Nervous System –part 1

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Fundamentals of the Nervous System & Neural Tissue

Nervous System

- The master controlling and communicating system of the body
- Functions
  - Sensory input – monitoring stimuli occurring inside and outside the body
  - Integration – interpretation of sensory input
  - Motor output – response to stimuli by activating effector organs

Nervous System

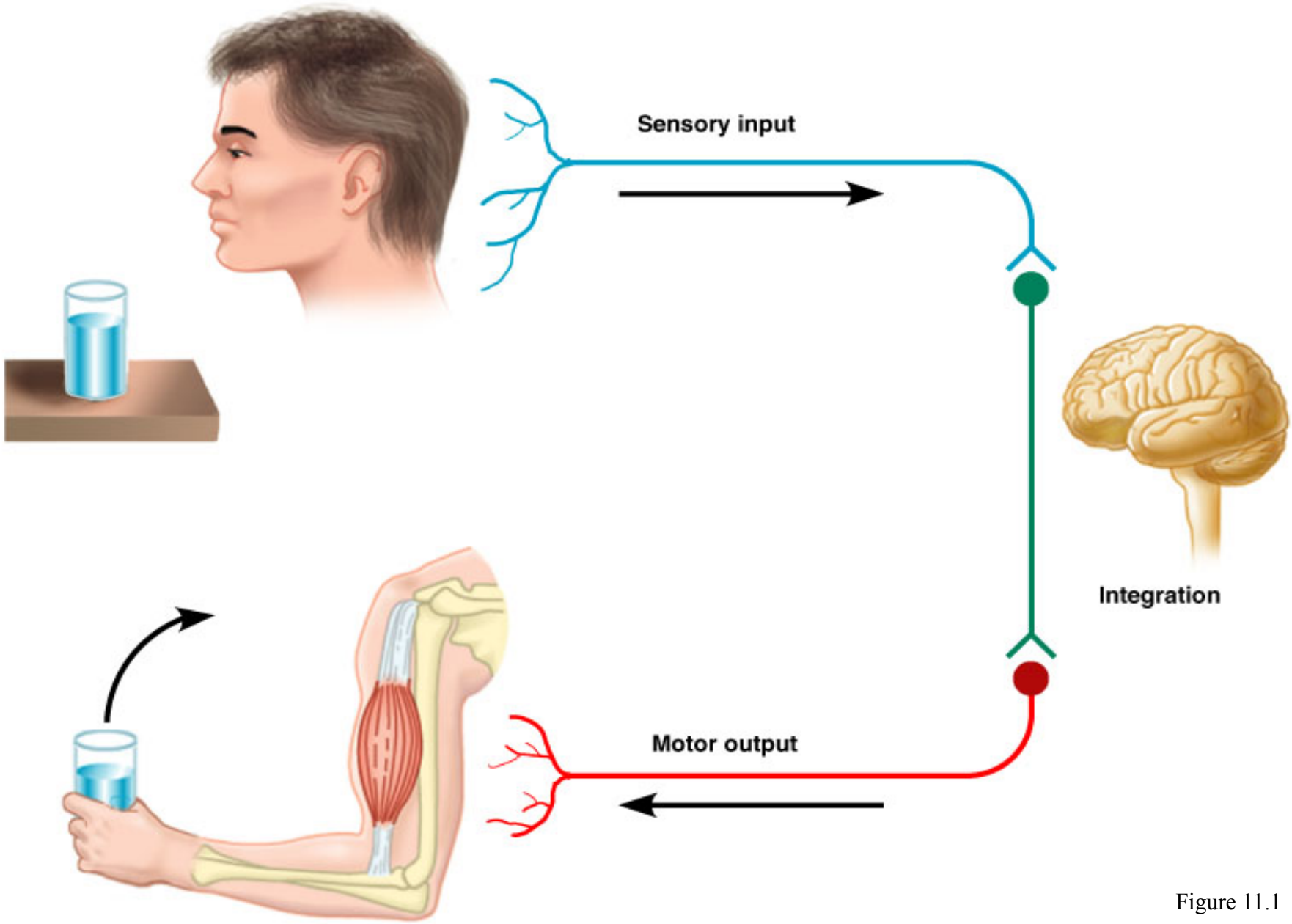
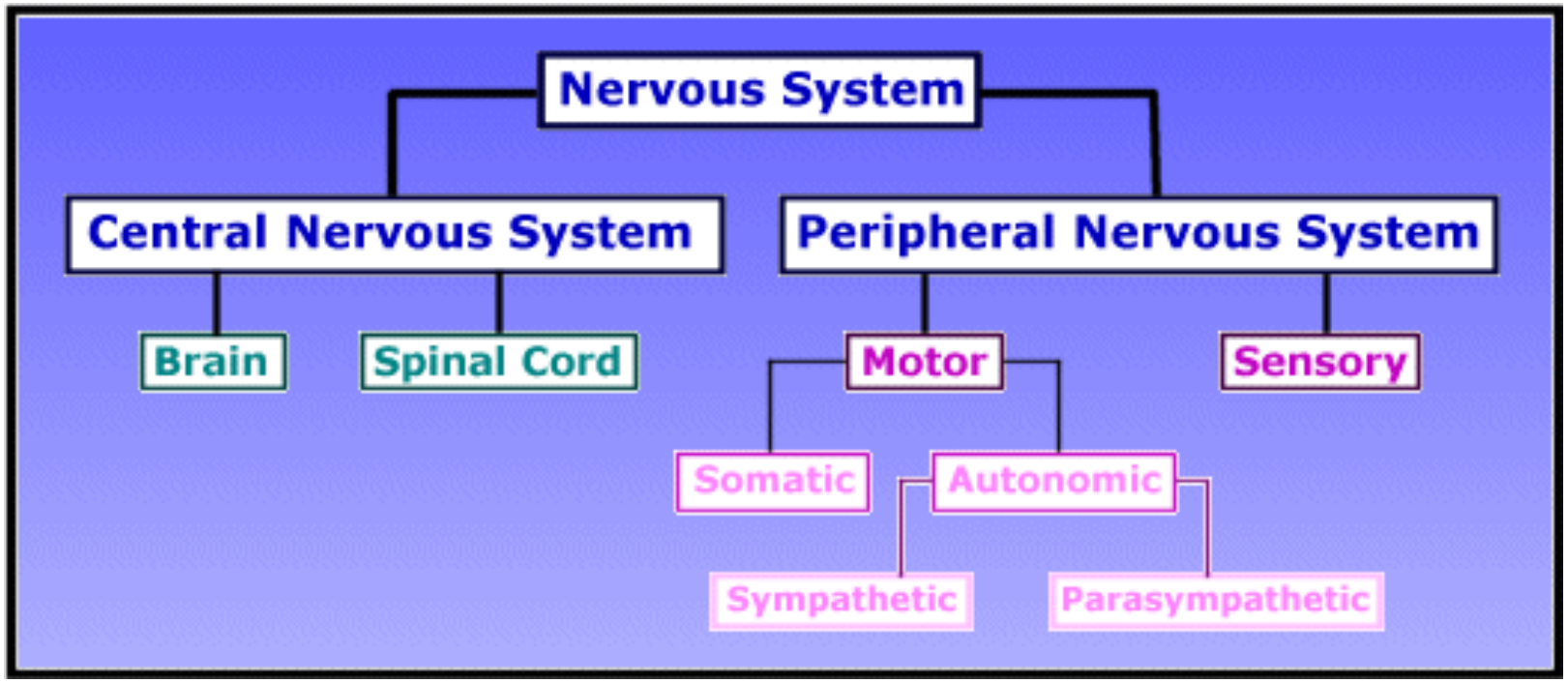


Figure 11.1

Organization of the Nervous System

- Central nervous system (CNS)
  - Brain and spinal cord
  - Integration and command center
- Peripheral nervous system (PNS)
  - Paired spinal and cranial nerves
  - Carries messages to and from the spinal cord and brain

Organization of the Nervous System (diagram form)



	CNS	PNS
What	Brain & spinal cord	Sensory & motor neurons
Where	Encased in bone	Not incased in bone
Function	Analyze & integrate information	Relays sensory information to CNS; Executes motor commands from CNS
Terminology	Nucleus (pl. Nuclei)	Ganglion (pl. Ganglia), Nerves

Peripheral Nervous System (PNS): Two Functional Divisions

- Sensory (afferent) division
  - Sensory afferent fibers – carry impulses from skin, skeletal muscles, and joints to the CNS
  - Visceral afferent fibers – transmit impulses from visceral organs (internal organs) to the CNS
- Motor (efferent) division
  - Transmits impulses from the CNS to effector organs

Motor Division: Two Main Parts

- Somatic nervous system
  - Conscious (voluntary) control of skeletal muscles
- Autonomic nervous system (ANS)-Involuntary control
  - Regulates smooth muscle, cardiac muscle, and glands
  - Divisions – sympathetic and parasympathetic

Histology of Nerve Tissue

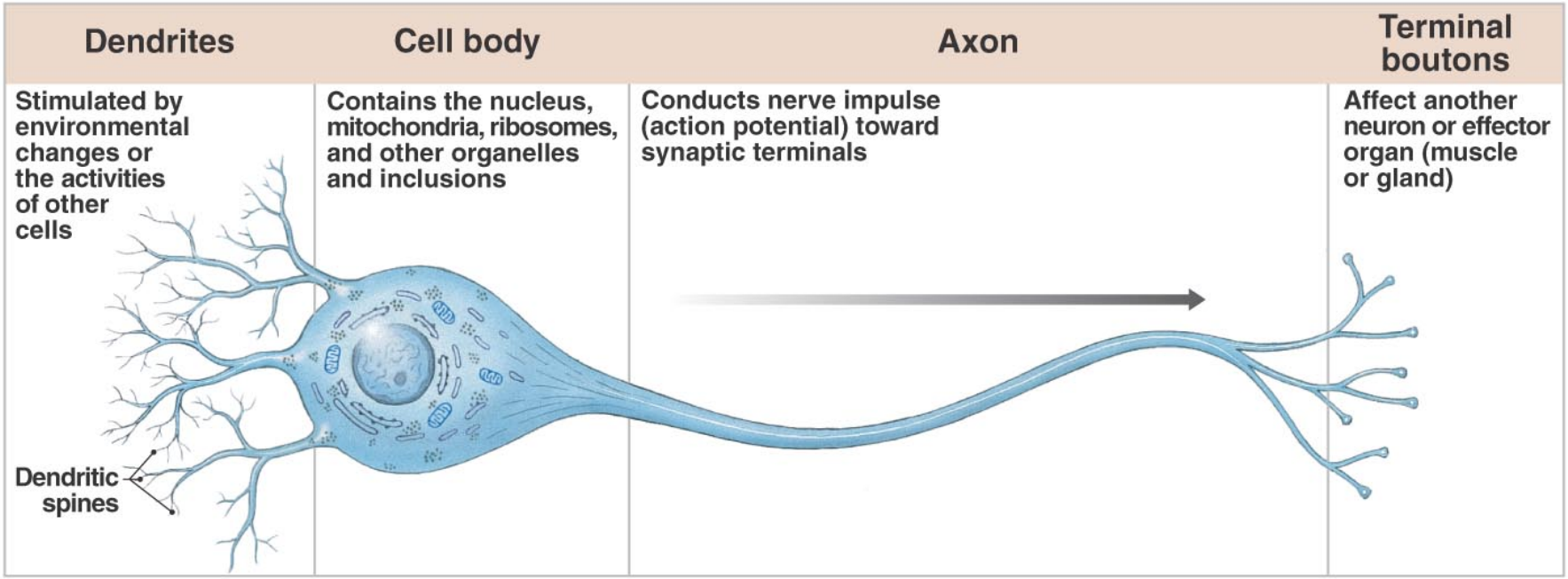
- The two principal cell types of the nervous system are:
  - Neurons – Nerve cells-excitable cells that transmit electrical signals
  - Neuroglia - (glia="glue") – supportive cells – smaller than neurons, most abundant cells in N.S.

    Function of neuroglia: to protect, support, and anchor Neurons in place.

Neurons (Nerve Cells)

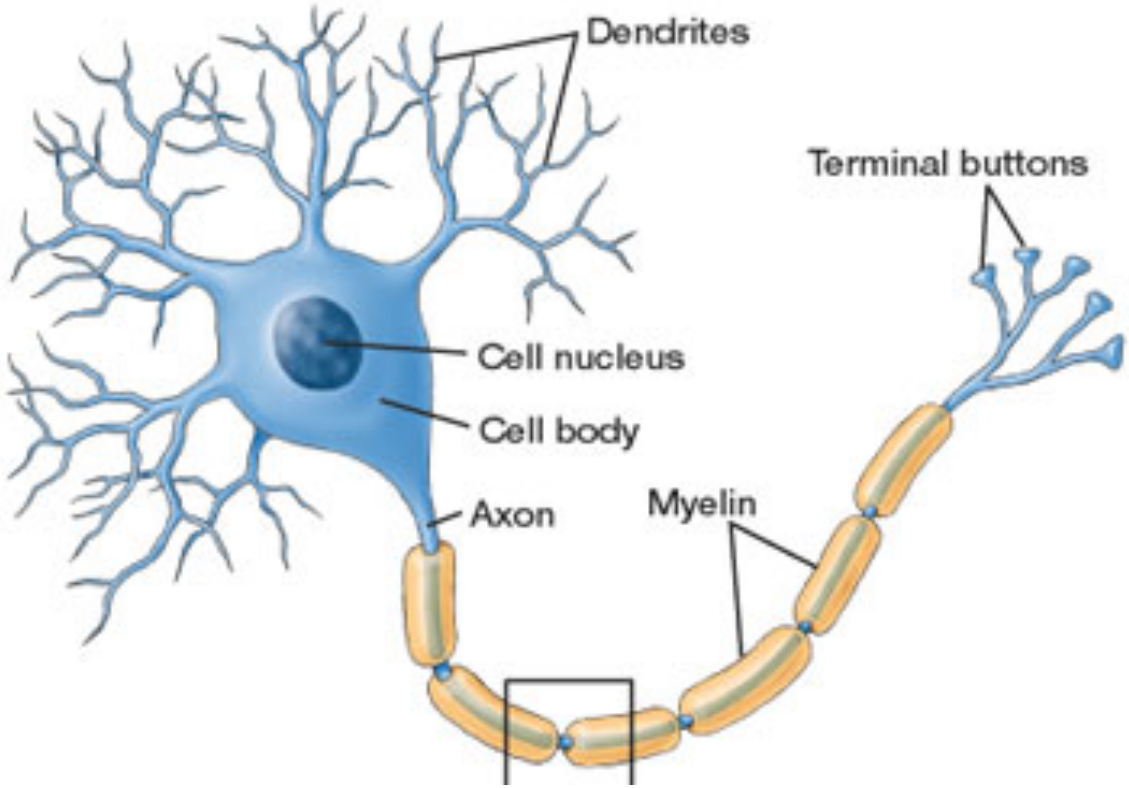
- Structural units of the nervous system
  - Composed of a body, axon, and dendrites
  - Long-lived, amitotic (don't divide), and have a high metabolic rate (lots of mitochondria).
- Functions in:
  - Electrical signaling
  - Cell-to-cell signaling
  - Transfer and processing of information

Typical Neuron



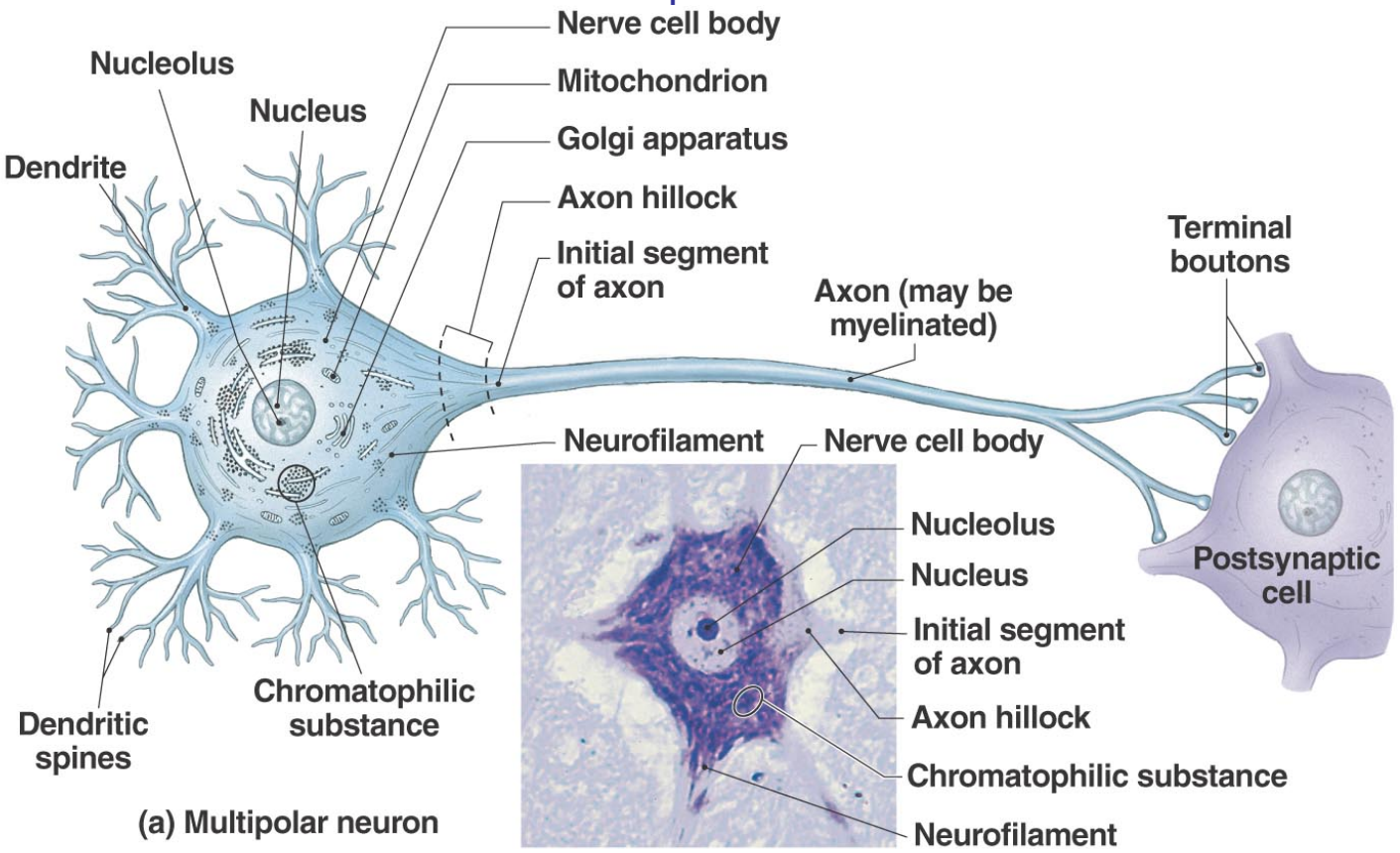
Processes

- Arm like extensions from the soma (cell body)
- There are two types: axons and dendrites



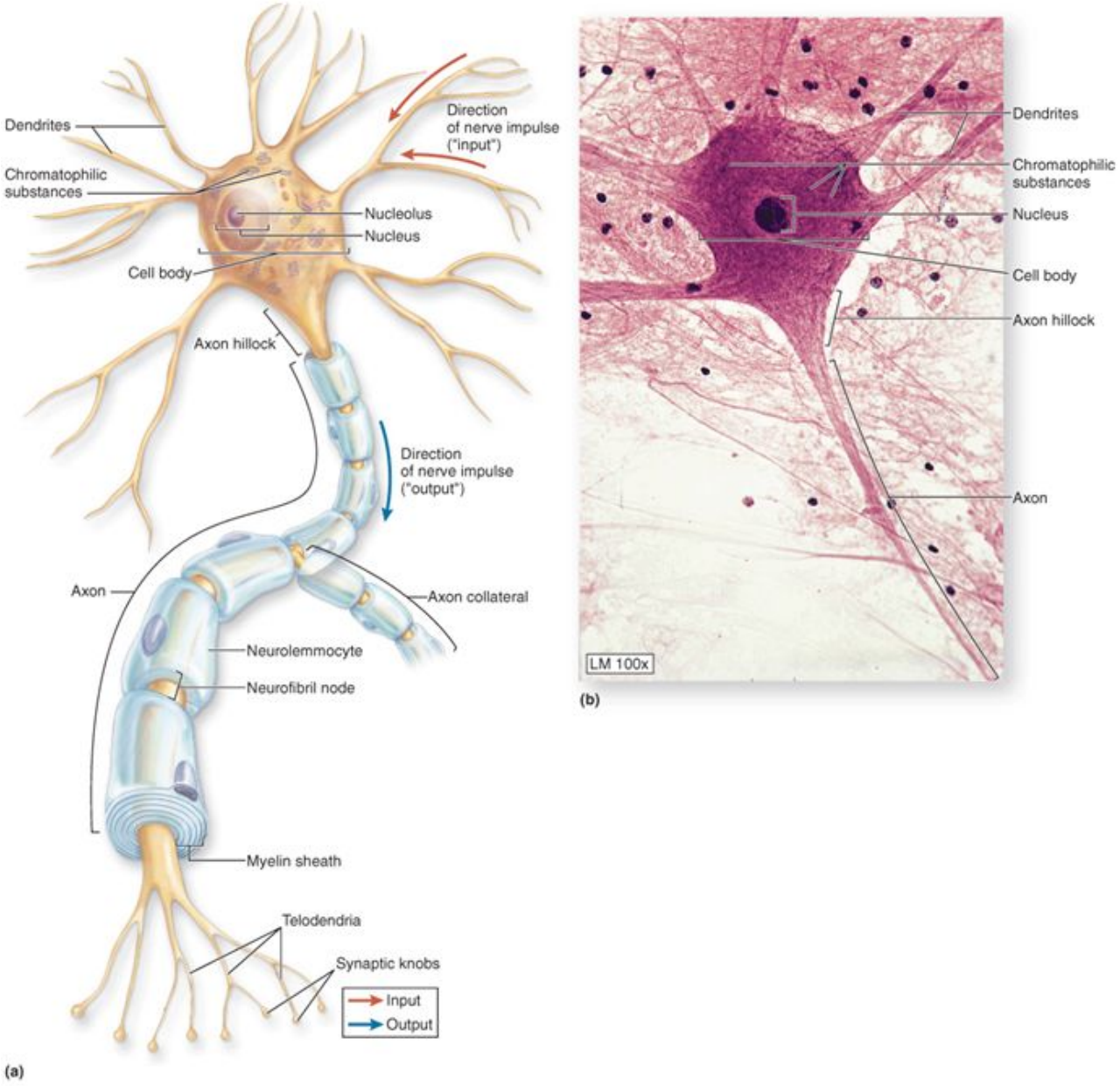
Nerve Cell Body (or Soma)

