
- ✓ originate in bone marrow (**mesodermal** origin)

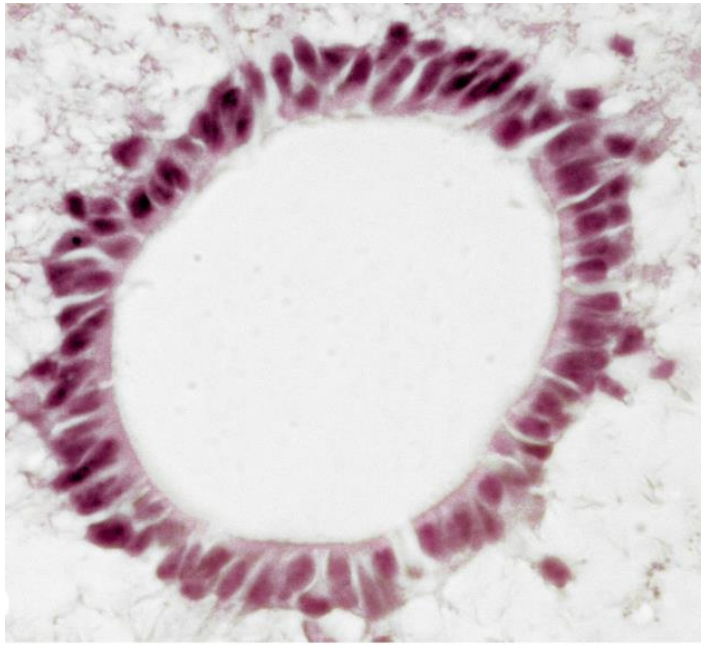




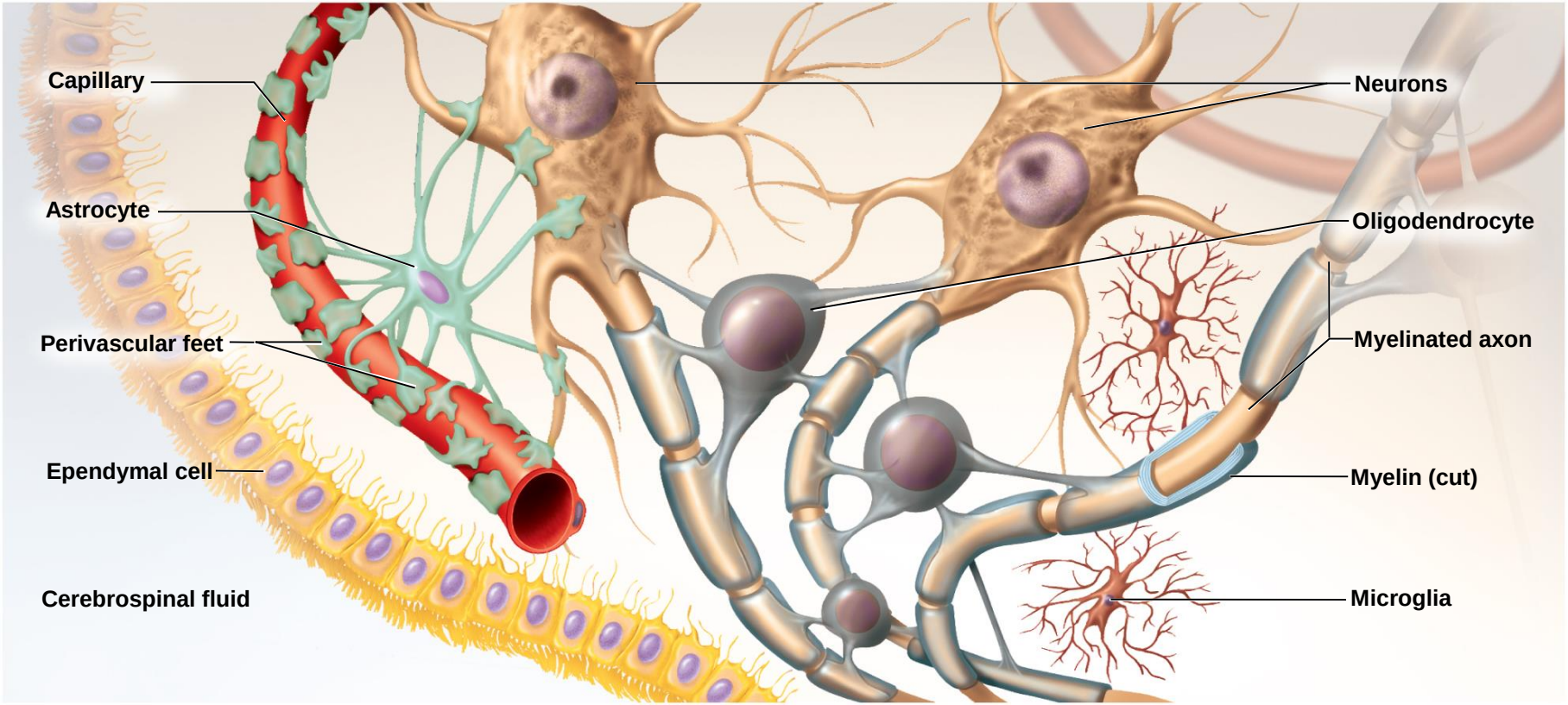
Neuroglia – Ependymal cells

- ✓ **line ventricles of CNS and central canal of spinal cord**
- ✓ **cuboidal** or low **columnar** shape
- ✓ no basal lamina
- ✓ **secrete** cerebrospinal fluid (CSF)
- ✓ some are **ciliated**, facilitate movement of CSF
- ✓ participate in formation of **Choroid plexus**





Neuroglia – Central - Summary



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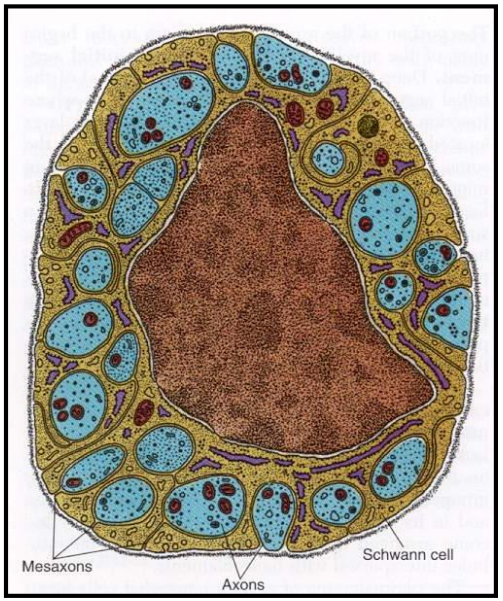
Neuroglia in PNS – Schwann cells

- cells that encircle all axons in PNS
- provide structural and metabolic support to axons
- provide guidance for axonal growth

Small diameter axons

Enveloping by only cytoplasm

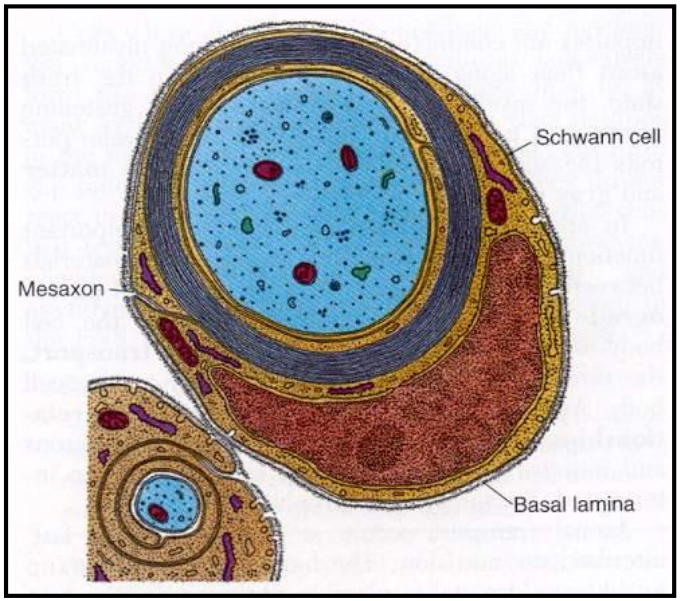


only Schwann sheath – gray nerve fiber

X

Large diameter axons

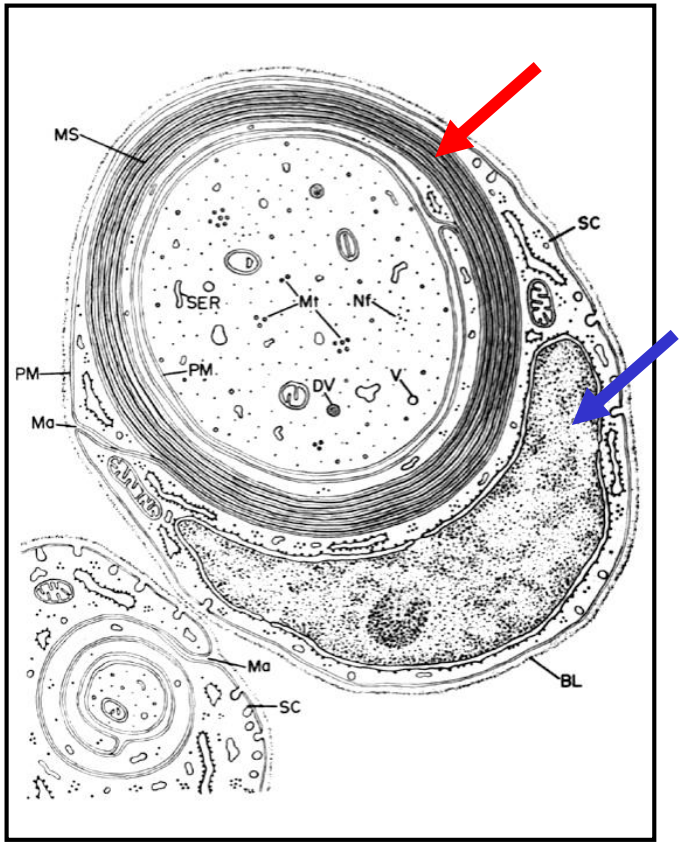
Wrapping by myelin sheaths

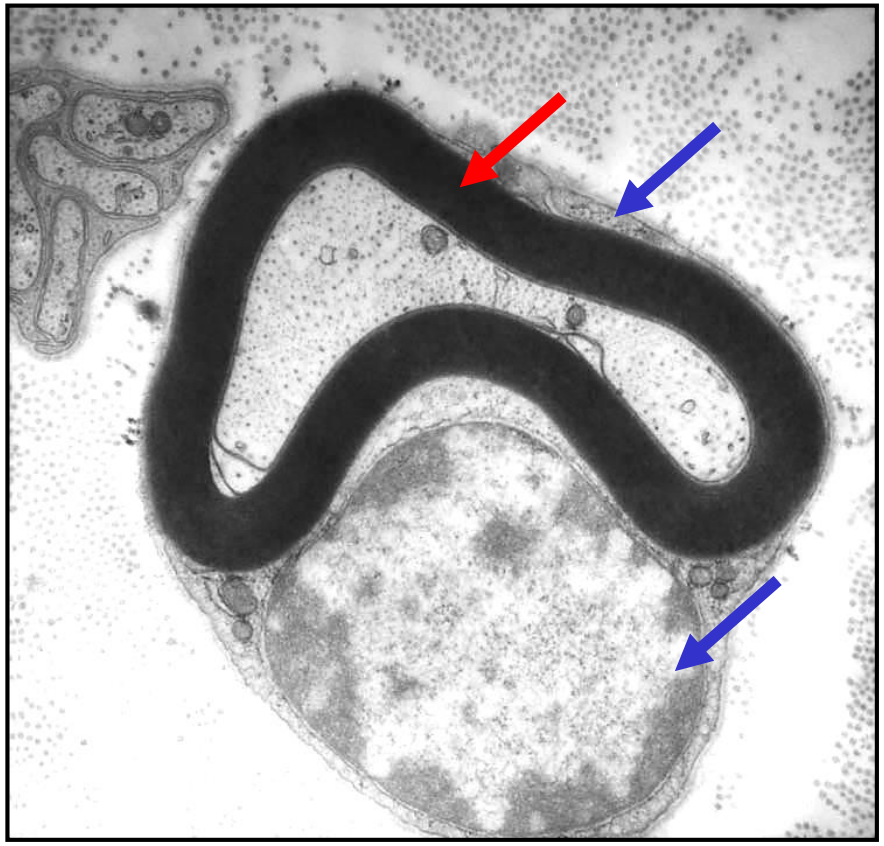


Schwann + myelin sheath – double contoured nerve fiber

Neuroglia in PNS – Schwann cells

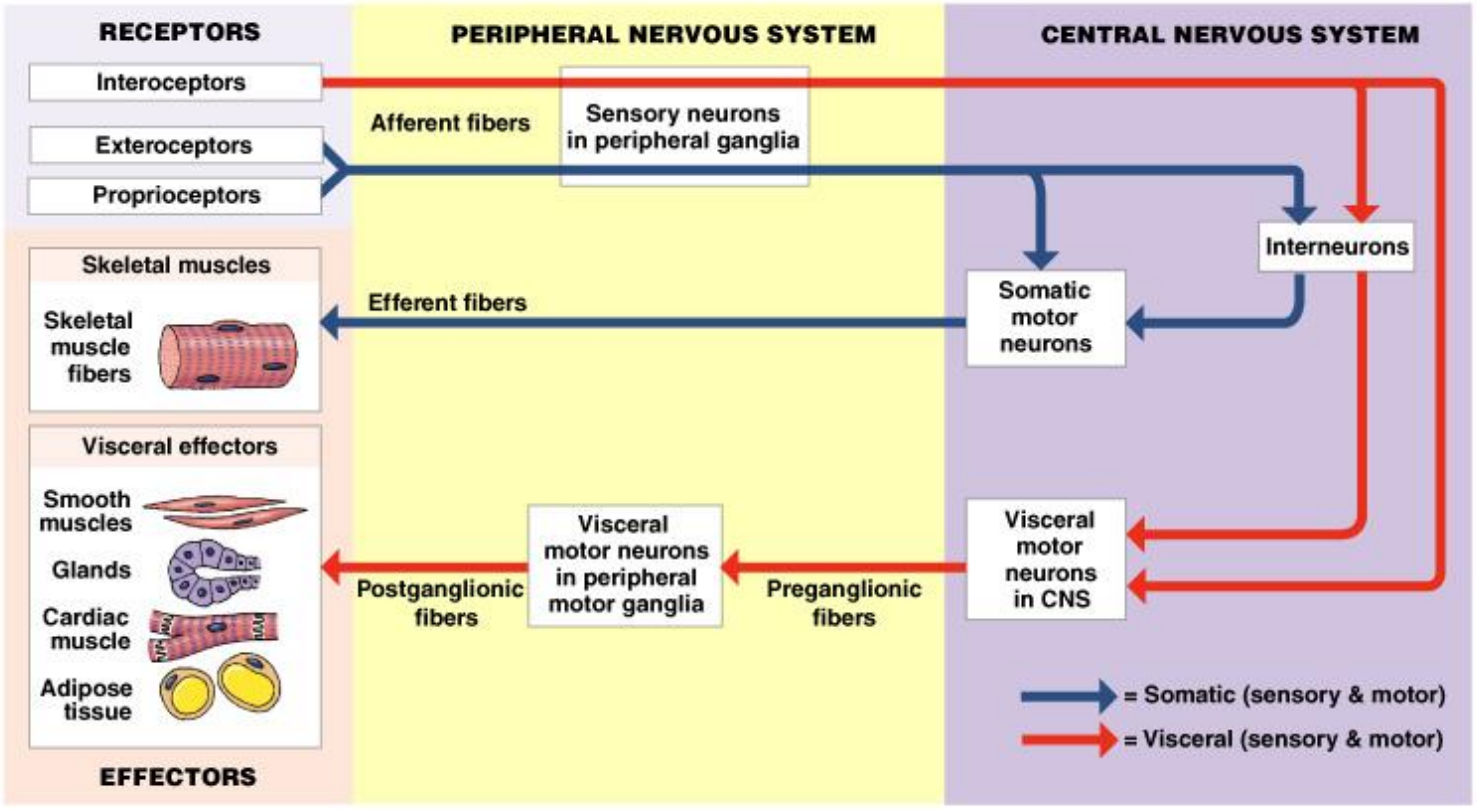
Double contoured nerve fiber ⇨ **Schwann sheath** + **Myelin sheath** = **Neurilemma**





Nervous system – Peripheral x Central

CNS is Brain and Spinal cord + PNS is everything else



Human Anatomy, 5e
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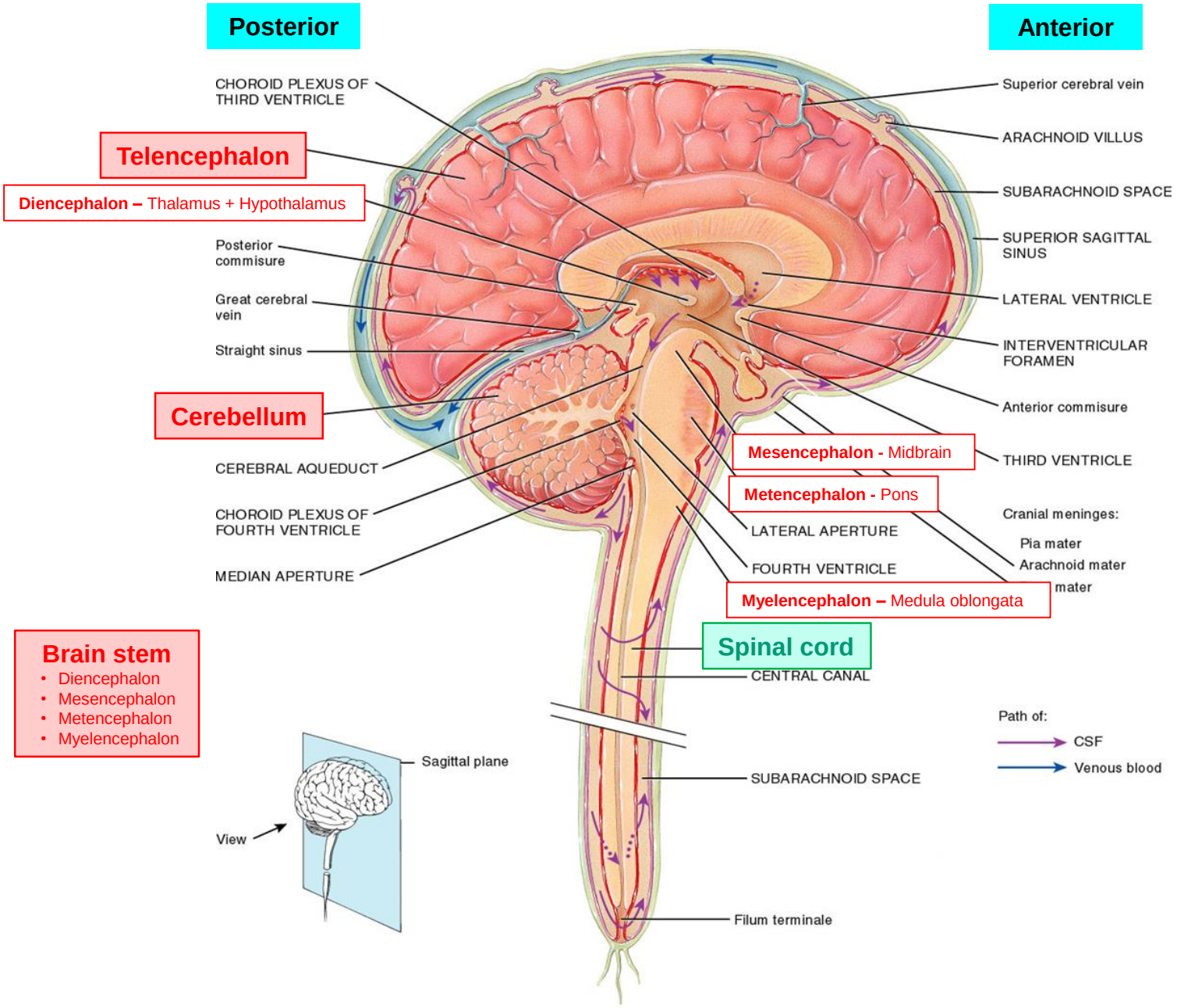
Central nervous system – Brain + Spinal cord



Central nervous system – Neuronal organization

Gray matter

- **Cell bodies**
- **Nonmyelinated neurons** (dendrites, proximal + distal ends of axons)
- **Neuroglia** (plasmatic astrocytes, microglia)
- **Capillaries** (Blood-Brain barrier)

- forms the outer layer of the cerebrum cerebral cortex

- also forms nuclei deep in the brain = clusters of neuronal cell bodies in CNS

- collections of nuclei can form a centers (higher brain function)

White matter

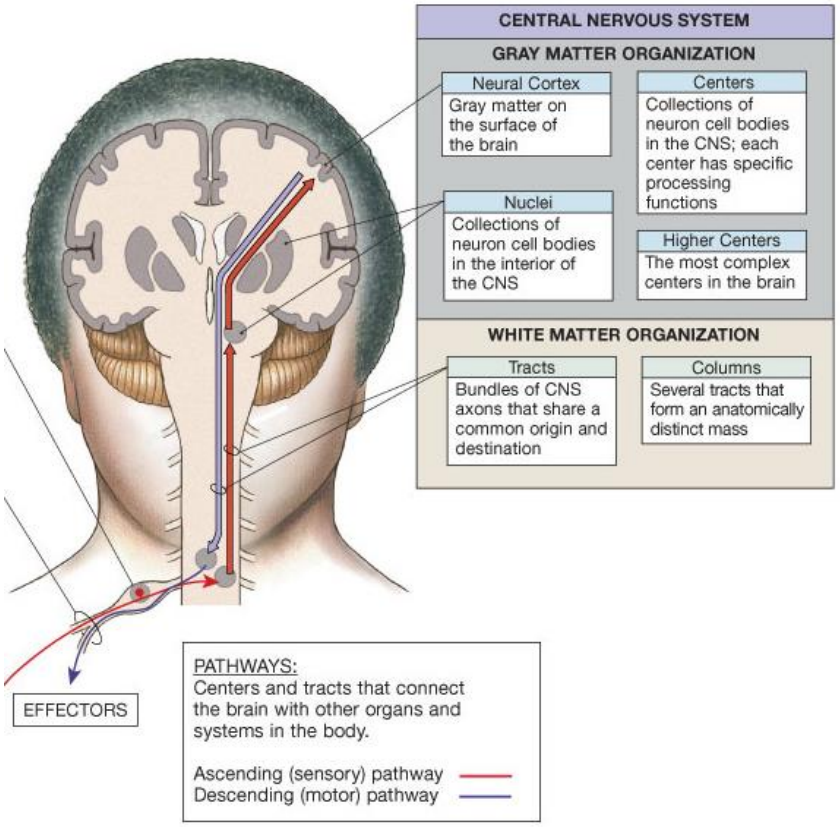
- **Myelinated axons of nerve cells**
- **Neuroglia** (oligodendrocytes, fibrilar astrocytes)
- **Blood capillaries** (lesser density than in the gray matter)

Brain

- axons are bundled together to form **white matter tracts** conduct nerve impulses from gray region to gray region
- three types of tracts (**commisural, association, projection)**

Spinal cord

- **sensory and motor tracts** (ascending and descending)



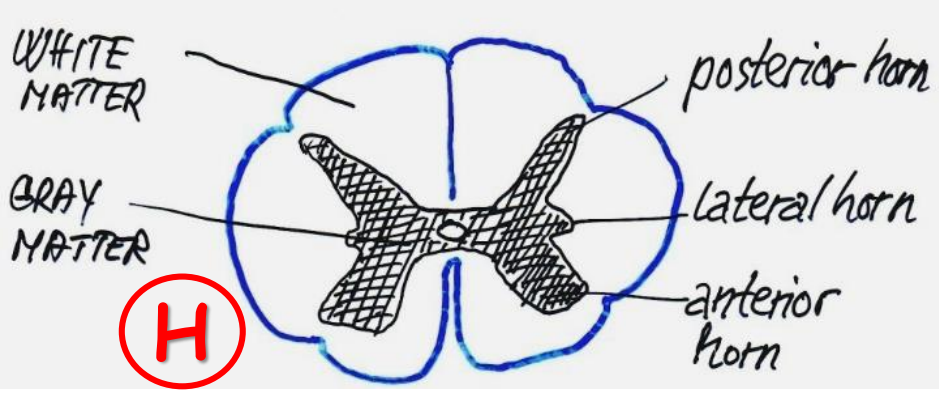
Central nervous system – Distribution of grey/white matter

Telencephalon + Cerebellum

Gray matter:
- covers surface of both hemispheres forming the folded plate - **cortex**
- forms islands nearby ventricular system – **telencephalic and/or cerebellar nuclei**
- centrally located **also in brain stem**

White matter:
- occupies the interior of hemispheres

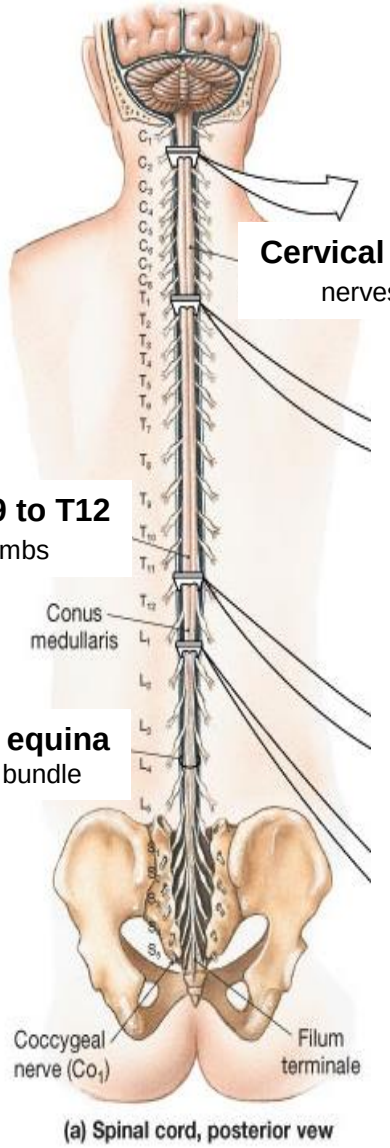
X



Spinal cord

Gray matter:
- **centrally** forms the **core of the organ** - resembles letter **H**
- **at the periphery** it is surrounded by funiculi of the white matter

Central nervous system – Spinal cord - Anatomy



(a) Spinal cord, posterior vew

Cervical enlargement - C4 to T1
nerves to and from upper limbs

Lumbar enlargement – T9 to T12
nerves to and from lower limbs

Cauda equina
nerve bundle

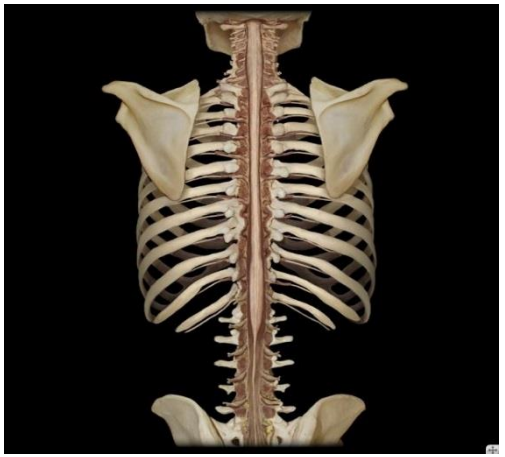
C1

Approx. 40-50 cm

L1

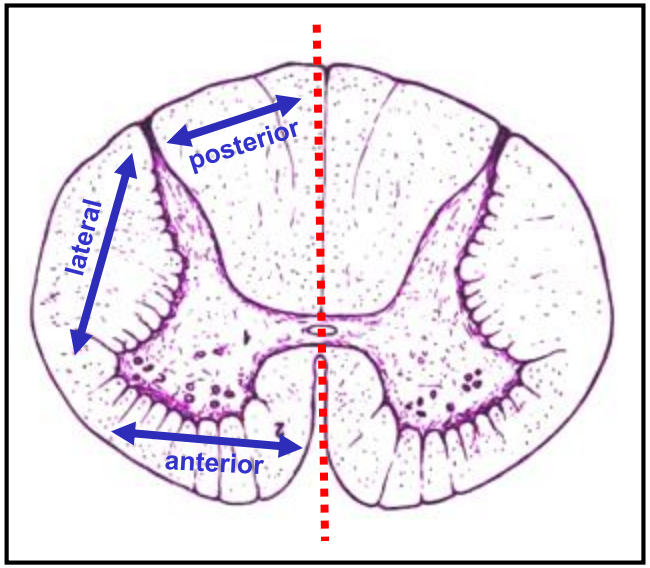
- **Cylindical strand**
- **Narrowed conically**
- **Bilaterally symmetrical**
- **Central canal**

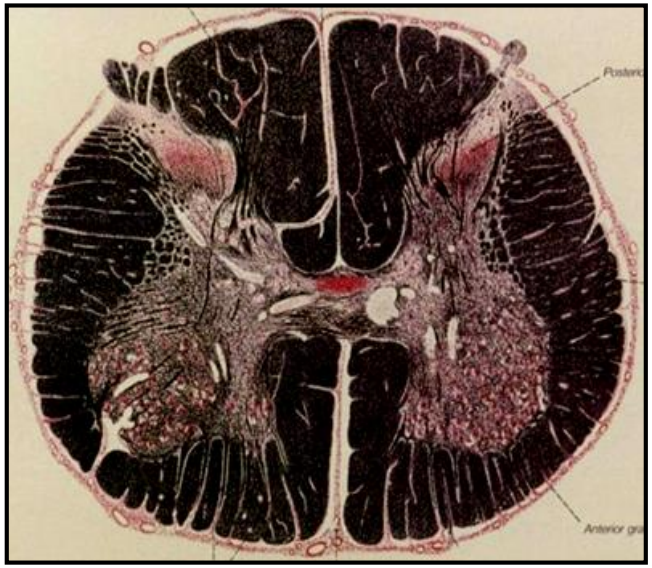
31 segments
+
31 pairs of *spinal nerves*



Central nervous system – Spinal cord – White matter

POSTERIOR





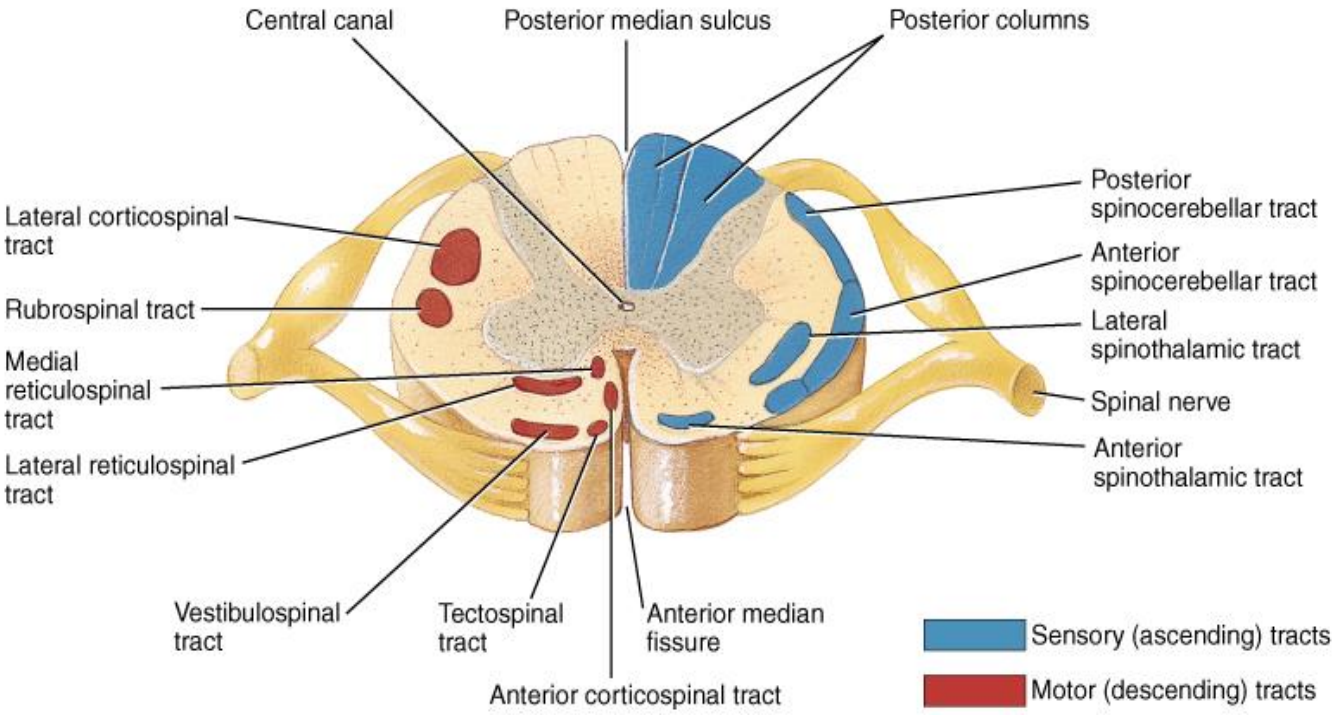
Fasciculi = Funiculi (= Collumns)

