Fundamentals of the Nervous System

Basic division of the Nervous System (although there is only ***one*** NS)

- Central nervous system ("CNS") – occupies cranium and vertebral column
  - Brain
  - Spinal cord

- Peripheral nervous system ("PNS")
  - Cranial nerves
  - Spinal nerves
  - Ganglia (clusters of cell bodies)

Terminology

- Input: sensory = ***sensory input***
  - Receptors monitor changes
  - Changes called “stimuli” (sing., stimulus)
  - Information sent by **“afferent”** nerves
- Integration
  - Info processed
  - Decision made about what should be done
- Output: motor = ***motor output***
  - Effector organs (muscles or glands) activated
  - Effected by **“efferent”** nerves

Remember the difference between the English words “affect” and “effect”

Terminology, continued

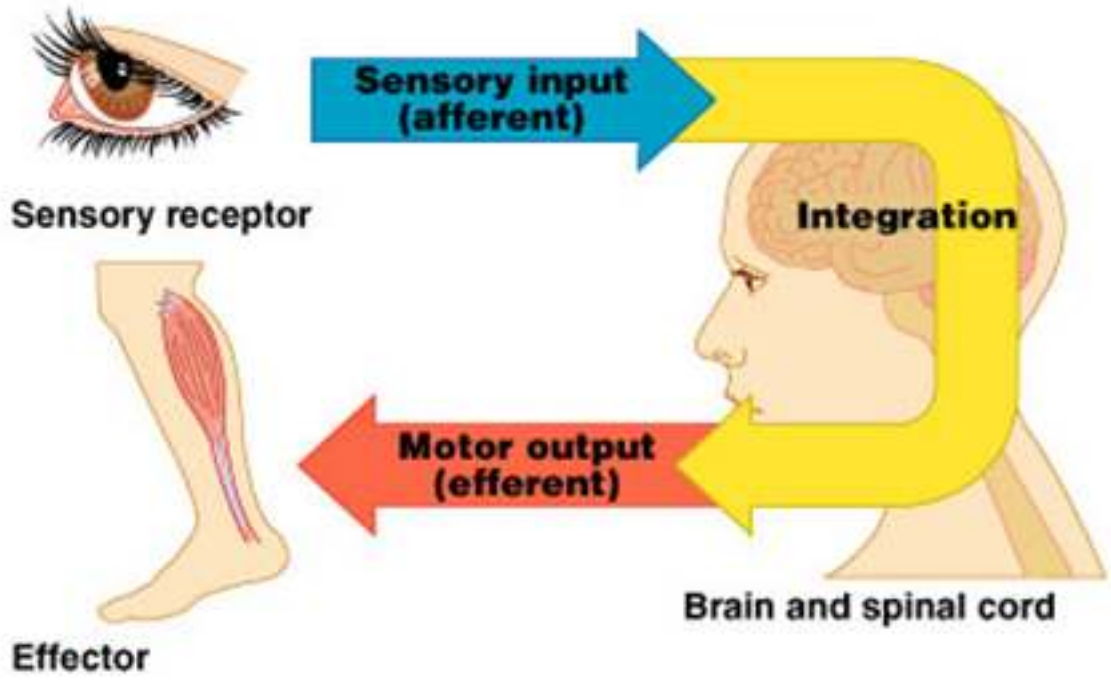
- "The music ***affected*** her deeply."

  (Something is experienced: sensory)

- "His protests had no ***effect***."

  (Something is done or not done: motor)

Simplified…


Sensory input
(afferent)
Sensory receptor
Integration
Motor output
(efferent)
Brain and spinal cord
Effector