- Contains the nucleus and a nucleolus
- Is the major biosynthetic center
- Is the focal point for the outgrowth of neuronal processes
- Has no centrioles (hence its amitotic (does not divide) nature)
- Has well-developed Nissl bodies (rough ER)-labeled here as "chromatophillic substance")
- Contains an axon hillock – cone-shaped area from which axons arise



Axons: Structure

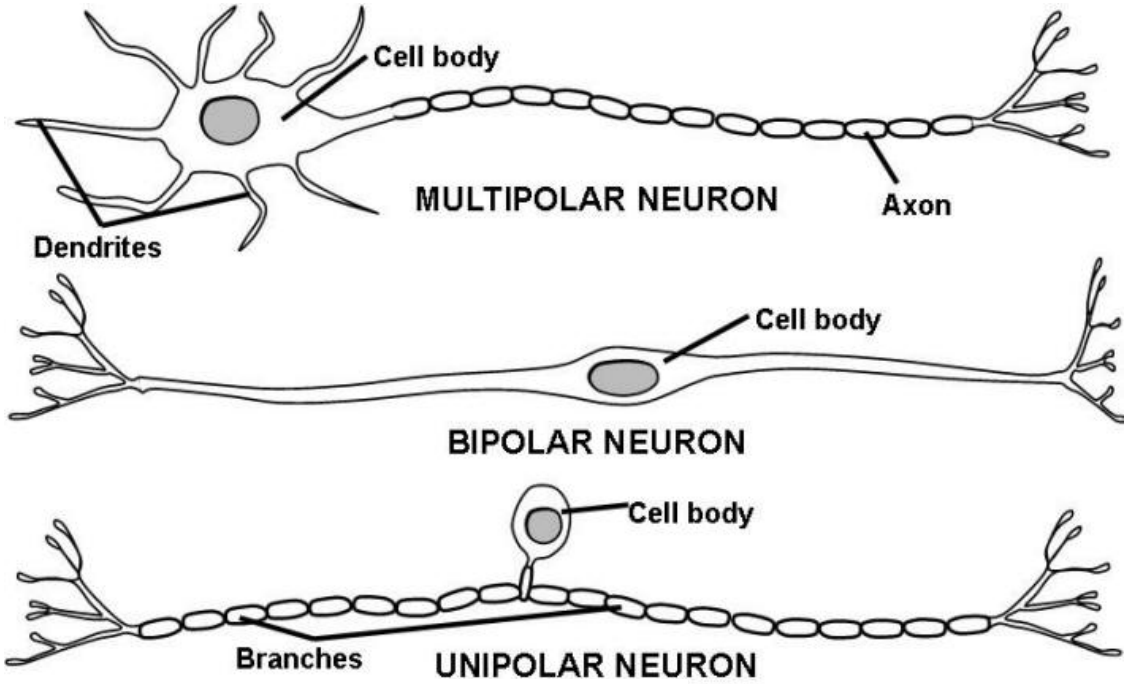
- Slender processes of uniform diameter arising from the hillock
- Long axons are called nerve fibers
- Usually there is only one unbranched axon per neuron
- Rare branches, if present, are called axon collaterals
- Axonal terminal – branched terminus of an axon aka synaptic knobs.
- This axon is myelinated



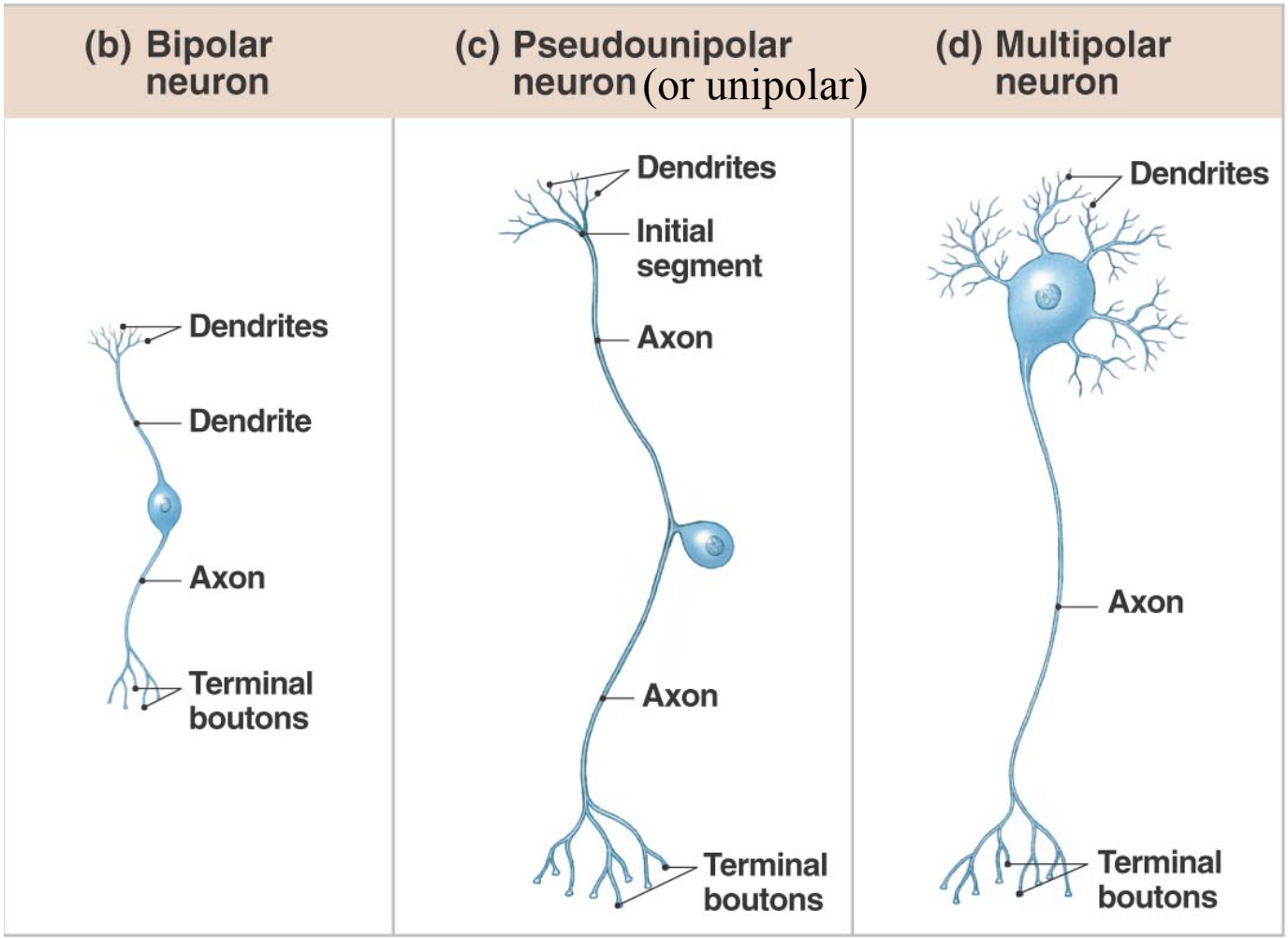
Neuron Classification - by structure or function

Structural: based on number of processes that project from the cell body

- **Multipolar** — three or more processes-most abundant in the body. Major neuron type found in the CNS
- **Bipolar** — two processes (axon and dendrite)-rare. Found in special sensory organs (olfactory and eye)
- **Unipolar** — single, short process-found mainly in the PNS

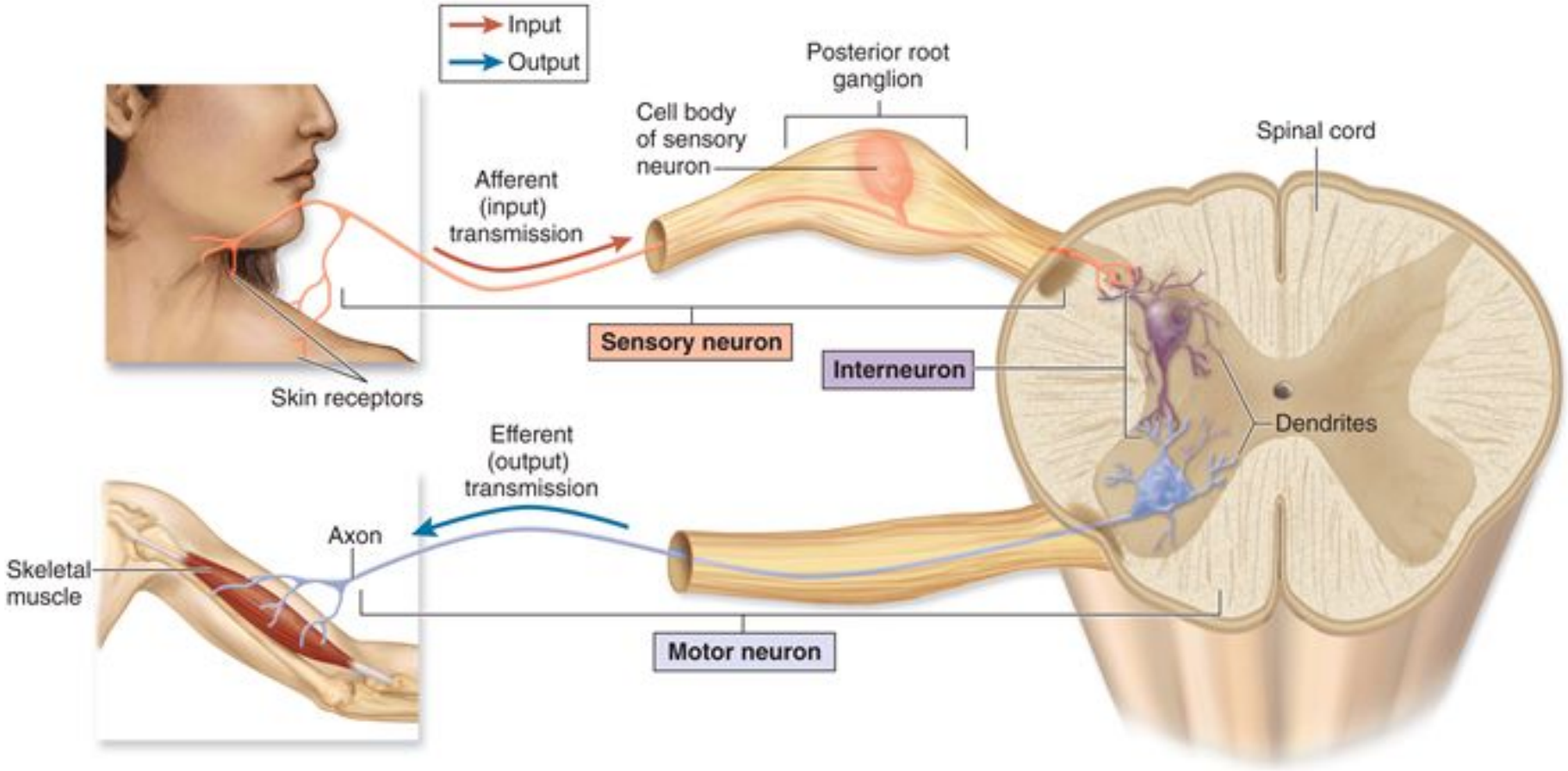


Neuron classification - another view



Neuron Classification - #2 by function

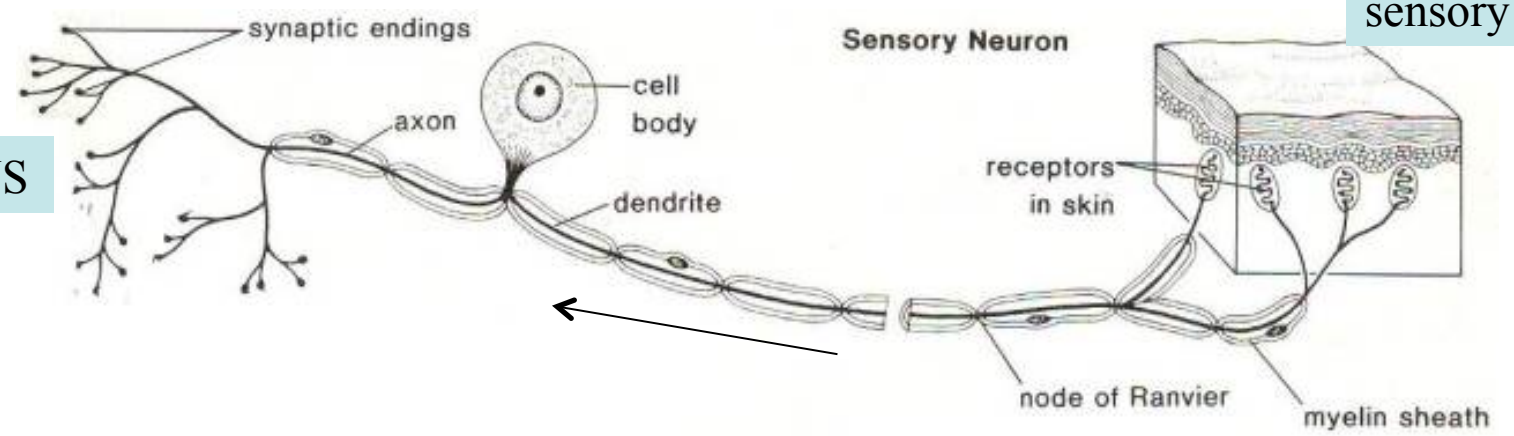
- **Functional:**
  - **Sensory (afferent)** — transmit impulses toward the CNS (unipolar neurons)
  - **Motor (efferent)** — carry impulses away from the CNS (multipolar neurons)
  - **Interneurons -** (association neurons) shuttle signals through CNS pathways (multipolar neurons)



Neuron classification # 2 continued: The breakdown

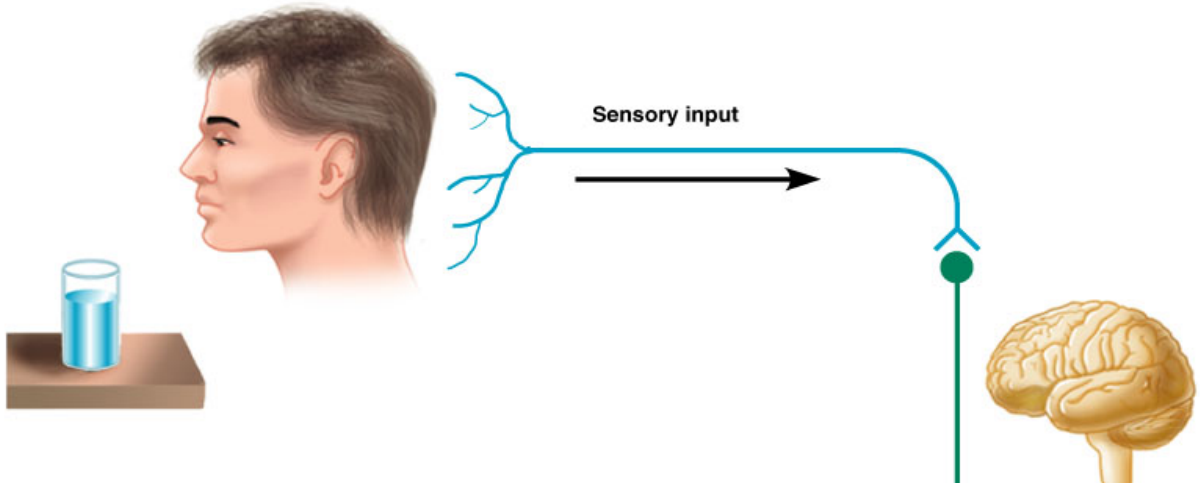
Sensory Neuron: Afferent Neuron (afferent "carrying towards" Relays messages from receptors TO the brain or spinal cord

sensory input



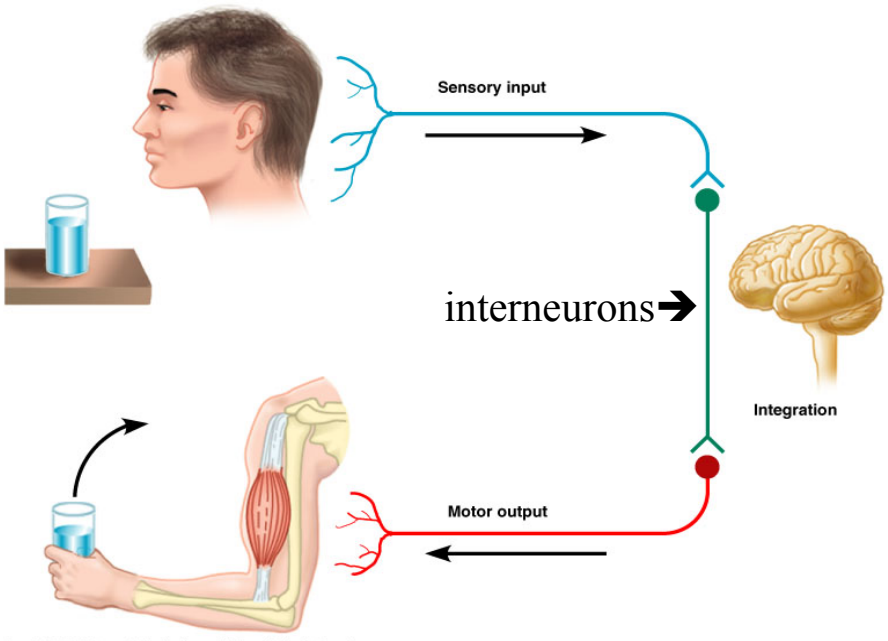
to CNS

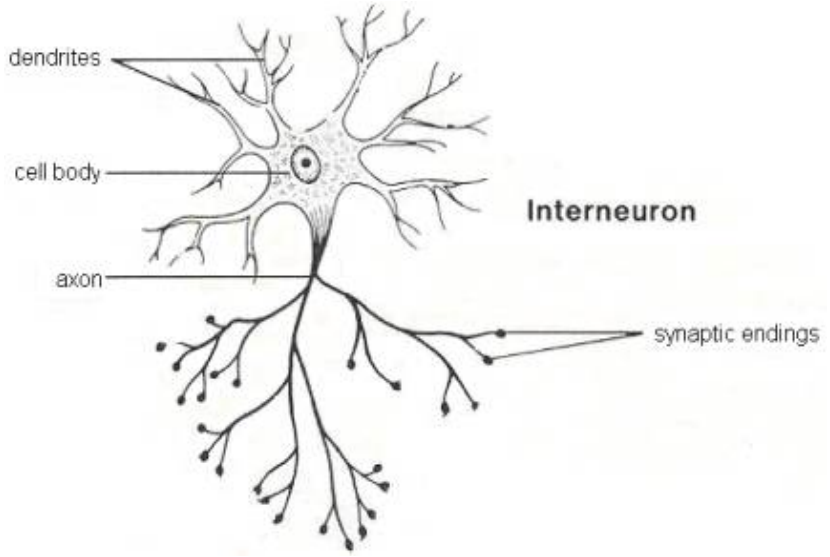
Sensory neurons: almost all are unipolar neurons with cell bodies located outside CNS.



Neuron classification # 2 continued: The breakdown

interneuron (relay neuron): Relays messages from sensory neurons to motor neurons. Located in the CNS. Interconnect the sensory neuron with appropriate motor neuron. All are multipolar neurons.

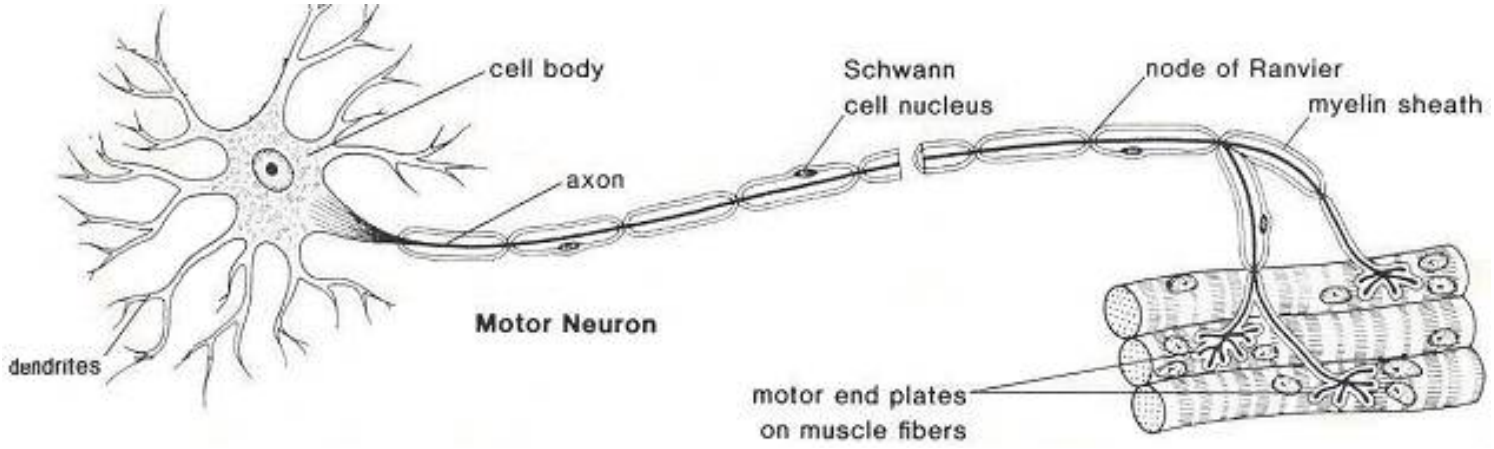




interneurons outnumber all other neurons combined. Interneurons are responsibel for analysis of sensory inputs and the coordination of motor outputs.