- **Anterior –** sensitive tracts + motoric tracts
- **Lateral –** sensitive tracts + motoric tracts
- **Posterior –** sensitive tracts

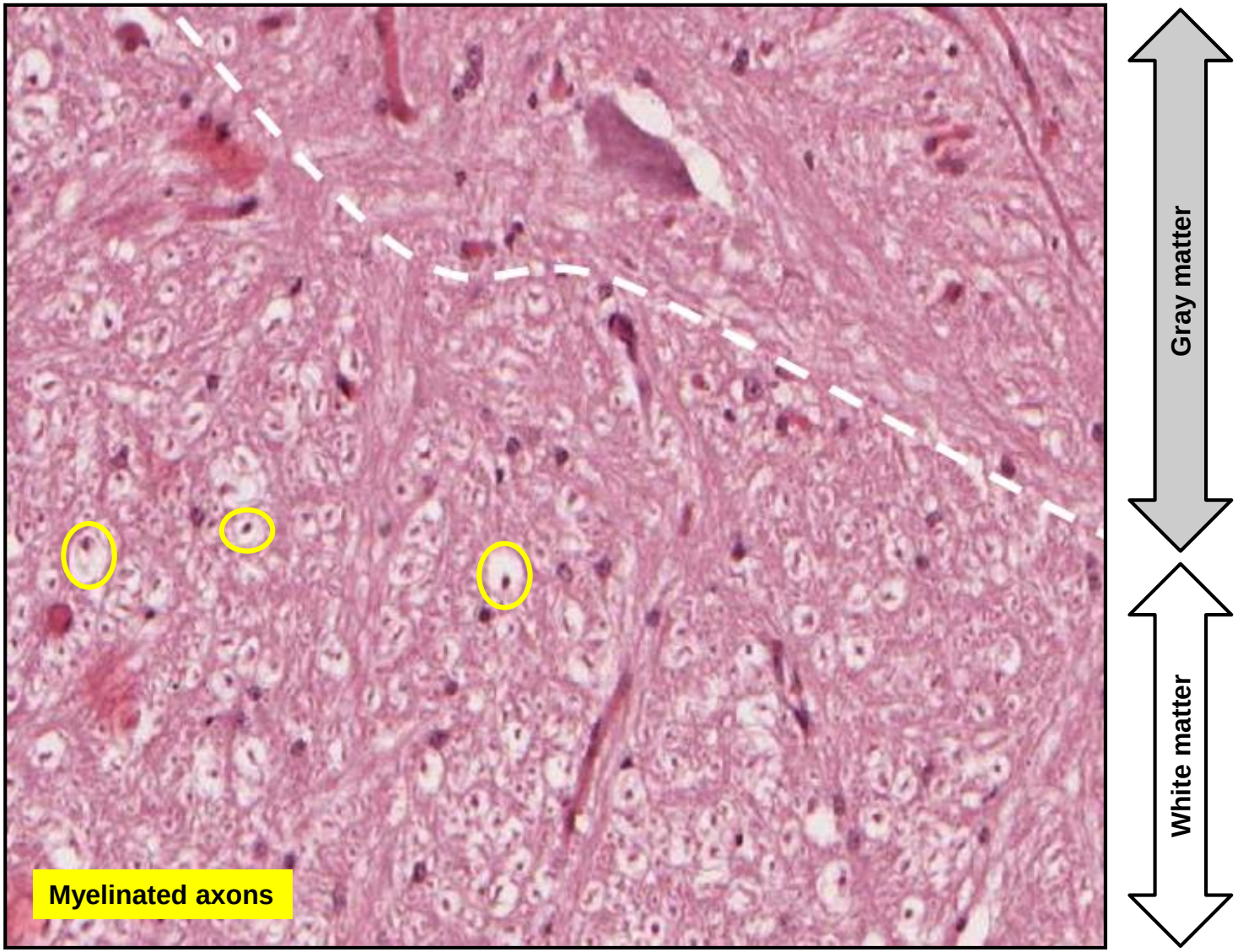
Sensitive = Ascending
Motoric = Descending

Spinal cord – White matter - Tracts

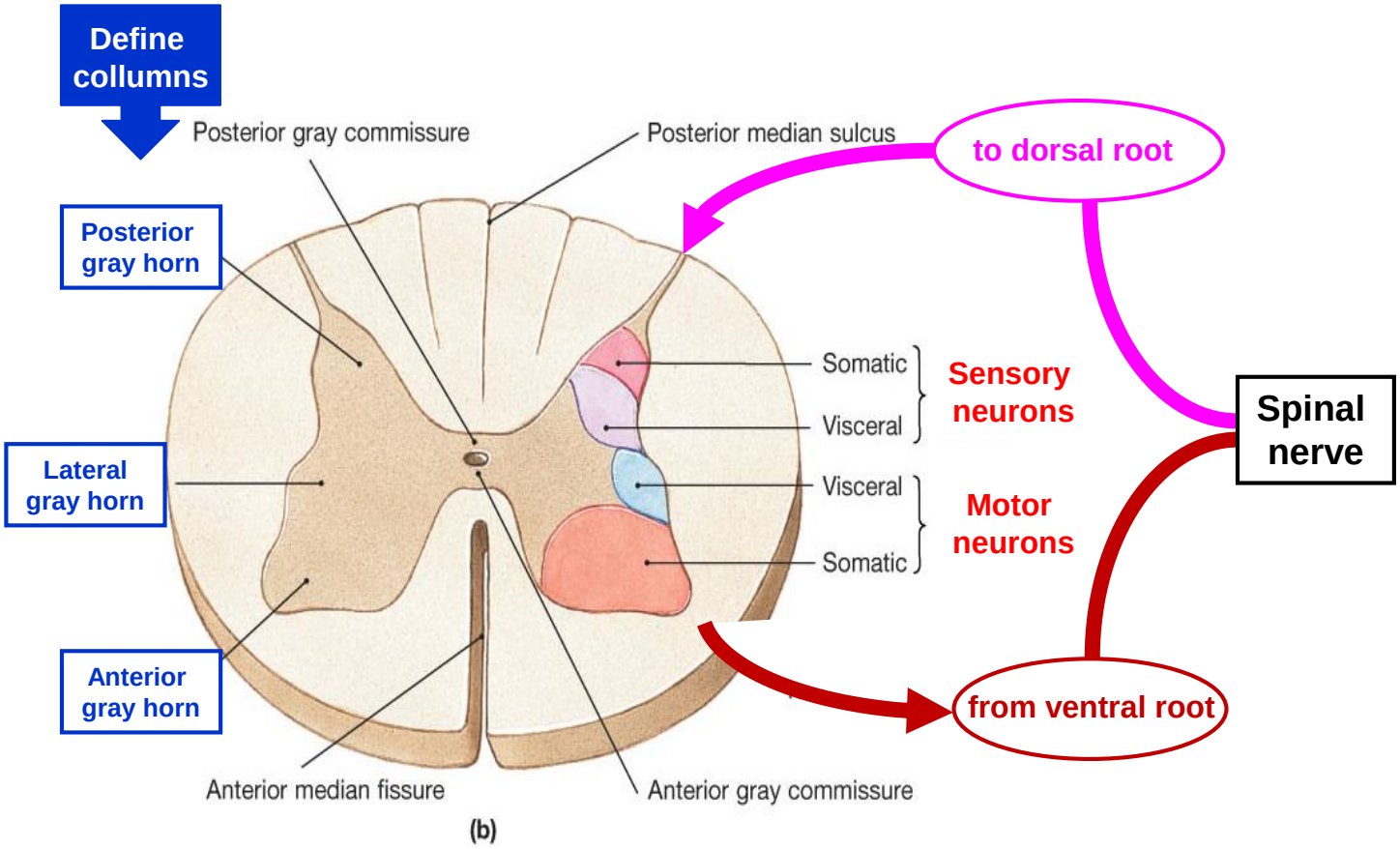
Only for demonstration purpose – no need of memorizing !!!



Spinal cord – White matter



Spinal cord – Gray matter – Organization



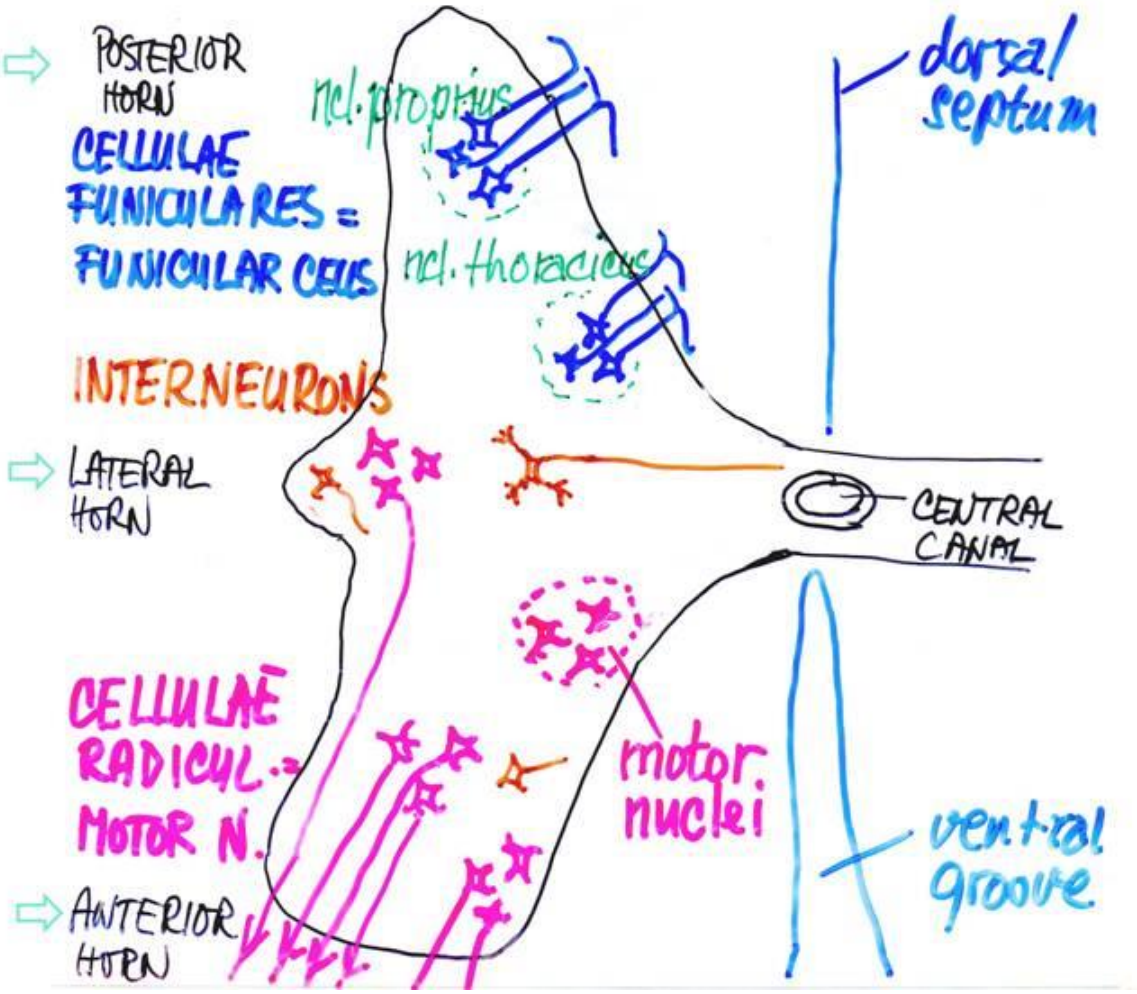
Neurons in gray matter – all are multipolar

Motor neurons (radicular)
- in the anterior (ventral) horns
- stellate shape, 150 μm in diameter
- send off long myelinated axons ending on muscle fibres

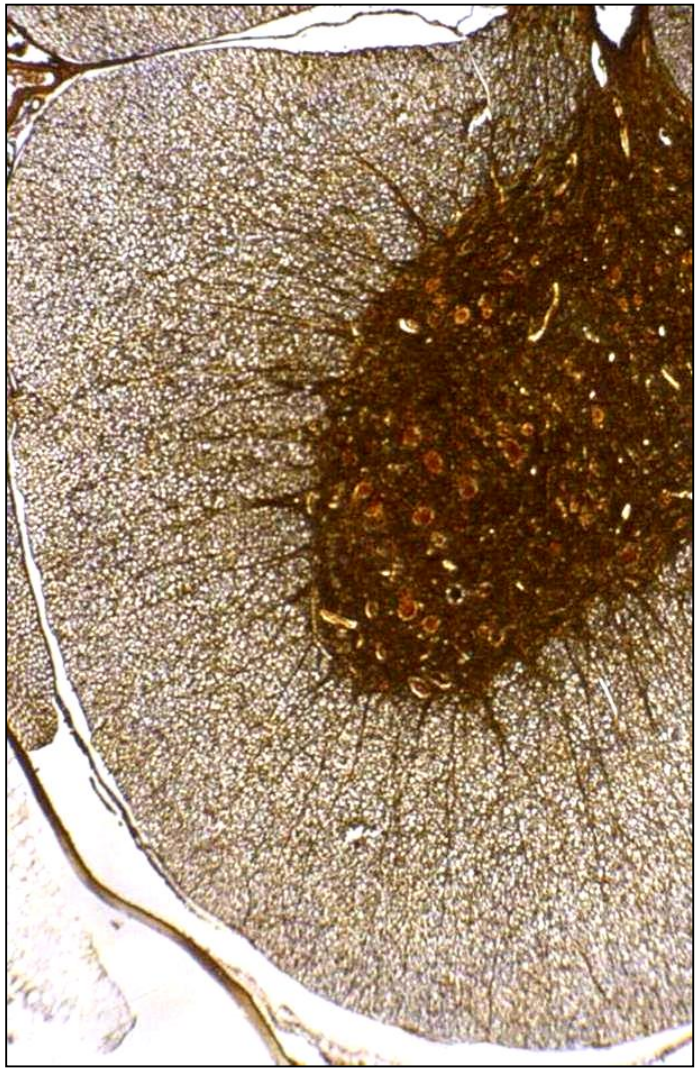
Funicular cells
- mainly in the posterior horns
- their axons enter the white matter and connect to other segments of SC and to brain stem

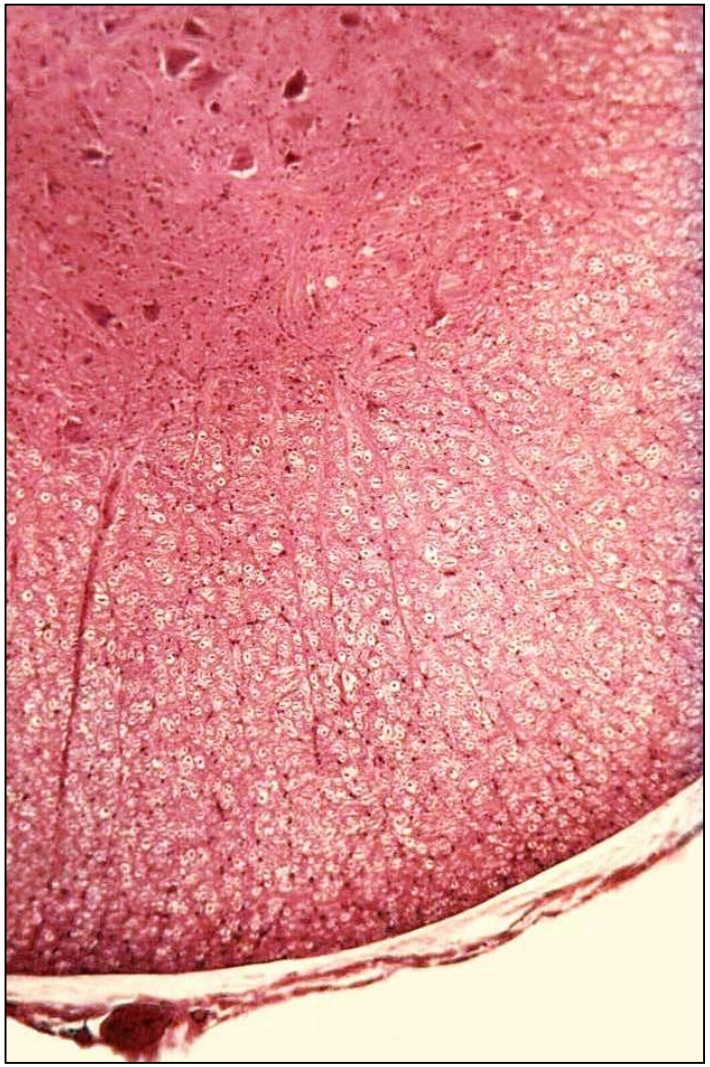
Interneurons
- small neurons
- diffusely distributed among motor and funicular cells

Spinal cord – Gray matter – Organization

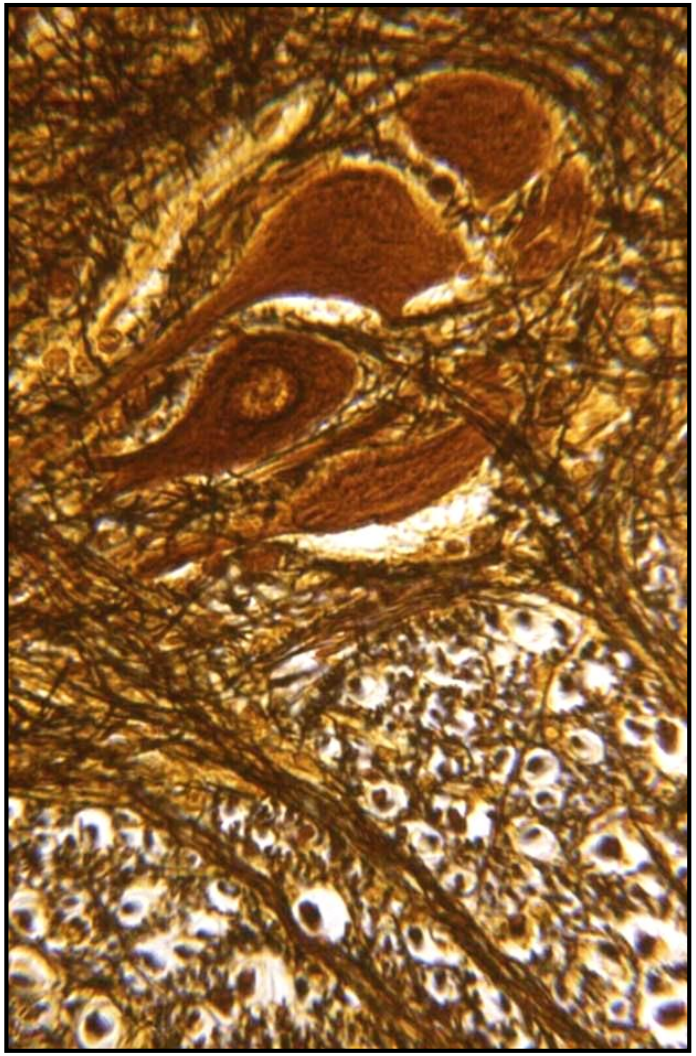


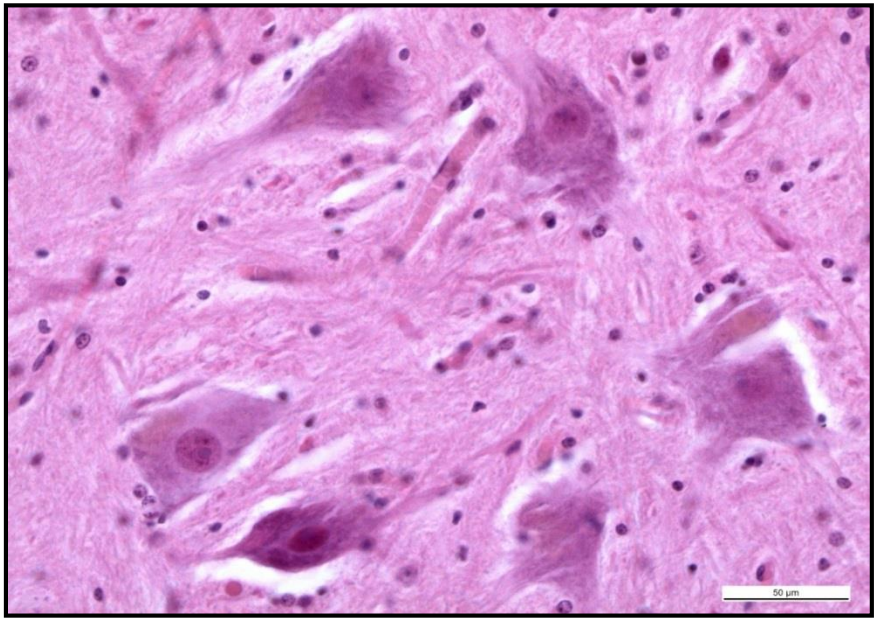
Spinal cord – Gray matter

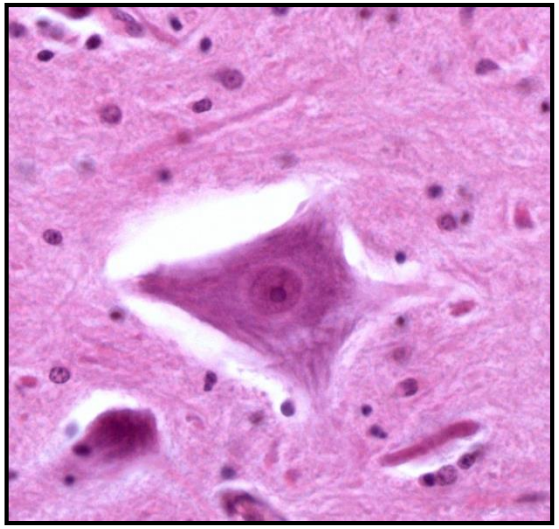


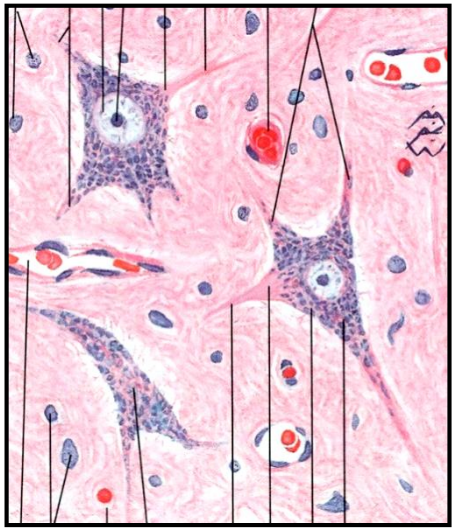


Spinal cord – Gray matter – Motor neurons



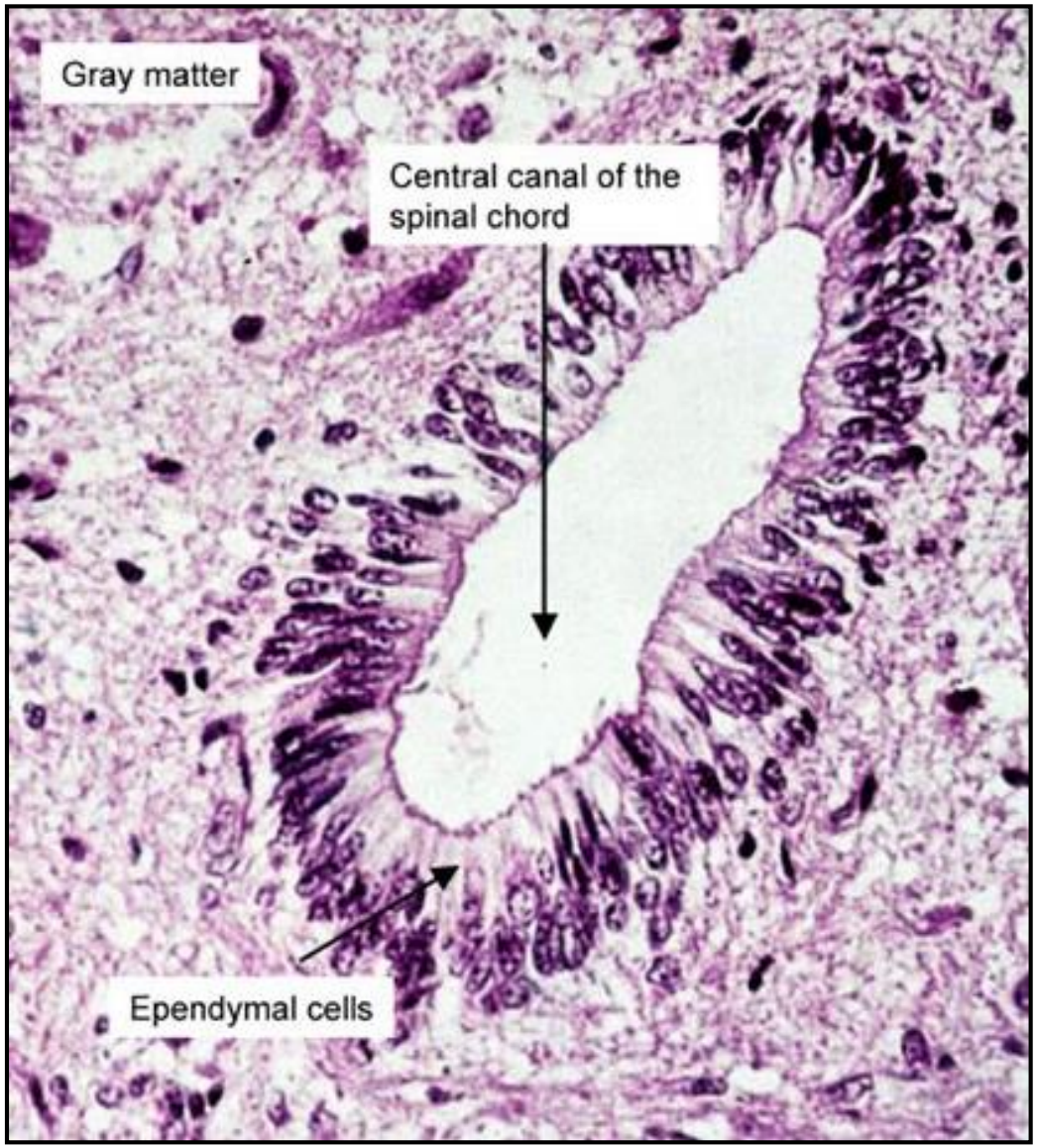






Spinal cord – Central spinal canal

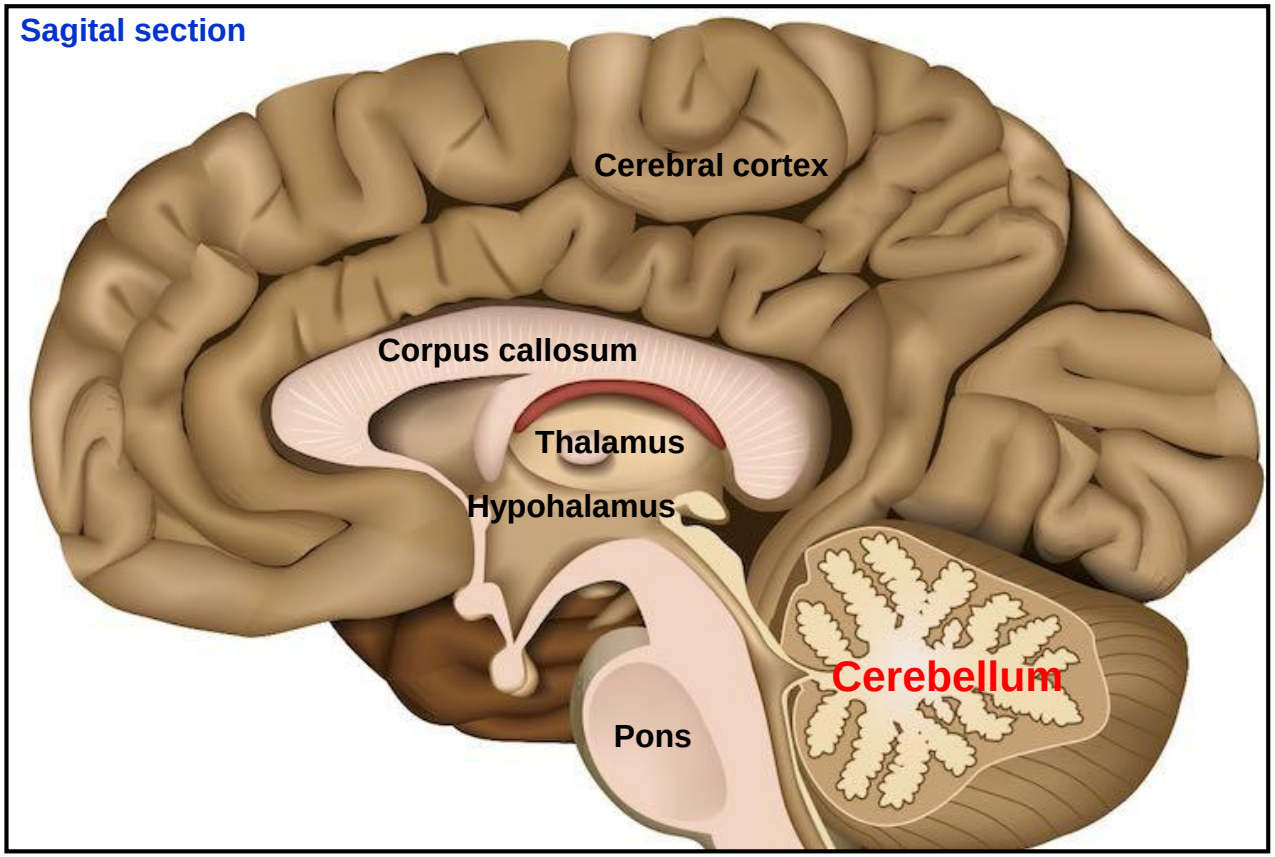
Spinal cord – Central spinal canal



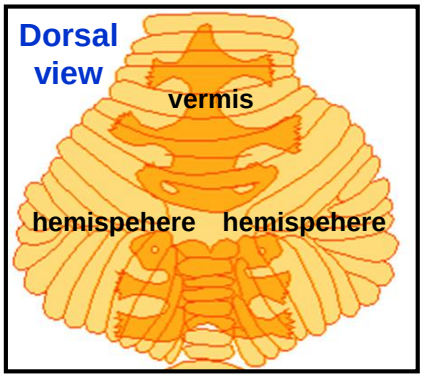
Cerebellum

Function

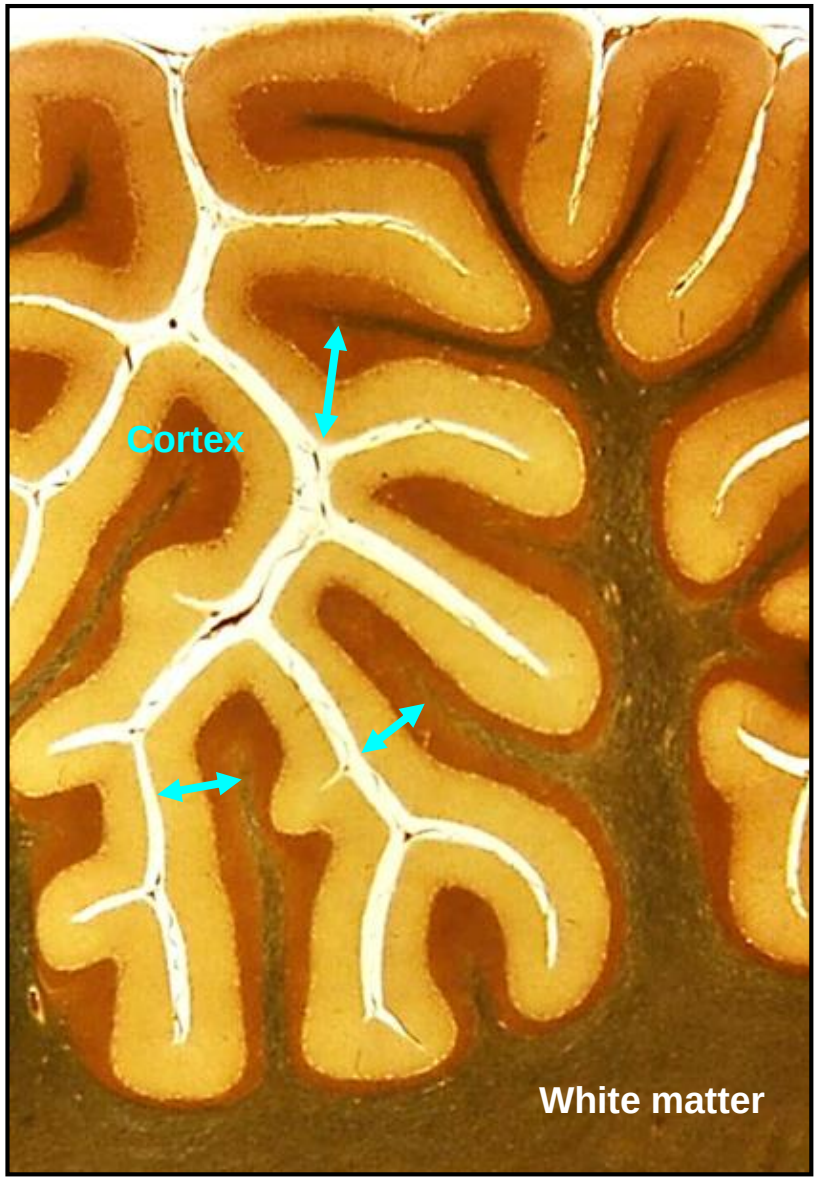
- co-ordination of voluntary movements and helping to maintain balance
- allows for smooth, co-ordinated movements by constantly adjusting muscle tone and posture