Nervous tissue: 2 types of cells

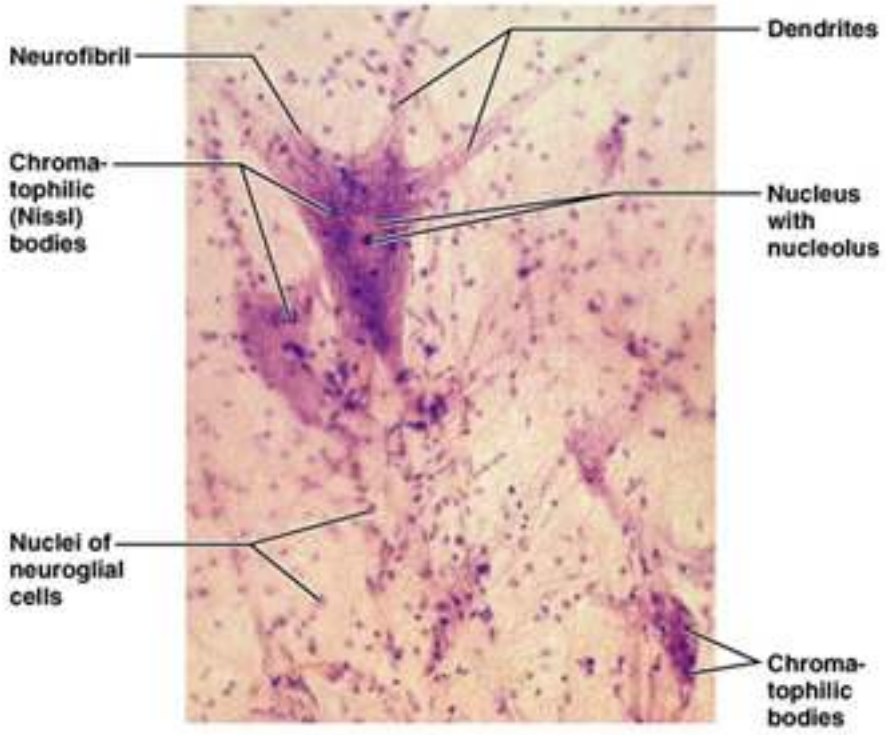
1. ***Neurons***
   - Excitable nerve cells
   - Transmit electrical signals

2. Supporting cells: ***neuroglia*** or just ***glia***
   - Means “nerve glue”

Neurons

- All have a cell body: with nucleus and cytoplasm

- Cell bodies are in clusters
  - CNS: clusters called ***nuclei***
  - PNS: clusters are called ***ganglia***
    (are *outside* the CNS)