Neuron classification # 2 continued: The breakdown

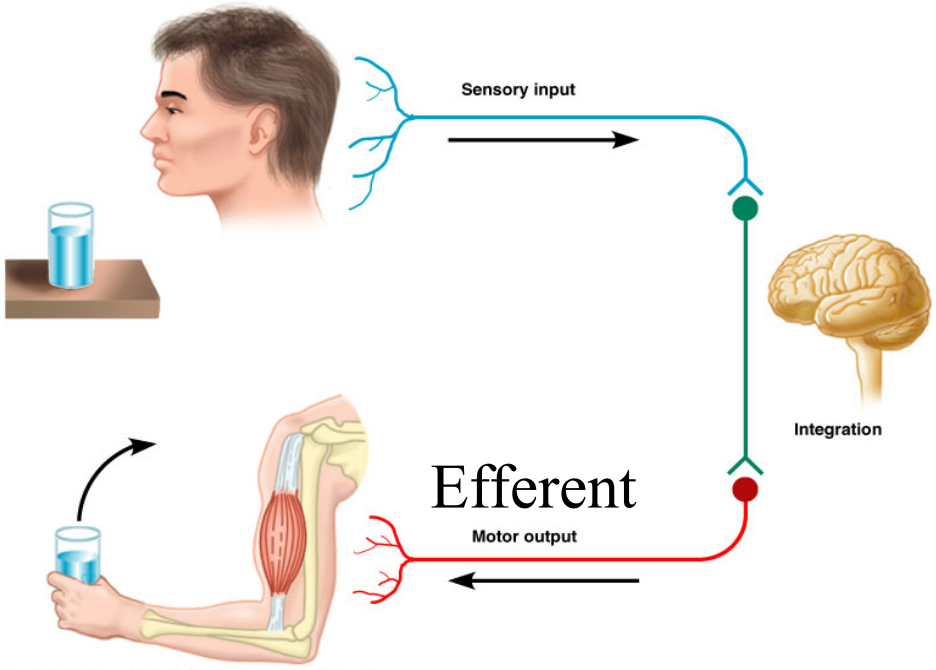
Motor Neuron:Efferent Neuron – (efferent "carrying away". Relays messages from (away) the brain or spinal cord to the muscles and organs



Efferent Neurons:

*Short dendrites and long axons

*Dendrites and the cell body are located in the spinal cord (CNS),
*multipolar neurons
*the neurons axon is outside of the spinal cord (in the PNS)
*Conduct impulse to an effector (muscle or gland)



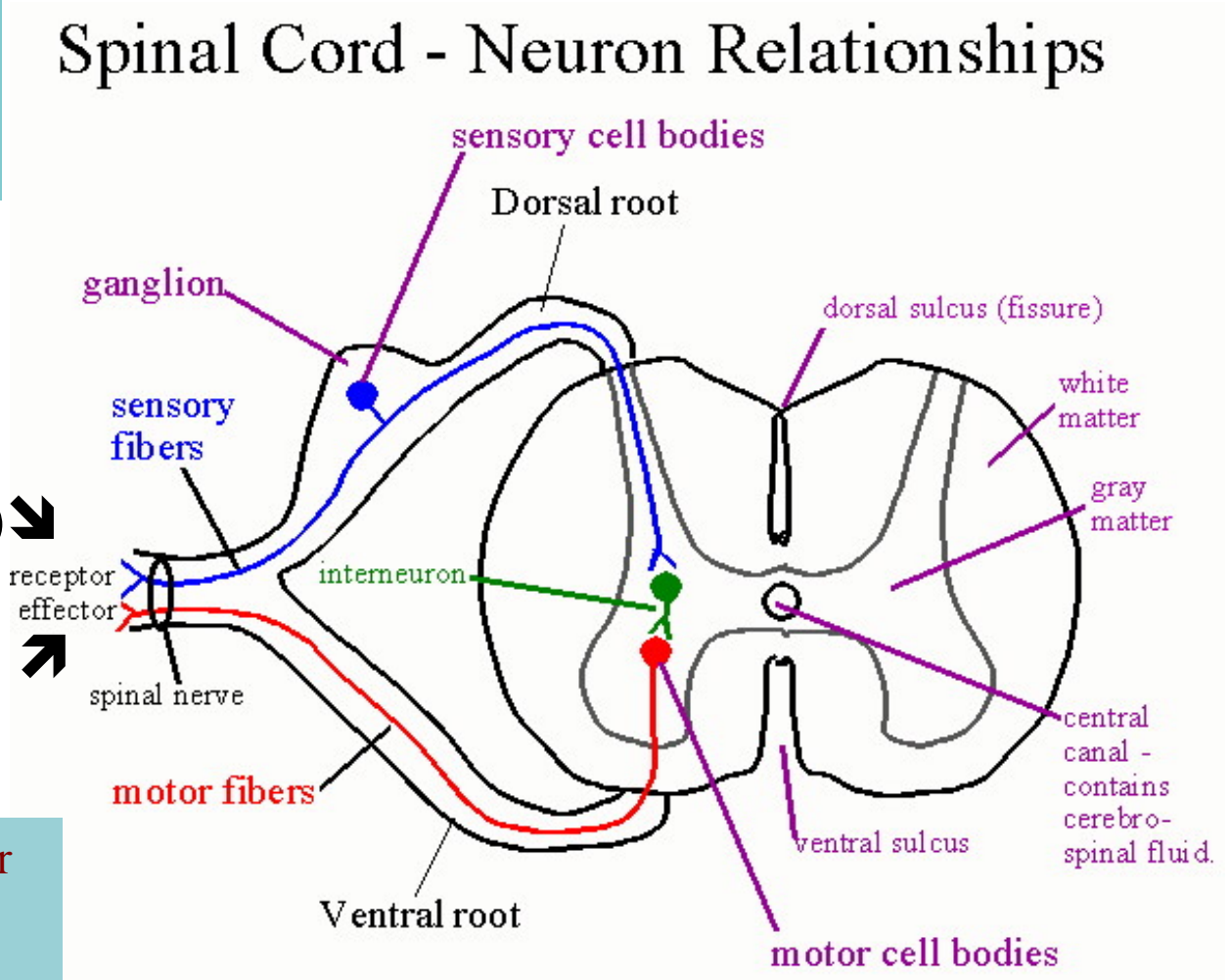
Functional classification of neurons continued:

Another way to look at it:we will be drawing this over and over, so if it doesn't make sense yet…it will!

Sensory-(afferent) almost all are unipolar neurons with cell bodies located in the PNS (in ganglia).

stimulus (affector)↘

response (effector) ↗

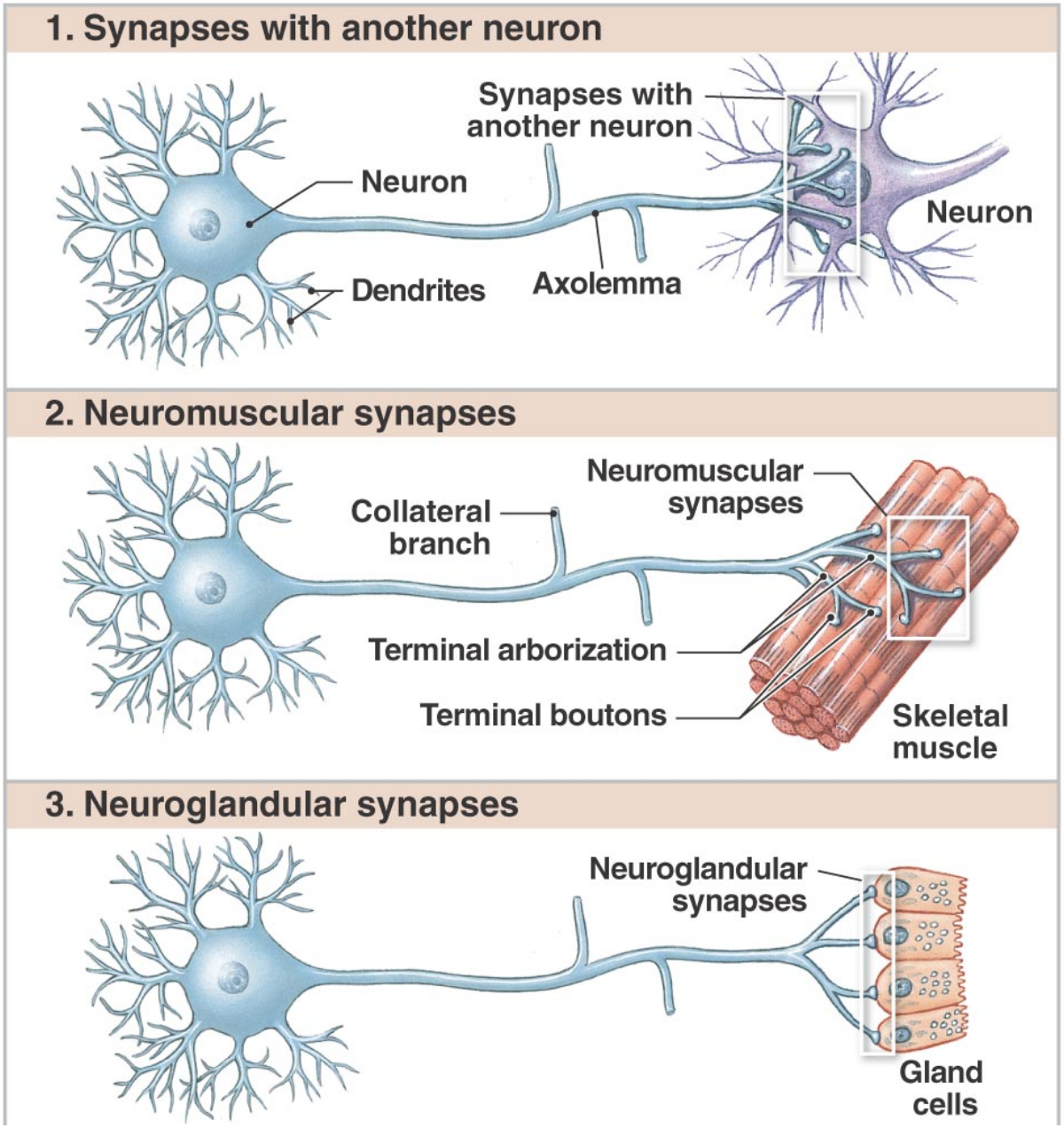


Motor-(efferent): multipolar neurons- most have cell bodies within CNS

Axons: Function

- Generate and transmit action potentials
- Secrete neurotransmitters (chemical messengers)from the axonal terminals (synaptic knobs)
- Conducts impulses away from the cell body
- Cytoplasm of axon contains many mitochondria and microtubules which transport material within the cell

Where an axon may go:

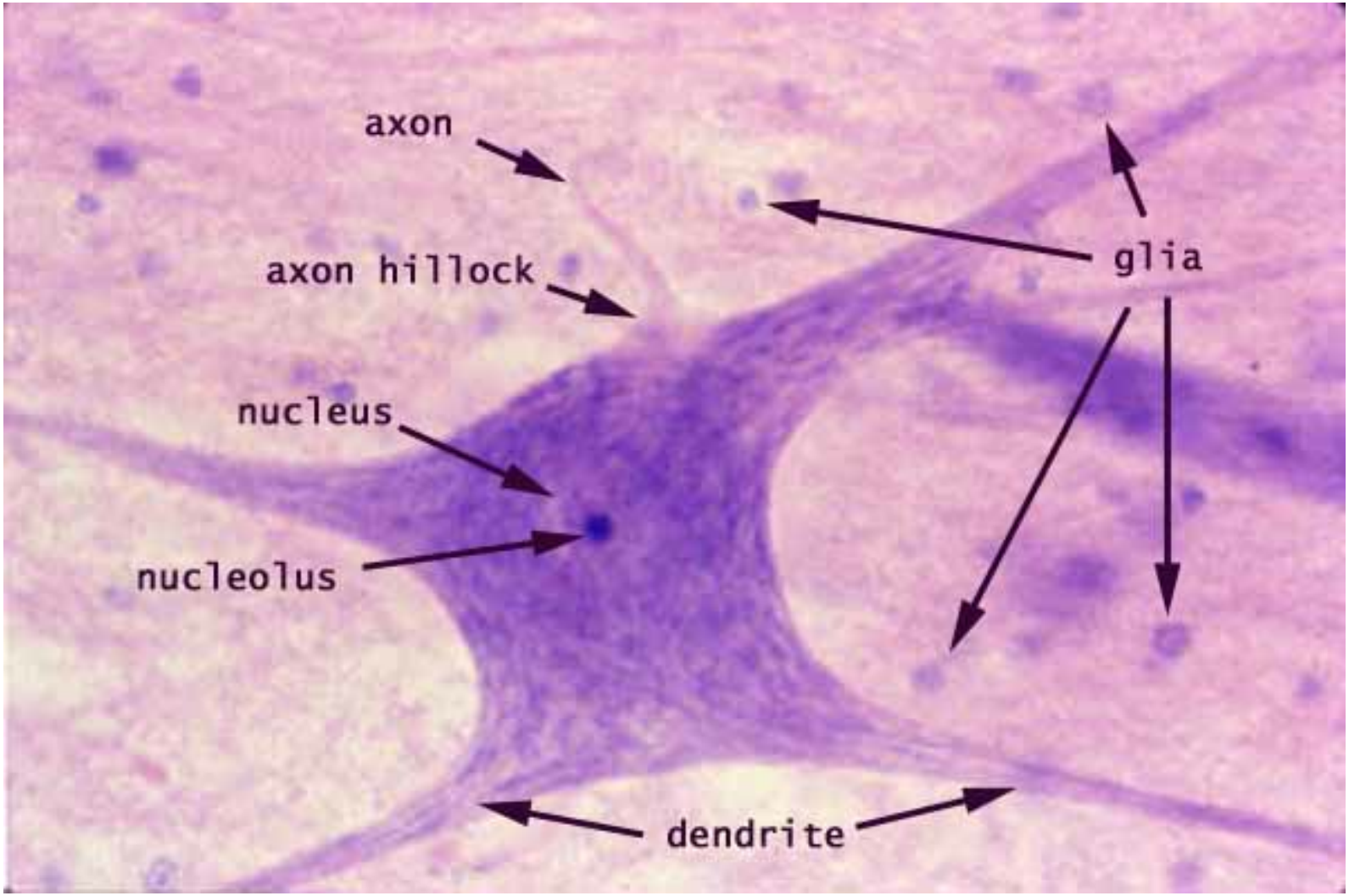


1. To another neuron

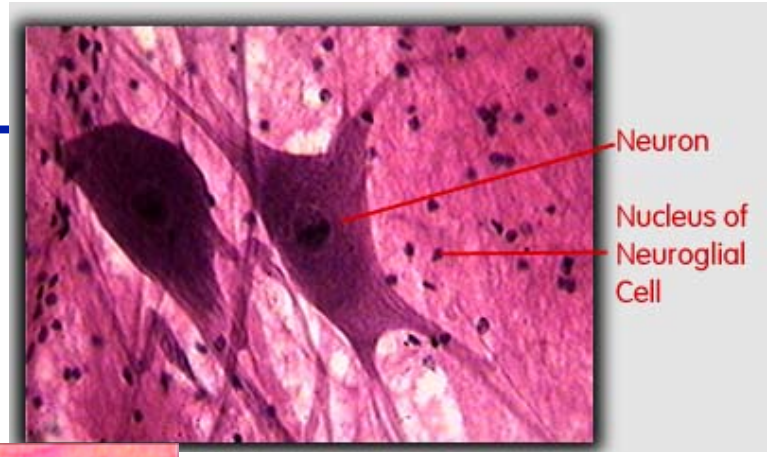
2. muscle fibers (skeletal, cardiac or smooth muscle)