Weight: 130 grams
Surface area: 0,10 - 0,15 m^2



Cerebellum – Gray matter



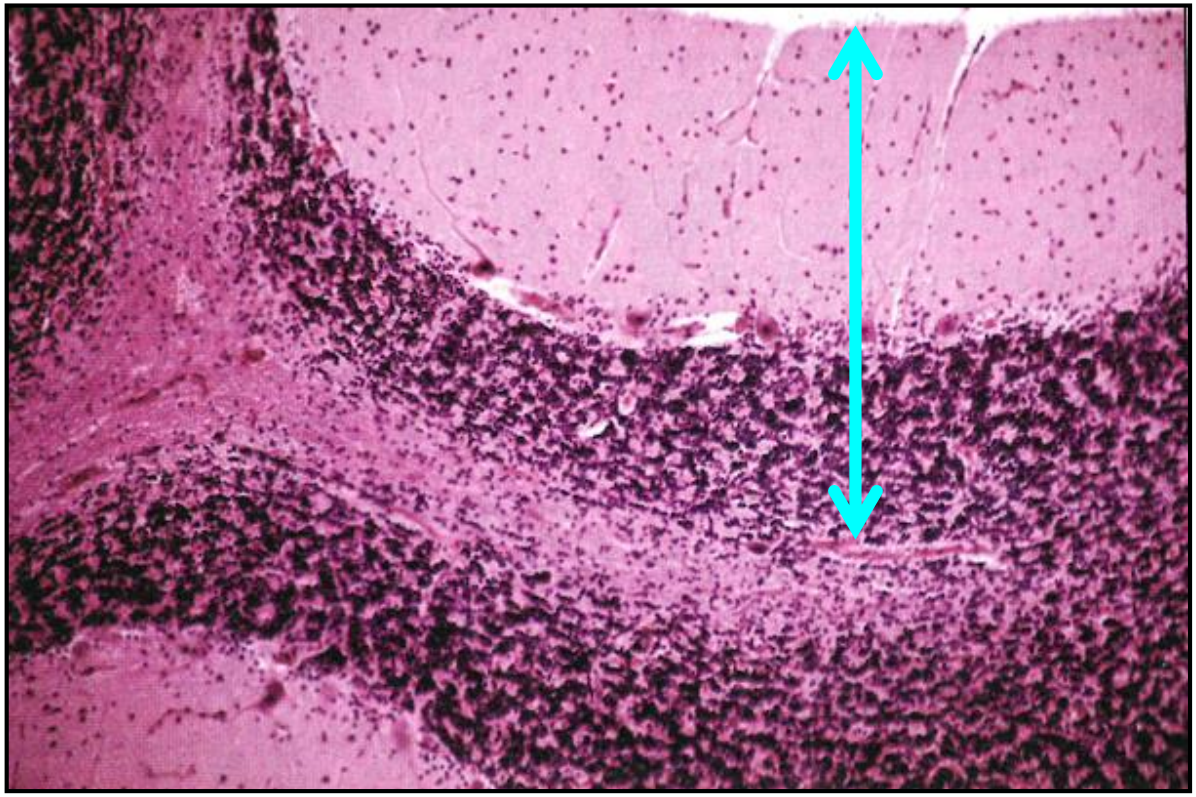
Gray matter

- **Cortex at the surface** (1 mm thick)
- **Nuclei in white matter** (nucleus dentatus, emboliformis, globusus, and fastigii)

Cerebellum – White matter

„Arbor vitae“ – white matter

Cerebellum – Cortex

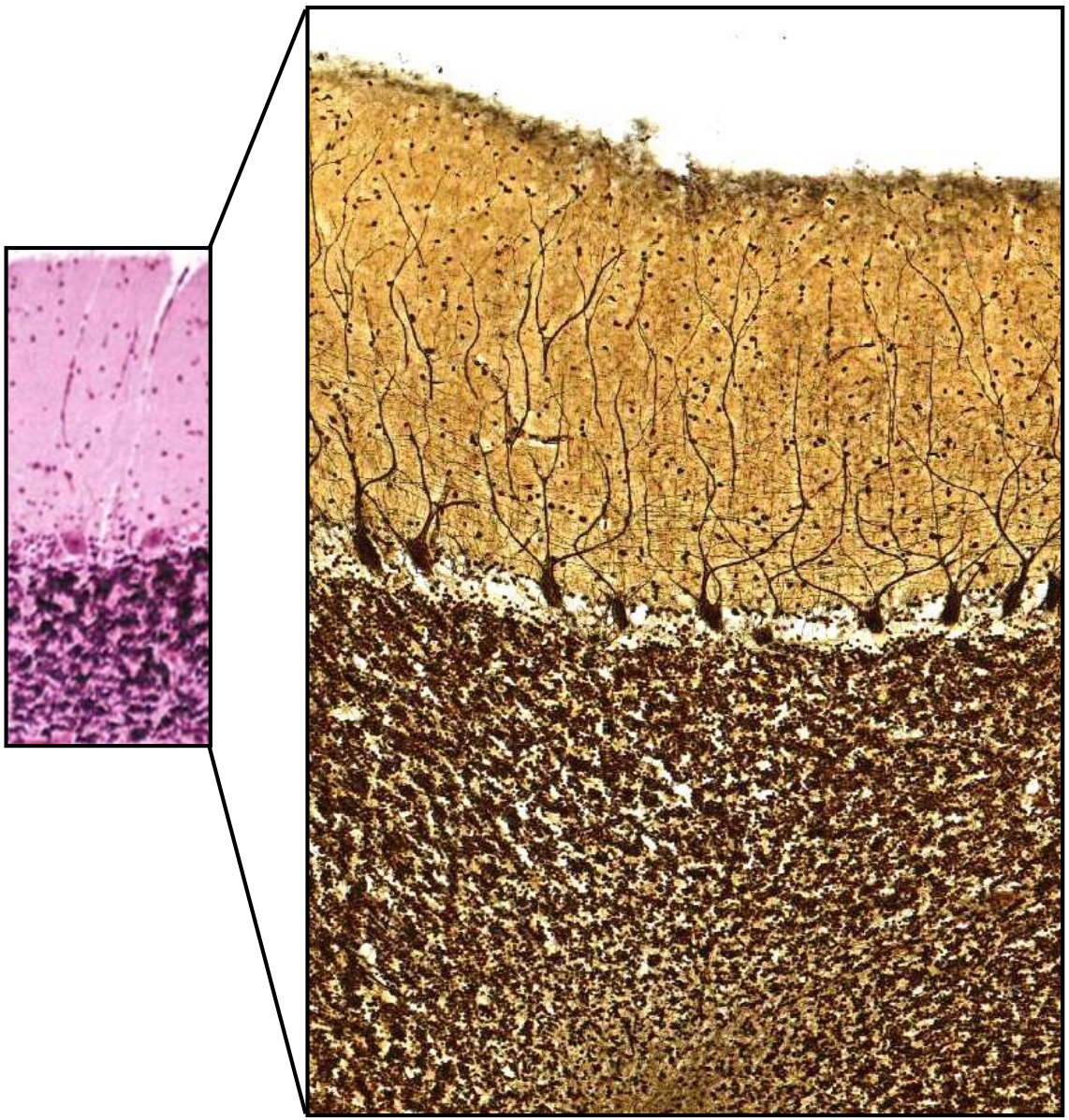


Molecular layer
(stratum moleculare)

Purkinje cell layer
(stratum gangliosum)

Granule cell layer
*(stratum granulosum**)***

Cerebellum – Cortex - Cells

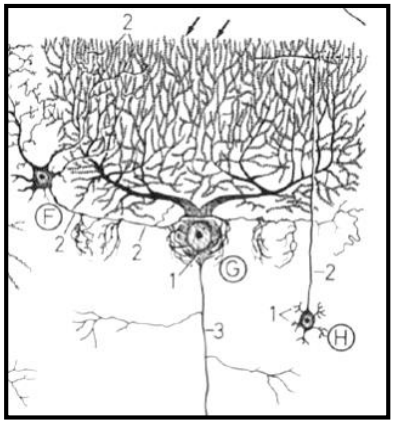


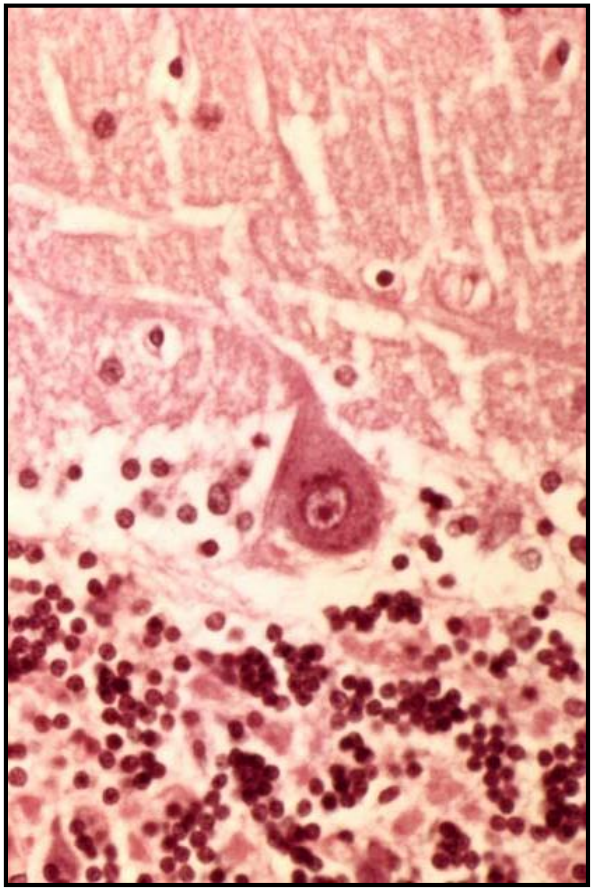
Molecular layer
(stratum moleculare)
- Basket cells
- Stellate cells

Purkinje cell layer
(stratum gangliosum)
- Perikaryons of Purkinje cells
- Golgi (Bergman) glial cells

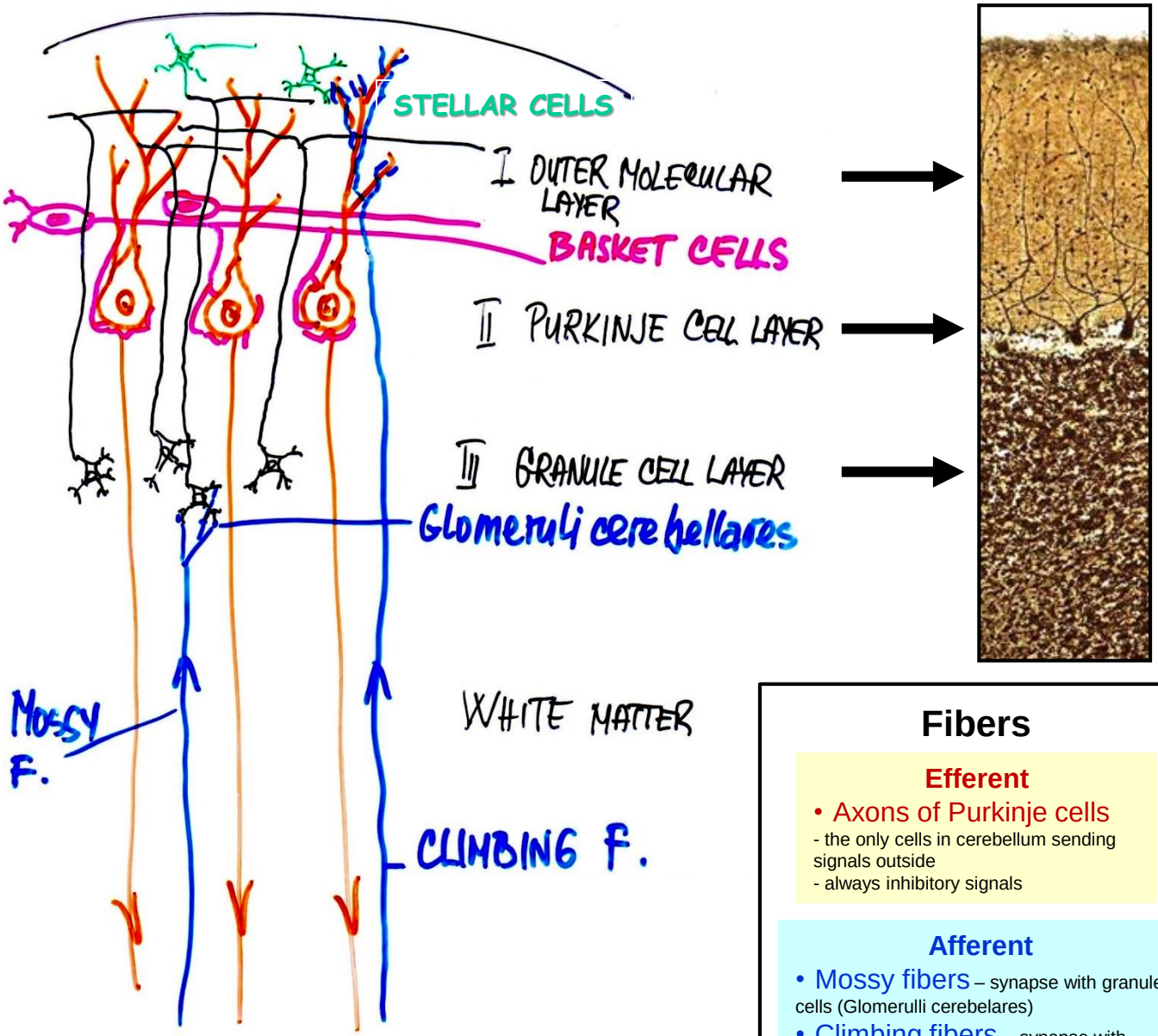
Granule cell layer
(stratum granulosum)
- Granule cells
- Golgi (Bergman) glial cells

Cerebellum – Purkinje cells





Cerebellum – Cortex – Cells and Fibers



Fibers

Efferent

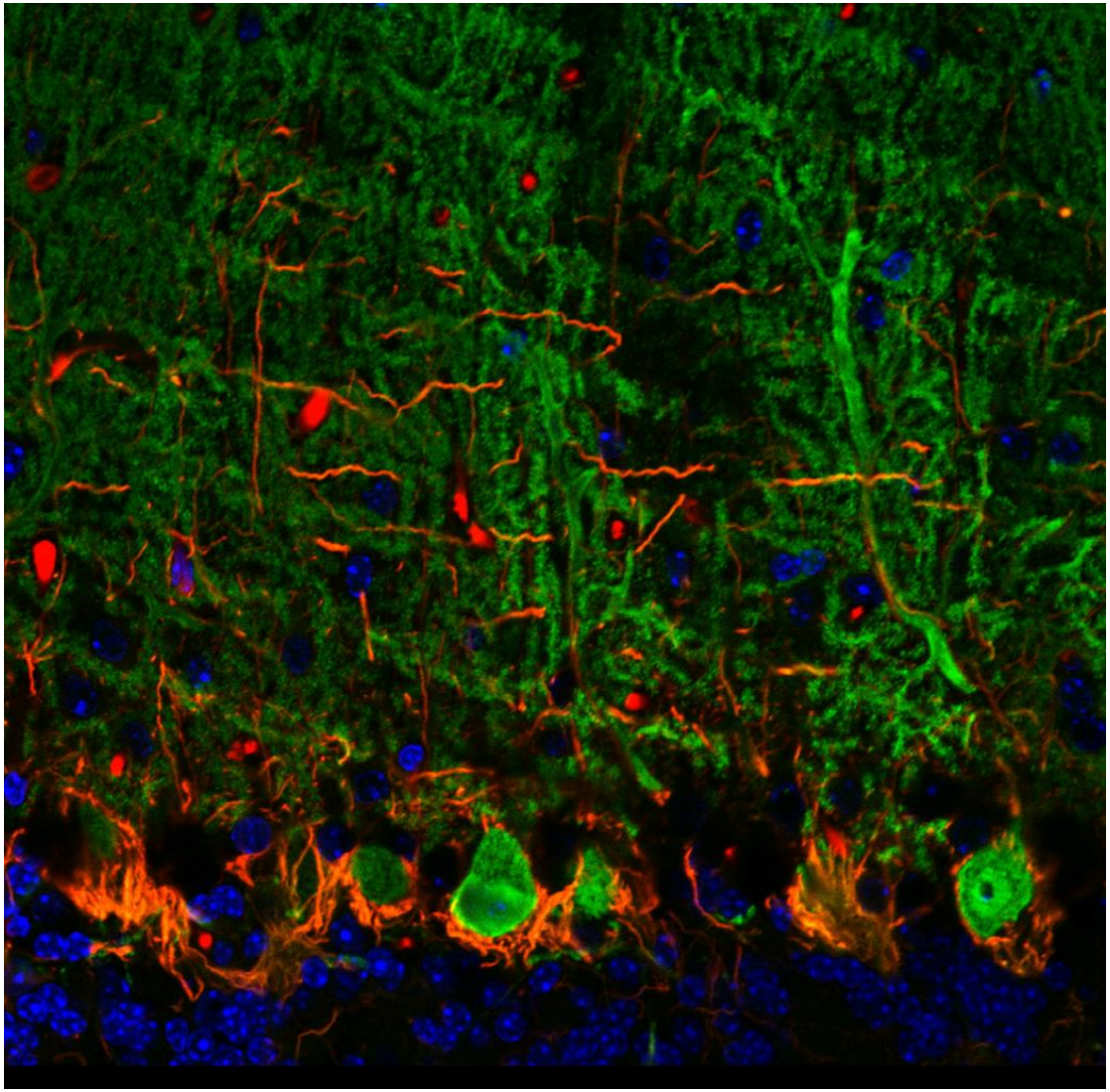
- Axons of Purkinje cells

- the only cells in cerebellum sending signals outside
- always inhibitory signals

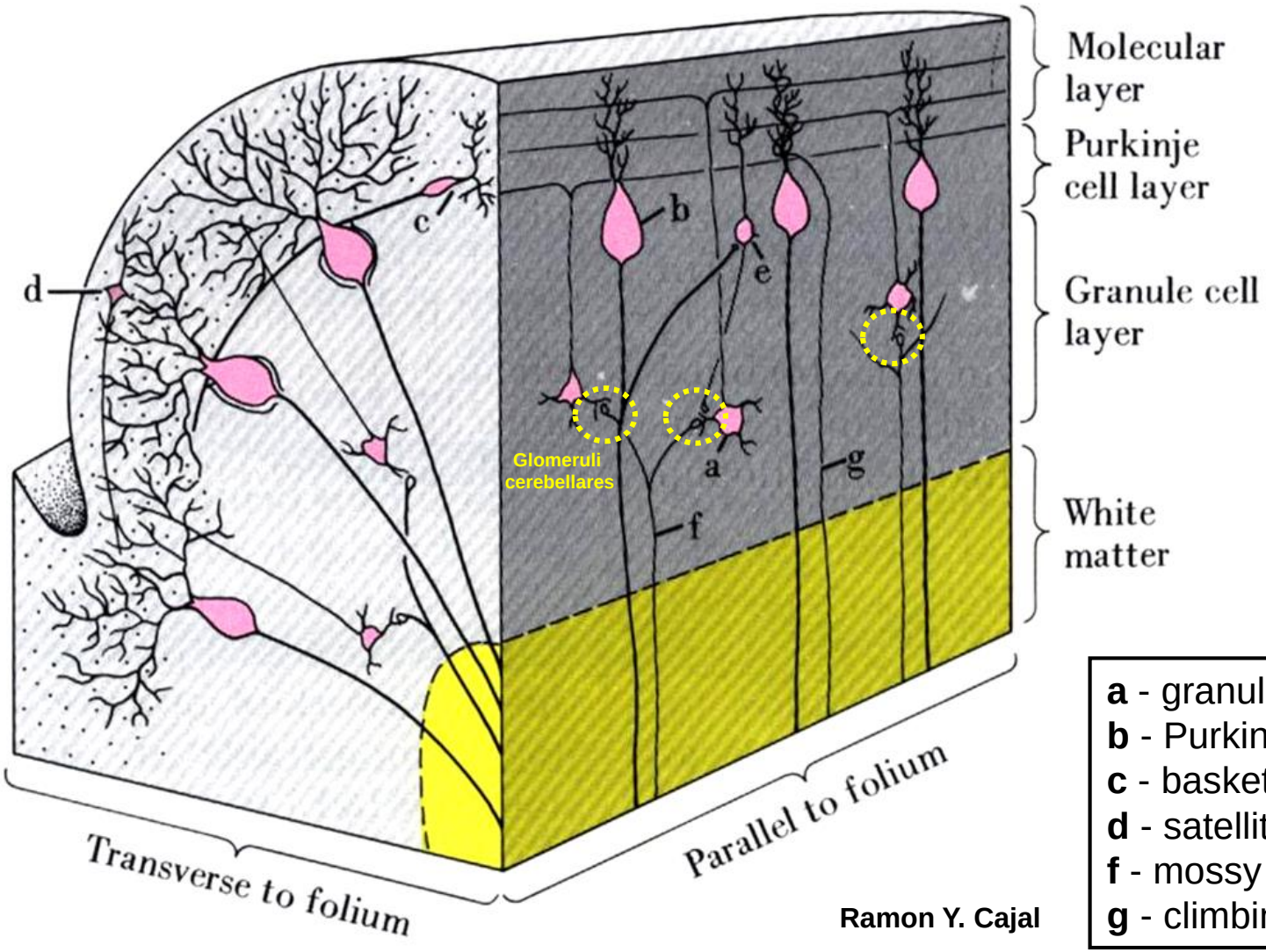
Afferent

- Mossy fibers – synapse with granule cells (Glomerulli cerebelares)
- Climbing fibers – synapse with dendrites of Purkinje cells

Cerebellum – Cortex – Cells and Fibers



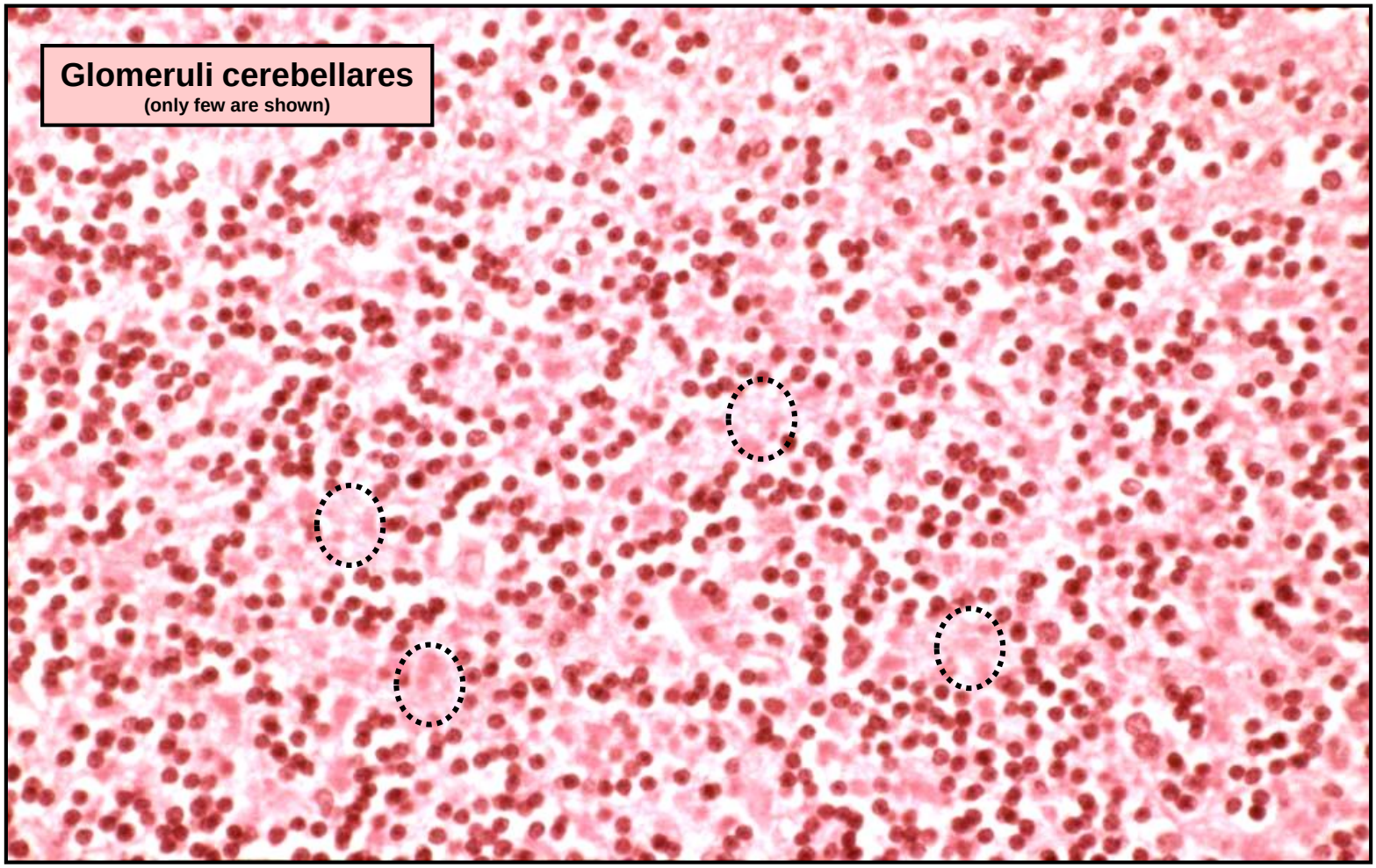
Cerebellum – Cortex – Cells and Fibers



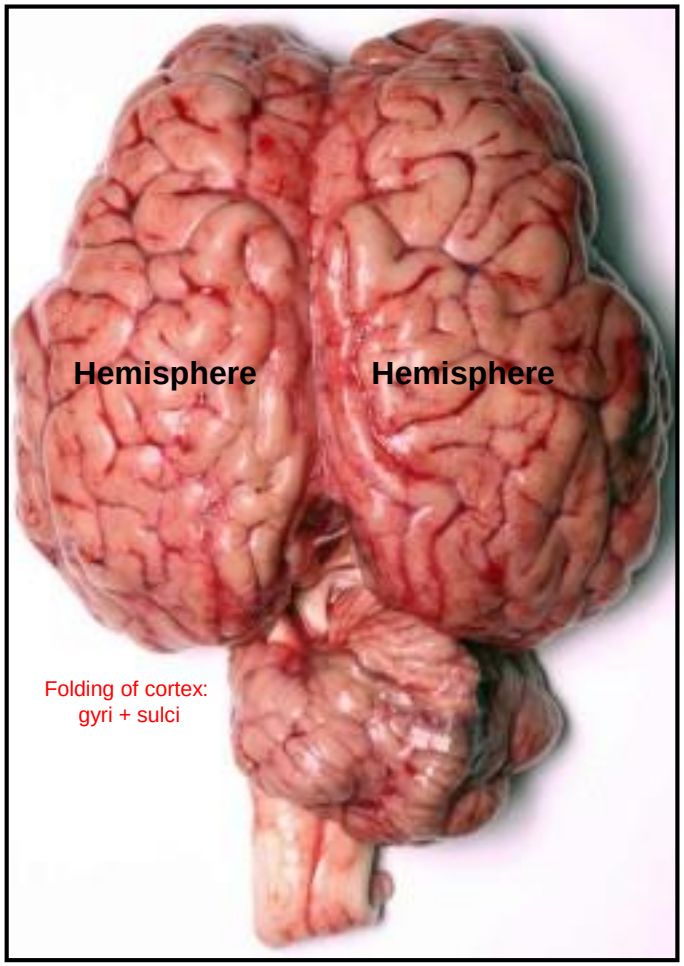
Ramon Y. Cajal

a - granule cells
b - Purkinje cells
c - basket cells
d - satellite cells
f - mossy fibers
g - climbing fibers

Cerebellum – Cortex – Cells and Fibers



Telencephalon



Gray matter

- Cortex at the surface
- Nuclei in white matter

White matter

- Among the cortex and nuclei

Telencephalon – Cerebral cortex

Functions:

- perception and conscious understanding of all sensations
- integration of different sensory modalities
- higher cognitive and advanced intellectual functions
- responsible for features such as emotion, personality and intellect
- involved in planning and executing complex motor activities

Overall characteristics:

- about 80% of the mass of the brain
- surface area about 0.20 – 0.25 m^2
- thickness about 2 - 5 mm
- contains about 10 billion neurons

Isocortex:

- = neocortex (phylogenetically youngest)
- only in mammals
- 90% of the cortex in humans
- 6 distinguishable layers of cells

Allocortex:

- = archicortex + paleocortex
- less layers of cells
  (e.g. olfactory cortex – 3 layers, hipocampus – 1 layer)

Telencephalon – Cerebral cortex – Neuron types + layers

Pyramidal

- efferent – projecting neurons
- triangular perikaryon (different size)
- axons with myelin sheets
- axons travel to different cortical layers and to subcortical areas

Non-pyramidal

- variety of different cells
- act as interneurons
- axons stay in the layer with their perikayons

(e.g. fusiform cells, granule (stellate) cells, horizontal cells (Cajal), vertical cells (Matinotti)

1. Molecular layer
- horizontal cells (of Cajal)

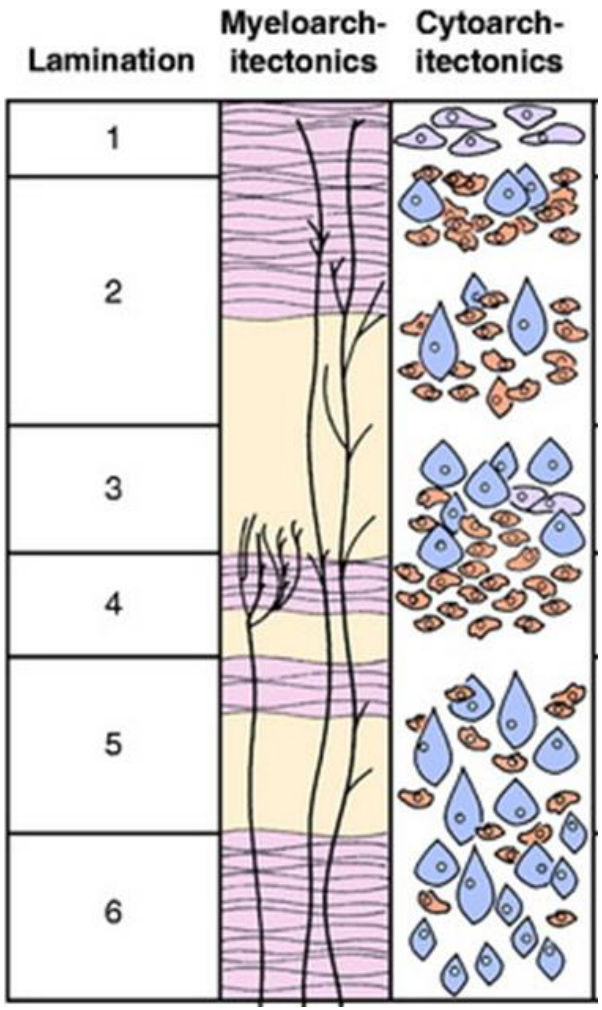
2. Outer granular layer
- small granular (stellate) cells

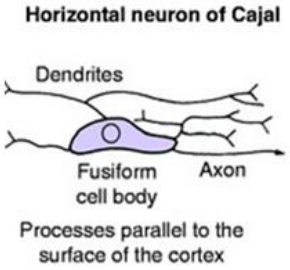
3. Outer pyramidal layer
- pyramidal cells (various sizes)

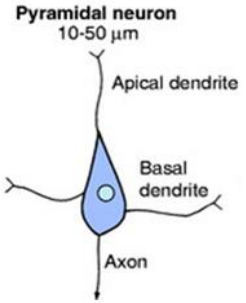
4. Inner granular layer
- small granular (stellate) cells

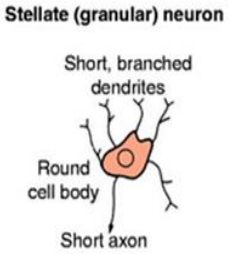
5. Inner pyramidal layer (ganglionic)
- large pyramidal cells (various sizes)

6. Multiform layer
- fusiform cells
- small granular (stellate(cells
- vertical cells (of Martinotti)

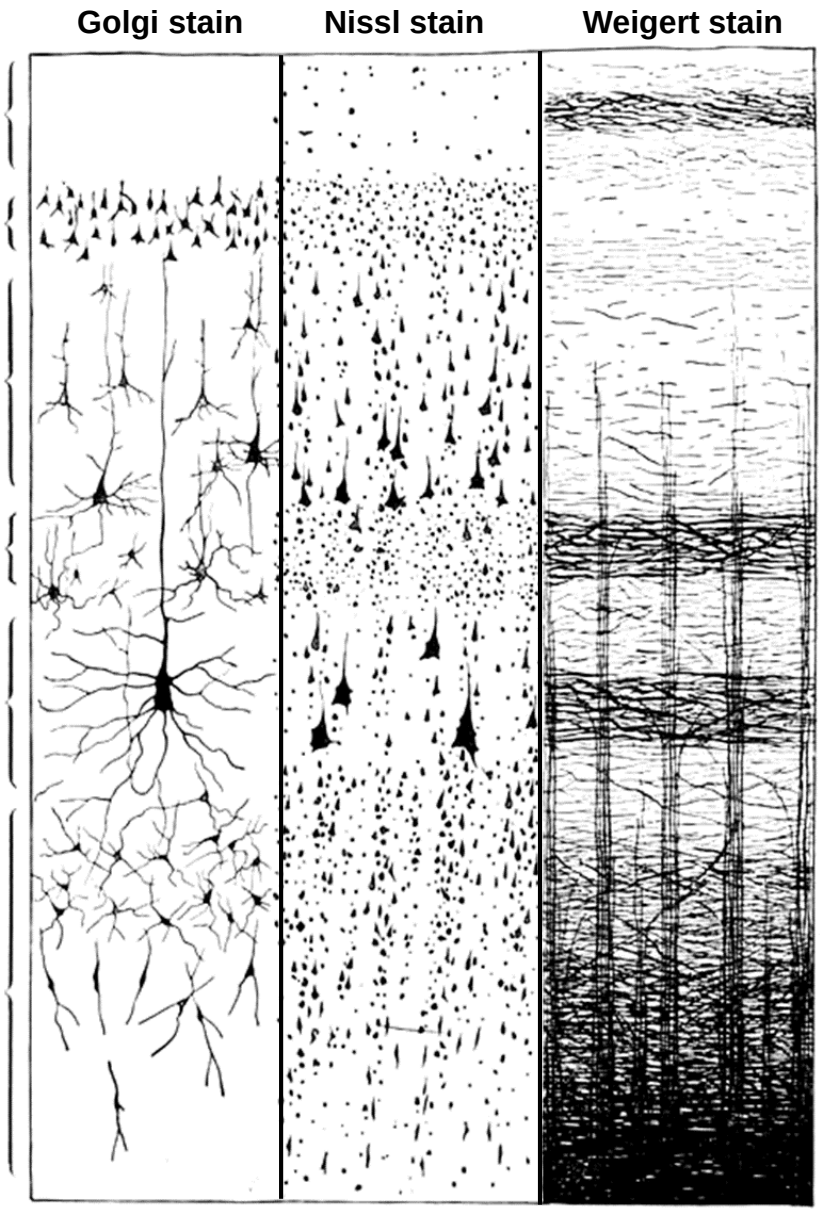








Telencephalon – Cerebral cortex – Cell types + Plexuses



1. Molecular layer
2. Outer granular layer
3. Outer pyramidal layer
4. Inner granular layer
5. Inner pyramidal layer (Ganglionic)
6. Multiform layer

Plexus of Exner

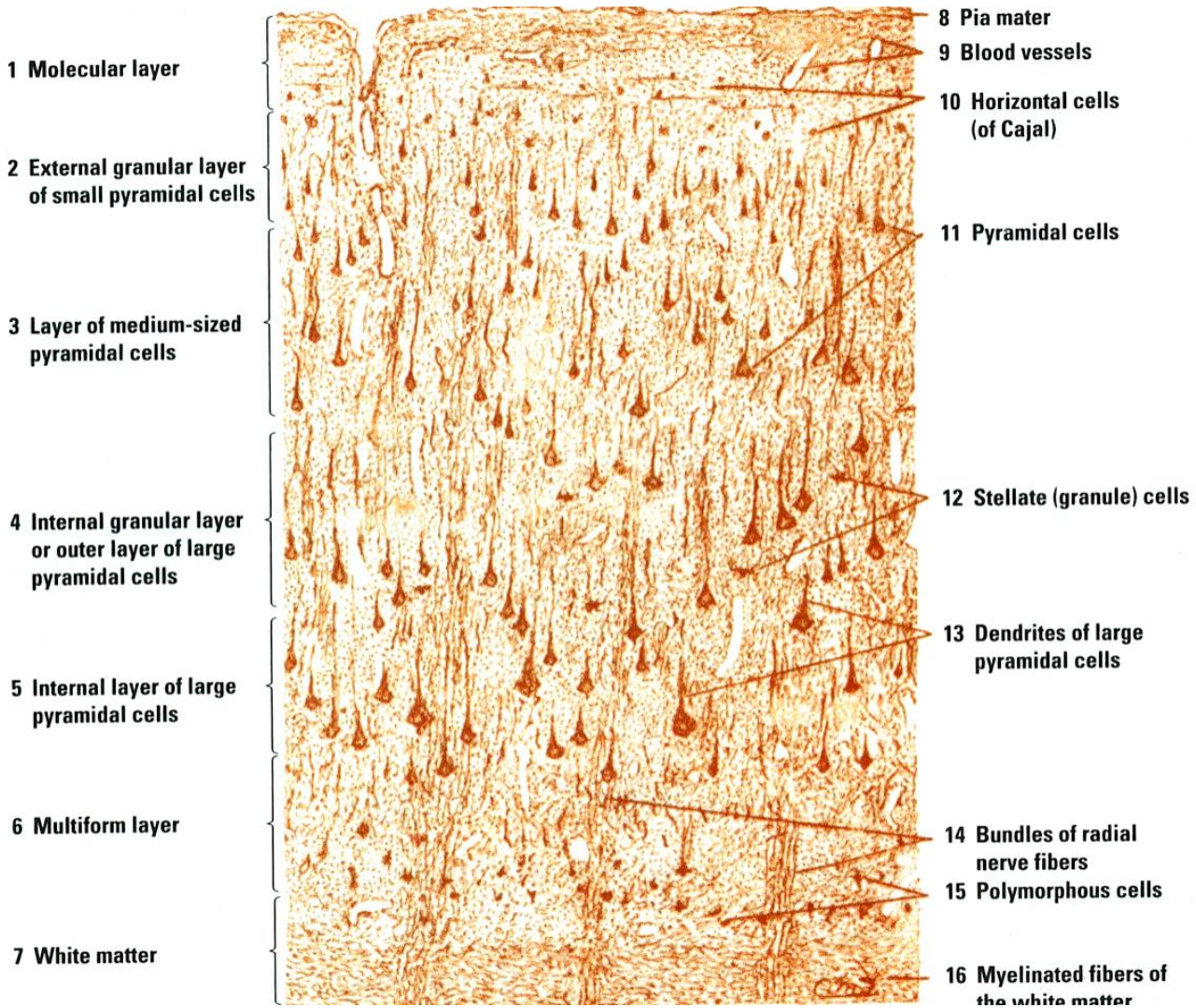
Band of Bechterev

External band of Baillarger

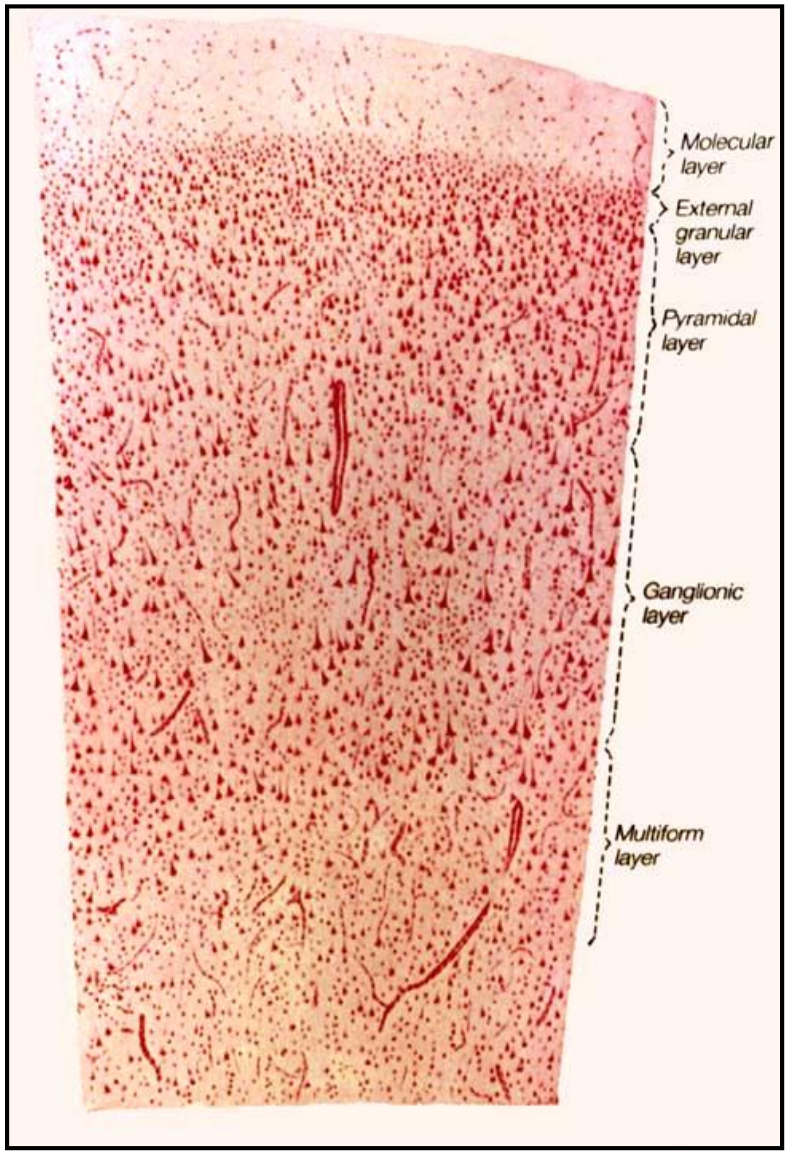
Internal band of Baillarger

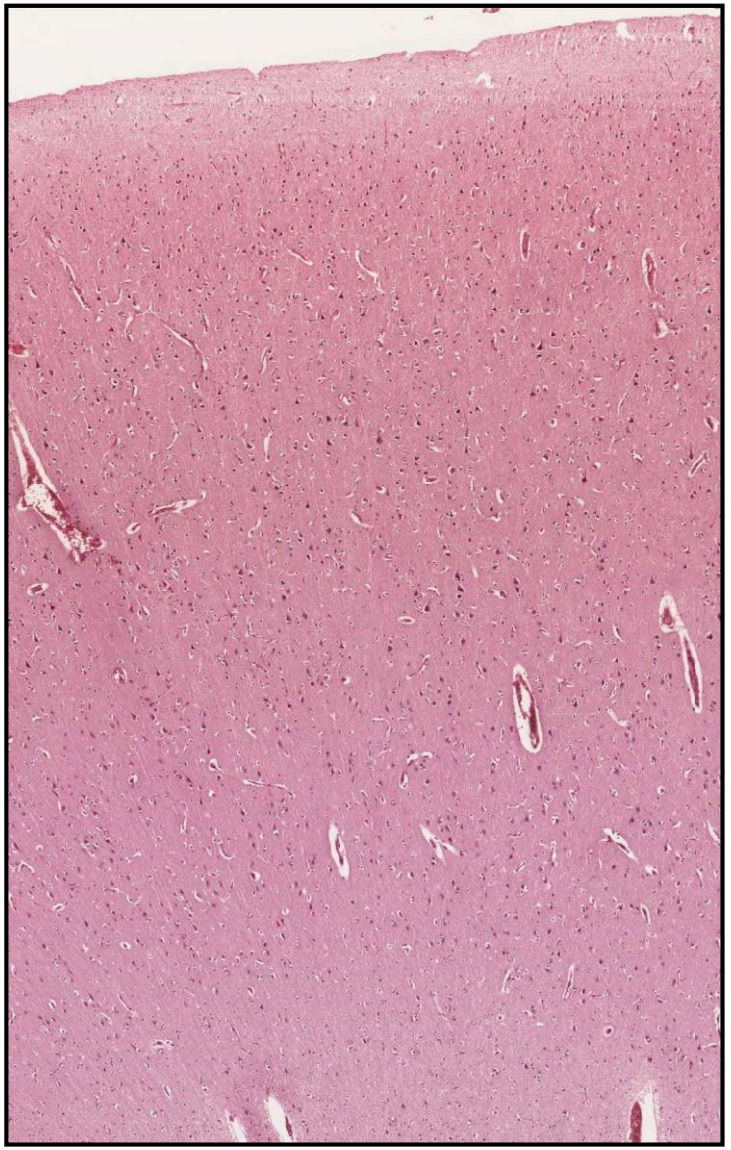
Deep tangential plexus of Meynert

Telencephalon - Isocortex

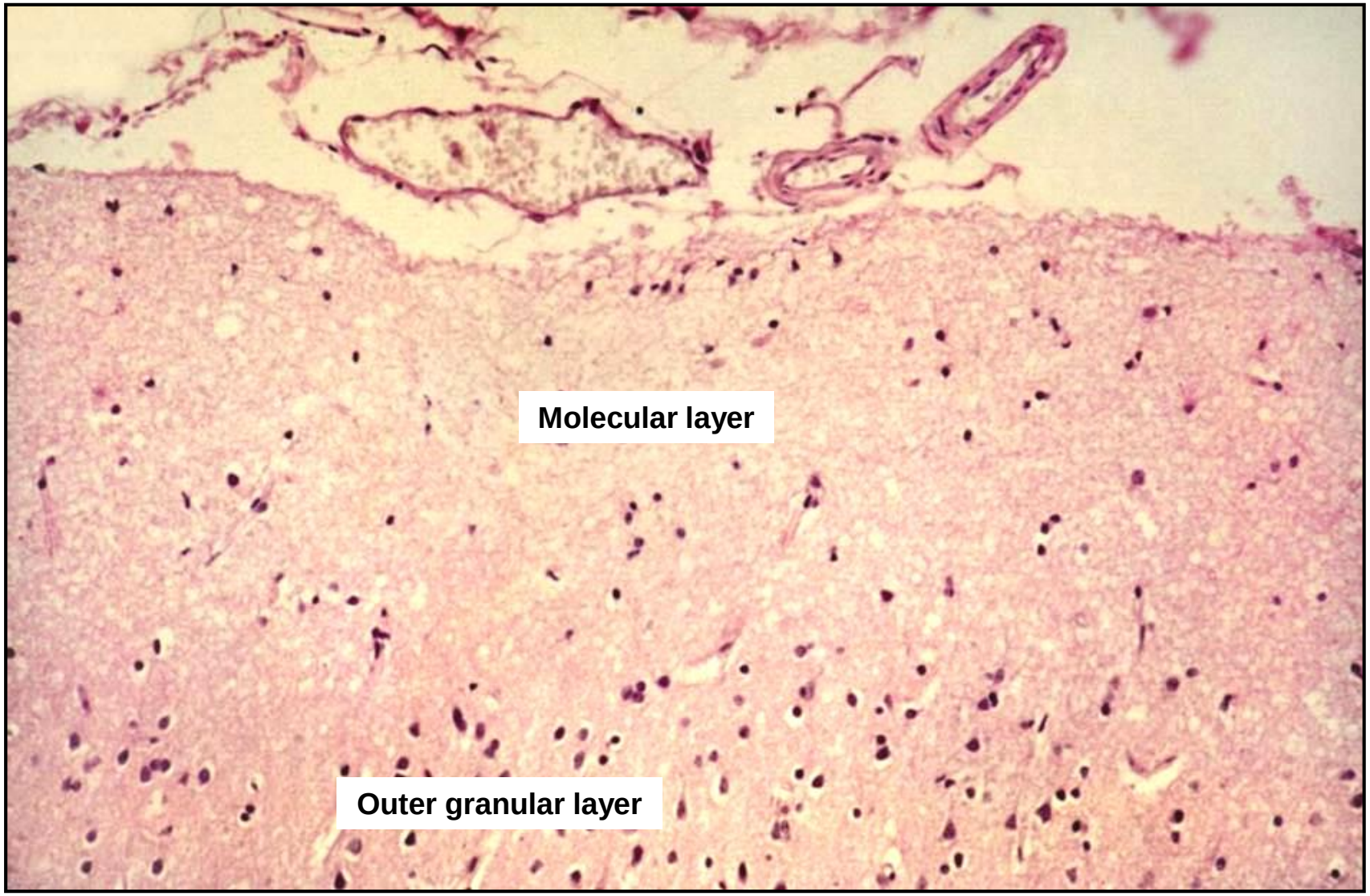


Telencephalon - Isocortex

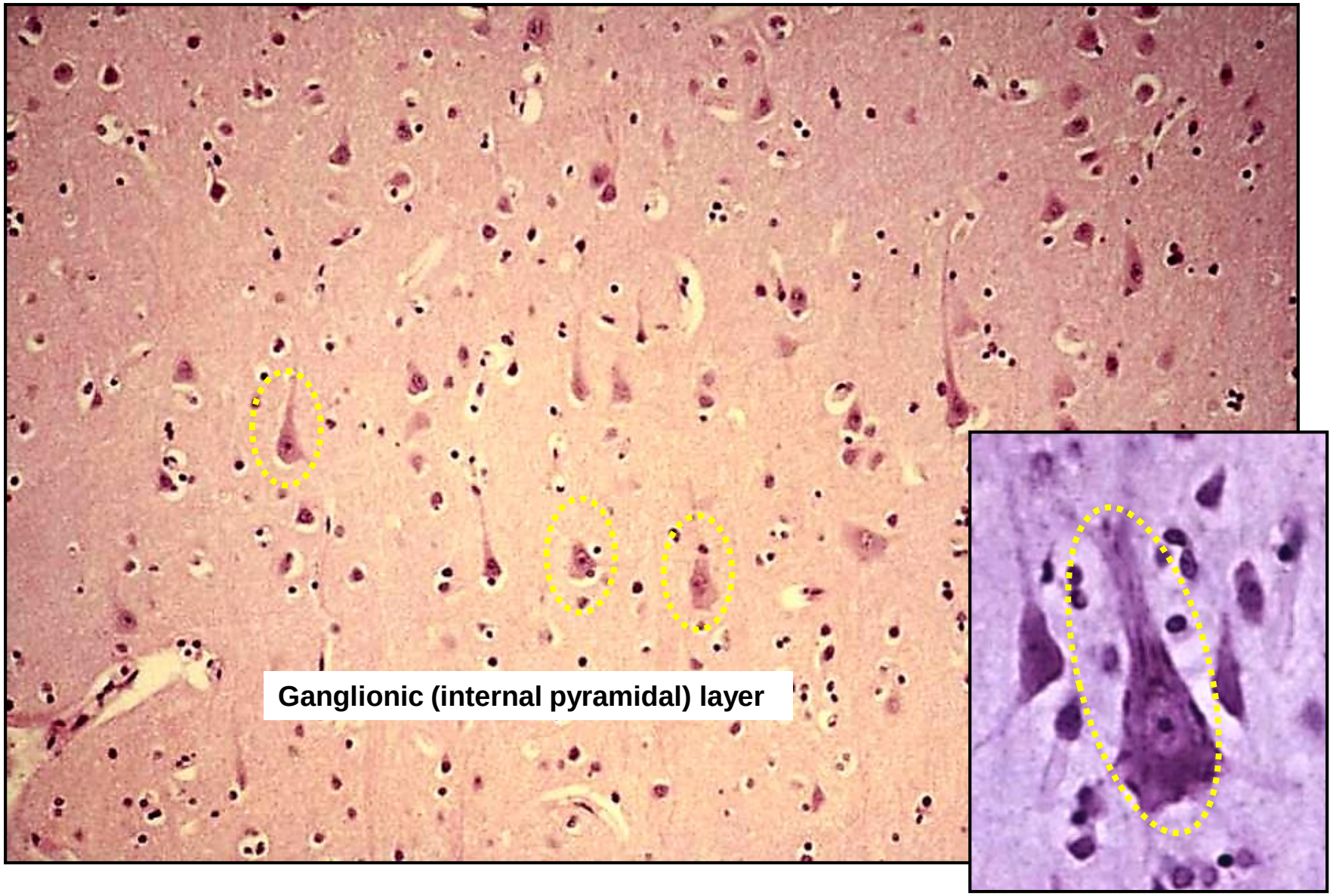




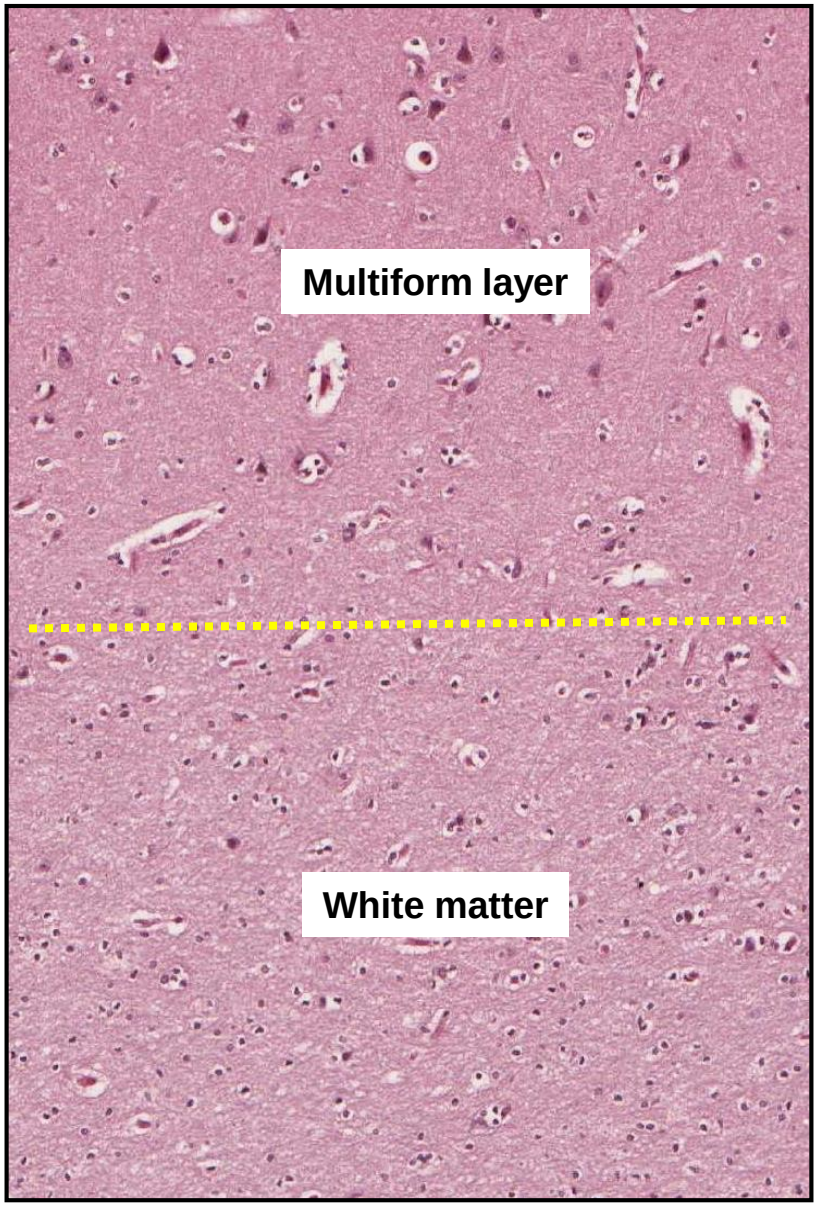
Telencephalon - Isocortex



Telencephalon - Isocortex



Telencephalon - Isocortex



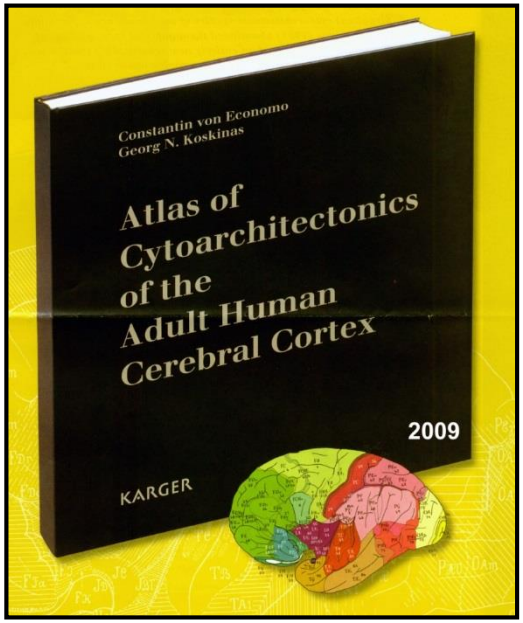
Telencephalon - Isocortex

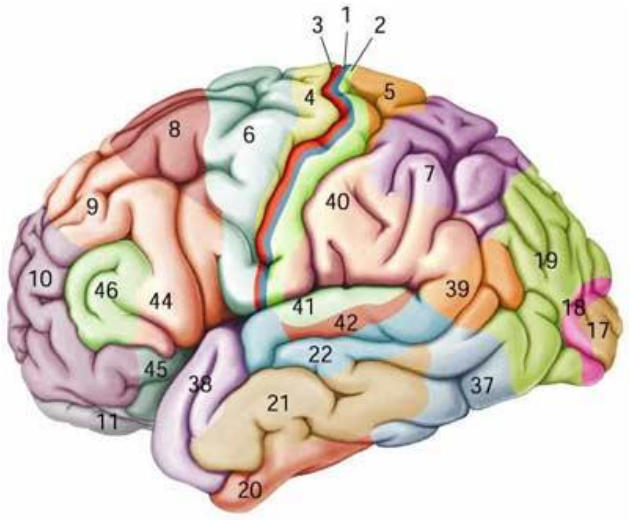
Homotypic
typical 6-layered architecture

Heterotypic
various divergences from the typical architecture
(cell numbers/density, relative propoertions, thickness, fibers, vessels, …)

Maps

- **cytoarchitectonic -** the density of perikarya
- **myeloarchitectonic -** the density of myelinated fibers
- **glioarchitectonic -** the type and density of glial cells
- **angioarchitectonic -** the density of blood capillaries or vascularization
- **synaptoarchitectonic -** the density synapses in the isocortex