3. gland cells exocrine or endocrine

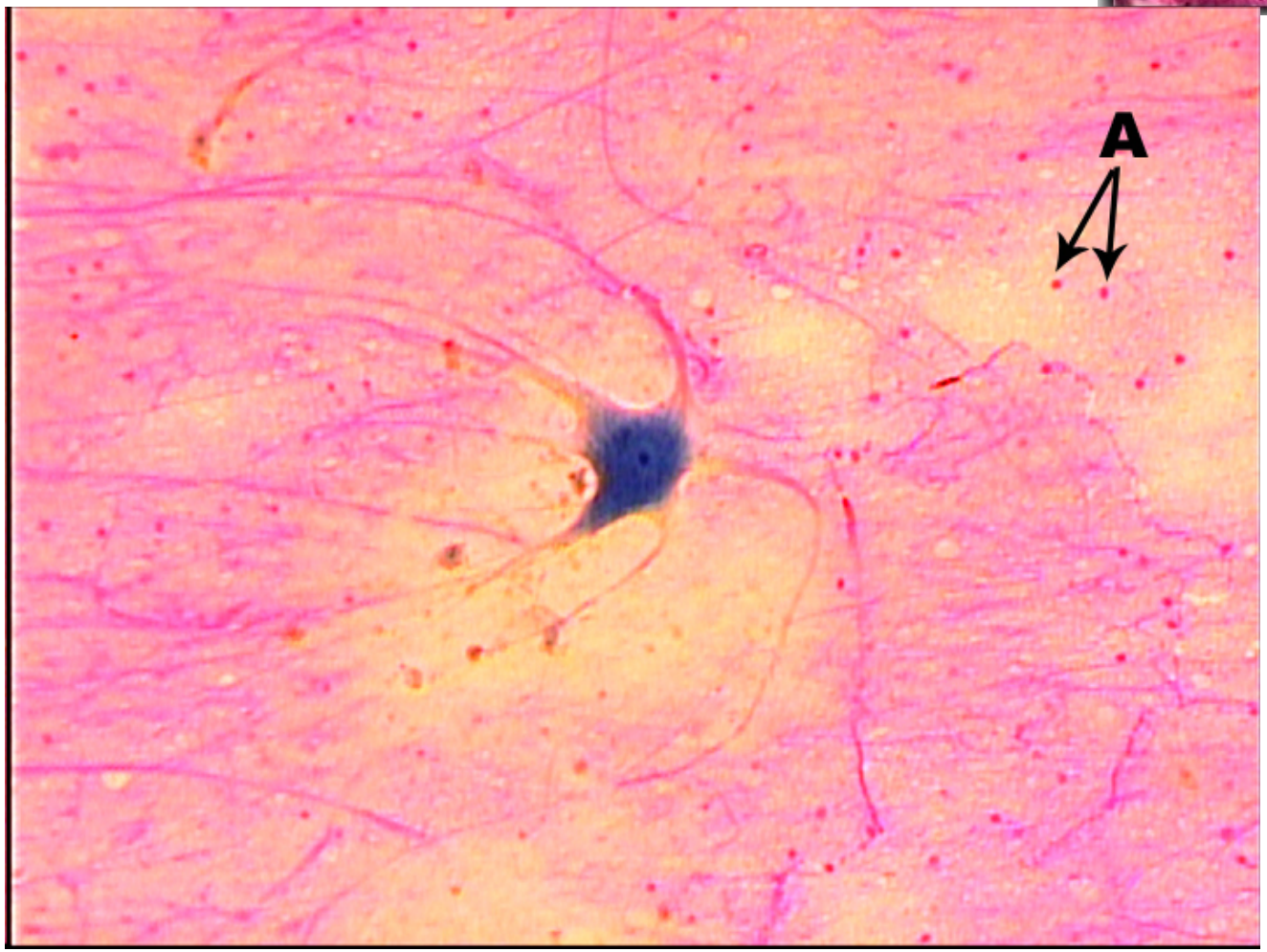
Motor Neuron from spinal cord



multipolar neuron



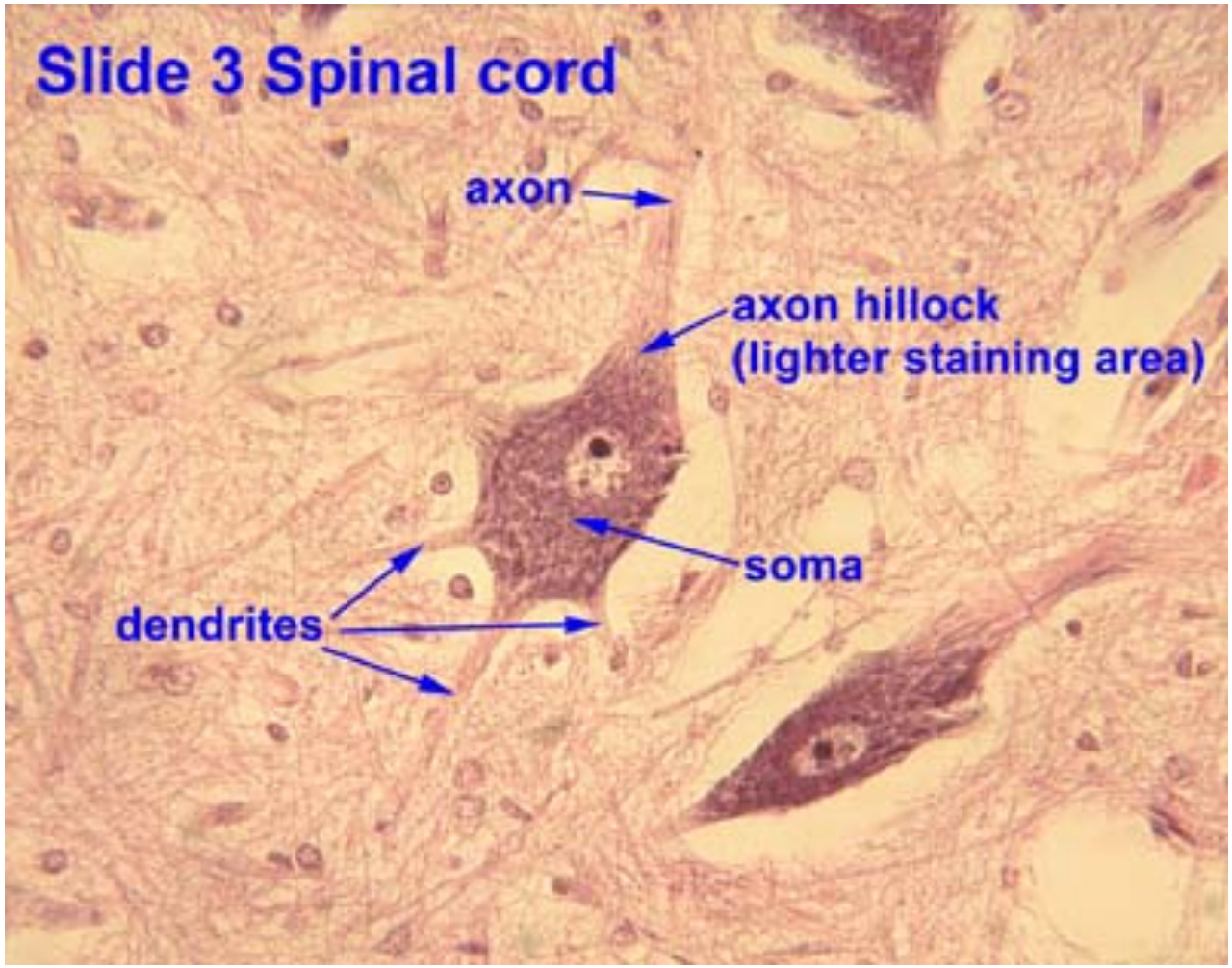
multipolar neuron



Neuron- large blue cell

A pointing to much smaller glia cells

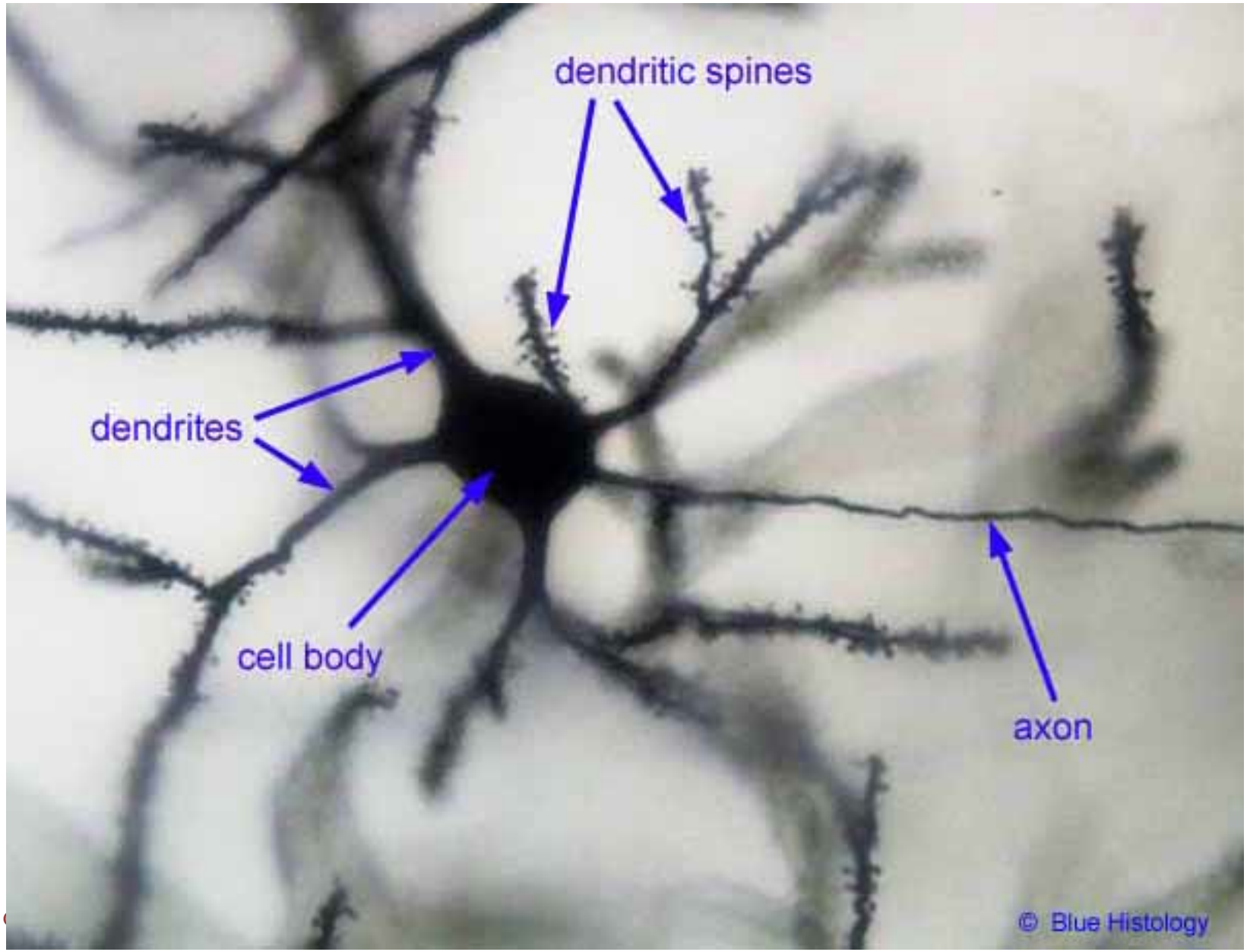
Another Neuron (nerve cell) from spinal cord



multiploar neuron

notice the light nucleus and dark nucleolus! Seen in neurons.

Nerve cell (neuron) from cerebral cortex



Supporting Cells: even neurons need a support group

The structures within the nervous system are made up of about 100 billion supporting cells called glia.(10 X the amount of neurons!) Neurons may be the more important cells in the brain that relay messages about what you're thinking, feeling, or doing, but they couldn't do it without a little help from their friends, the glial cells.

Neuroglia (aka Glia): Retain the ability to DIVIDE.(glia means"glue")

- Provide a supportive framework for neurons.
  Segregate and insulate neurons
- In CNS involved with production of CSF
- Promote health and growth
- Act as phagocytes

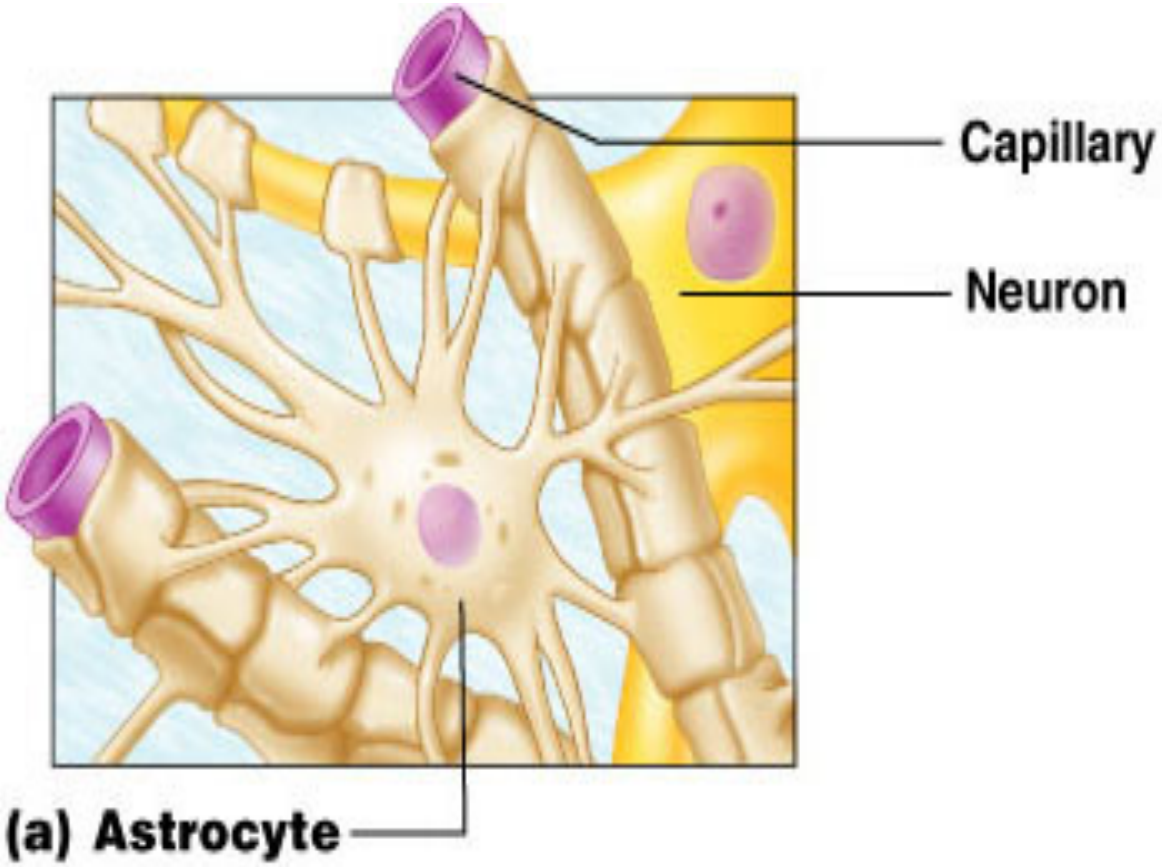
Differences in CNS & PNS primarily due to differences in glial cell population

Neuroglia of the CNS – 4 types

1. Astrocytes:

- Most abundant, versatile, largest, and highly branched glial cells
- They cling to neurons and their synaptic endings, and cover capillaries
- Functionally, they:
  - Support and brace neurons- will form scar tissue after damage to neural tissue
  - Anchor neurons to their nutrient supplies- help maintain the blood brain barrier.
  - recycle neuro transmitters
  - Control the chemical environment

Astrocytes

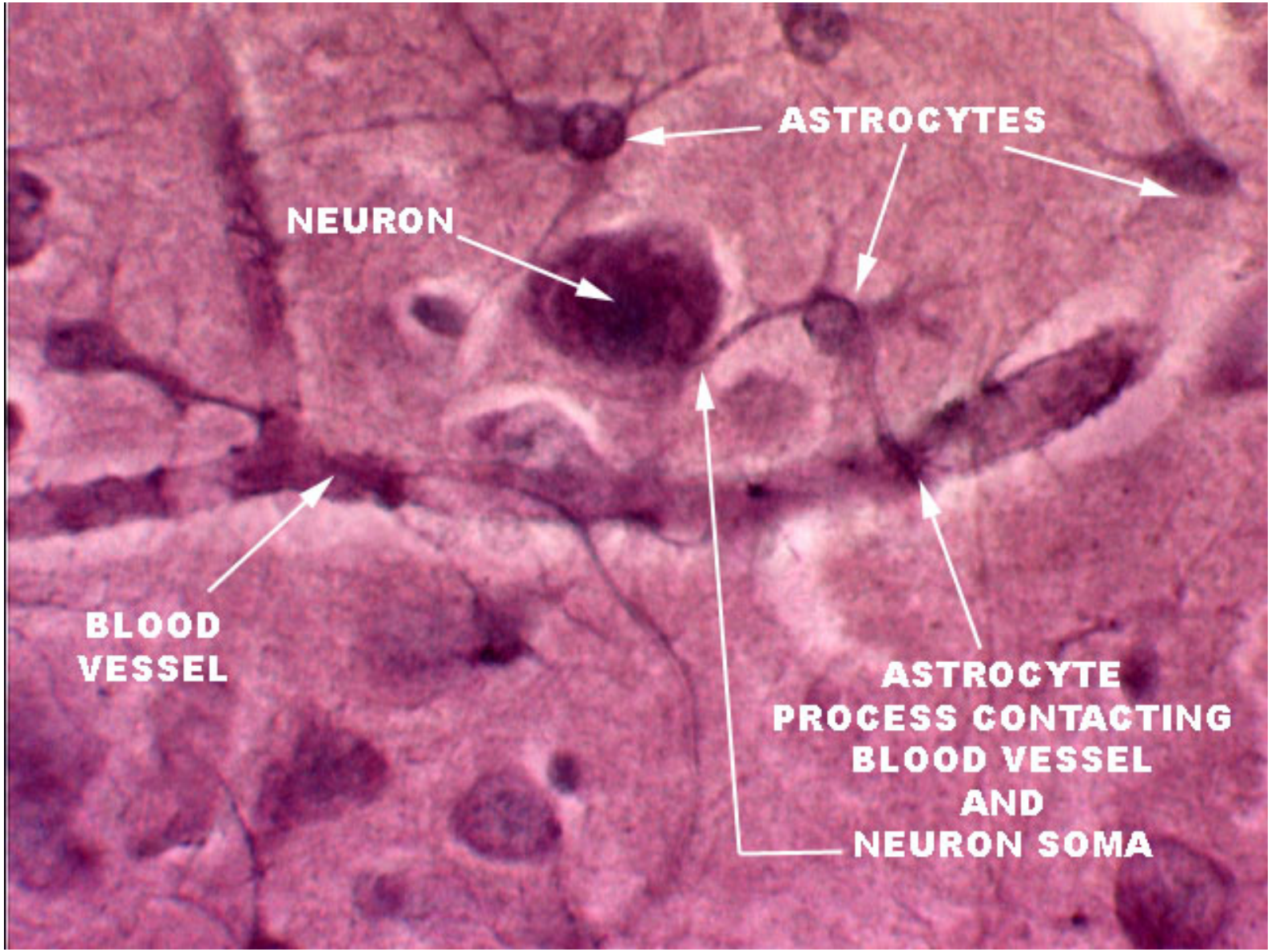


"End-feet" connect to blood vessels in the brain. By signaling blood vessels to expand or narrow, astrocytes regulate local blood flow to provide oxygen and nutrients to neurons in need

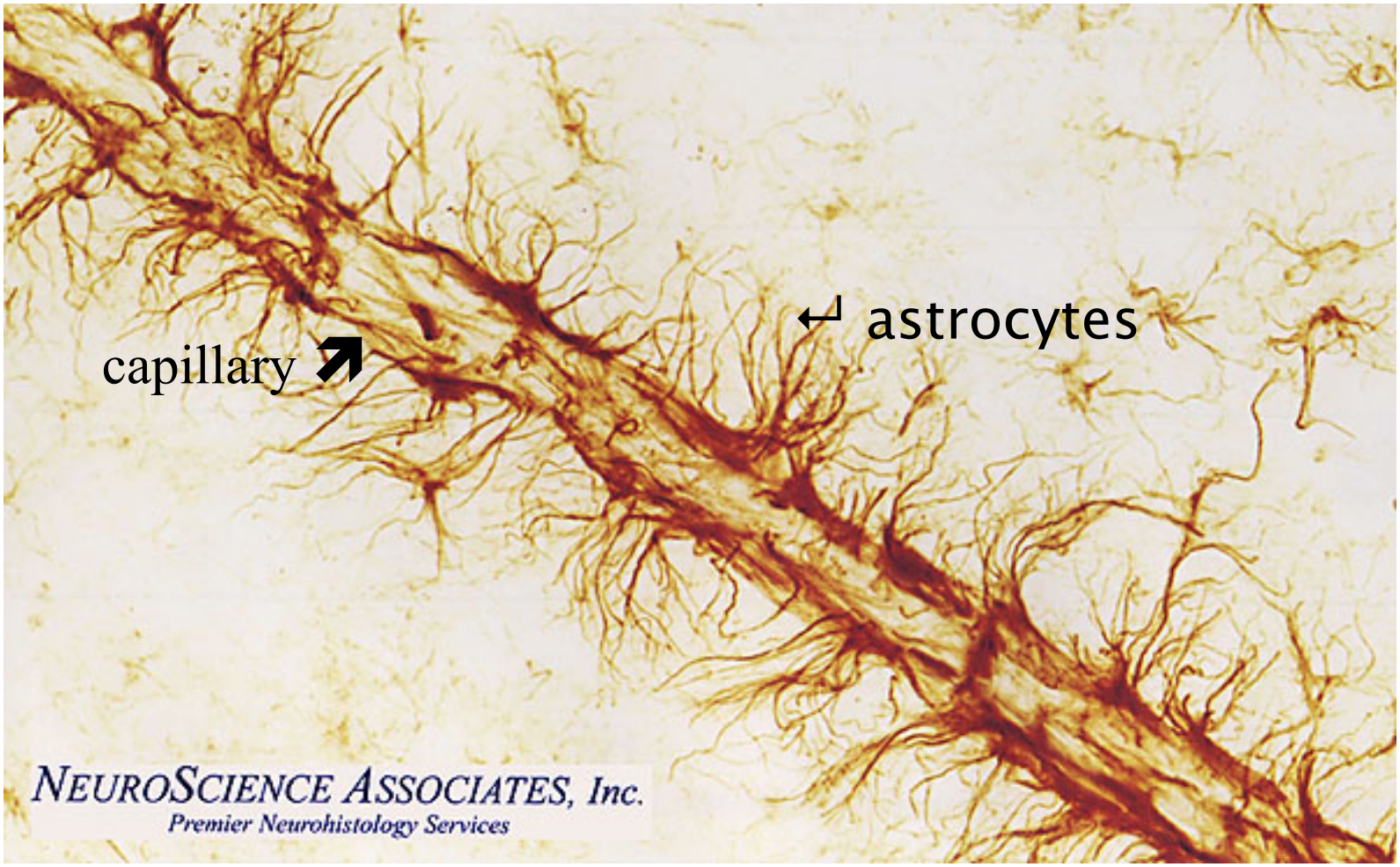
Each astrocyte has its own territory (they don't overlap), and each may interact with several neurons and hundreds to thousands of synapses to properly integrate information.

Figure 11.3a

Astrocyte Histology



Association of astroglia processes with a blood vessel



This is a very close relationship!

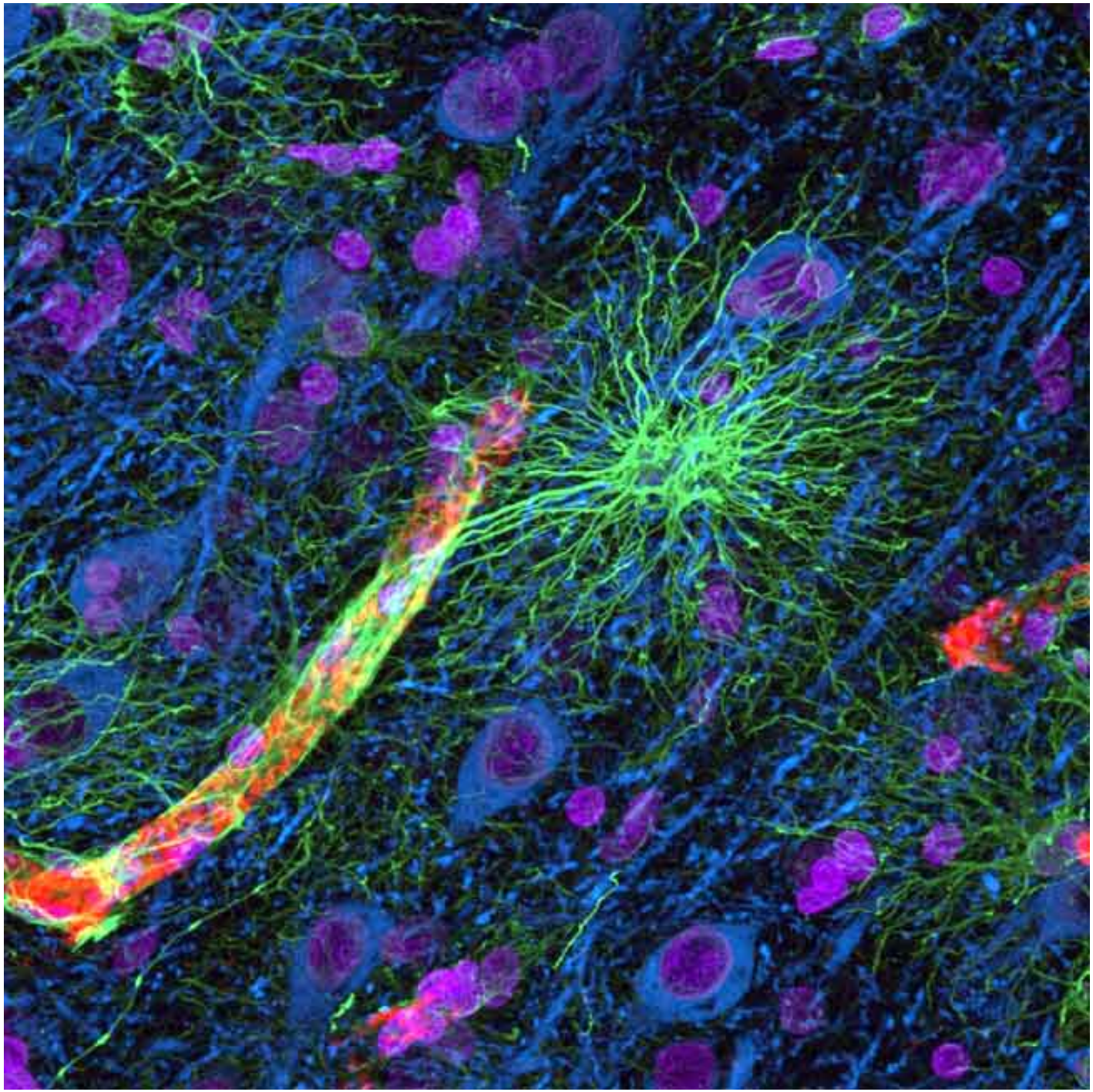


Image from human brain

Astrocytes- green

Capillaries- yellow

Neurons- blue

So Pretty!