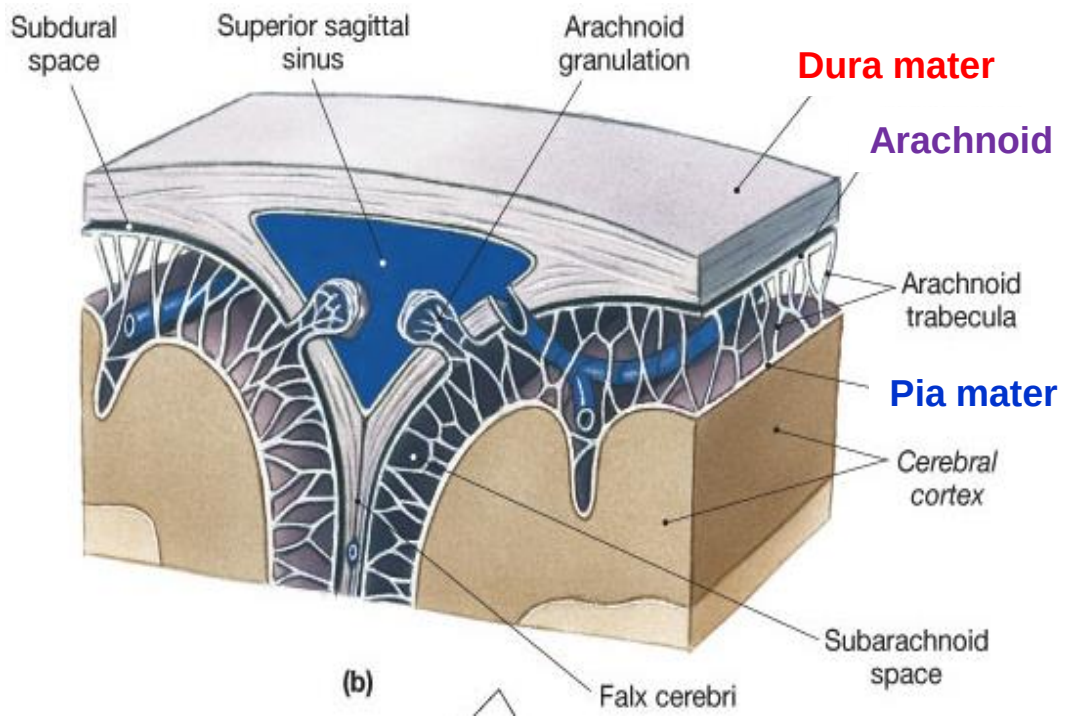




1909 - K. Brodman
11 regions and 52 areas

Meninges

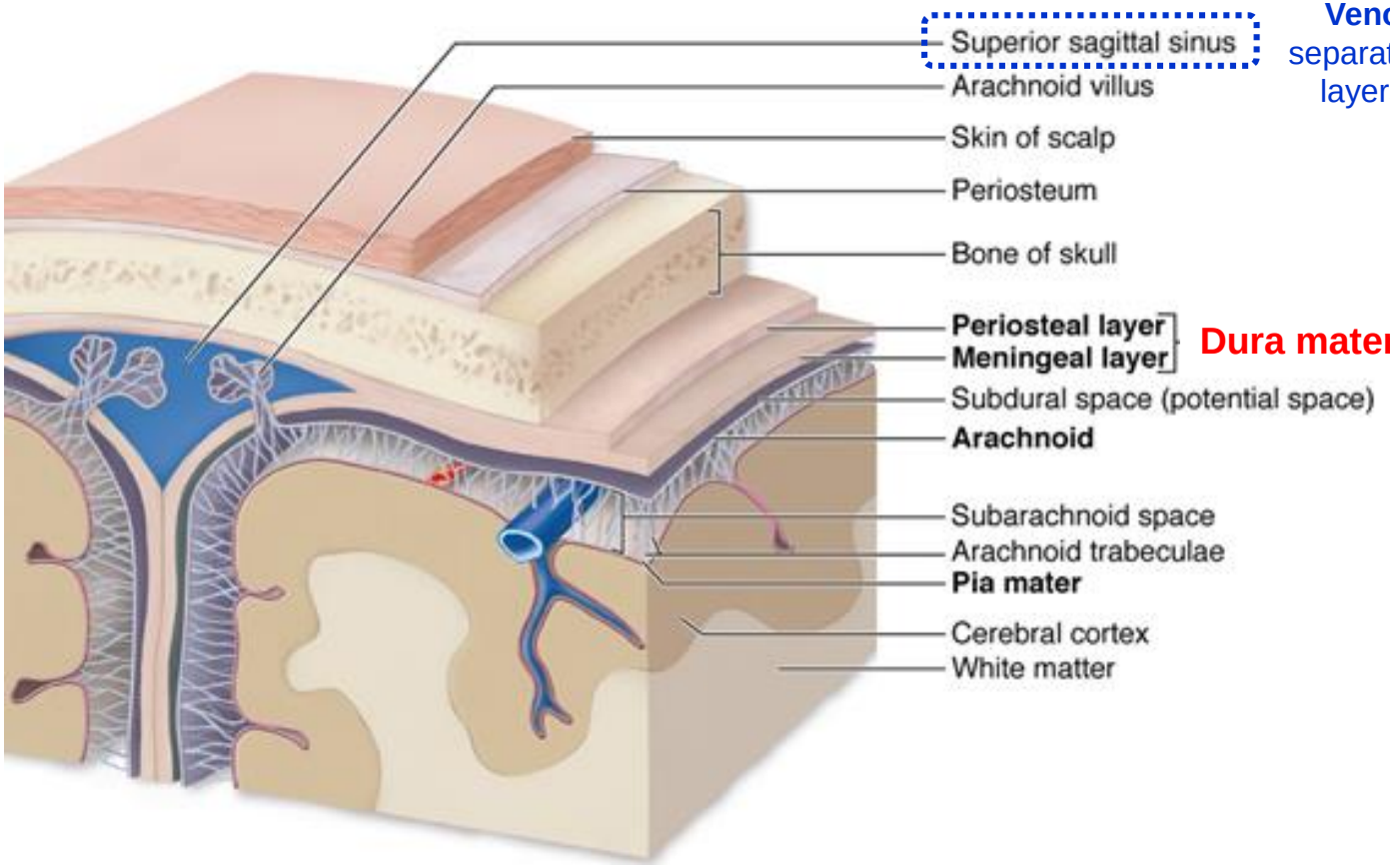
- membranes
- protect CNS + contriubute to distribution of liquor
- cover both brain and spinal cord (are continuos)



Pachymeninx (hard)	Leptomeninx (soft)
Dura mater	Arachnoid + Pia mater

Meninges – Dura mater

the outermost + robust (fibrous)



Venous (dural) sinuses
separations of inner and outer layers at ceratin locations

Cranial dura

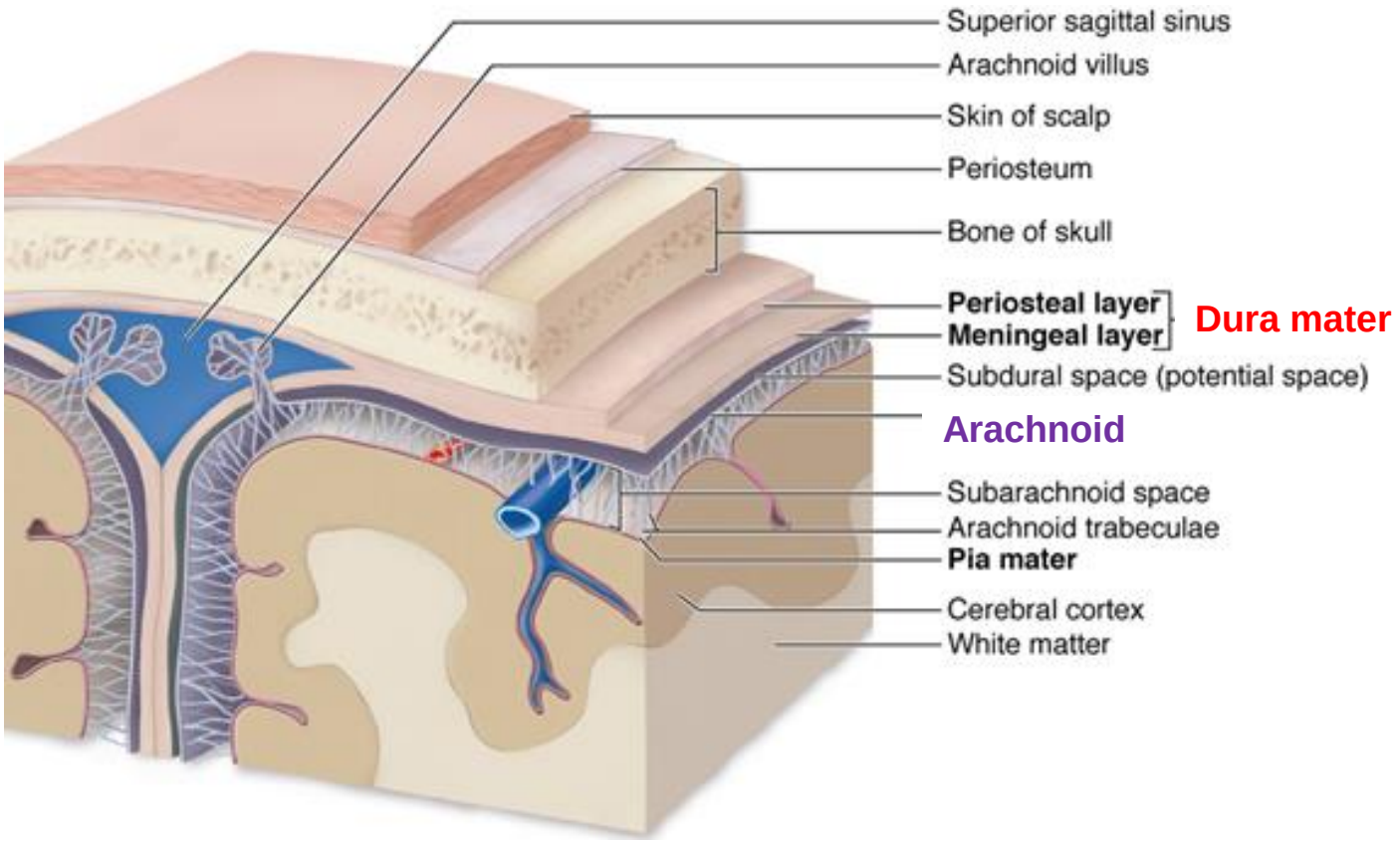
- **Endosteal layer (periosteal; outer)** - adhering to the inner surface of the bones of the skull
- **Meningeal layer (inner)** - thinner fibrous tissue membrane, inner surface covered by mesothelial cells

Spinal dura

- continuation of the inner layer of cranial dura

Meninges – Arachnoid

middle + spider web-like + avascular



Arachnoid

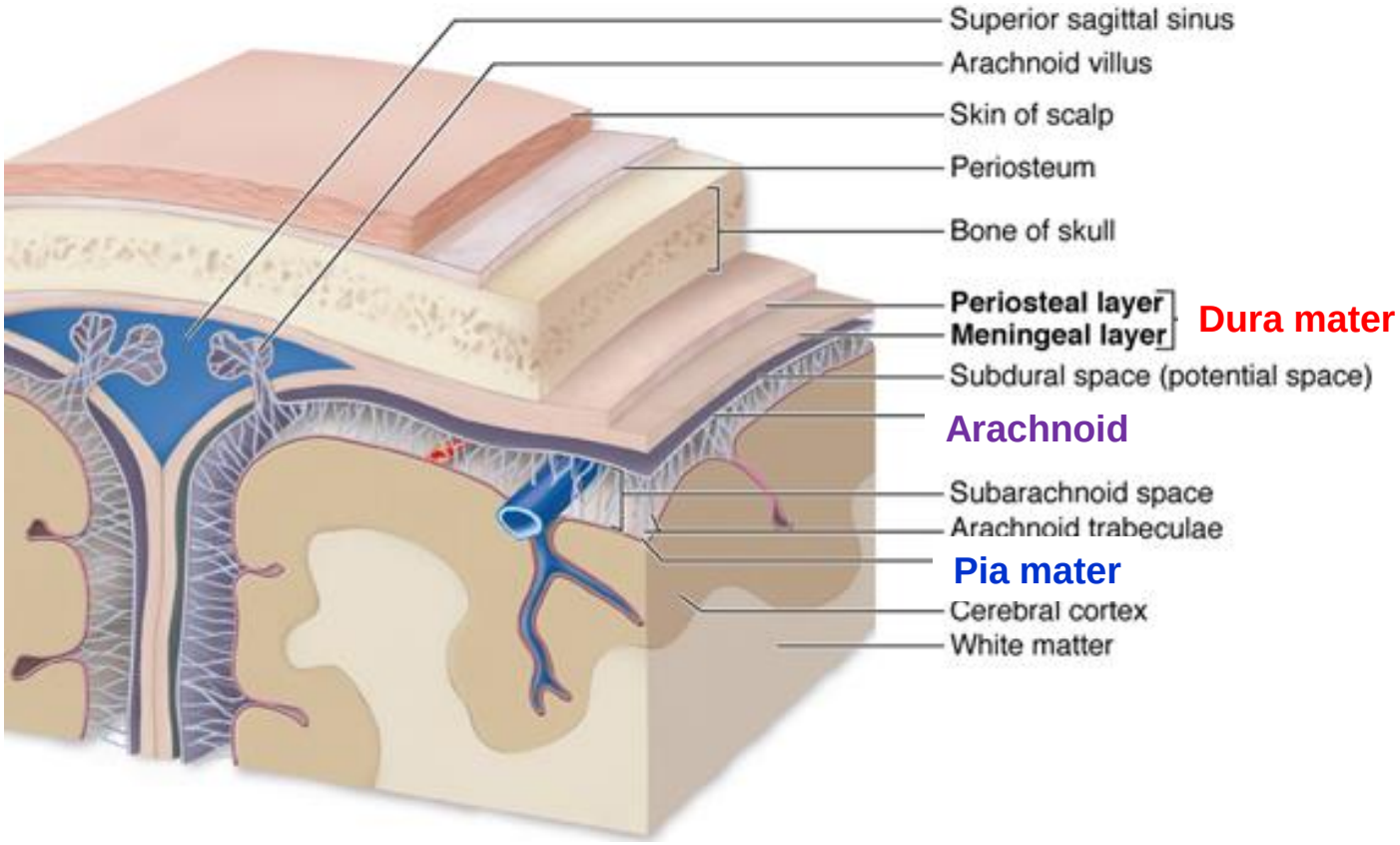
- **Neurothel (*lamina neurothelialis*)** - adhering to the inner layer of dura mater, tight junctions – barrier between CSF and blood in dura mater
- **Trabeculae** – delicate fibers covered by flat (meningeal) cells

Subarachnoid space

- enclosed between the arachnoid and pia mater
- filled by **cerebrospinal fluid** (CSF)

Meninges – Pia mater

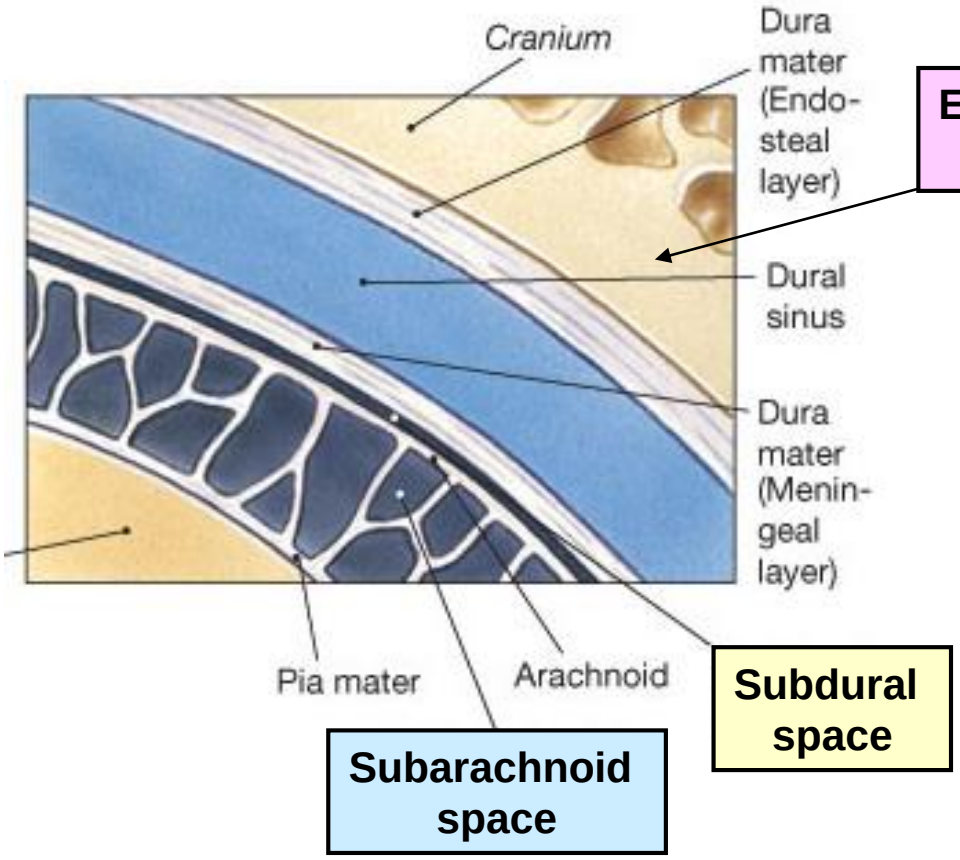
the innermost + delicate + vascular + adheres to and follows the surface of brain



Pia mater

- **Superficial layer**- receives trabeculae of the arachnoid
- **Inner layer** – elastic and reticular fibers, firmly attached to the under-lying nervous tissue, covered from outside with simple squamous cells of mesodermal origin

Meninges – Spaces between the membranes

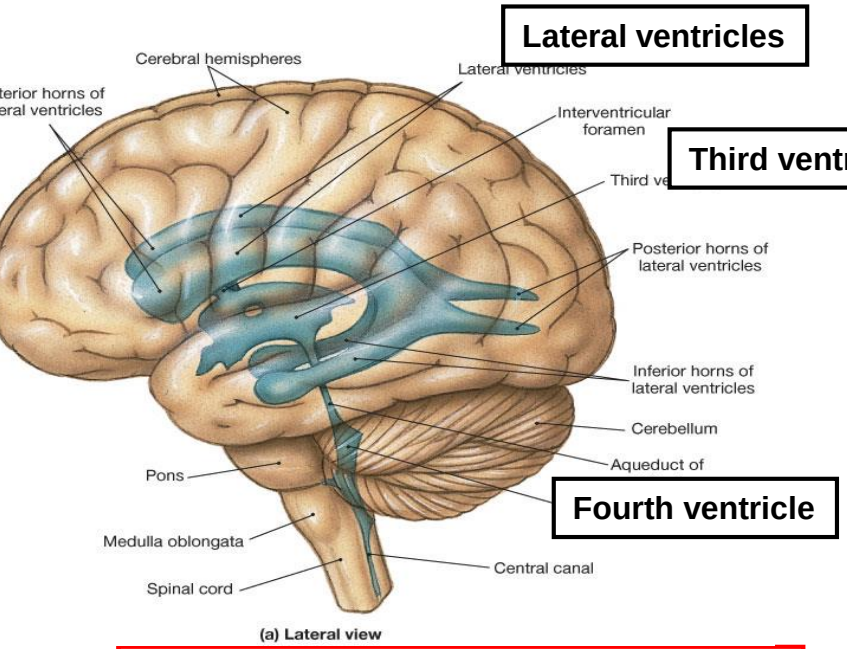


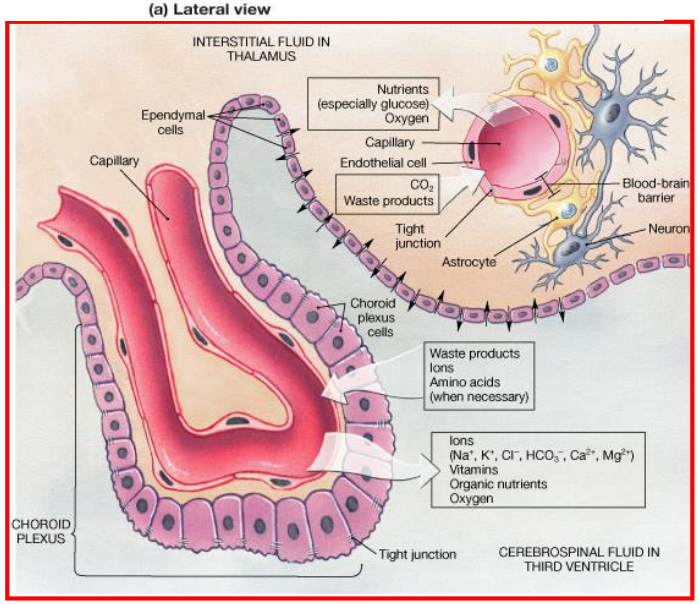
Epidural space
• between the **dura mater** and the **vertebral canal** in the spinal column
(potential space in the cranial region)

Subdural space
• between the **arachnoid** and the **dura mater**
(potential space in the cranial region)

Subarachnoid space
• between the **arachnoid** and **pia mater**
(large veins run through the subarachnoid space - e.g. cerebral veins)

Cerebrospinal fluid





Brain ventricles (chambers)

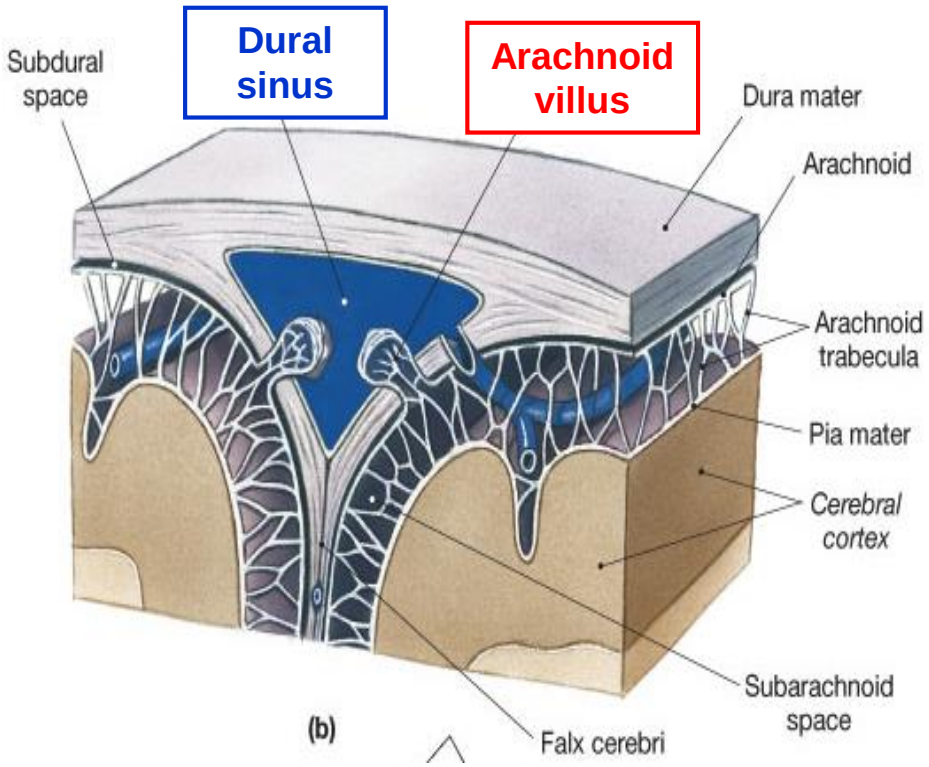
2x lateral ventricles + 1x third ventricle + 1x fourth ventricle

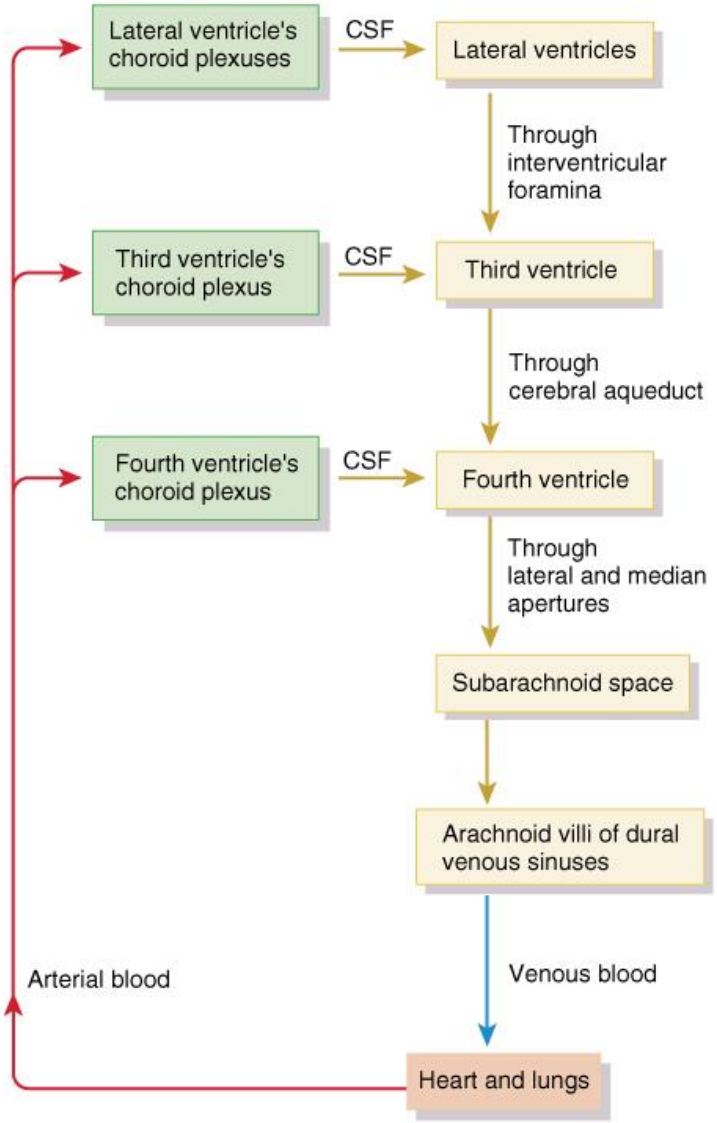
- connect to central canal which runs to spinal cord
- contain cerebrospinal fluid (CSF)
- CSF is produced by **ependymal cells of chorid plexuses**

Cerebrospinal fluid - Circulation

Arachnoid villi

- fingerlike projections into the dural venous sinuses
- mediate gradual reabsorbtion of CSF into the blood





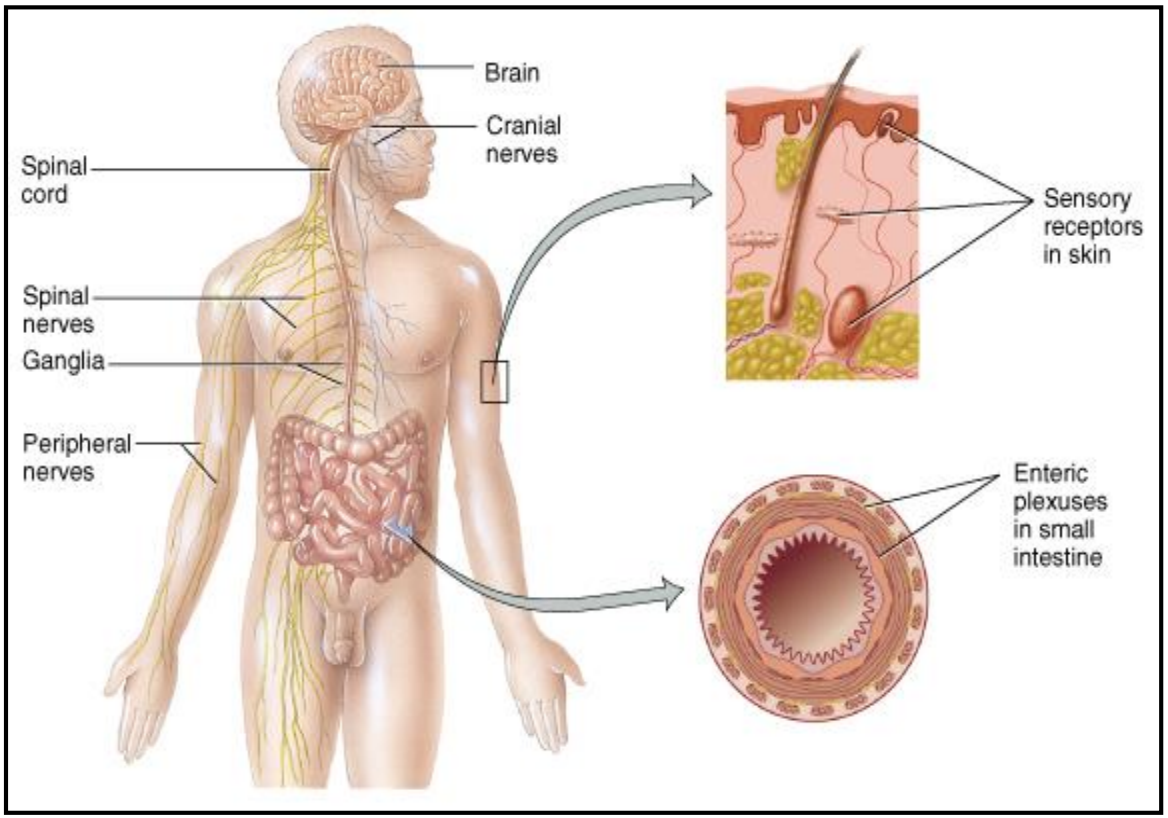
Peripheral nervous system - Components

Definition:
Made up of transmission pathways carrying information between the CNS and external/internal environments.

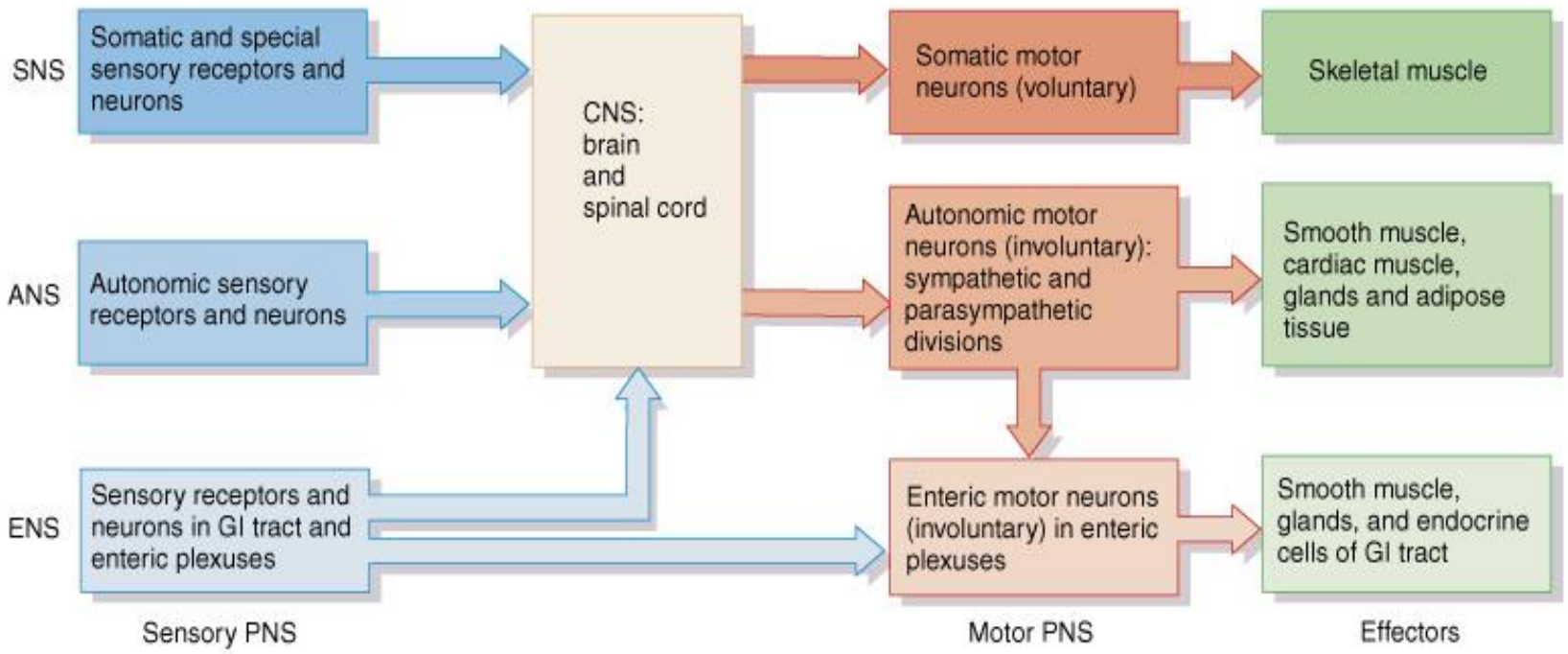
Afferent (sensory) pathways:
Carry information to the CNS.

Efferent (motor) pathways:
Carry information from the CNS.

Includes:
- Cranial nerves (12 pairs)
- Spinal nerves (31 pairs)
- Peripheral nerves
- Ganglia
- Sensory receptors



Peripheral nervous system – Overall organization



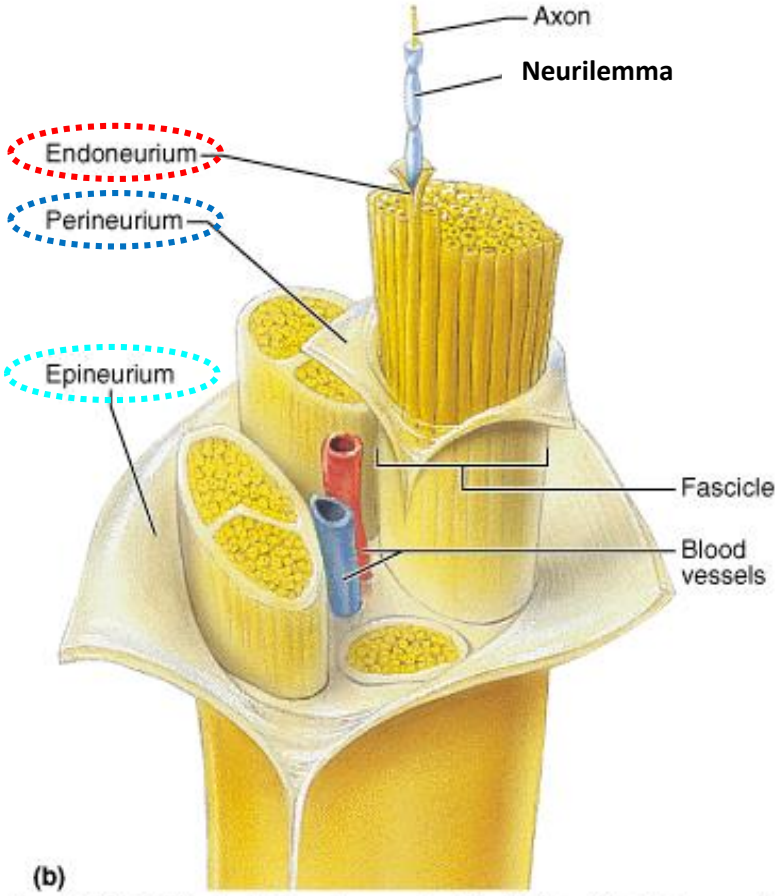
Somatic (voluntary) nervous system (SNS)
- neurons from cutaneous and special sensory receptors to the CNS
- motor neurons to skeletal muscle tissue

Autonomic (involuntary) nervous systems (ANS)
- sensory neurons from visceral organs to CNS
- motor neurons to smooth & cardiac muscle and glands
  1.sympathetic division *(speeds up heart rate)*
  2.parasympathetic division *(slow down heart rate)*

Enteric nervous system (ENS)
- involuntary sensory & motor neurons control GI tract
- neurons function independently of ANS & CNS

Peripheral nervous system - Nerves

Consists of 100's to 100,000's of myelinated and unmyelinated axons (nerve fibers).



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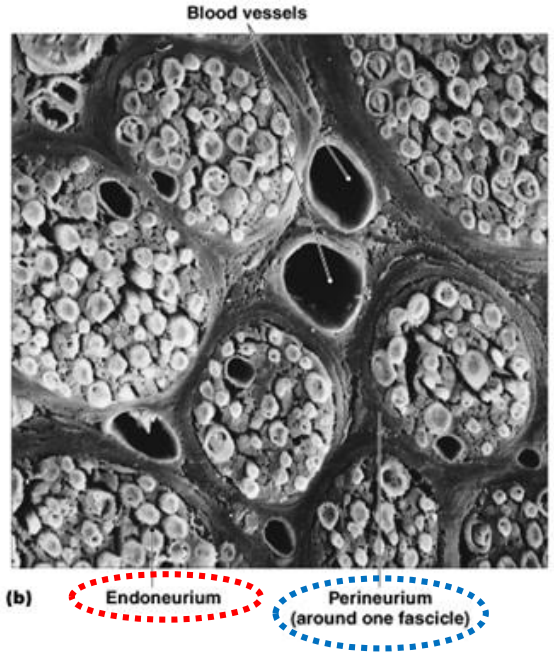
Connective tissue layers composing nerves:

- **Endoneurium** - surrounds axons - **primary nerve bundles**
- **Perineurium** - surrounds fascicles – **secondary n. bundles**
- **Epineurium** - surrounds the entire nerve



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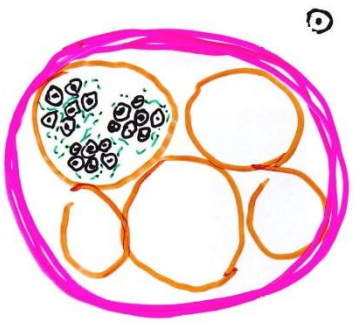
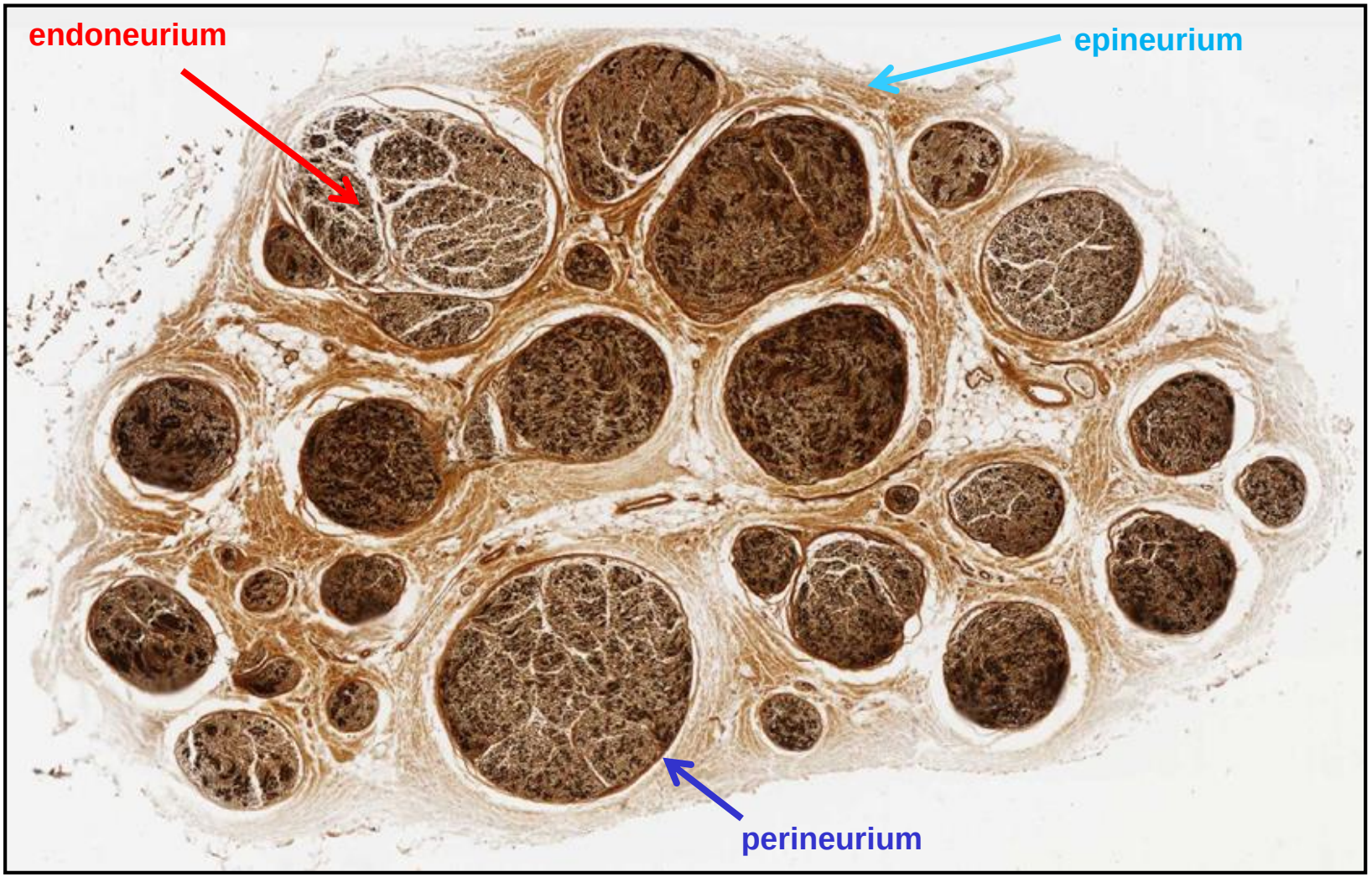
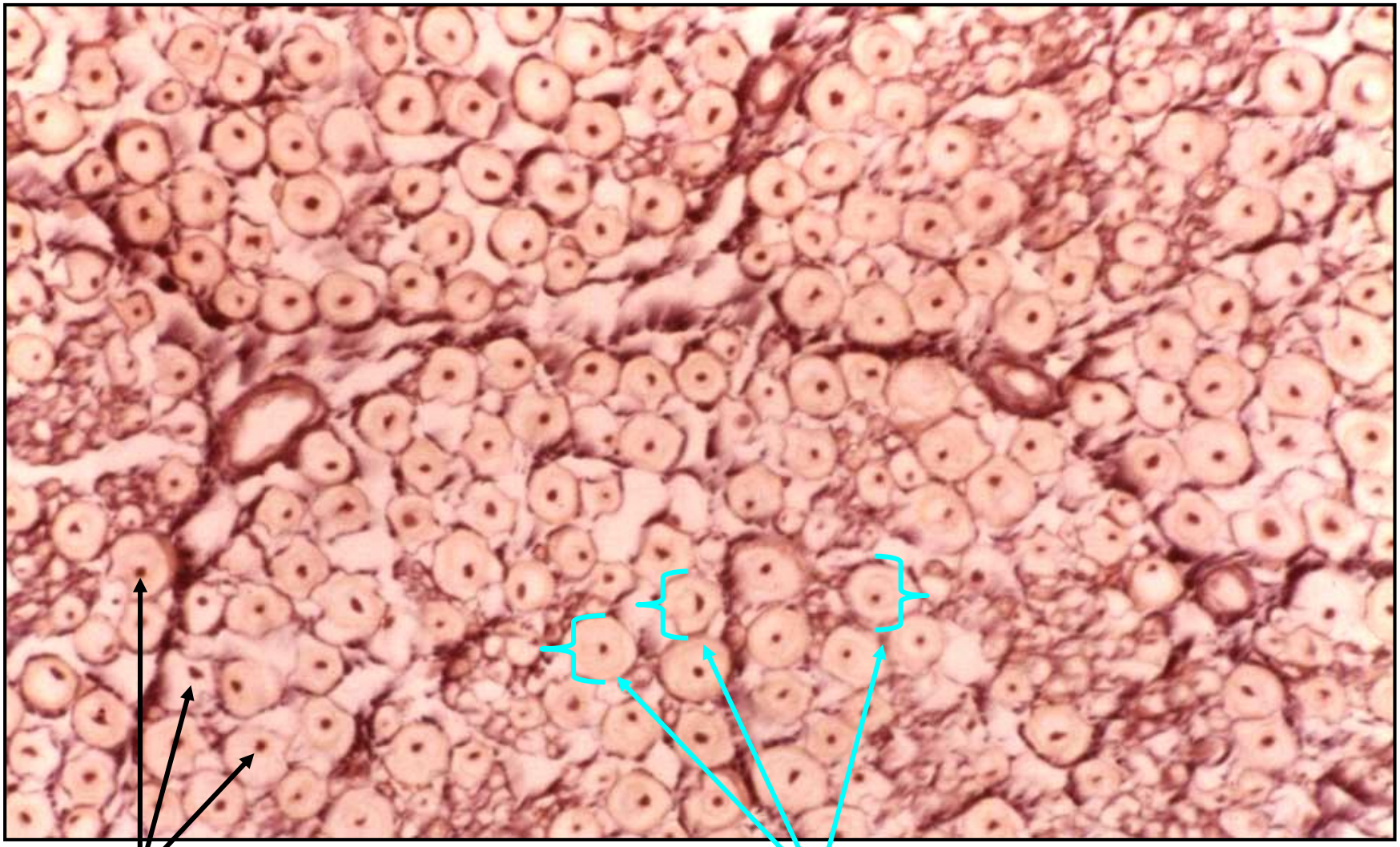
Peripheral nervous system - Nerves



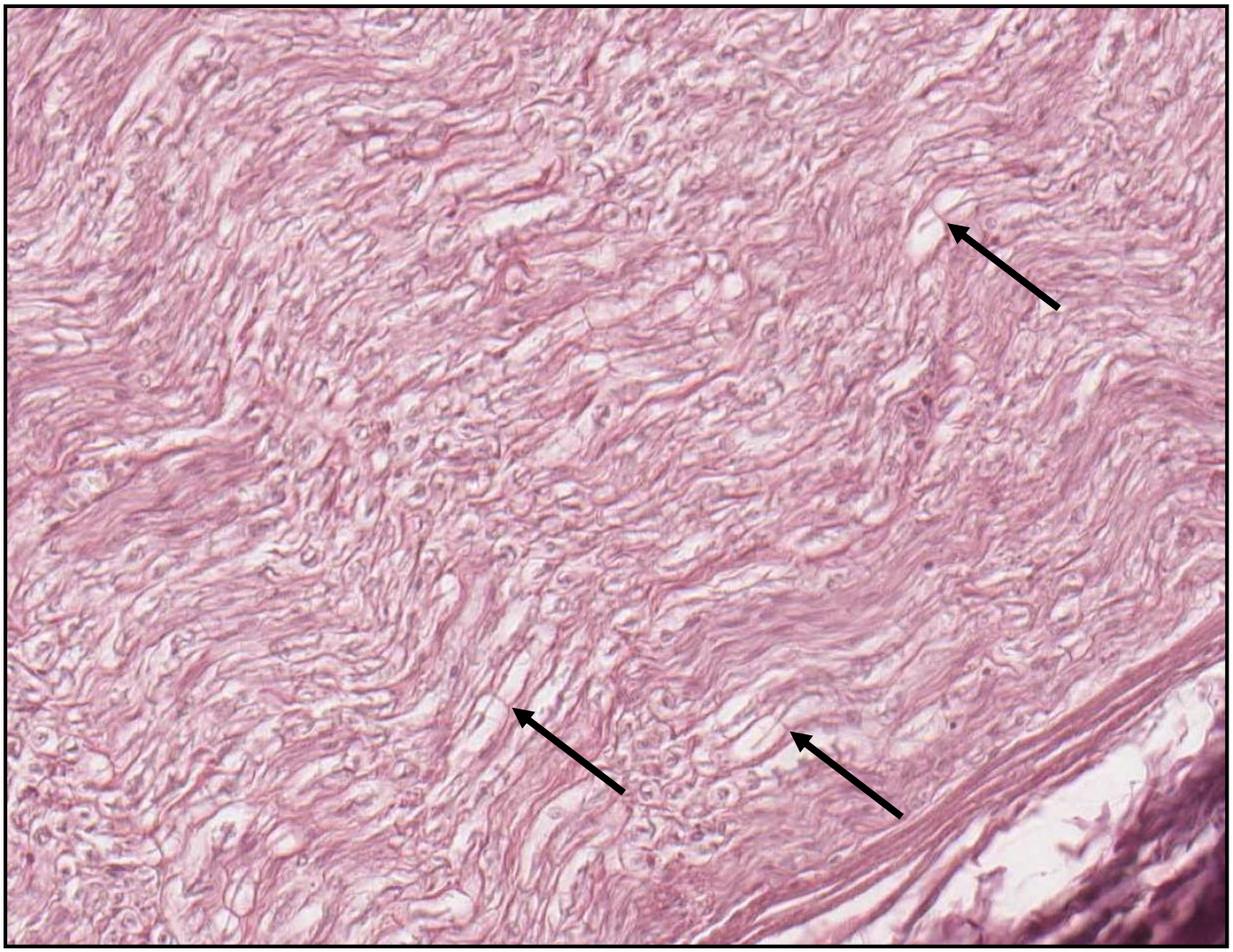
Peripheral nervous system – Nerves



Peripheral nervous system – Nerves



Peripheral nervous system – Nerves



Nodes of Ranvier

Peripheral nervous system – Ganglia

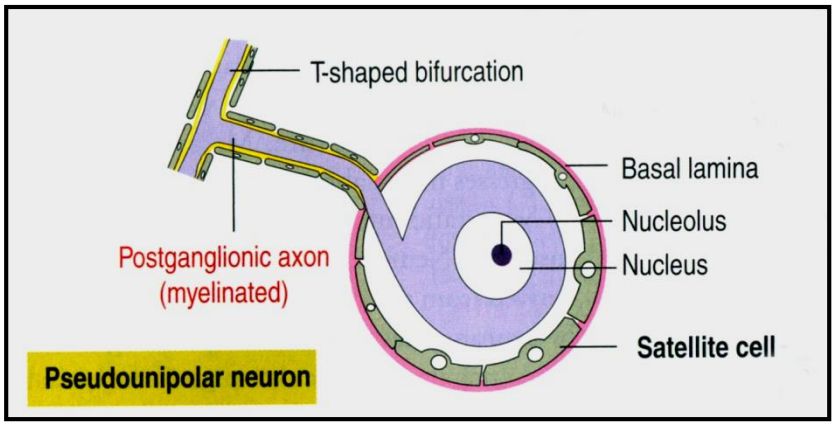
= aggregations of cell bodies of neurons located outside of CNS

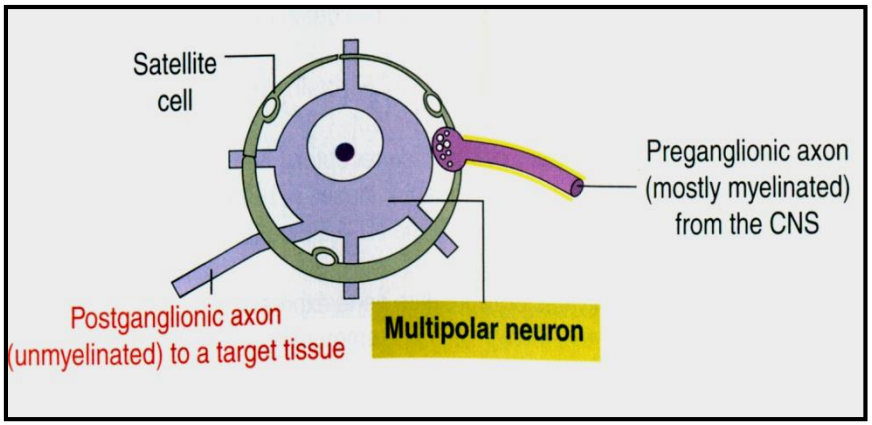
Sensory ganglia

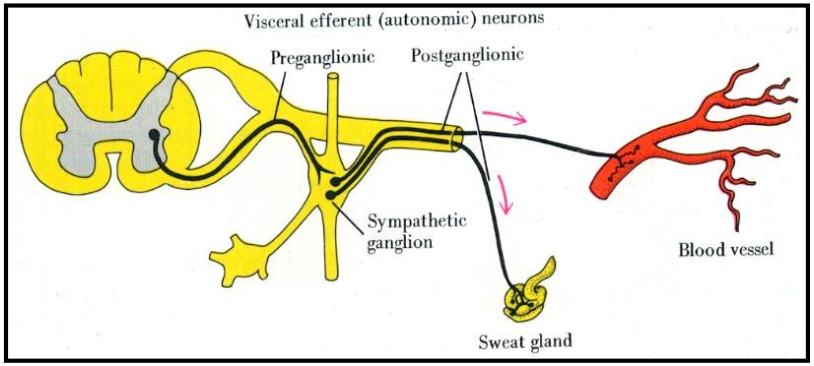
- associated with cranial nerves (V, VII, IX, X; ***cranial ganglia***) and with all spinal nerves ***(dorsal root ganglia)***
- contain **pseudounipolar neurons**
- neurons are enveloped by **satellite cells**

Autonomic ganglia

- associated with nerves of the autonomic nervous system
- contain medium-sized **multipolar neurons**
- neurons are **motor** by function (smooth and cardiac muscle, glands)
- neurons are enveloped by **satellite cells**

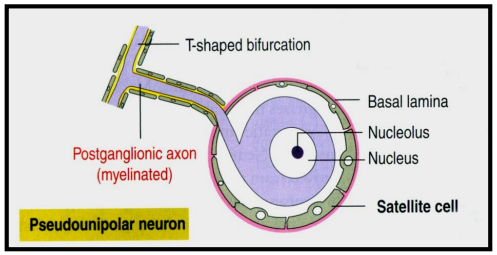




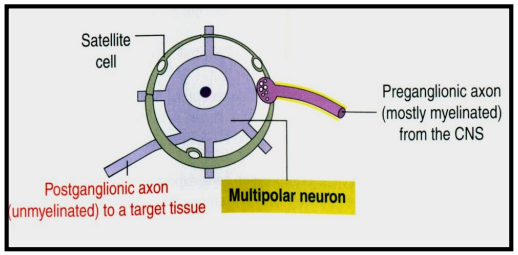


Peripheral nervous system – Ganglia

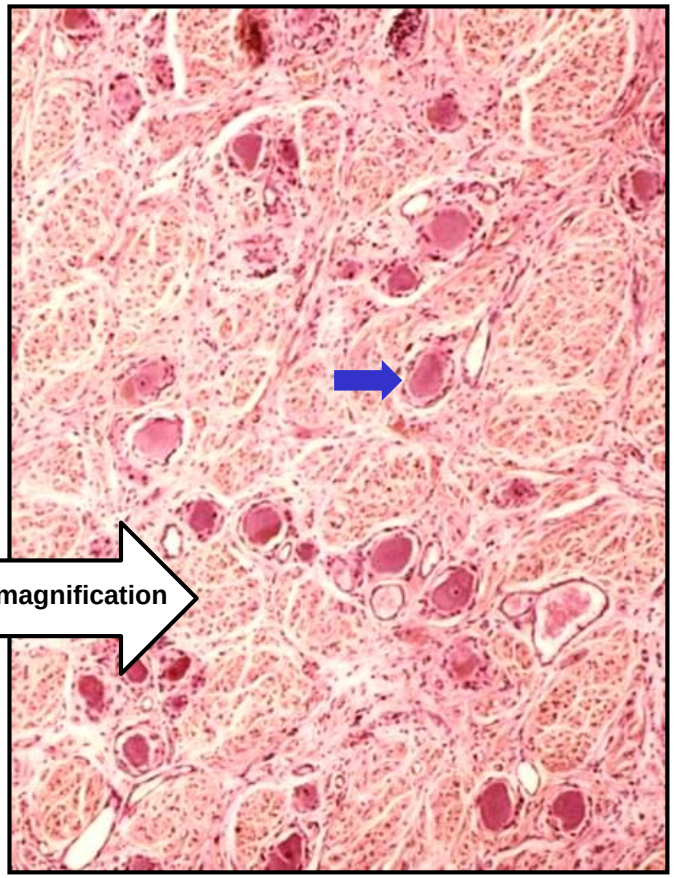
Sensory ganglion



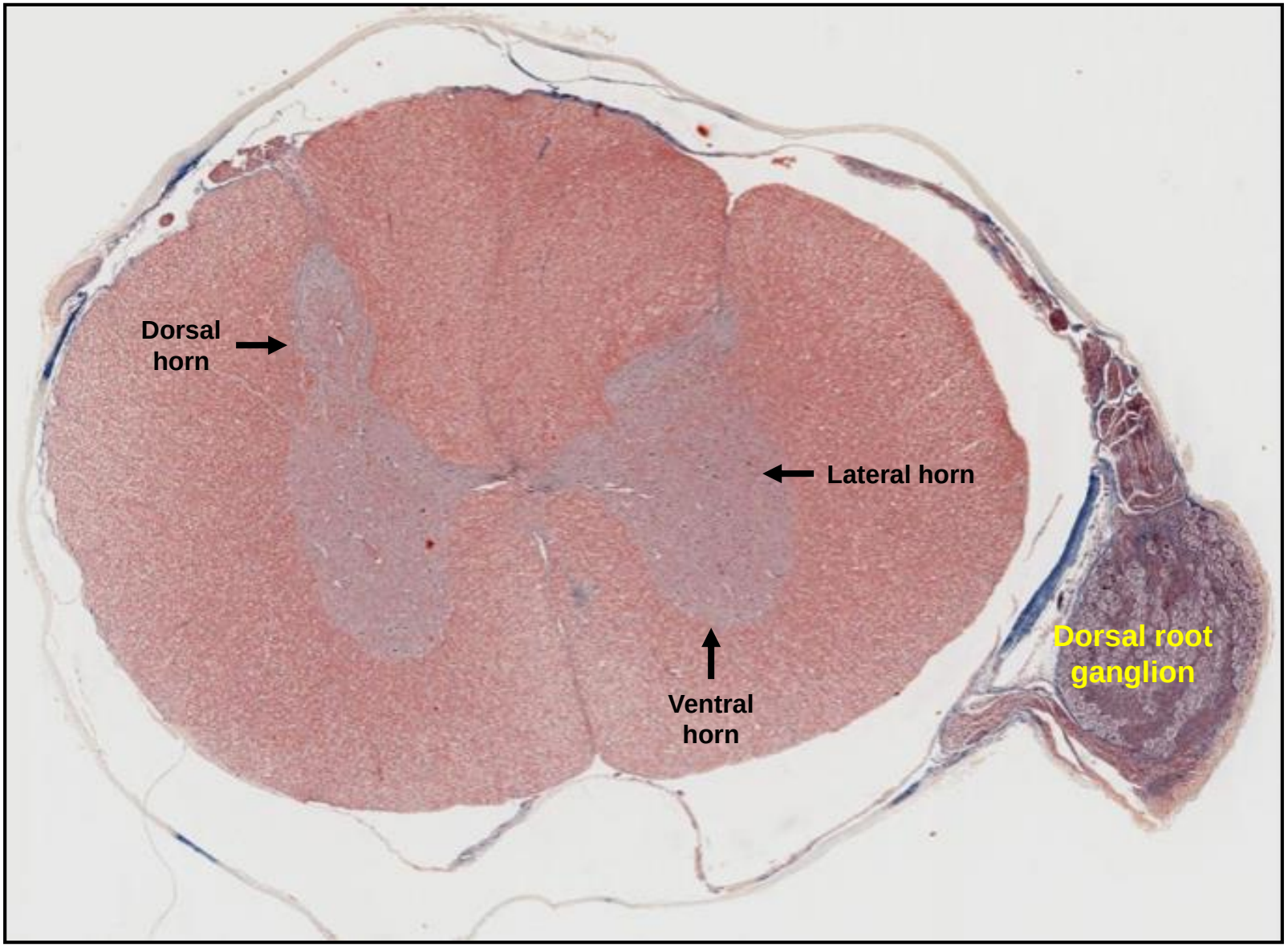
Autonomic ganglion



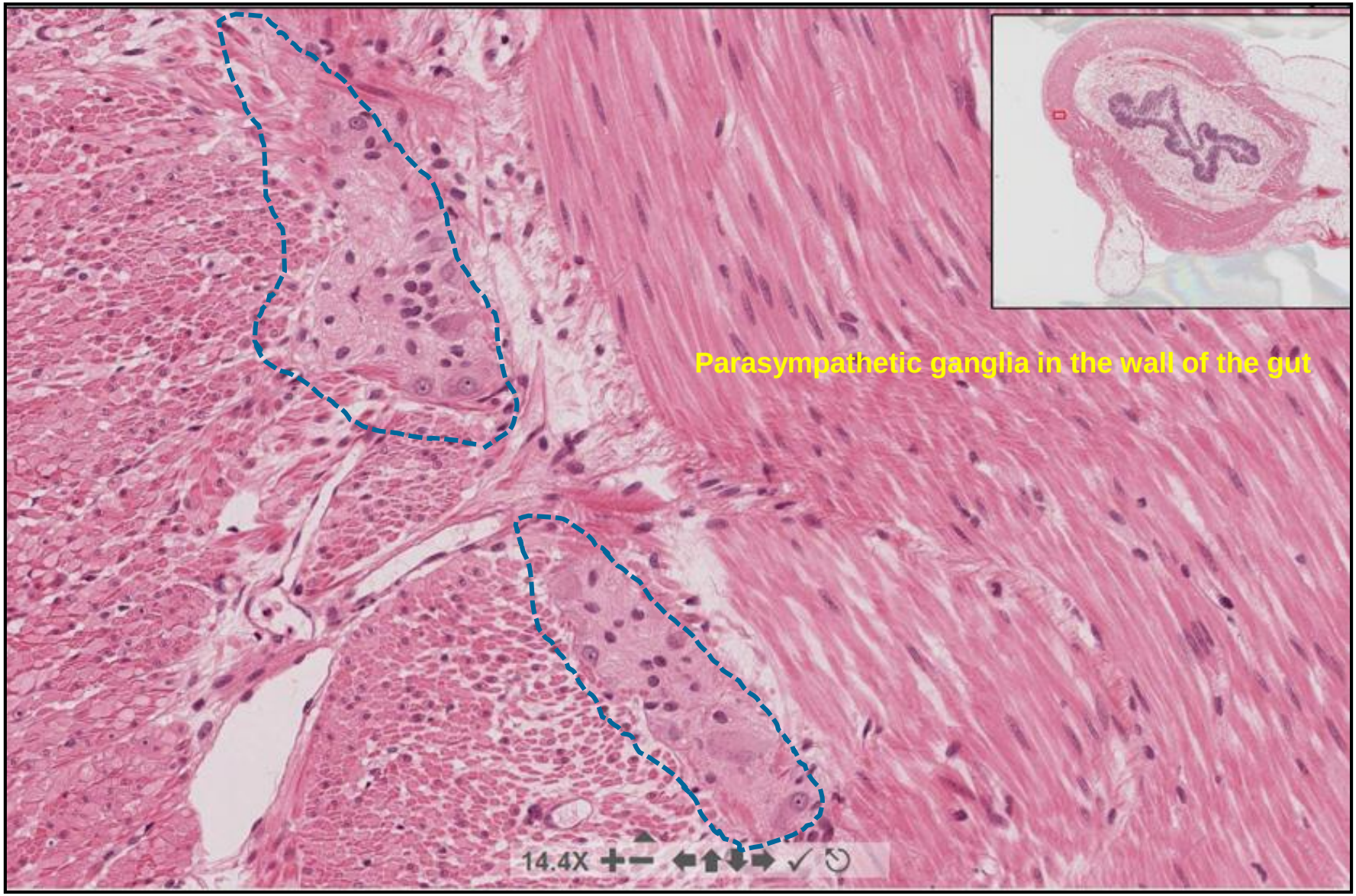
About the same magnification



Spinal cord + Dorsal root ganglion



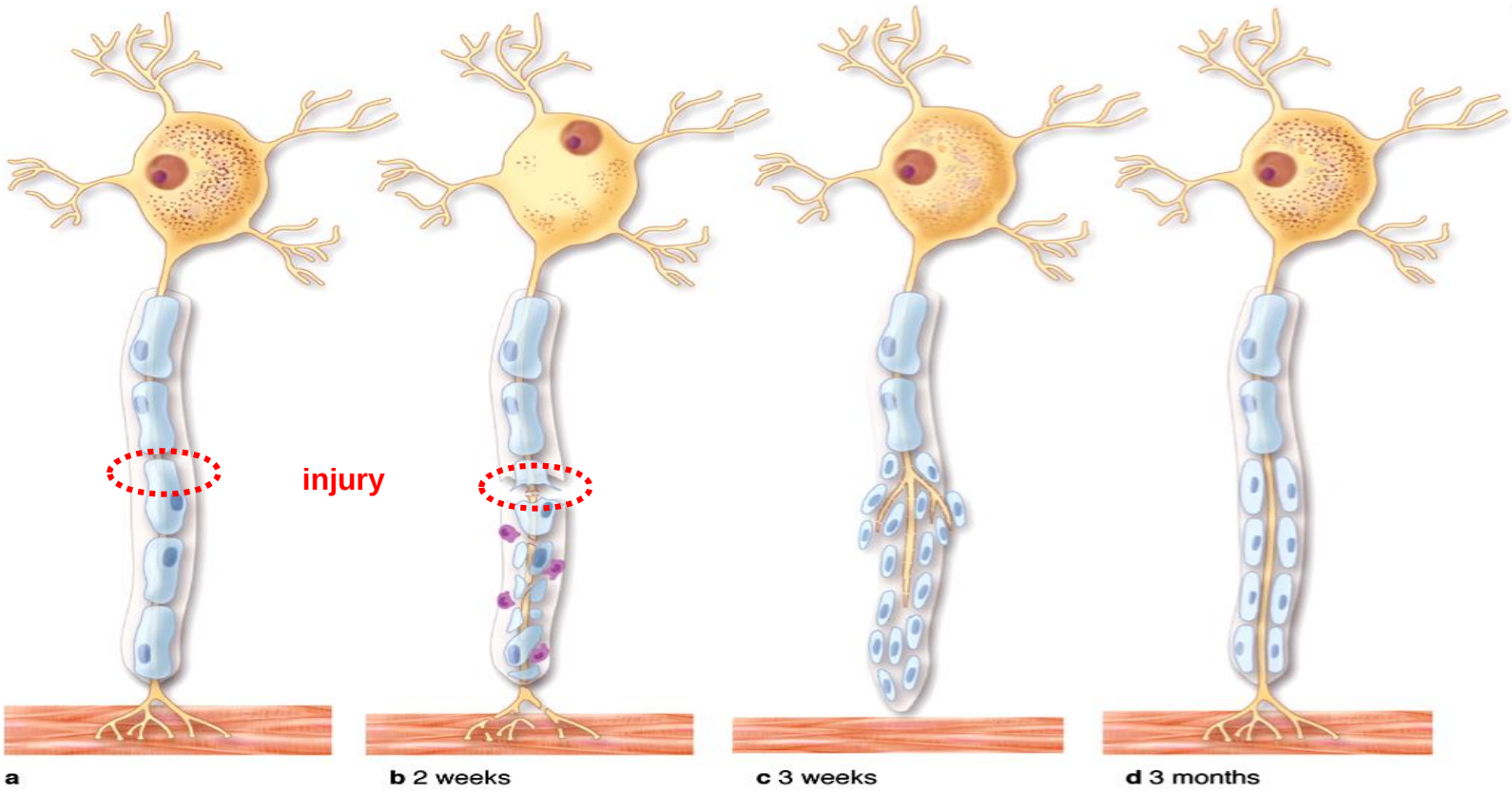
Autonomic ganglion



Nerve tissue regeneration - PNS

Axons and dendrites may be repaired if:

- Neuron cell body remains intact
- Schwann cels remains active and form tube
- Scar tissue does not form too rapidly



Breakdown of axon
Breakdown of myelin sheath

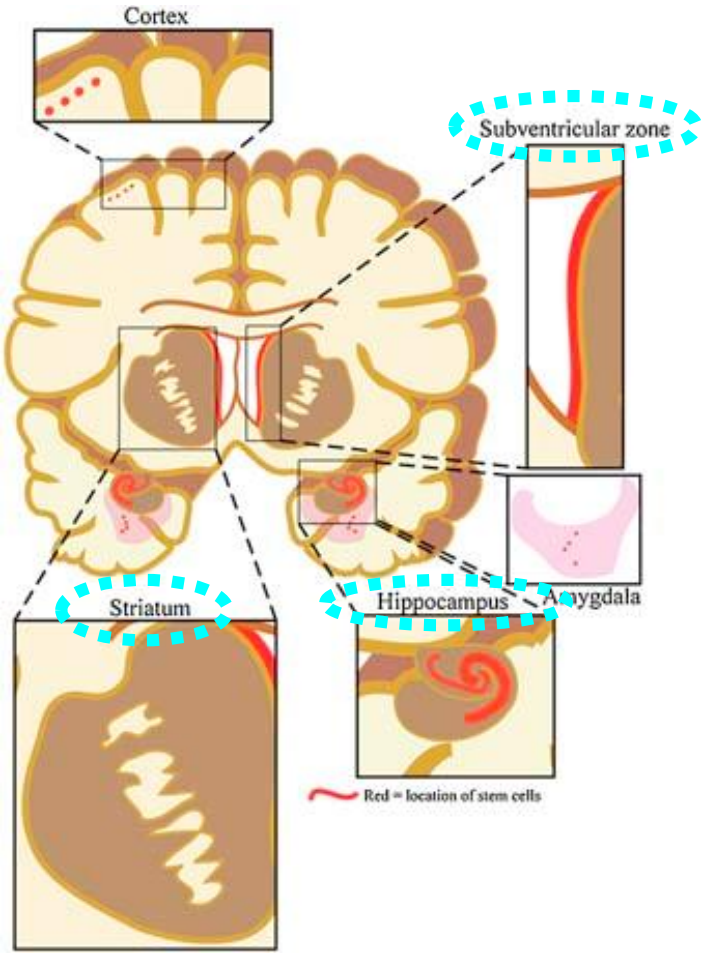
Schwann cells divide
Axon begins to grow
(1.5 mm/day)
Navigaion by Schwann cells
Collaterals will die

Nerve tissue regeneration - CNS

Stem / progenitor cells resiging in some areas of adult brain

Life-long plasticity of CNS

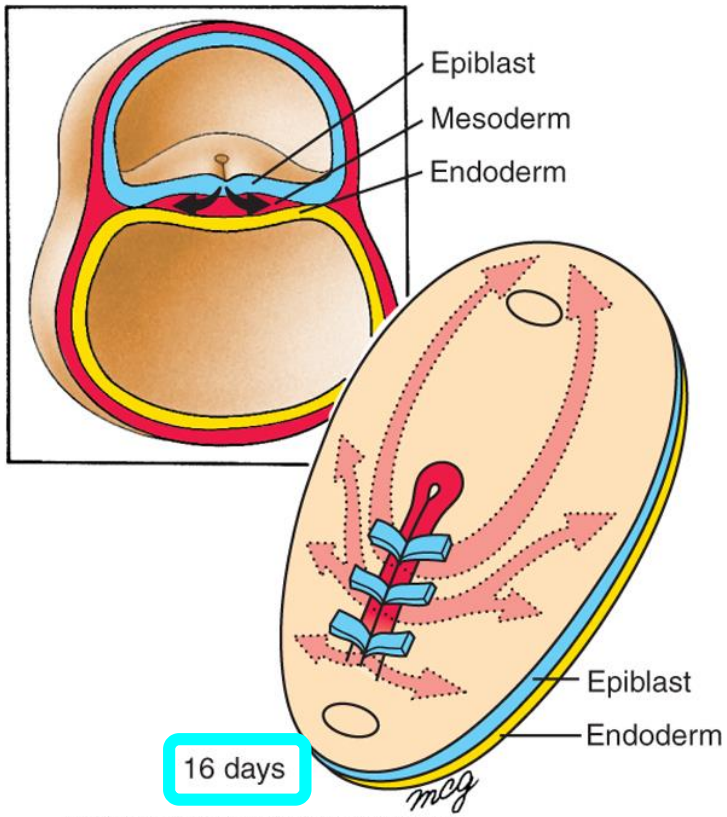
- Sprouting new dendrites
- Synthesis of new proteins
- Changes of synaptic contacts



Nerve tissue – Ectoderm

Gastrulation

Formation of the three germ layers



Schoenwolf et al: Larsen's Human Embryology, 4th Edition.
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Ectoderm: outside, surrounds other layers later in development, generates **skin** and **nervous tissue.**

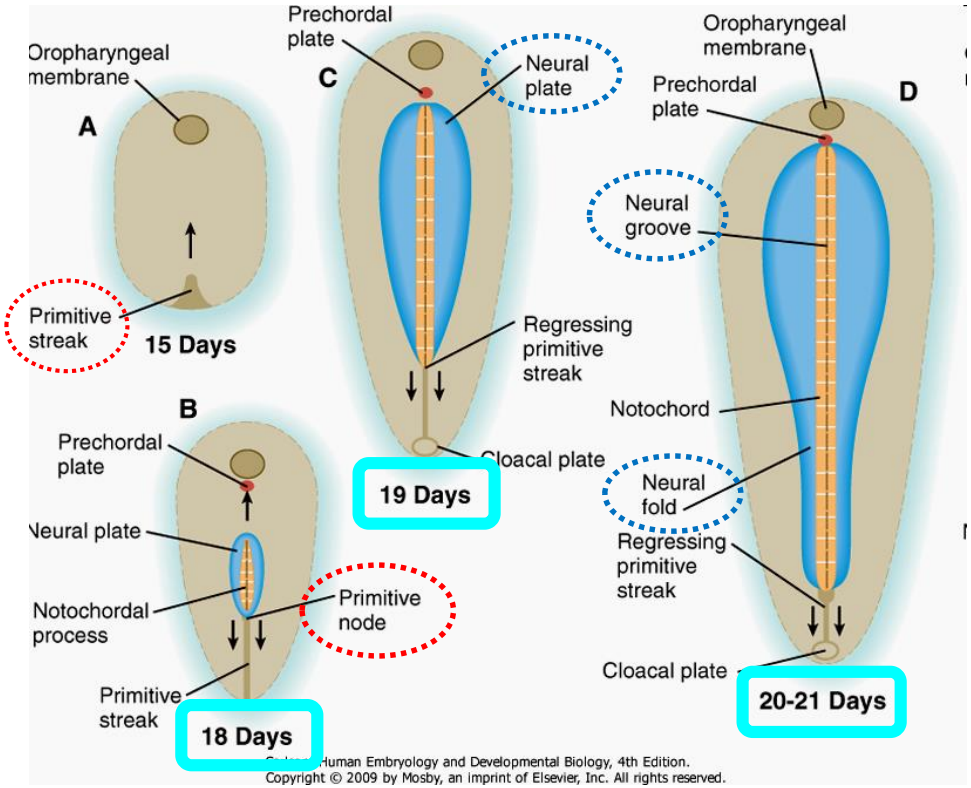
Mesoderm: middle layer, generates most of the **muscle, blood** and **connective tissues** of the body and placenta.

Endoderm: eventually most interior of embryo, generates the **epithelial lining** and associated **glands** of the **gut**, **lung**, and **urogenital tracts.**

Nerve tissue – Neural plate

Neural Induction

In addition to patterning the forming mesoderm, the **primitive node** **also sets up the** **neural plate**



Endoderm + Mesoderm

BMP-4

Ectoderm to Skin

X

Notochord

noggin
chordin
follistatin

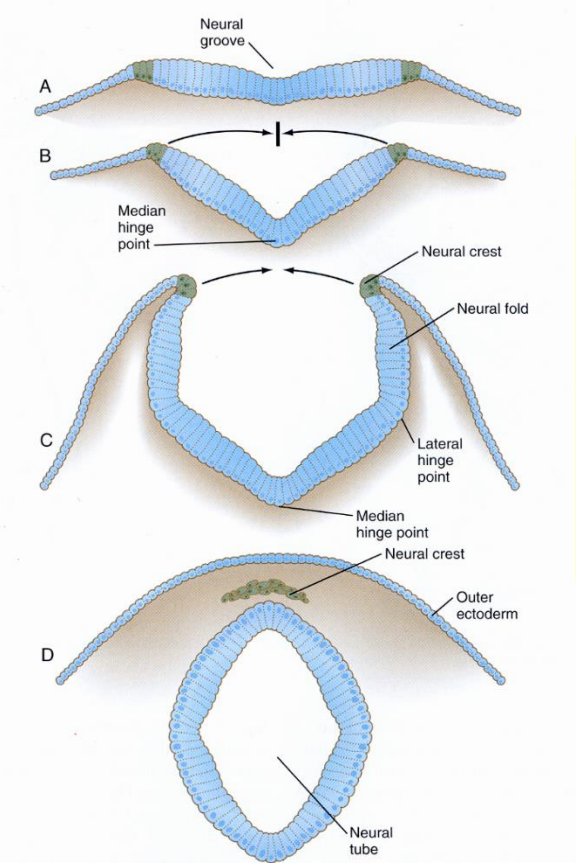
BMP-4 antagonists

Ectoderm to Nerve tissue

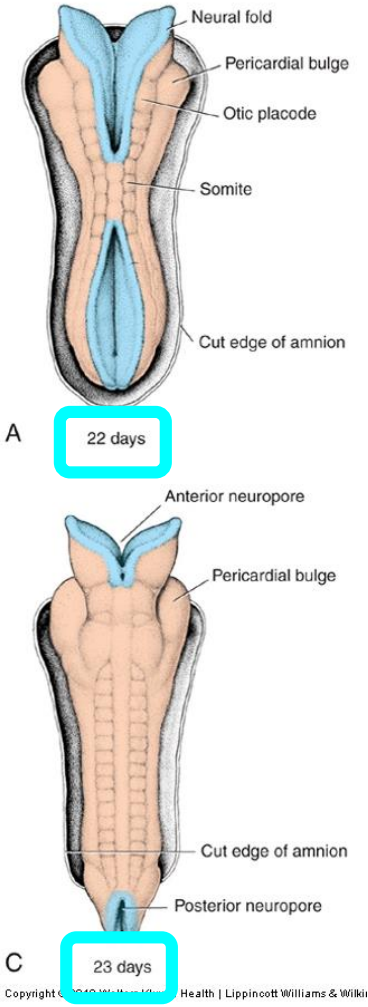
Nerve tissue – Neural tube

Neurulation

Folding and closure of the neural plate



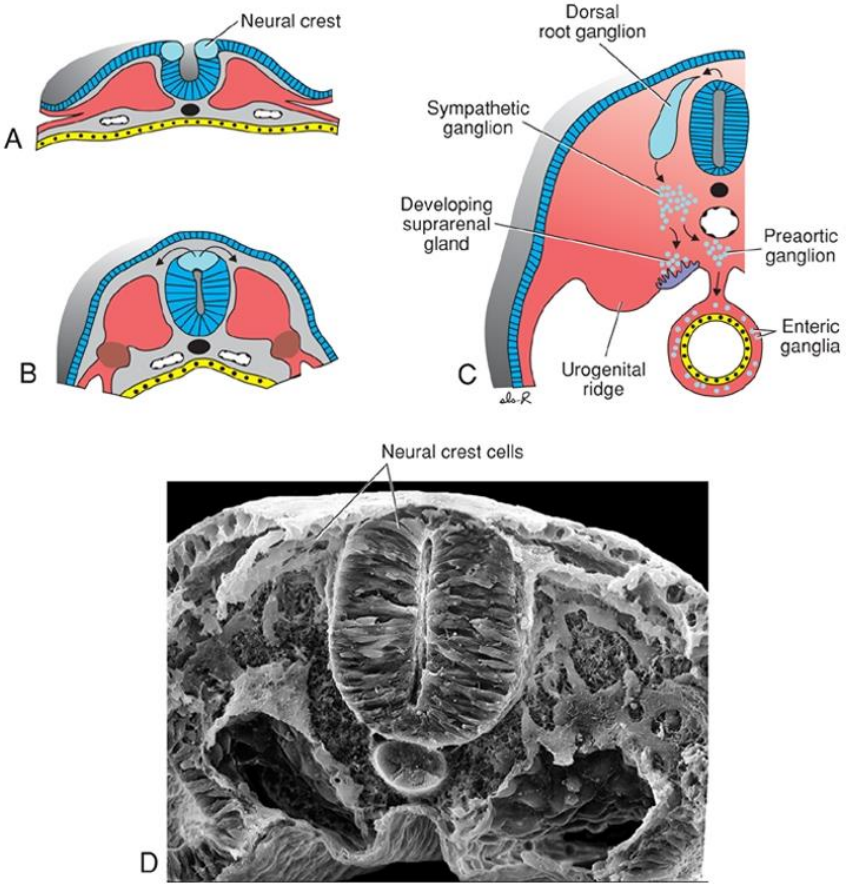
- **neural folds close**
- **neural crest delaminates** and migrates away
- **closure** happens **first in middle** of the tube and then **zips rostrally and caudally**
- **anterior neuropore closes** around **day 25**
- **posterior neuropore closes around day 28**



Nerve tissue – Neural crest

Neural crest

the "4th germ layer"



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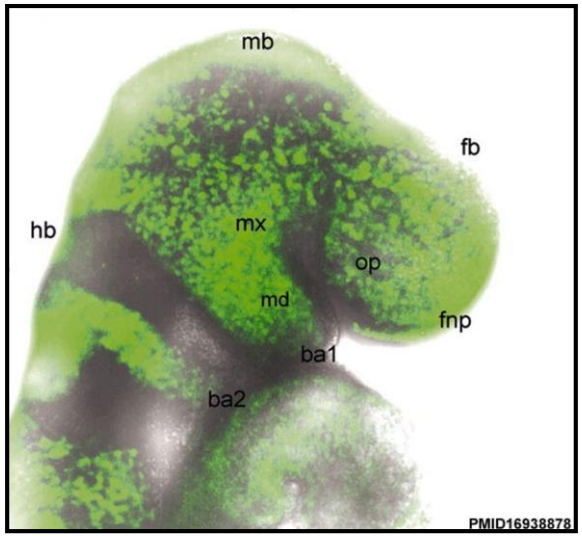
Signals from:

- Mesoderm
- Adjacent skin
- Neural plate

Neural crest cells

- Down-regulate cadherin
- Delaminate from neuroepithelium
- Transform into migratory mesenchymal cells
- Give rise to many cell types

Nerve tissue – Neural crest derivates

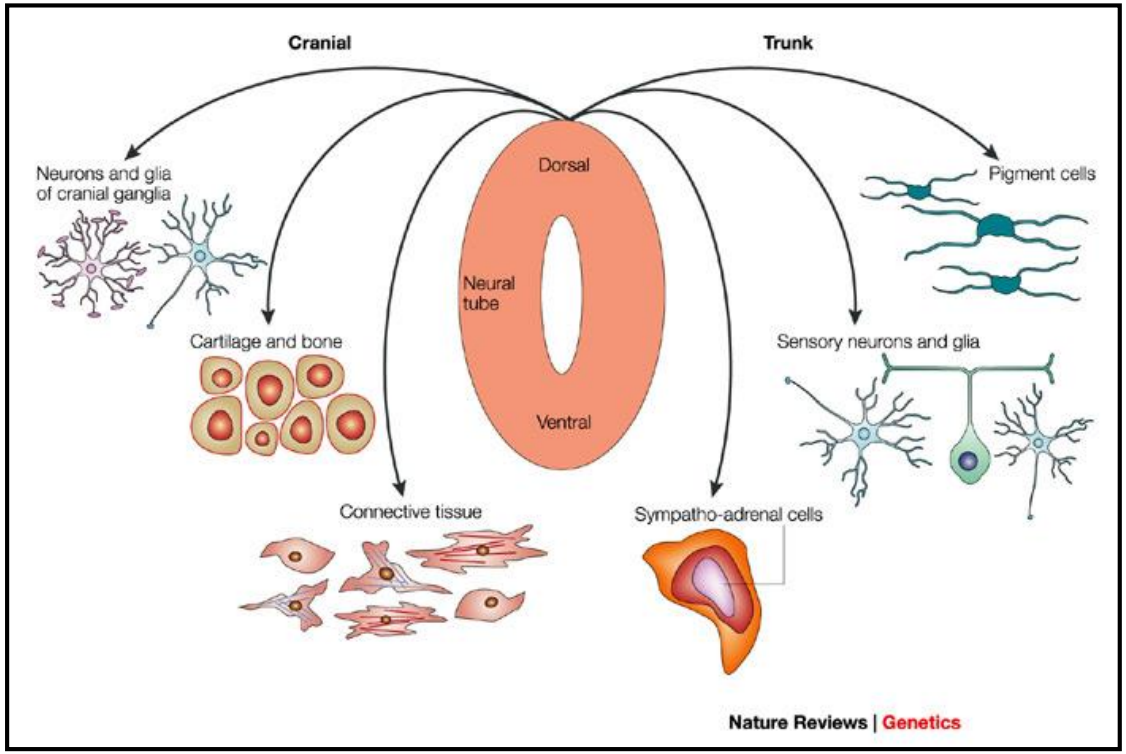


Neuroblasts
- **psedounipolar** neurons of spinal ganglia
- **multipolar** neurons of autonomic ganglia
- **chromaffin cells** of the adrenal medulla

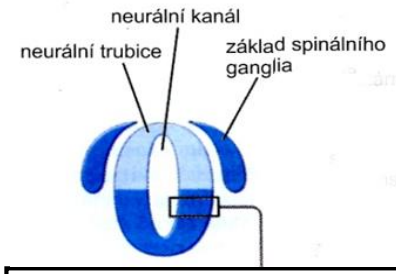
Spongioblasts
- **Schwann cells**
- **satellite cells**

Melanocytes
- migrate to the epidermis

Ectomesenchymocytes
- migrate into the branchial arches
- replace the mesenchyme of mesodermal origin



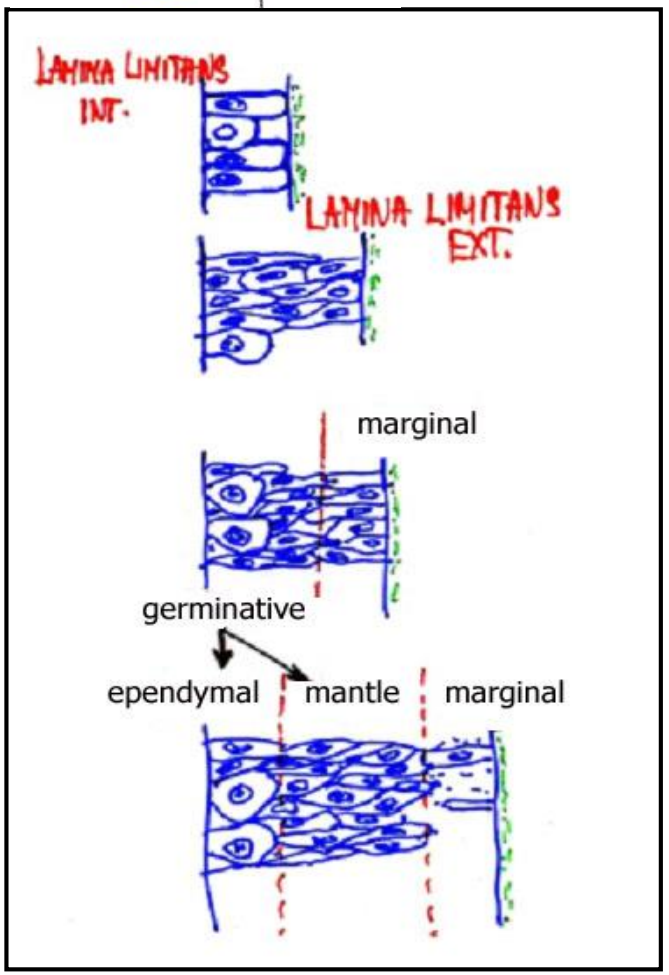
Nerve tissue – Histogenesis of neural tube



- initial state - **pseudostratified columnar** epithelium
- initially cells divide in whole thickness of the wall
- later mitotic activity is reduced only tocells situated near the luminal aspect of the neural tube

- neural tube develops 2 zones: **germinative** (inner) + **marginal** (outer)
- cells of the germinative zone continue dividing and migrate peripherally to form **mantle layer**

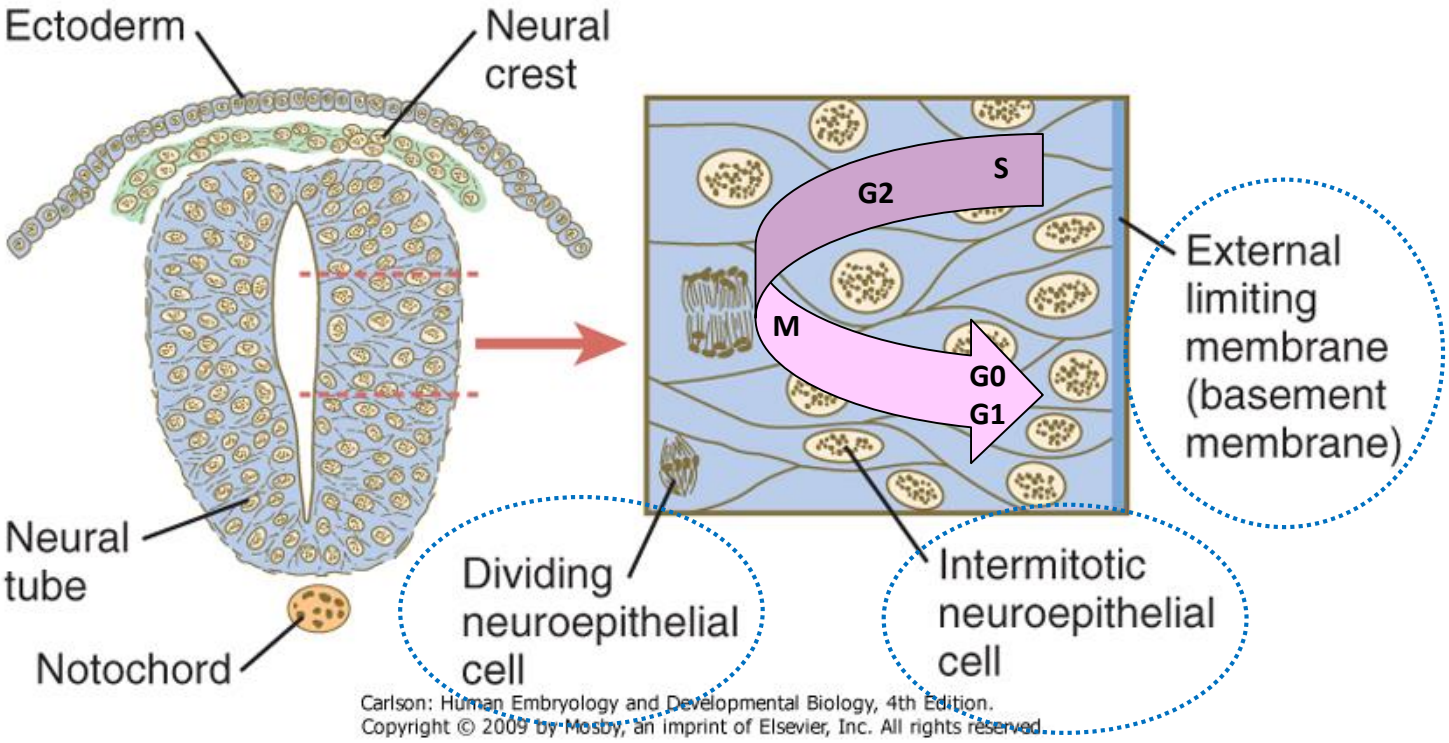
- **ependymal** layer = **ependyma**
- **mantle** layer = **gray matter** - differentiate into primitive neurons - neuroblasts and spongioblasts (glioblasts)
- **marginal** layer = **white matter** (contains no cells)



Nerve tissue – Neural tube

The **early neural tube** is a pseudostratified epithelium

- The **"apical" portion** abuts the **central canal**
- The **"basal" portion** abuts the **surrounding tissue** (e.g. somites, notochord, etc.).
- Cell division occurs in the apical portion.



Carlson: Human Embryology and Developmental Biology, 4th Edition.
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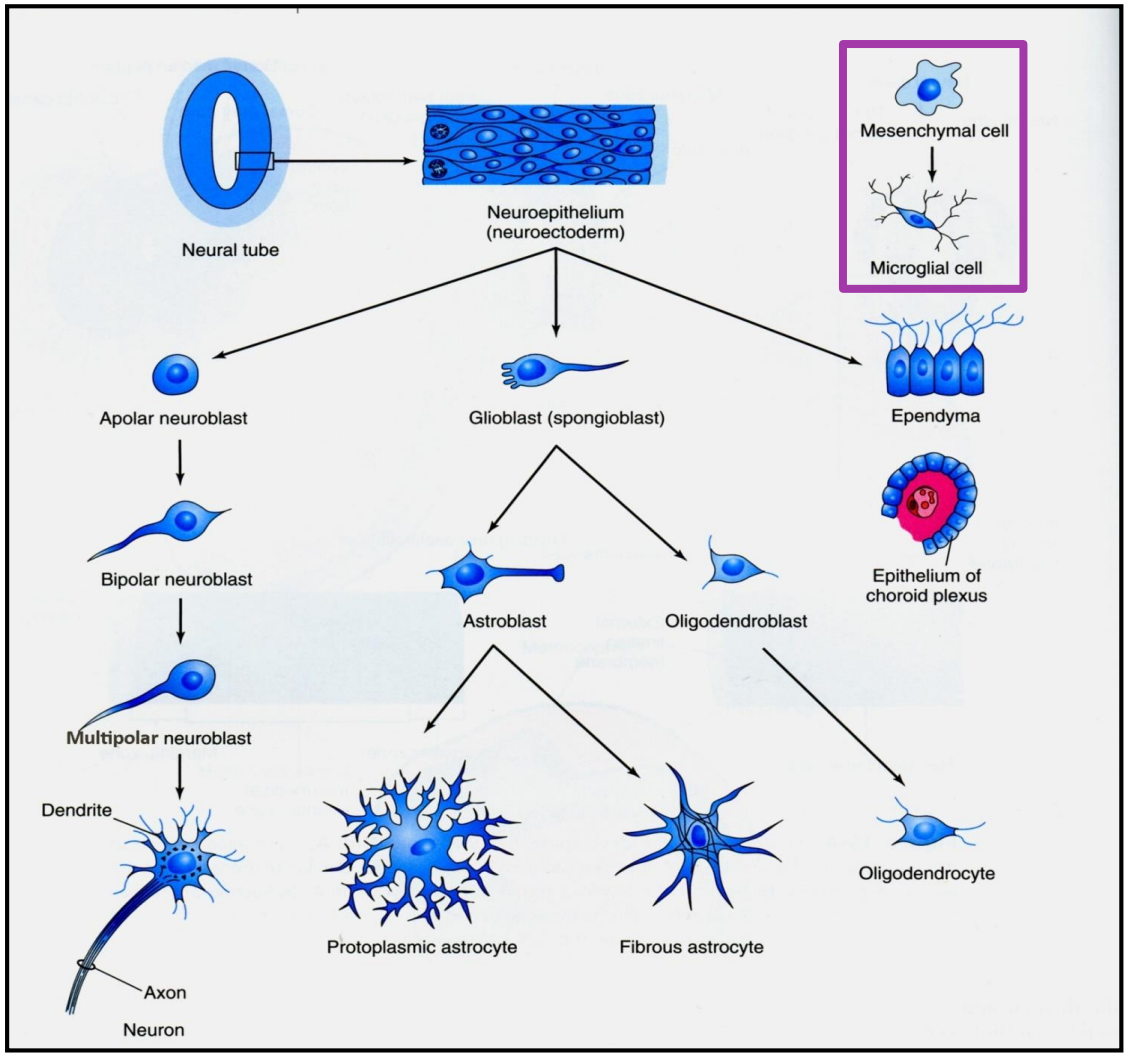
Nerve tissue – Neural tube – Cell differentiation

Ependymal layer:
- **ependymal cells** (ependymocytes)

Mantle layer:
- **neuroblasts** - to neurons
- **spongioblasts (glioblasts)** – to:
  - astrocytoblasts
  - olidodendrocytoblasts

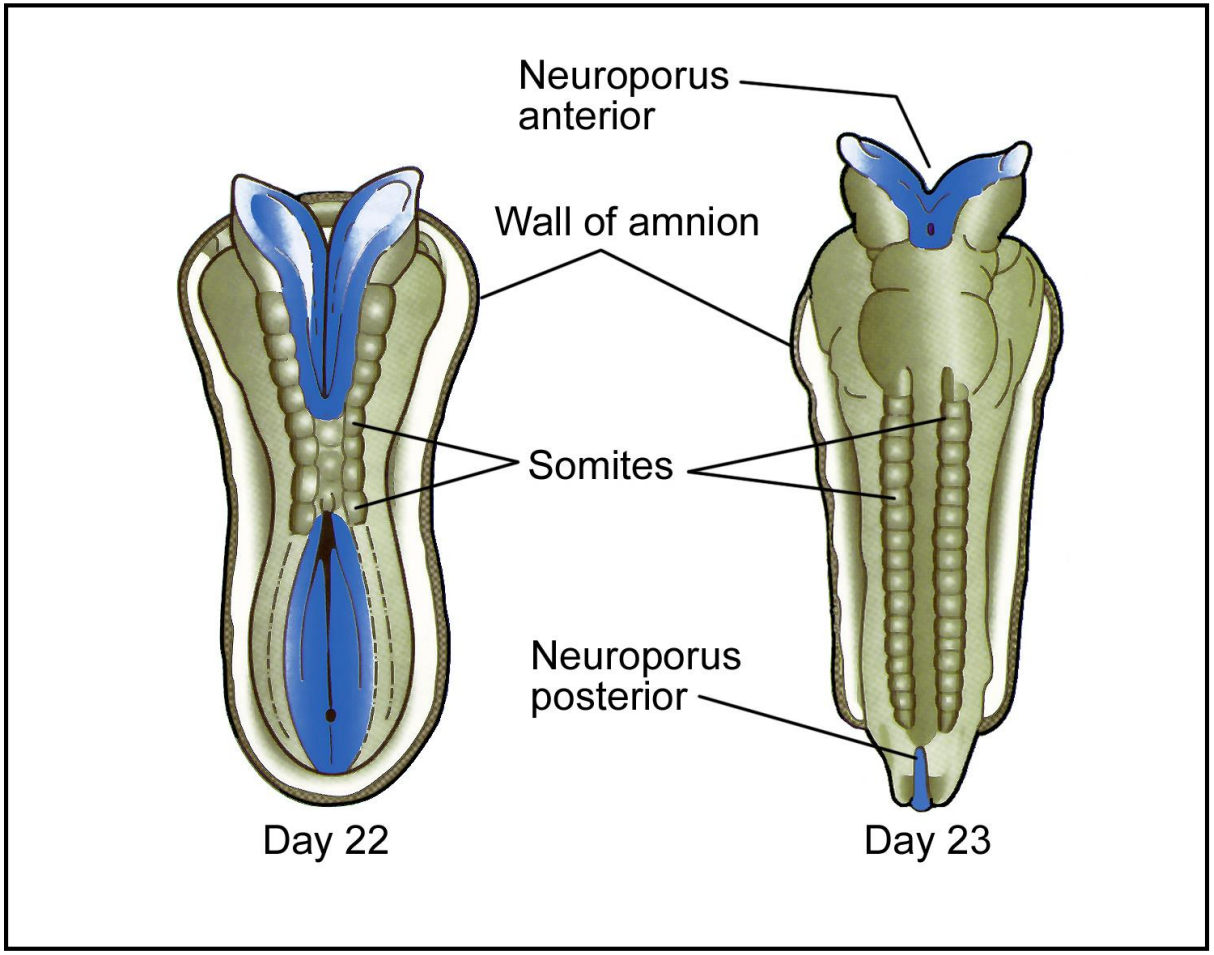
Marginal layer:
- no cells



Nerve tissue – Morphogenesis

Brain – develops from the proximal segment of the neural tube that is broadened from the very beginning