CNS glia cells continued: microglia & ependymal cells

- **2. Microglia** – small, ovoid cells with spiny processes
  - Phagocytes that monitor the health of neurons
- **3. Ependymal** cells –simple epithelium- range in shape from squamous to columnar
  - They line the central cavities of the brain and spinal column (Line the CSF).

Microglia and Ependymal Cells

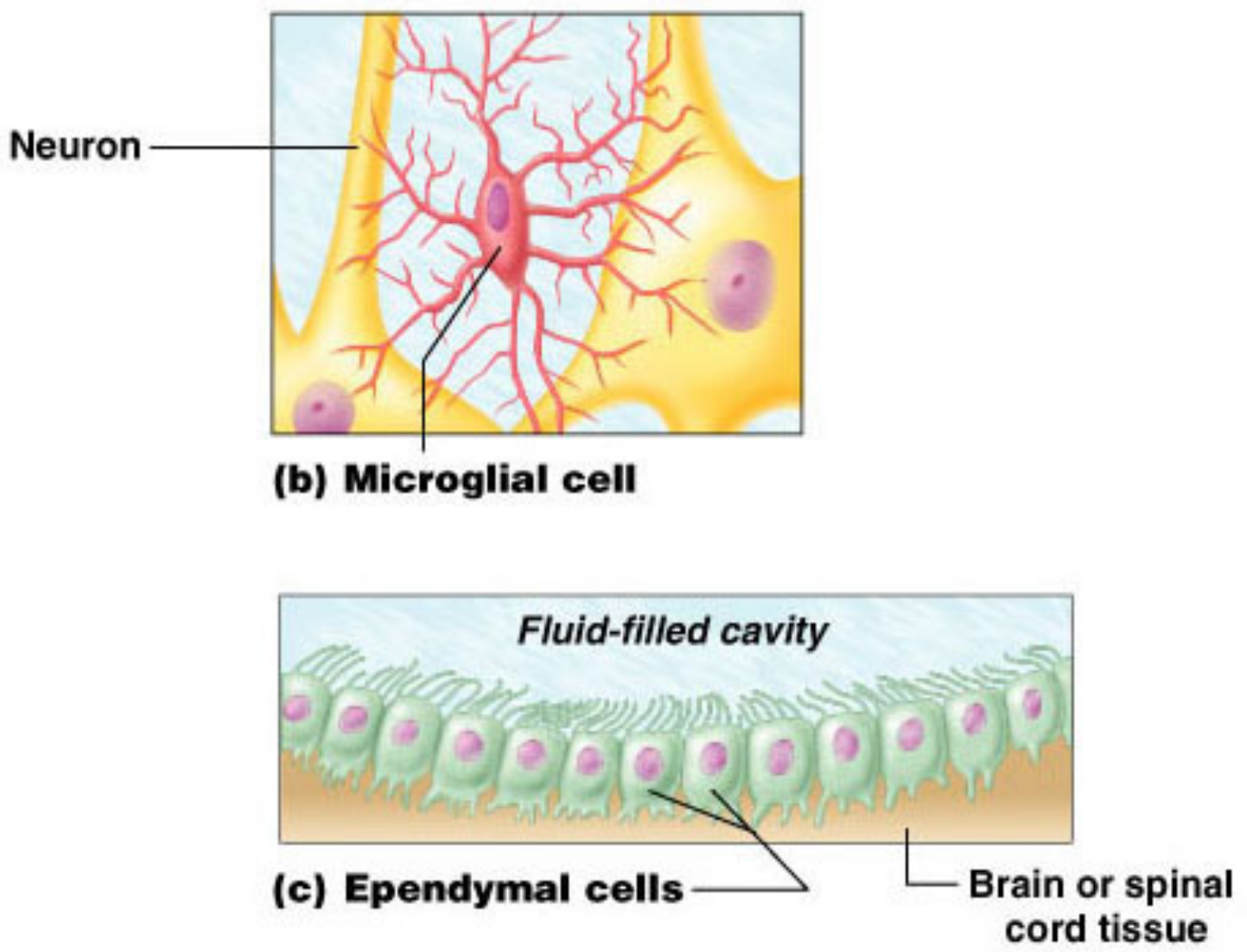
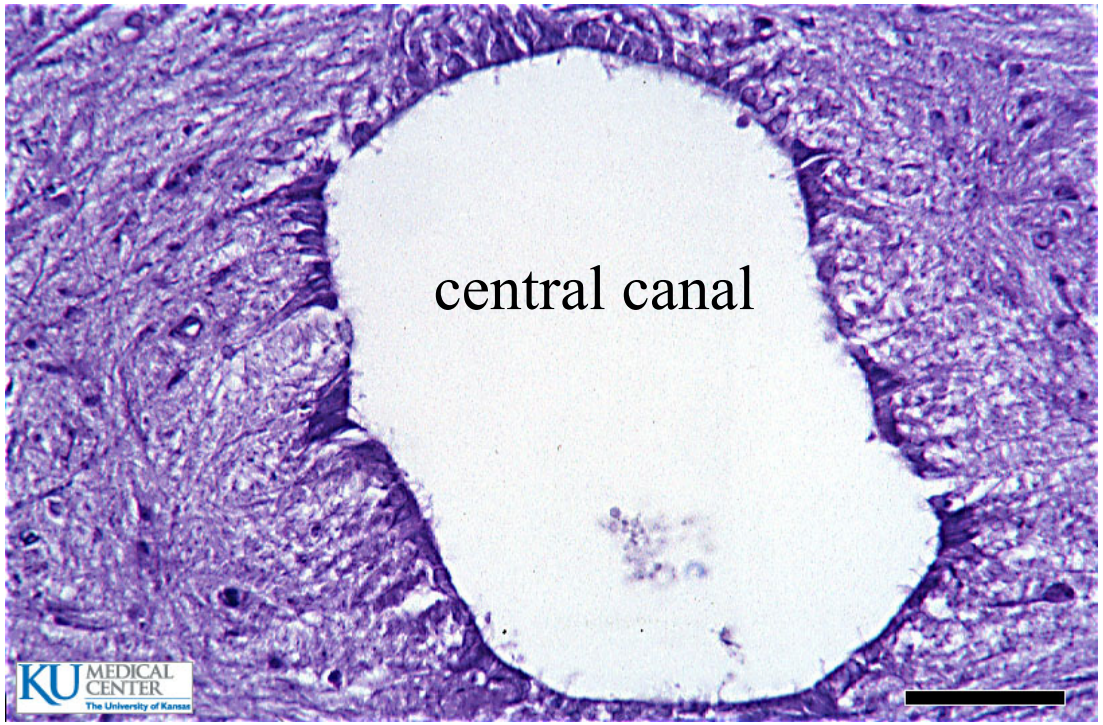
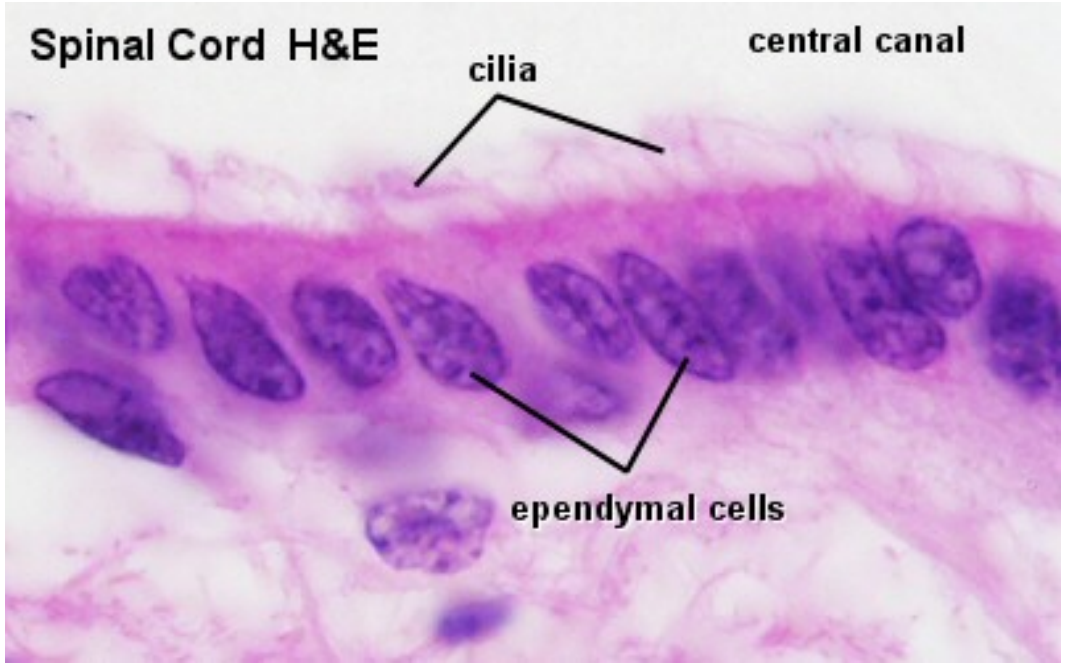


Figure 11.3b, c

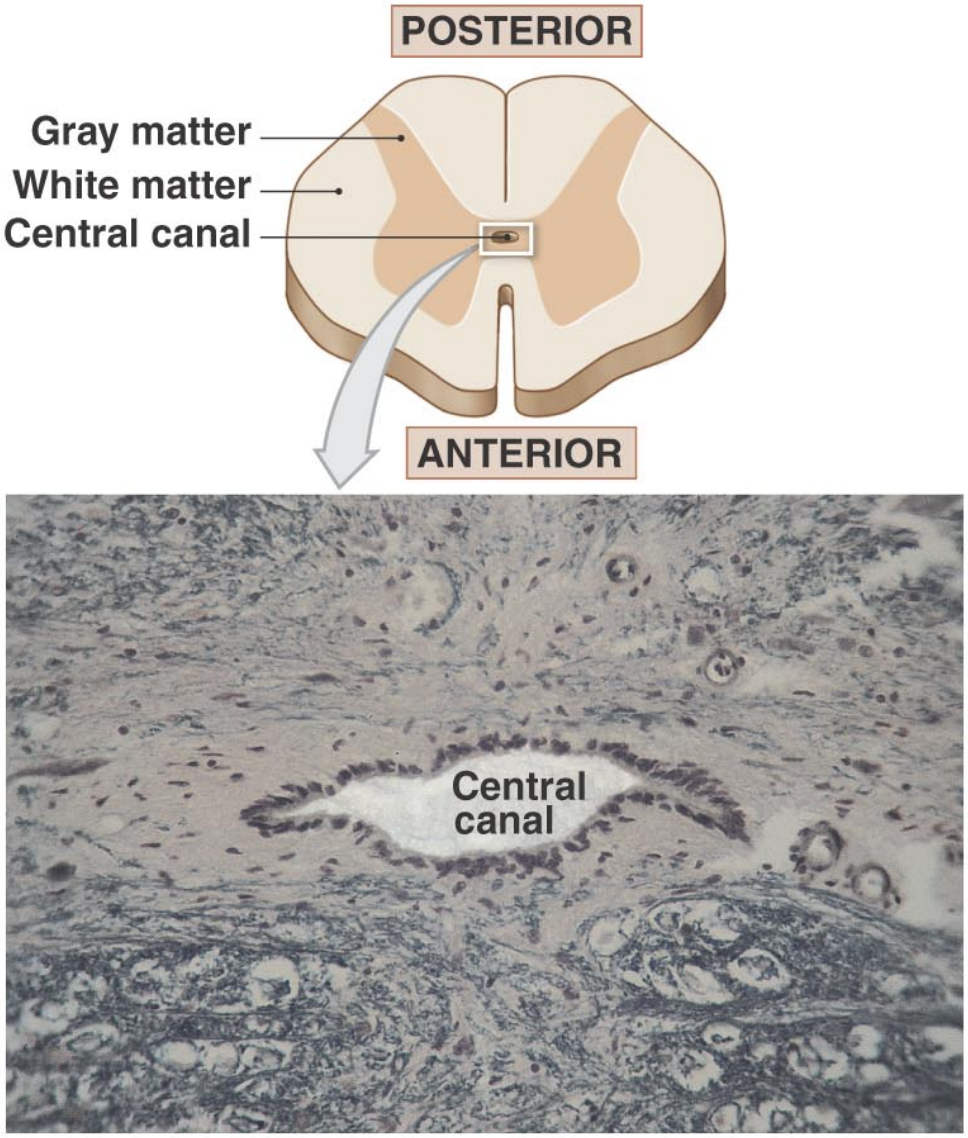




Ependymal Cells

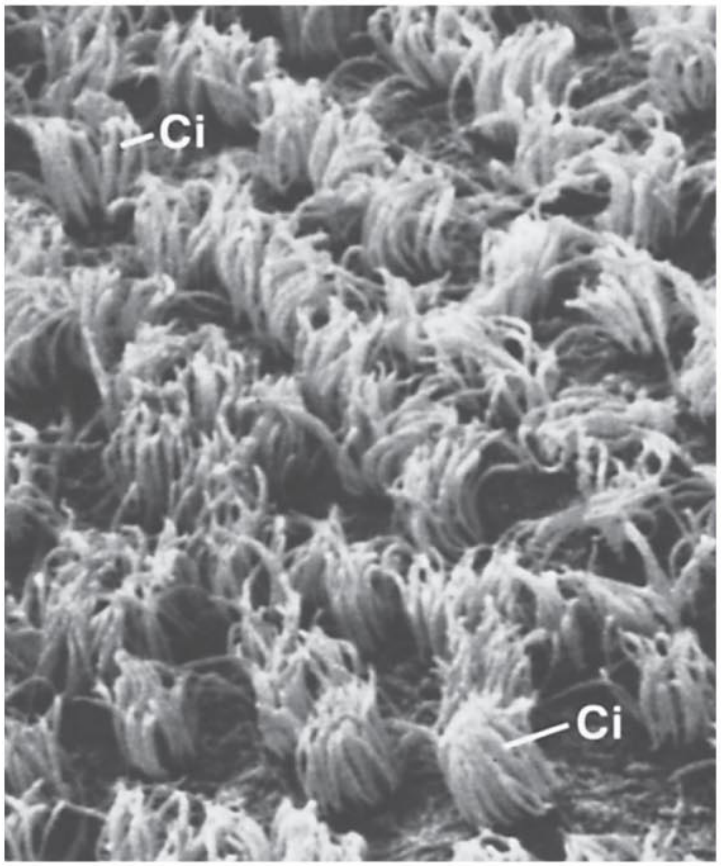
Central Canal:
Within the spinal cord is the central canal that contains cerebrospinal fluid (CSF). Note the ependymal cells (simple columnar with cilia) that line the lumen.

Ependyma cells continued



(a)

Ci= cilia



(b) scanning electron microscopy

4. **Oligodendrocytes**- last type of glia cell in the CNS

Oligo=few. Have fewer proceses than astrocytes
Function: Wrap around neuron fibers (axons) in the CNS.
Produce insulating coverings called **Myelin Sheaths.**

Myelin sheaths are a fatty membranous coating composed primarily of phospholipids. Myelin improves the speed of nerve impulse conduction down an axon and insulates.

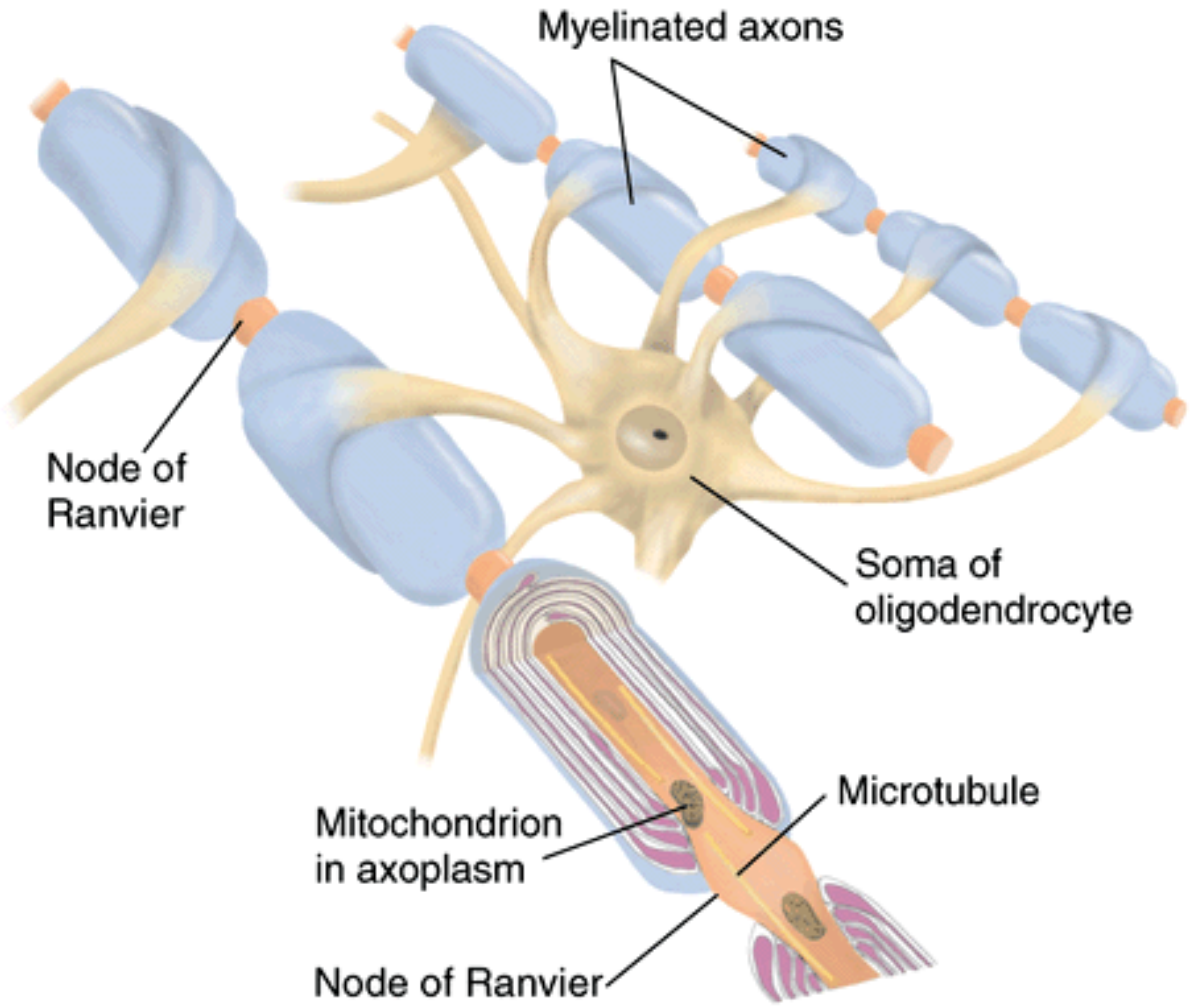
High fat content of myelin gives these axons a white color.
Not all axons in CNS myelinated.

Regions in the CNS dominated by myelinated axons =
White Matter of CNS

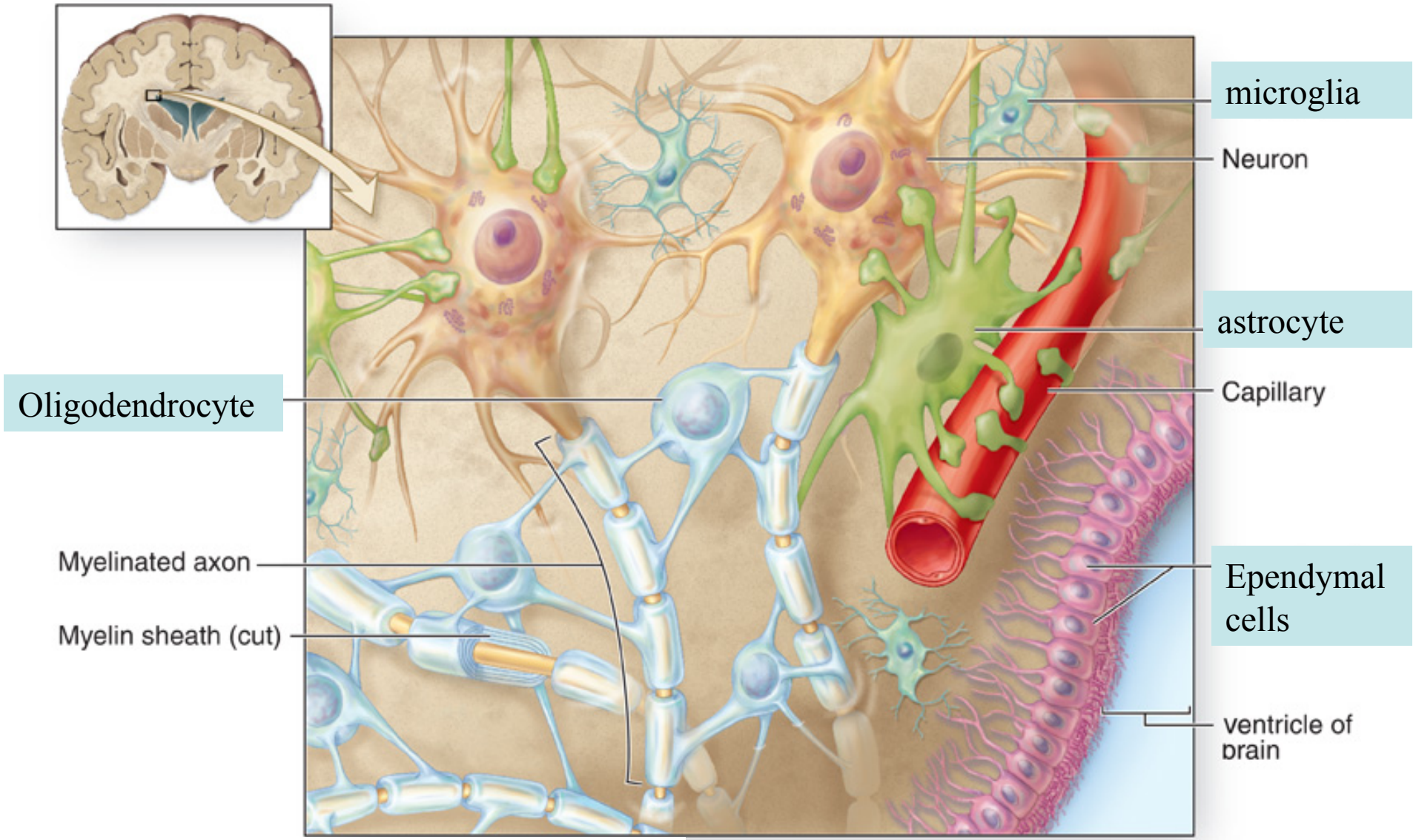
Bundles of axons in the CNS = tracts

Oligodendrocyte- found only in CNS

- **An Oligodendrocyte**

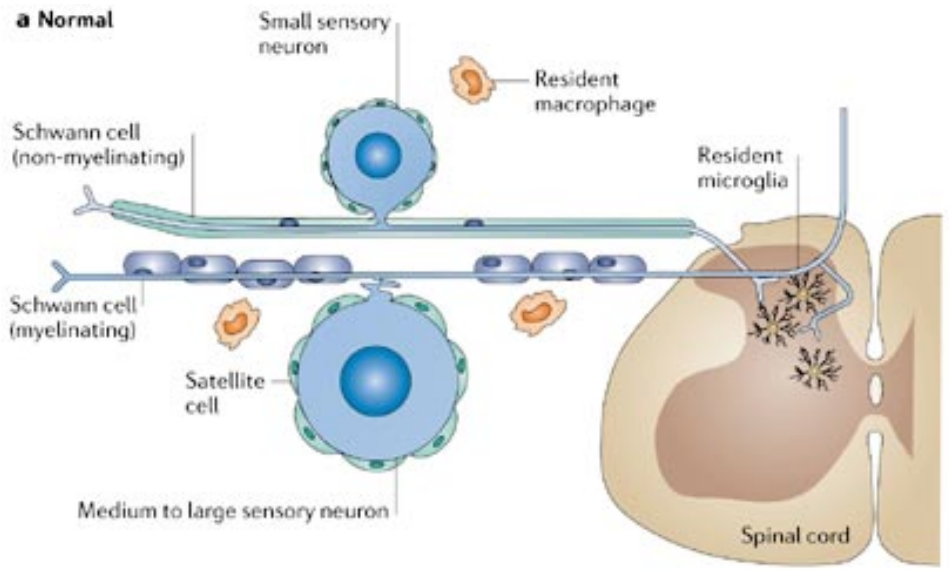


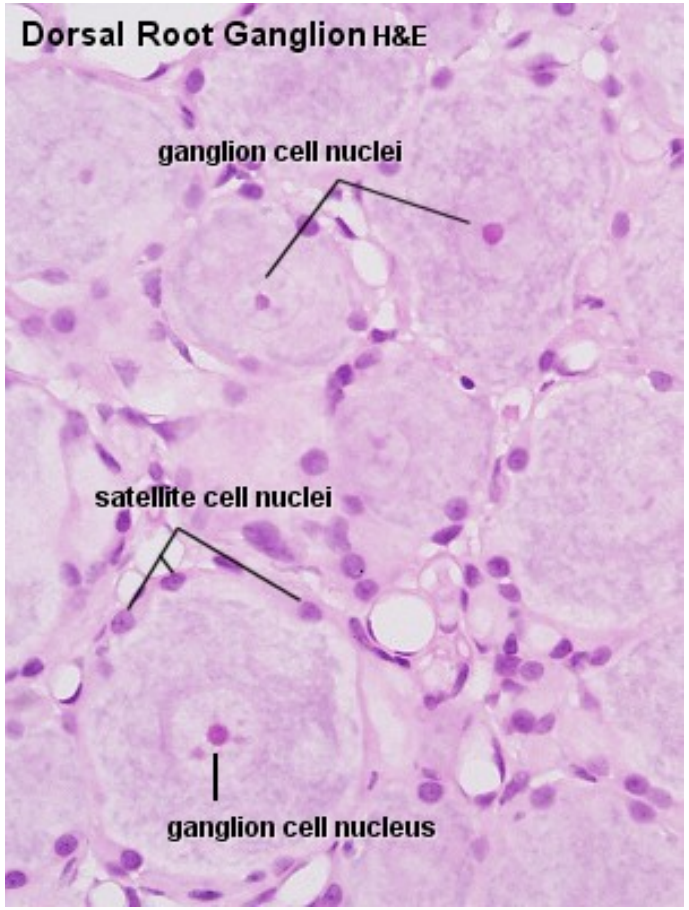
Summary of CNS glial cells



Only 2 Neuroglia of PNS- Satellite cells and Schwann cells

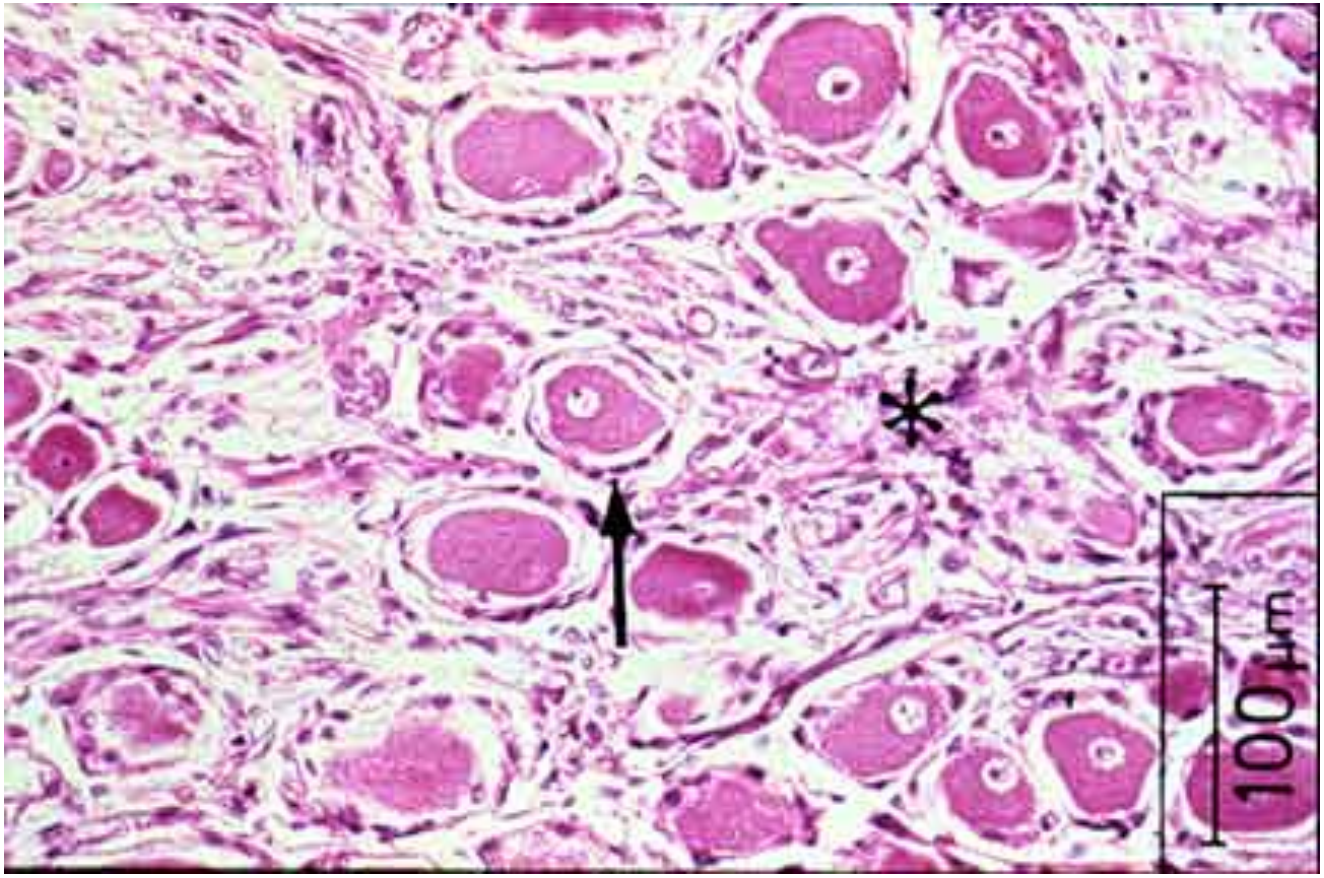
Satellite cells- Surround neuron cell bodies in the PNS
Function- regulate exchange of nutrients & wastes between neuron cell bodies and the extracellular fluid.





ganglion = collection of cell bodies in PNS

More satellite cells

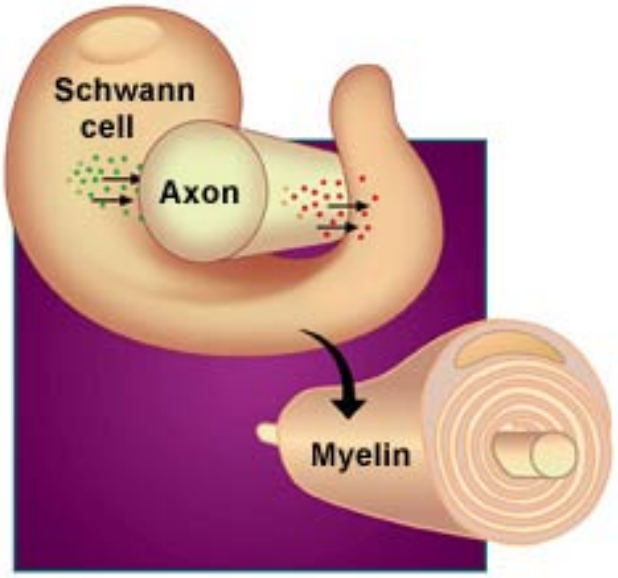


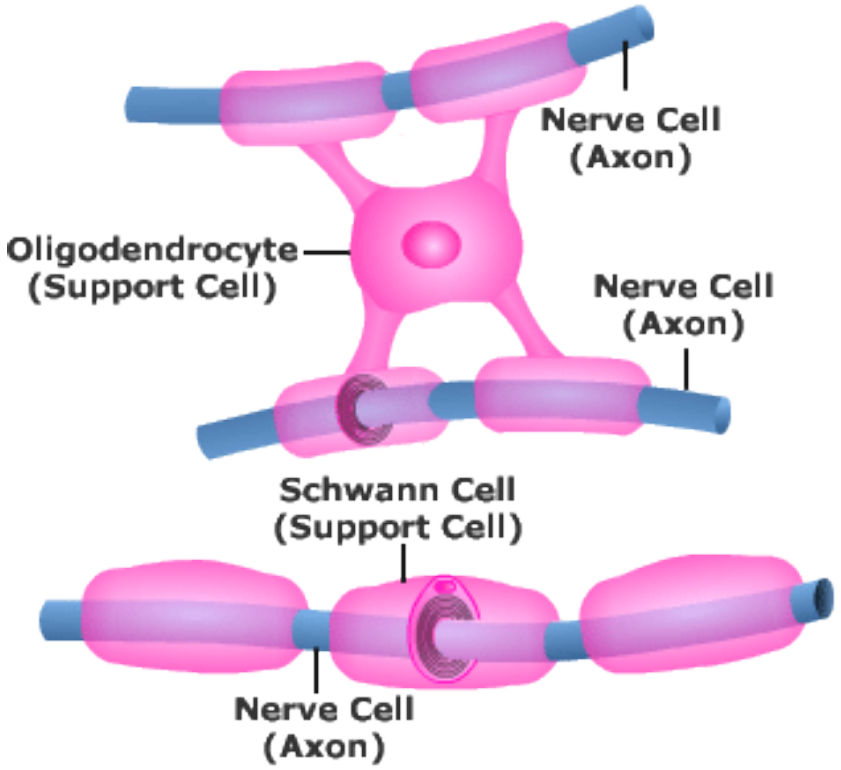
This image shows the size of the satellite cells surrounding the neuron cell bodies. (arrow pointing to satellite cells).
Notice the larger uniploar neurons cell bodies with easily seen light nucleus and dark nucleolus)

Neuroglia of PNS- The Schwann Cells

- **Schwann cells** (neurolemmocytes) – surround and form myelin sheaths around the larger nerve fibers (axons) in the PNS.

Schwann cells are the supporting cells of the PNS. Like oligodendrocytes, schwann cells wrap themselves around nerve axons, but the difference is that a single schwann cell makes up a single segment of an axon's myelin sheath. Oligodendrocytes on the other hand, wrap themselves around numerous axons at once.

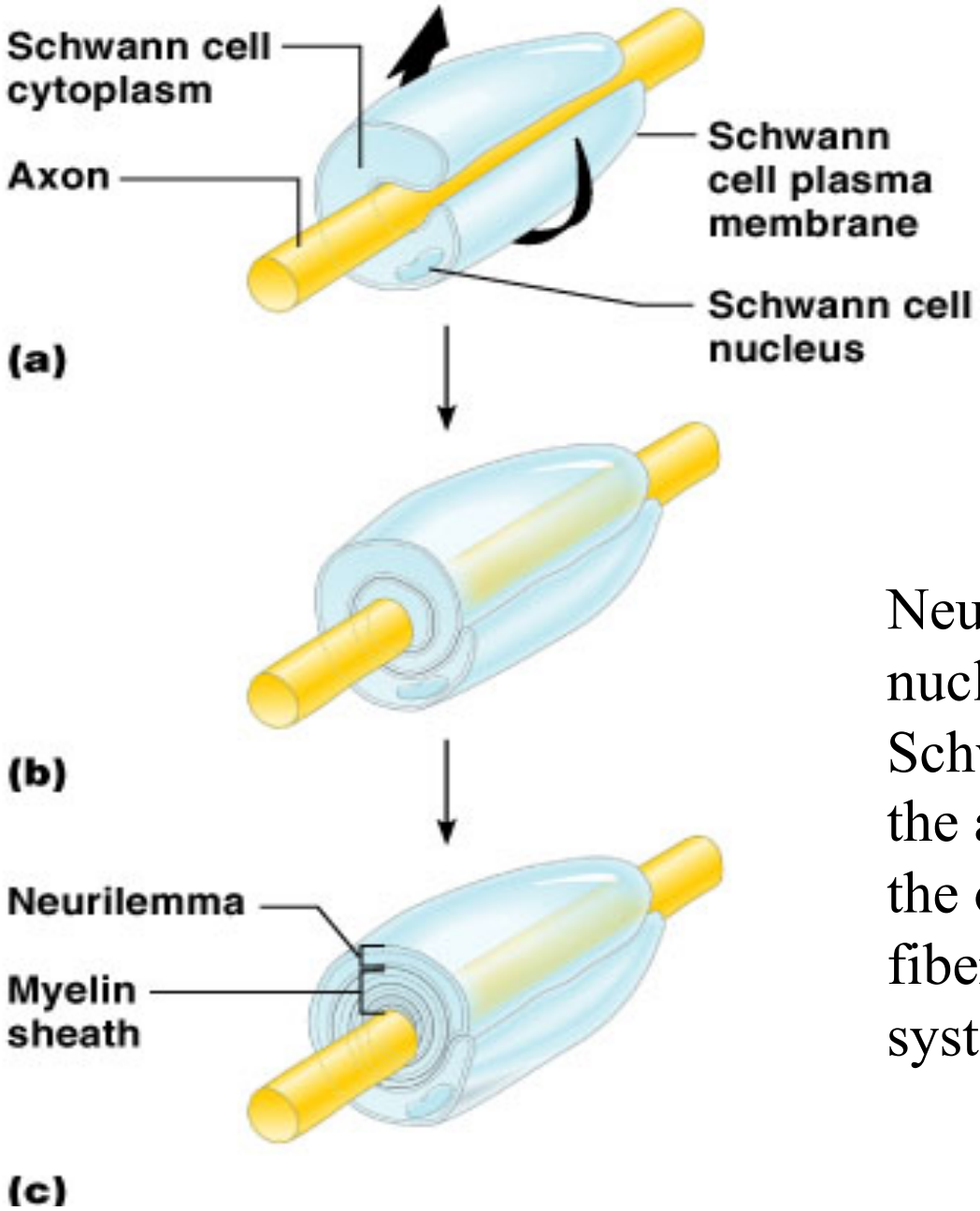




Myelin Sheath and Neurilemma: Formation

- Formed by Schwann cells in the PNS
- A Schwann cell:
  - Envelopes an axon
  - Encloses the axon with its plasma membrane
  - Has concentric layers of membrane that make up the myelin sheath
- Neurilemma – remaining nucleus and cytoplasm of a Schwann cell