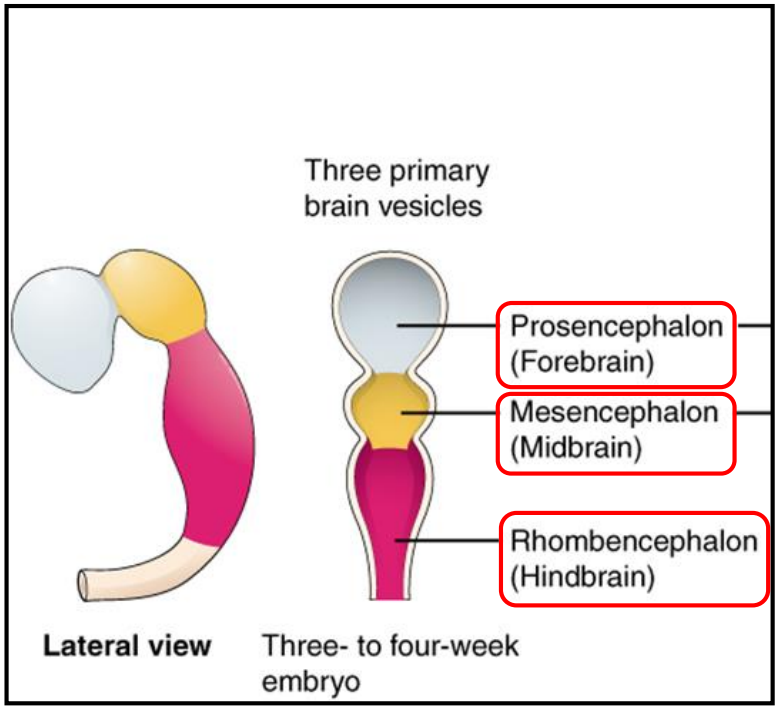
Spinal cord – develops from the narrower caudal segment of the neural tube



Nerve tissue – Brain development

Brain develops from the cranial part of the neural tube at **4th week** - **3 primary brain vesicles**

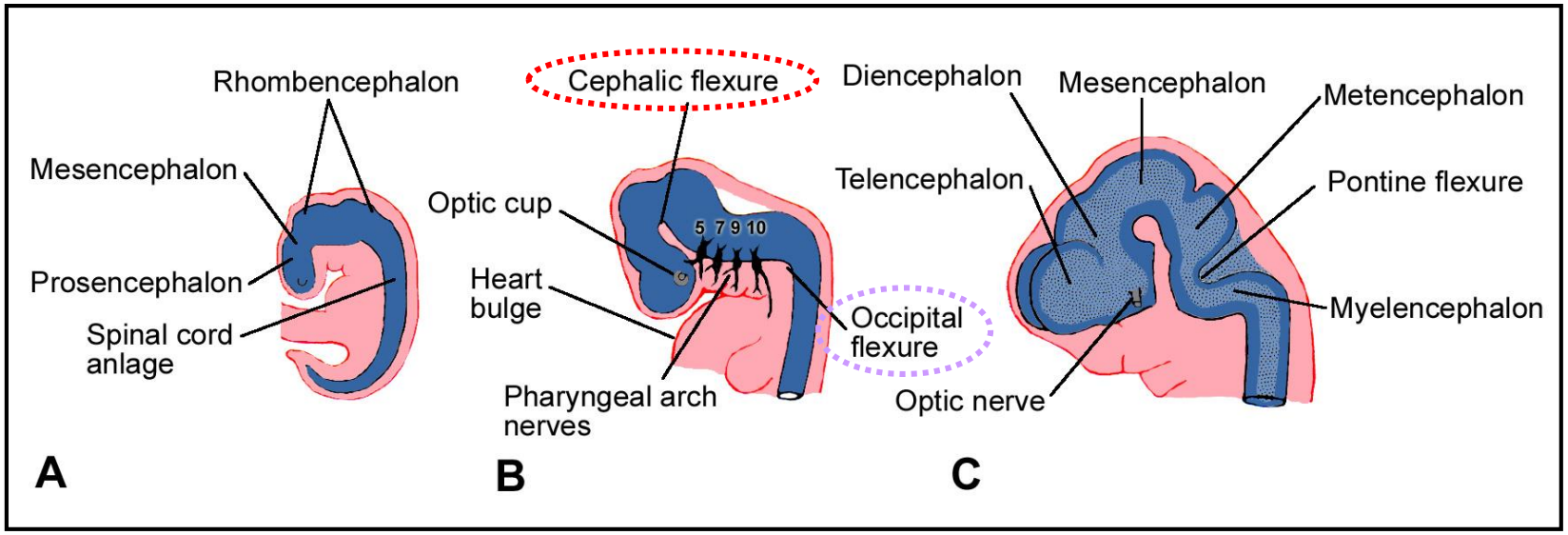
- **Forebrain - prosencephalon**
- **Midbrain - mesencephalon**
- **Hindbrain - rhombencephalon**



Nerve tissue – Brain development

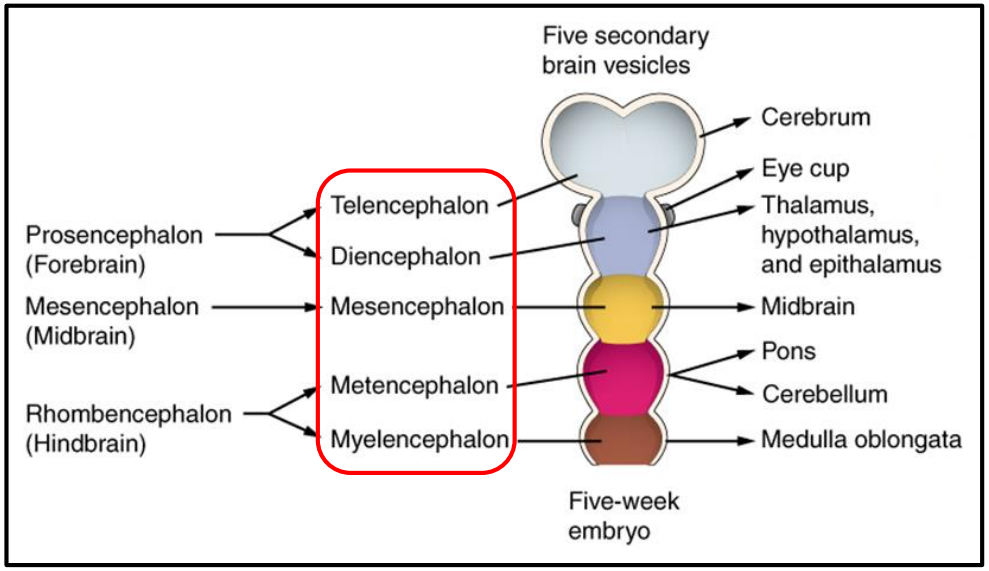
vesicles are not followed each to other linearly, but are bent in the sagittal plane

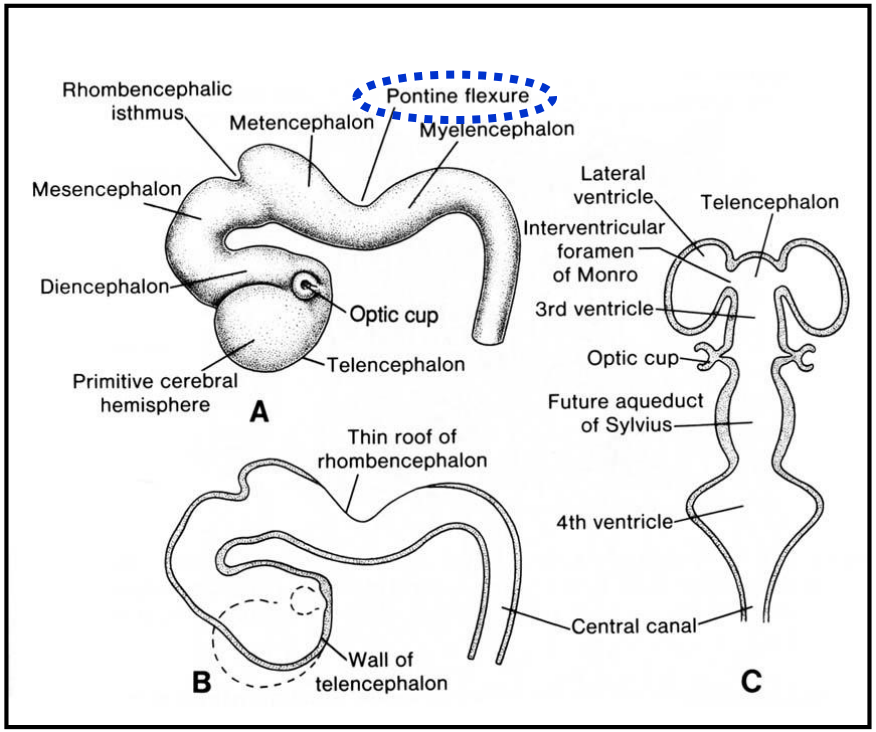
Cephalic flexure - permanent
Occipital (cervical) flexure - after 2 months it is on straightening, so is not evident in the adulthood



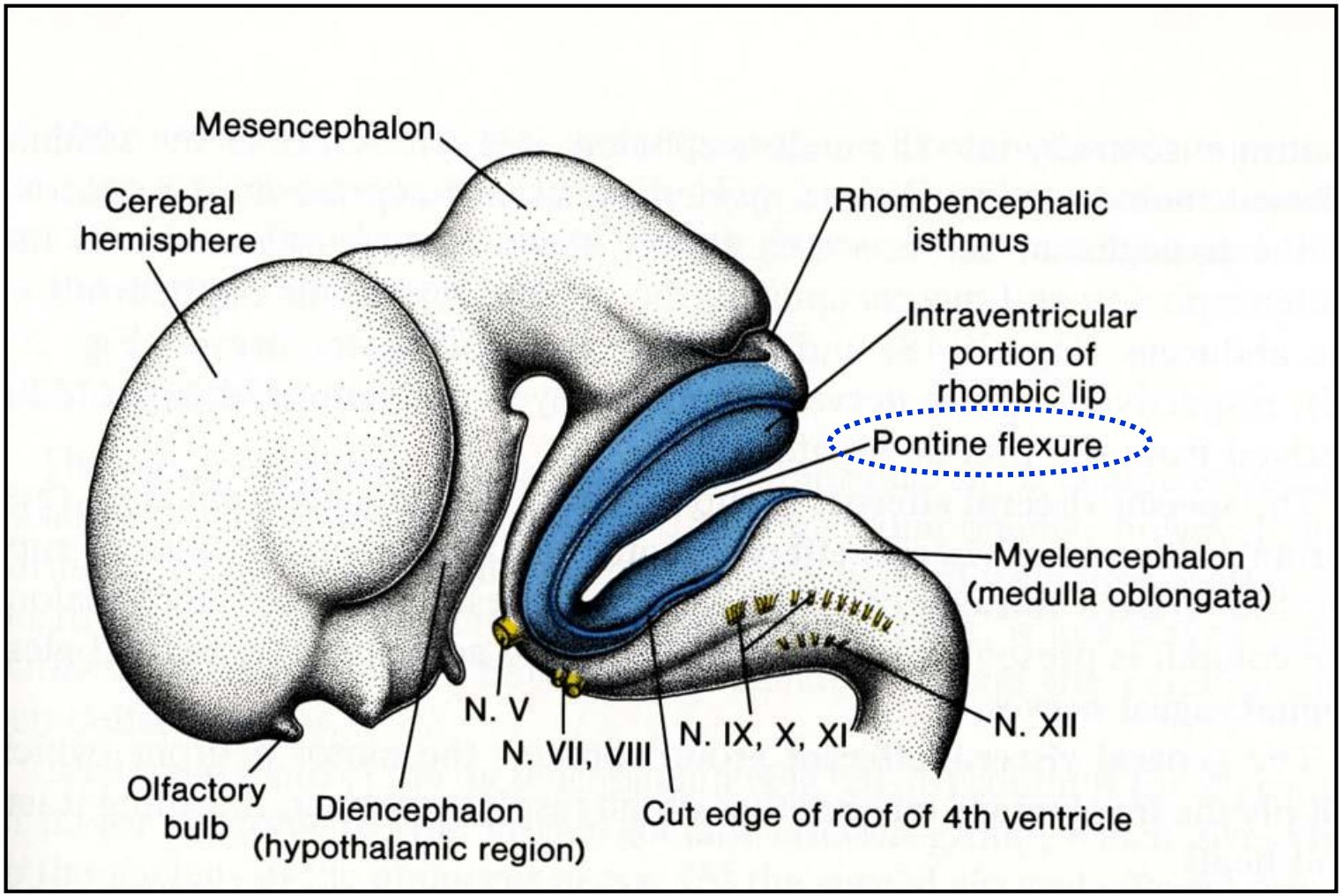
Nerve tissue – Brain development

- **5th week**
- **5 secondary vesicles**
- **Pontine flexure** – remains to adulthood





Nerve tissue – Brain development

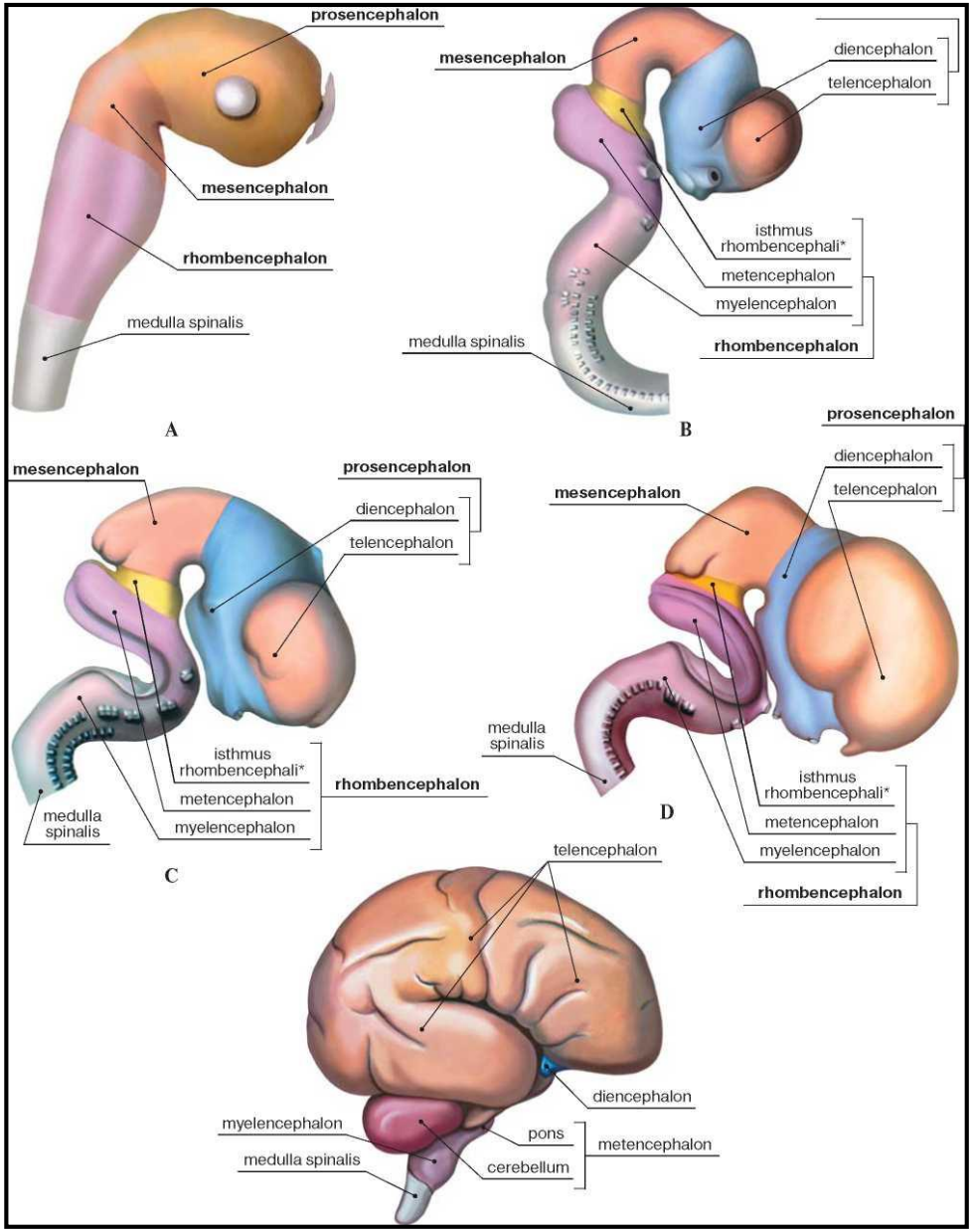


Nerve tissue – Brain development

Early brain development results in:

- **deflection of the brain base**
- **constitution of five final brain sections**

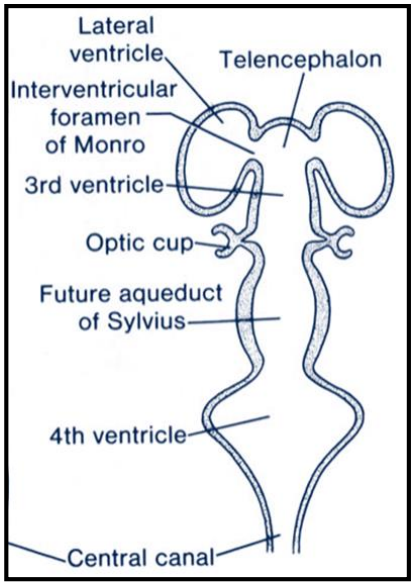
Definitive position compared to the baseline situation is highly complicated due to different growth rates of individual sections.

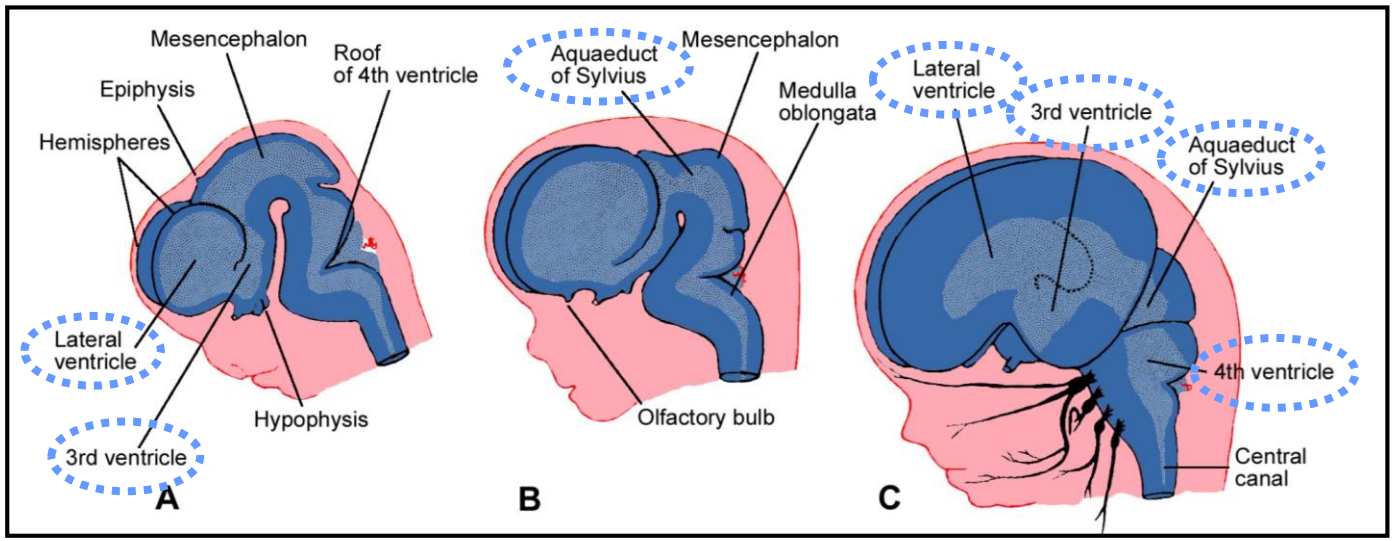


Nerve tissue – Brain development - Ventricles

You must memorize !

Prosencephalon	Telencephalon	Ventriculi laterali cerebri
	Diencephalon	Ventriculus tertius
Mesencephalon	Mesencephalon	Aquaeductus cerebri
Rhombencephalon	Metencephalon	Ventriculus quartus
	Myelencephalon	



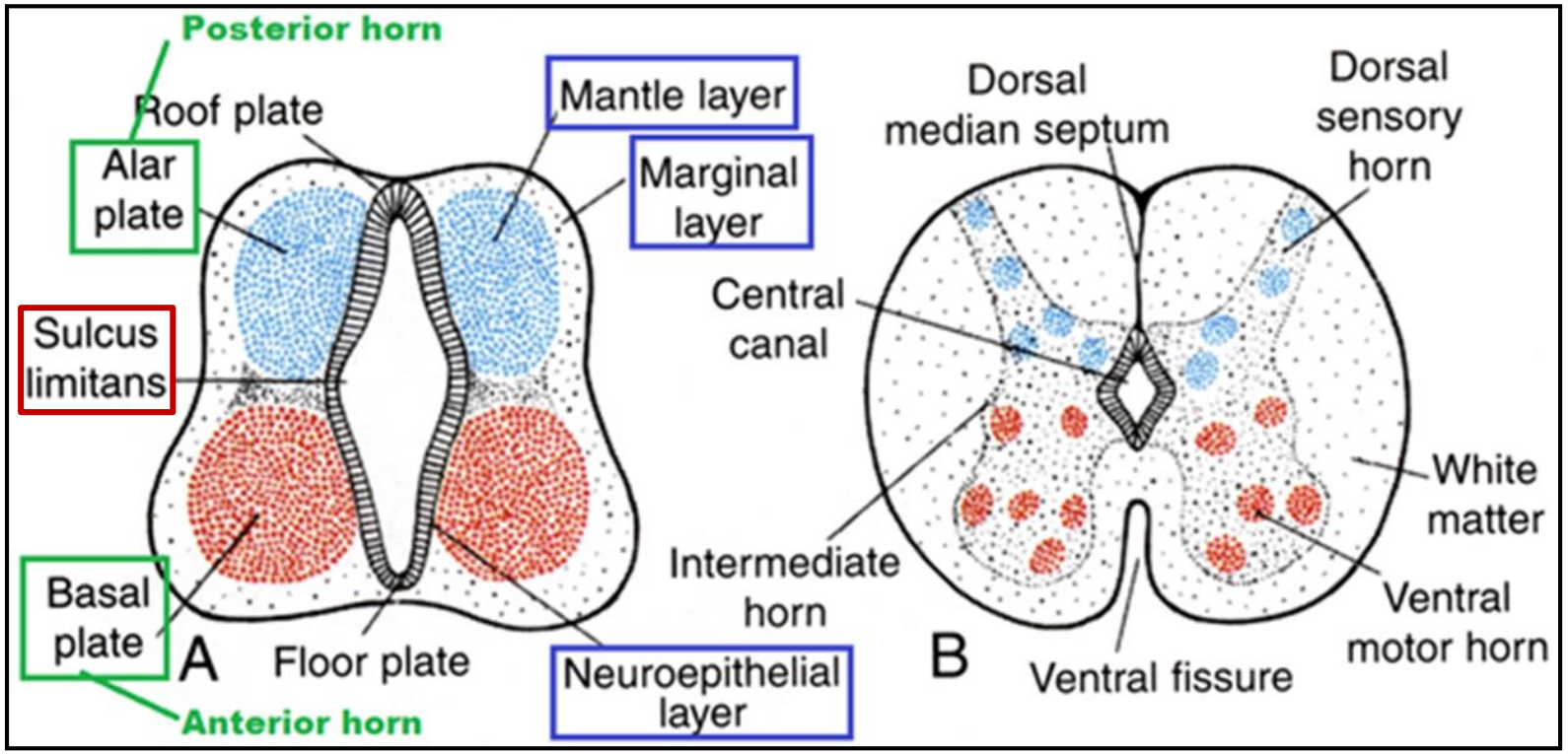


Nerve tissue – Spinal cord development

- it develops from the caudal part of neural tube

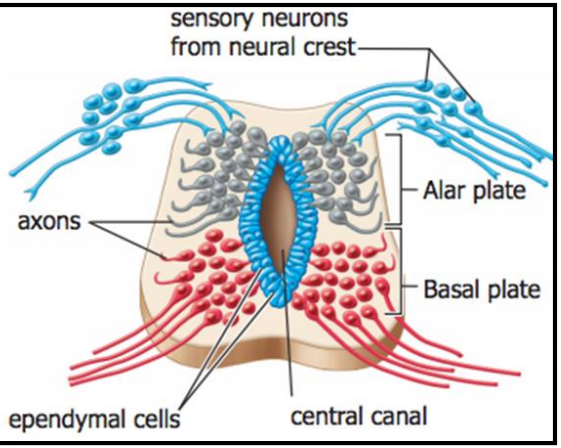
- cells of mantle layer proliferate and produce 2 sheets - the dorsal **alar plate** and ventral **basal plate**, which are separated by longitudinal groove called the **sulcus limitans**

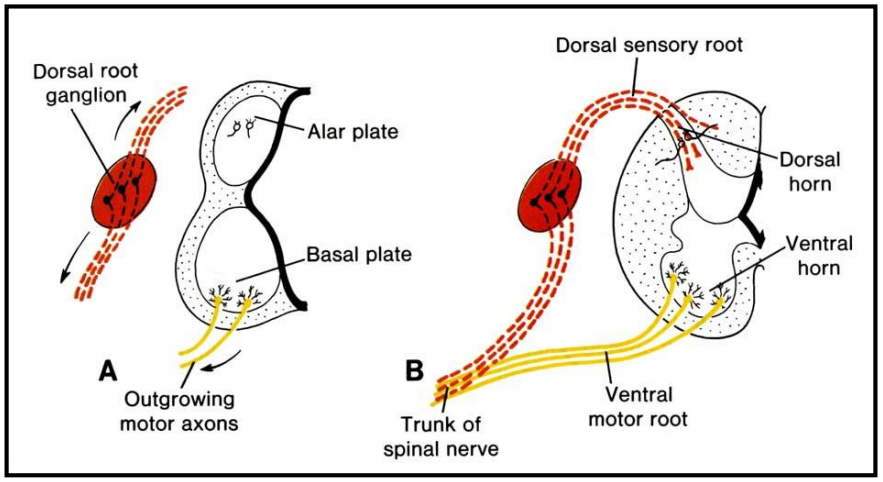
To remember:
- **alar plate -** gives rise to **dorsal horn**
- **basal plate -** gives rise to **ventral horn**



Nerve tissue – Spinal cord development

- Alar plate
  - Dorsal neuroblasts form sensory interneurons
- Basal plate
  - Ventral neuroblasts form motor neurons
- Axons form white matter.



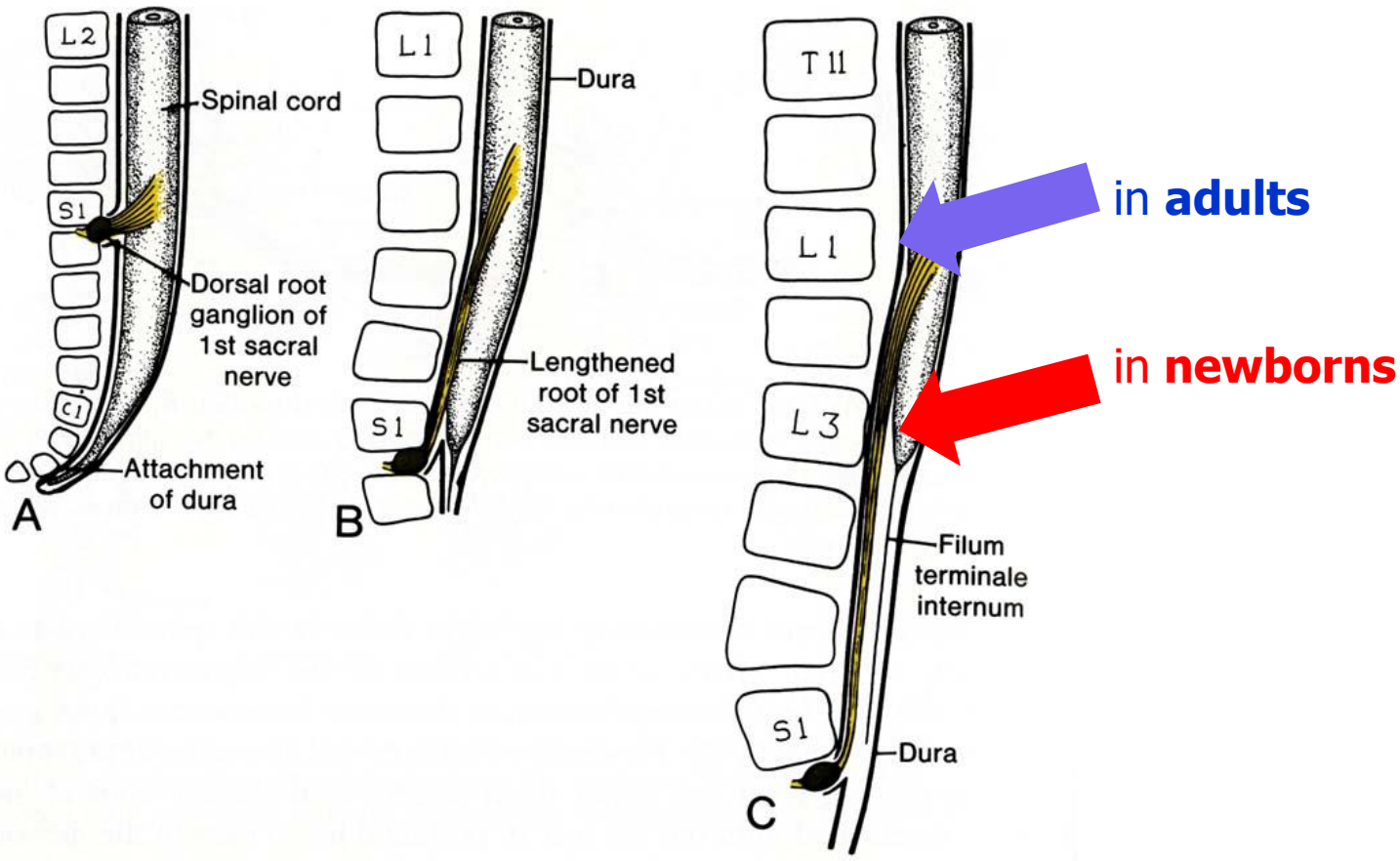


Axons of neuroblasts of anterior horns unite with peripheral processes of corresponding spinal ganglia neuroblasts and together leave the spinal canal as a trunk of **spinal nerve.**

Nerve tissue – Spinal cord development

Positional changes of the spinal cord

•initially, length of spinal cord correlates with length of the vertebral canal
•during further development, the vertebral canal grows more rapidly than spinal cord so that its caudal end gradually comes to lie at relatively higher levels of the canal
•in adults, it usually terminates at the inferior border of the first lumbar vertebra



Thank you for your attention !

Questions and comments at:
ahampl@med.muni.cz