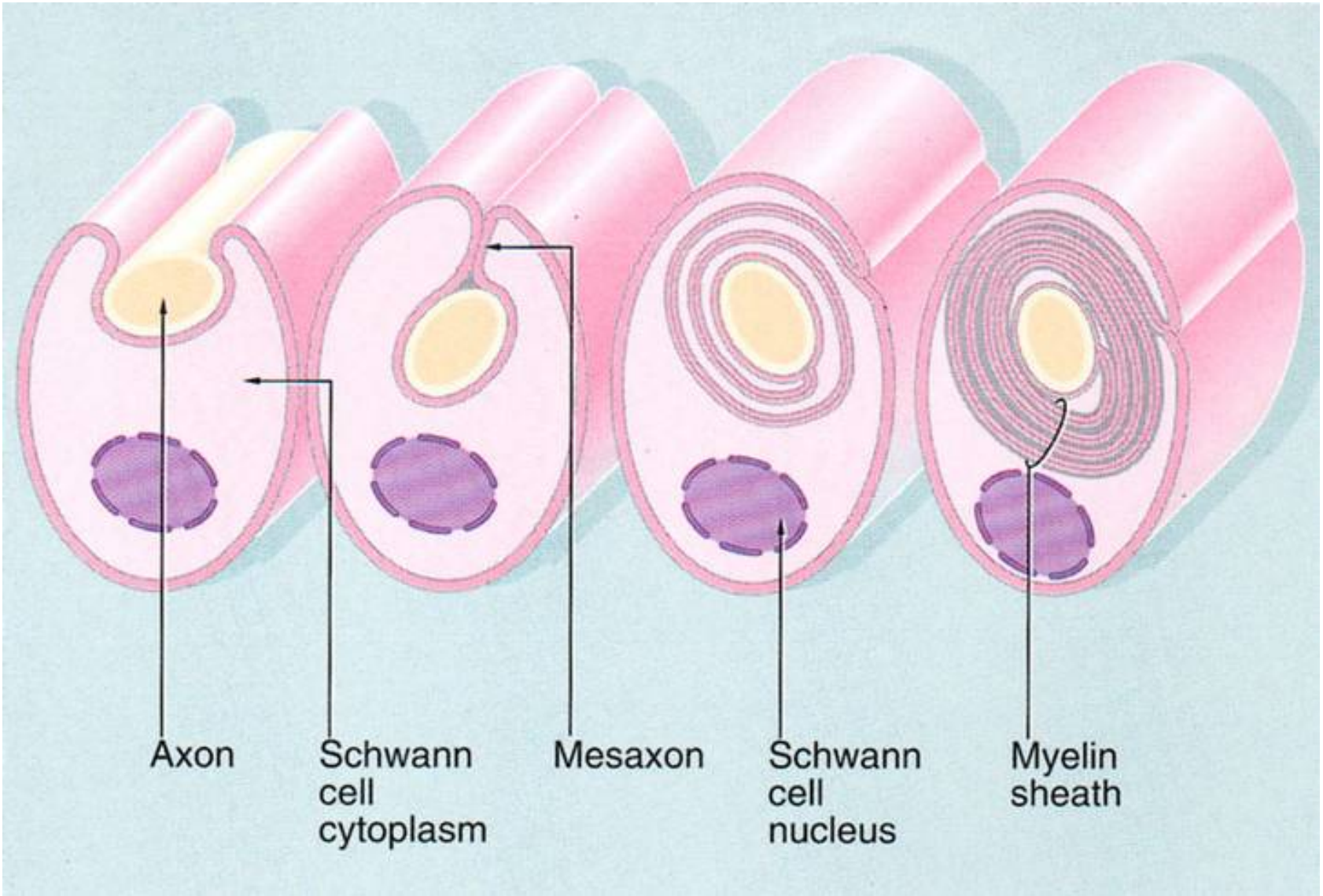
Myelin Sheath and Neurilemma: Formation



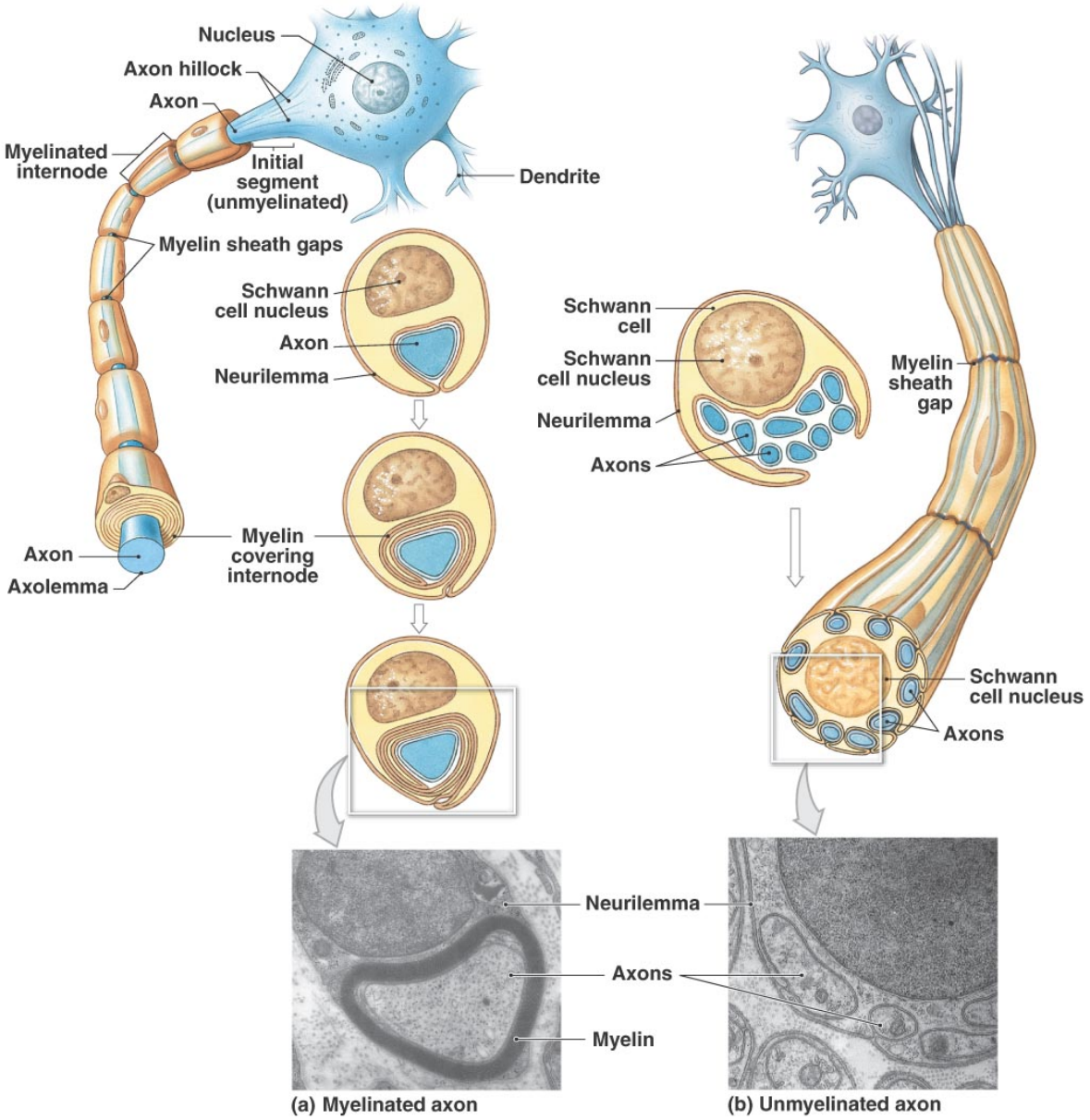
Neurilemma is the outermost nucleated cytoplasmic layer of Schwann cells that surrounds the axon of the neuron. It forms the outermost layer of the nerve fiber in the peripheral nervous system.

Figure 11.5a-c

One segment of one axon is all a schwamm cell can myelinate



Schwann cells –myelinated vs unmyelinated axons

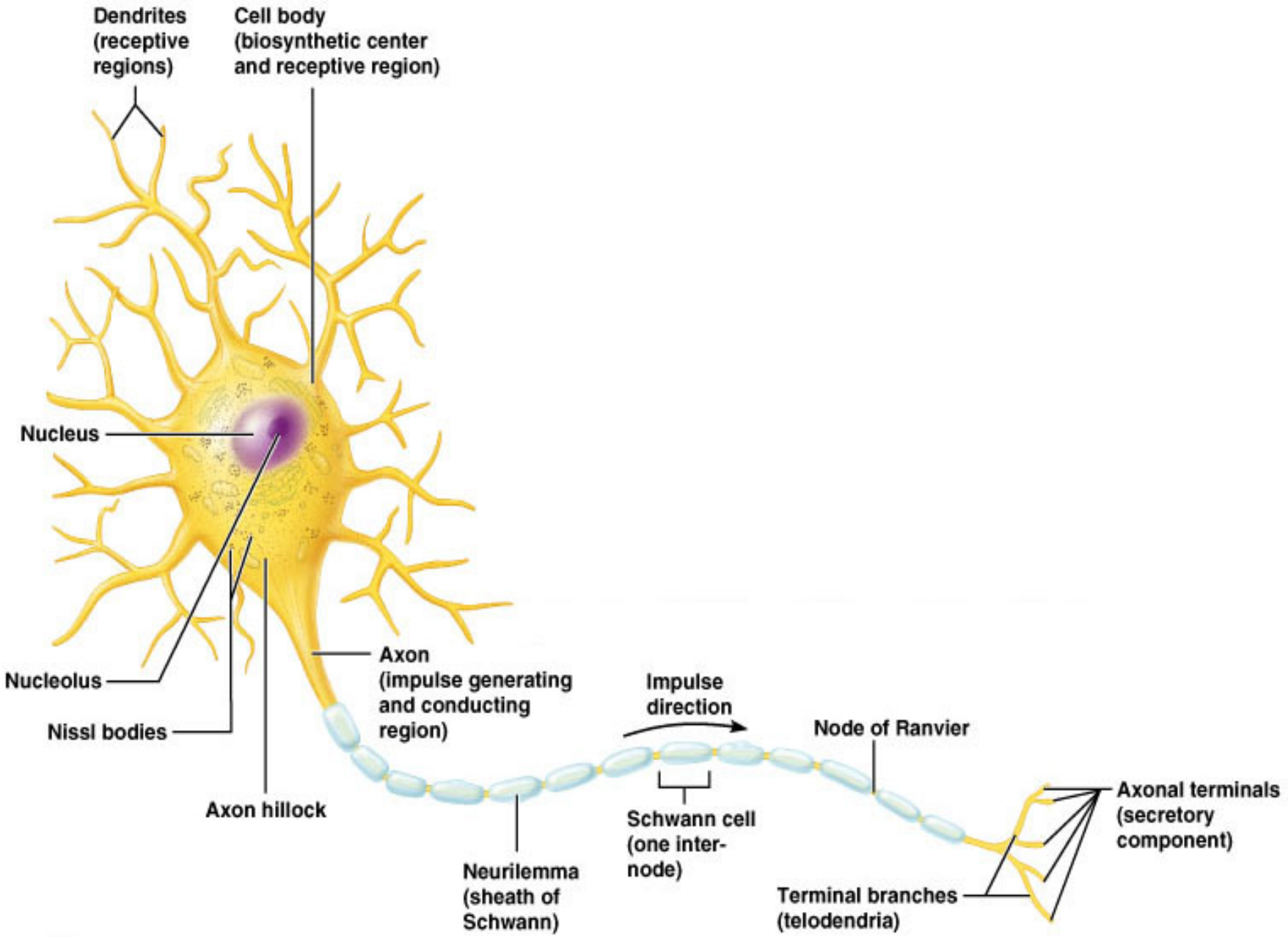


Unmyelinated Axons

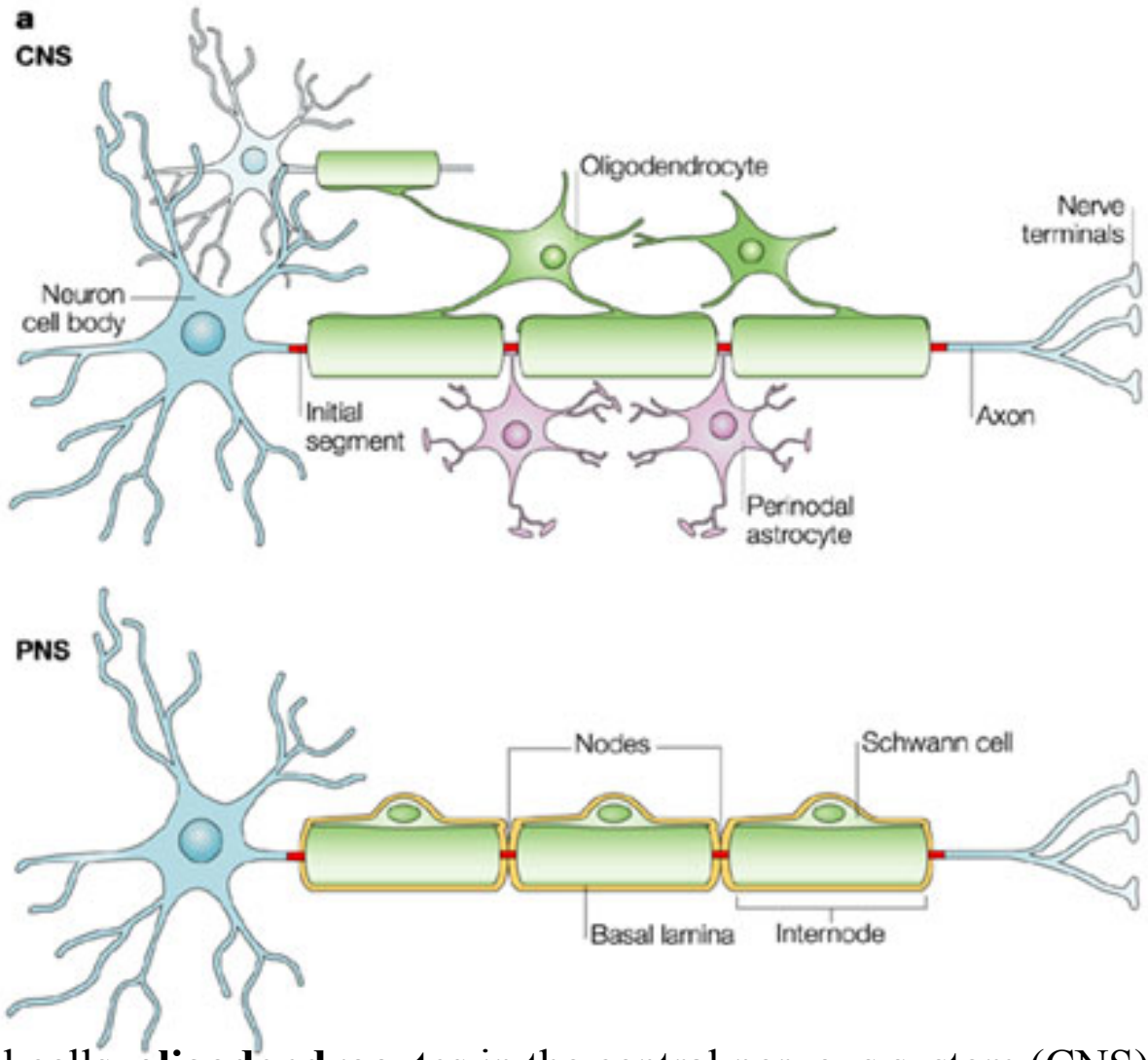
- A Schwann cell surrounds nerve fibers but coiling does not take place

Usually several axons are surrounded by a single Schwann cell in the unmyelinated nerve fibers. Therefore, each unmyelinated fiber is not completely covered by the MYELIN SHEATH formed by the Schwann cell. Unmyelinated nerve fibers conduct impulses at low velocities. They represent the majority of peripheral sensory and autonomic fibers.

Neuron (Nerve Cell) –



b



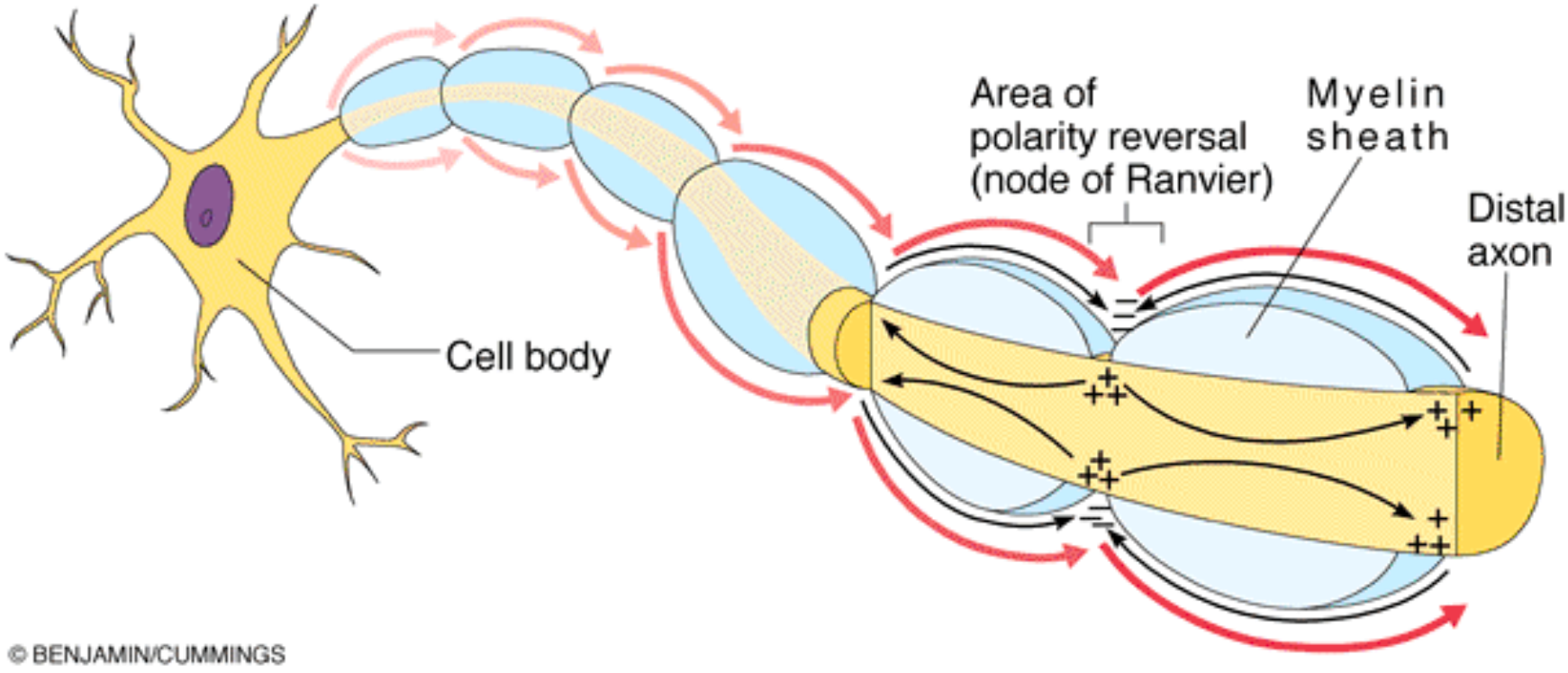
Myelinating glial cells, **oligodendrocytes** in the central nervous system (CNS) & **Schwann cells** in the peripheral nervous system (PNS), form the myelin sheath by enwrapping their membrane several times around the axon. Myelin covers the axon at intervals (internodes), leaving bare gaps (the nodes of Ranvier.) Oligodendrocytes can myelinate different axons and several internodes per axon, whereas Schwann cells myelinate a single internode in a single axon**.**

Myelin Sheath

- Whitish, fatty (protein-lipoid), segmented sheath around most long axons
- It functions to:
  - Protect the axon
  - Electrically insulate fibers from one another
  - Increase the speed of nerve impulse transmission

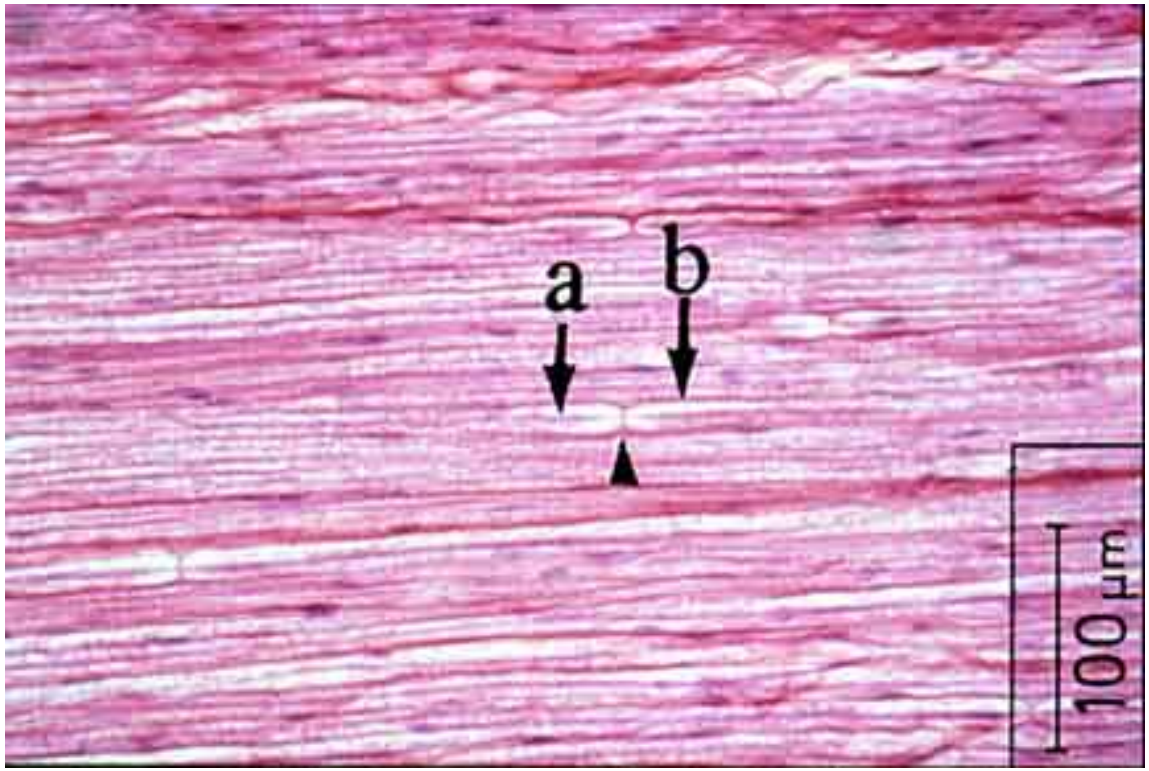
Nodes of Ranvier

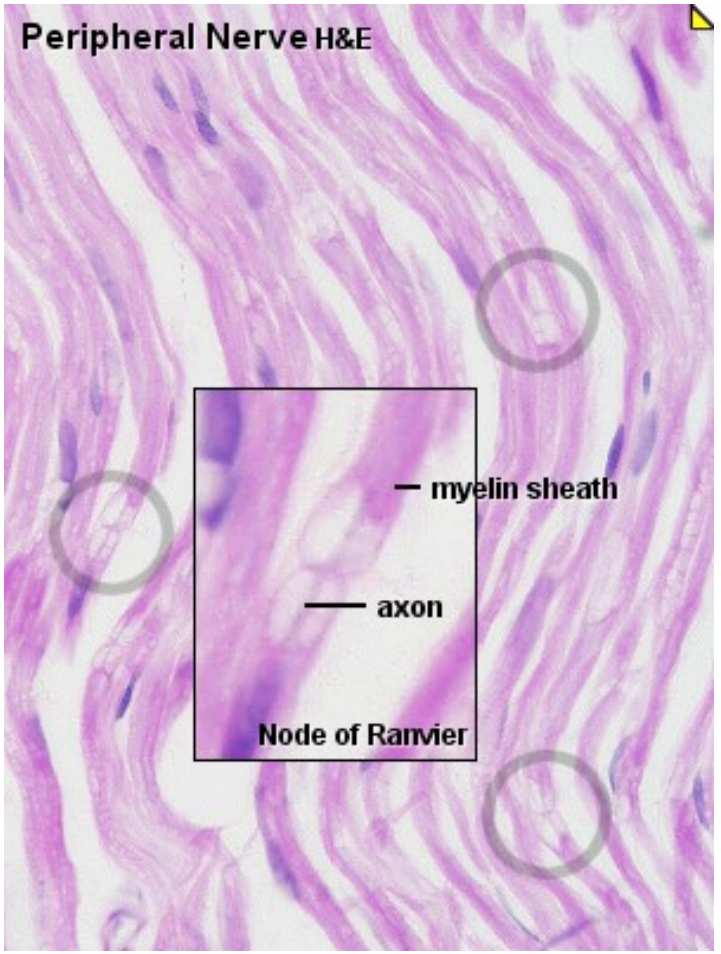
- Gaps in the myelin sheath



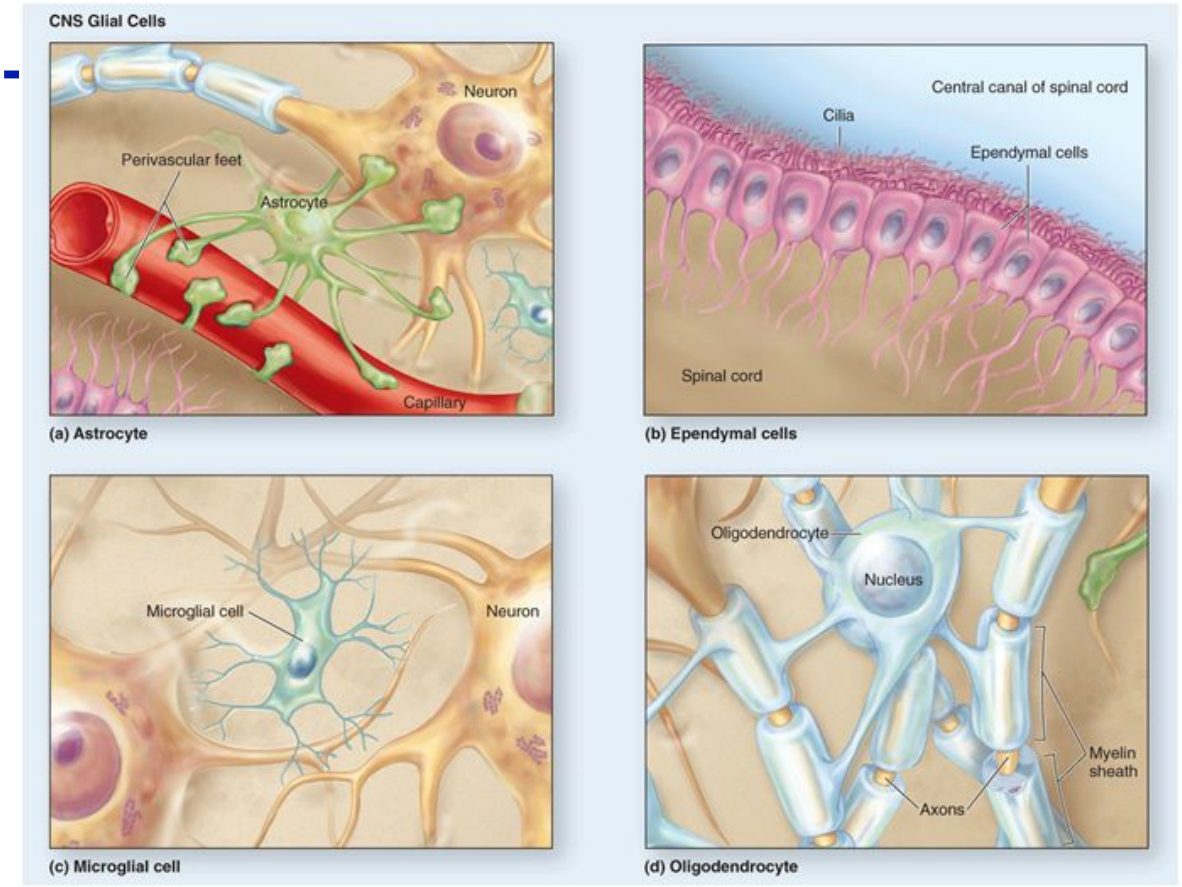
Schwann cells & Nodes of Ranvier in PNS

a=axon
b=myelin shealth



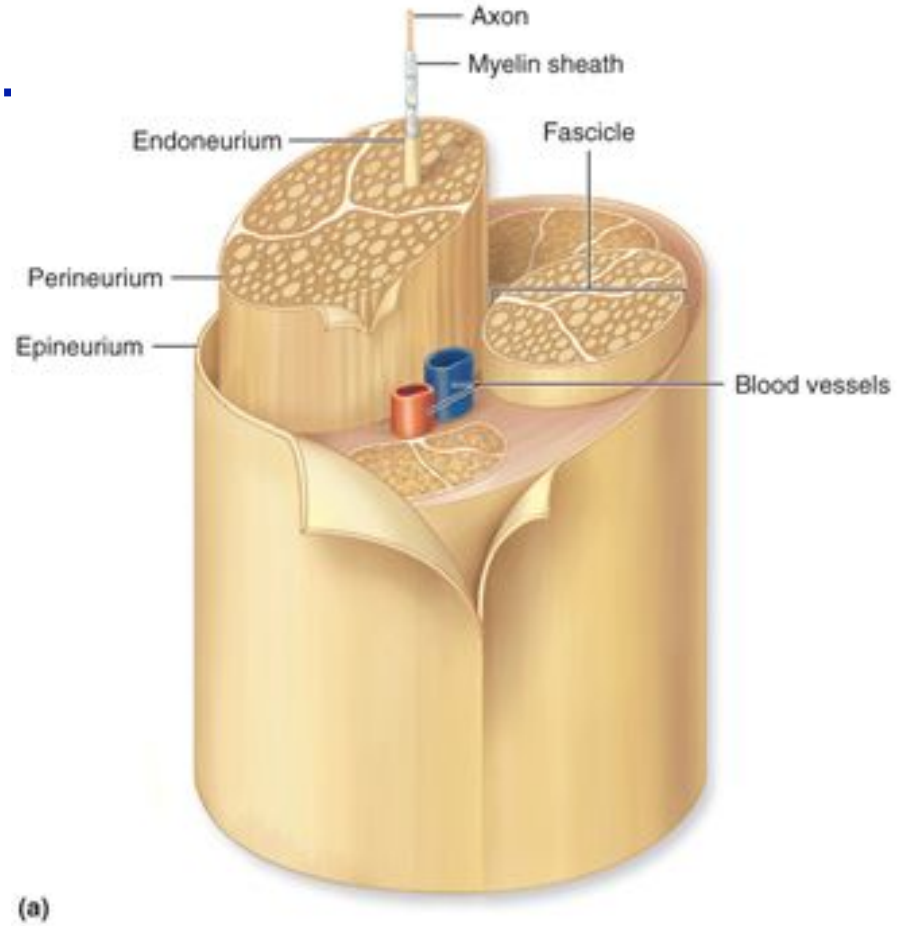


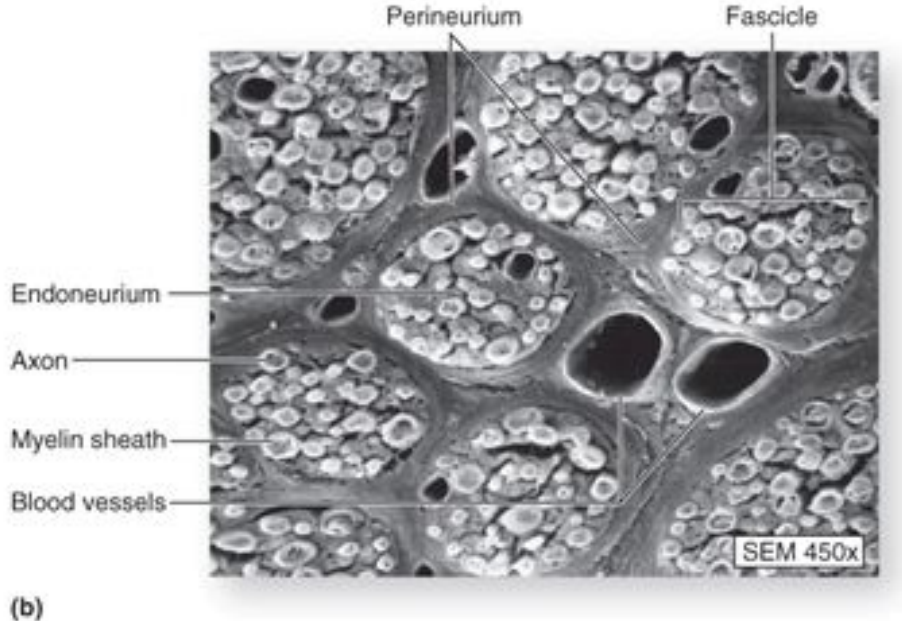
A longitudinal view of myelinated axons. the arrowhead points to a well-defined Node of Ranvier. Find others. Do you understand what this structure is and could you draw it in simplified form at the ultrastructural level? To what cells do the nuclei seen on this image correspond?



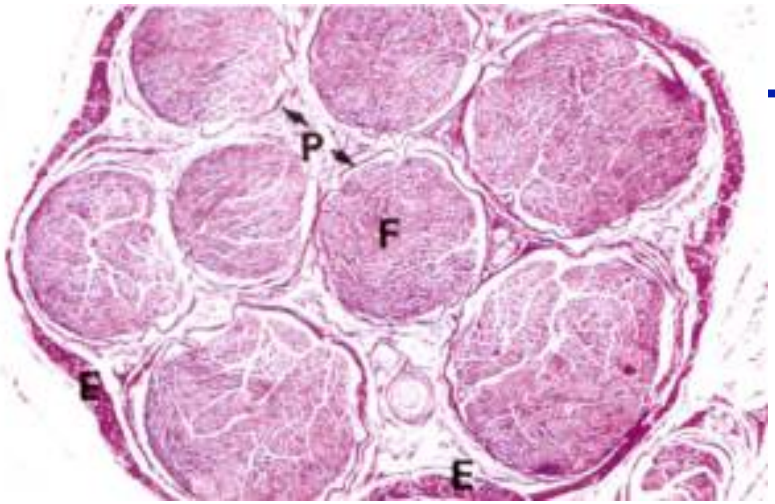
Summary of your glial cells

neurolemmocytes aka schwann cells

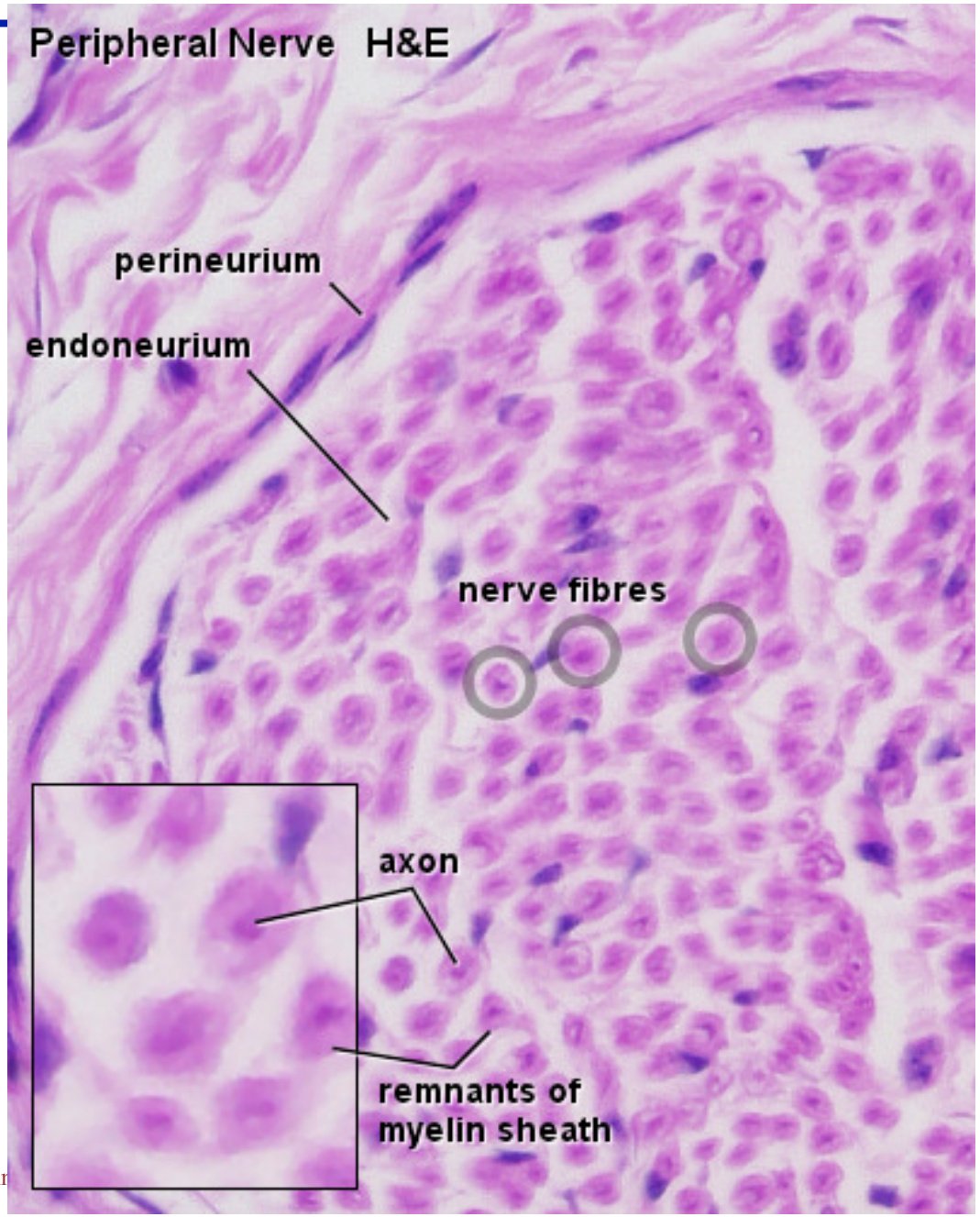


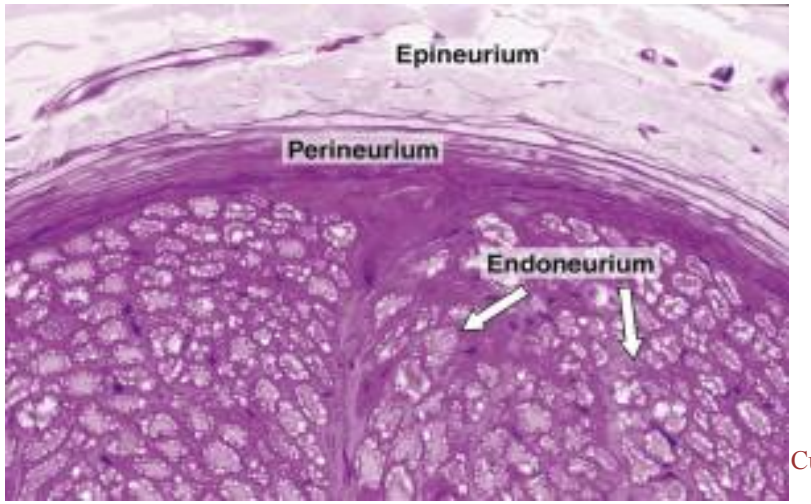


A Nerve ONLY IN PNS- a bundle of fascicles wrapped in the CT epineurium.



F=fascicle (collection of nerve fibers/axons)
P= perineurium
E=epineurium –the CT that covers bundles of fascicles to form a NERVE)





Regions of the Brain and Spinal Cord

- **White matter** – dense collections of myelinated fibers (information transfer "highways")

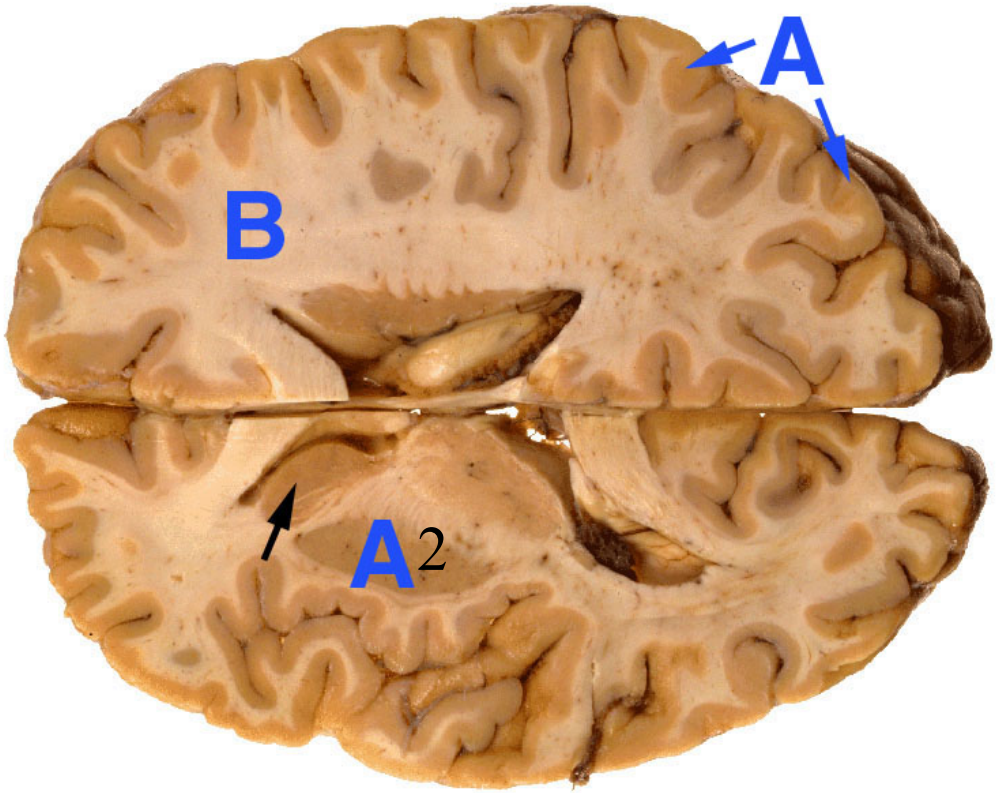
Tracts = a bundle of axons in the CNS

- **Gray matter** – mostly cell bodies (soma) and unmyelinated fibers (high concentration of neuron cell bodies="thinking/processing centers")

Gray matter found in the White matter of the brain called Nuclei (plural), nucleus (singular)

Grey & white matter brain

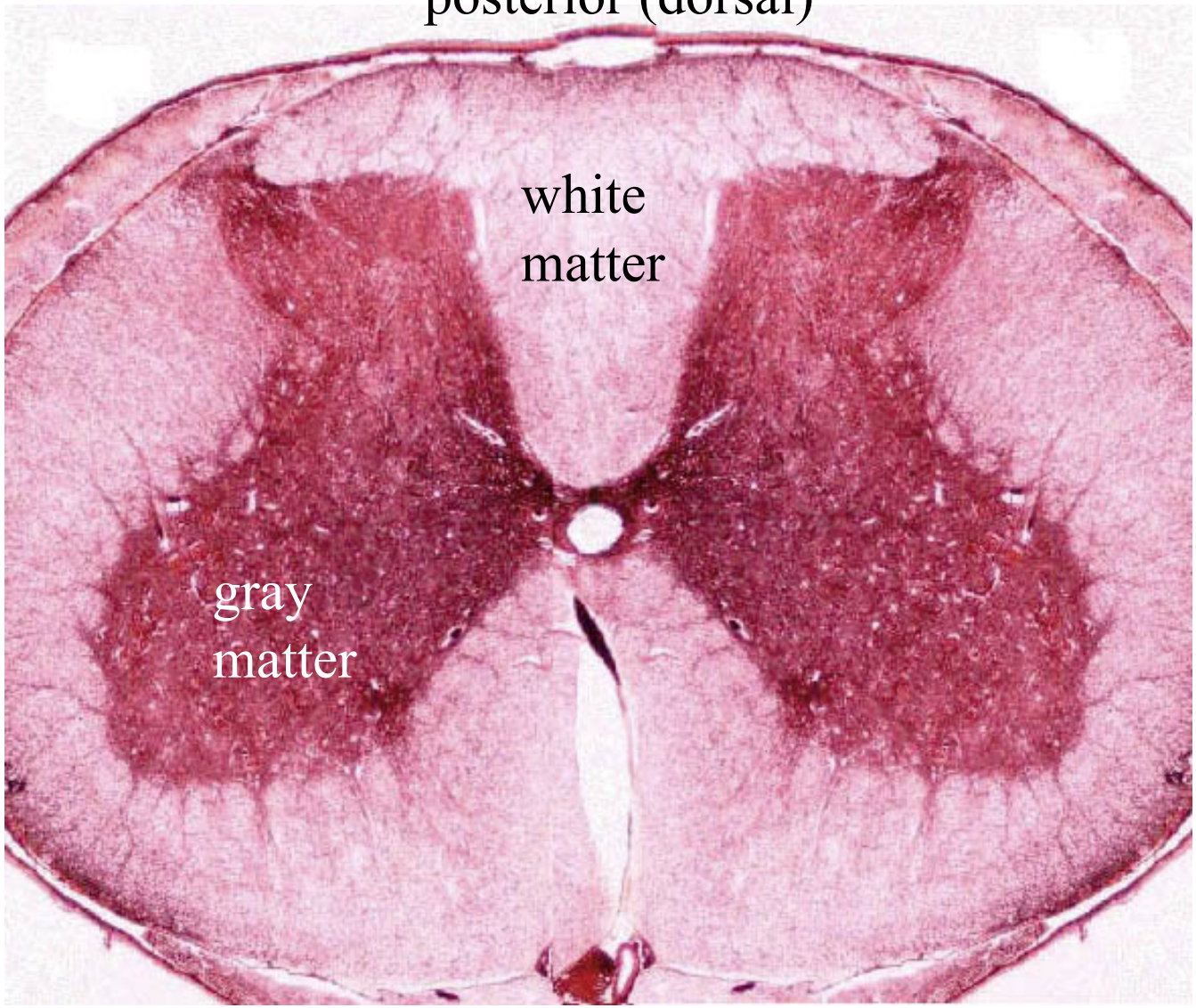
Questions:
This section is cut in the horizontal plane. Can you describe what this means?
Where is the grey matter in this photograph (A or B)?
The white matter (A or B)?
The structure marked by the black arrow is a collection of neurons.What are such collections of neurons called in the brain?



Answers:
This plane of this section would be parallel to the ground if the man or woman were standing upright.
A - Grey matter
B - White matter
A2 nuclei (pl); the arrow points to the caudate nucleus (singular)

Gray & White Matter-spinal cord

posterior (dorsal)



anterior (ventral)

Putting it all together!