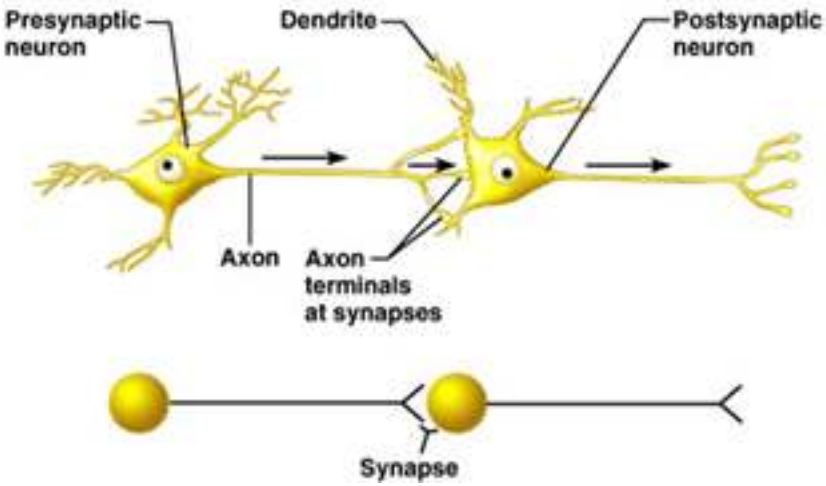


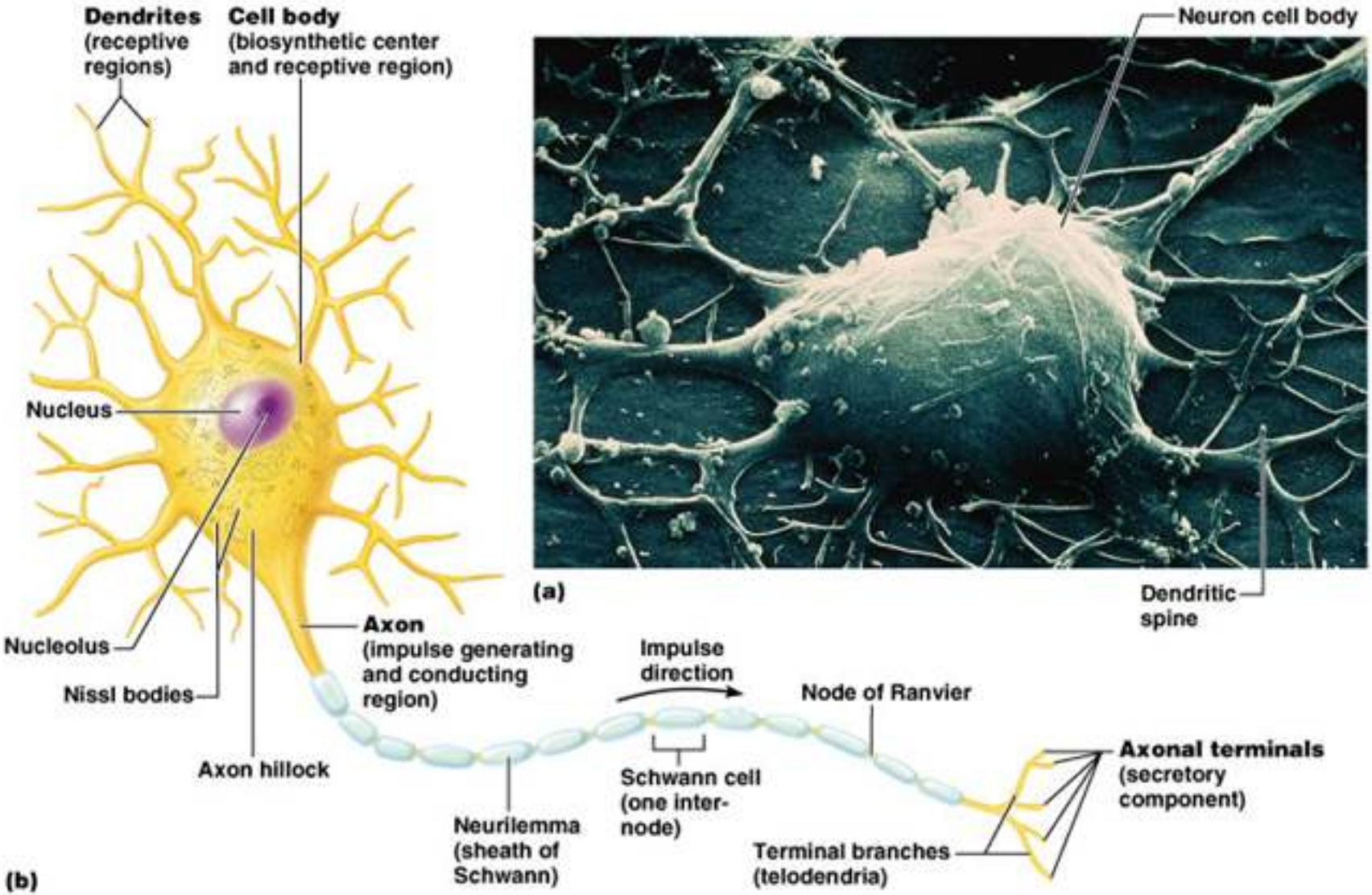
Neurons, continued

- Can live for a lifetime (i.e. over 100 years)
- Do not divide
  - (exception: recent neural stem cells identified)
  - Cannot replace themselves
- High metabolic rate
  - Require continuous oxygen and glucose
  - Die within a few minutes without oxygen

Neuron "processes"
(armlike; extend from the cell body)

- Nerve fibers = ***axons***
  - Nerve impulse generators & transmitters
  - One per neuron, although can branch into "collaterals"
  - At terminal end branch *a lot* (e.g. 10,000/terminus)
- Receptive regions called ***dendrites***
  - Have receptors for neurotransmitters (chemicals released by other neurons)
  - Neurons may have many



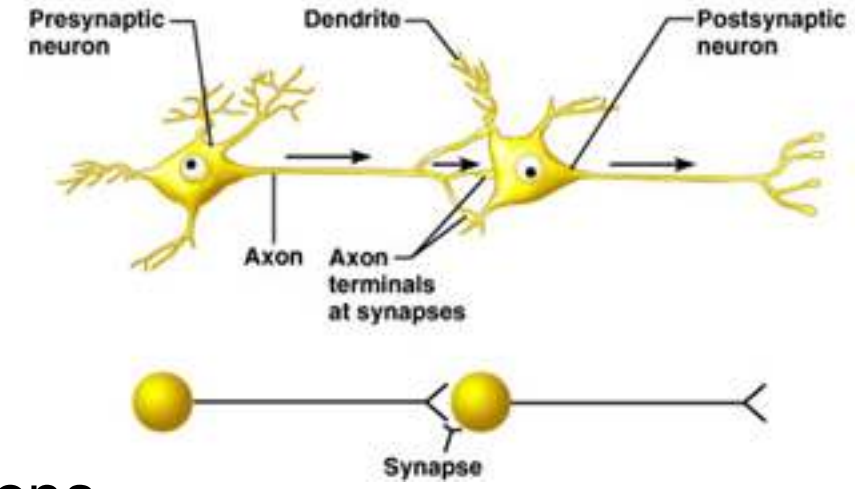


Neuron processes

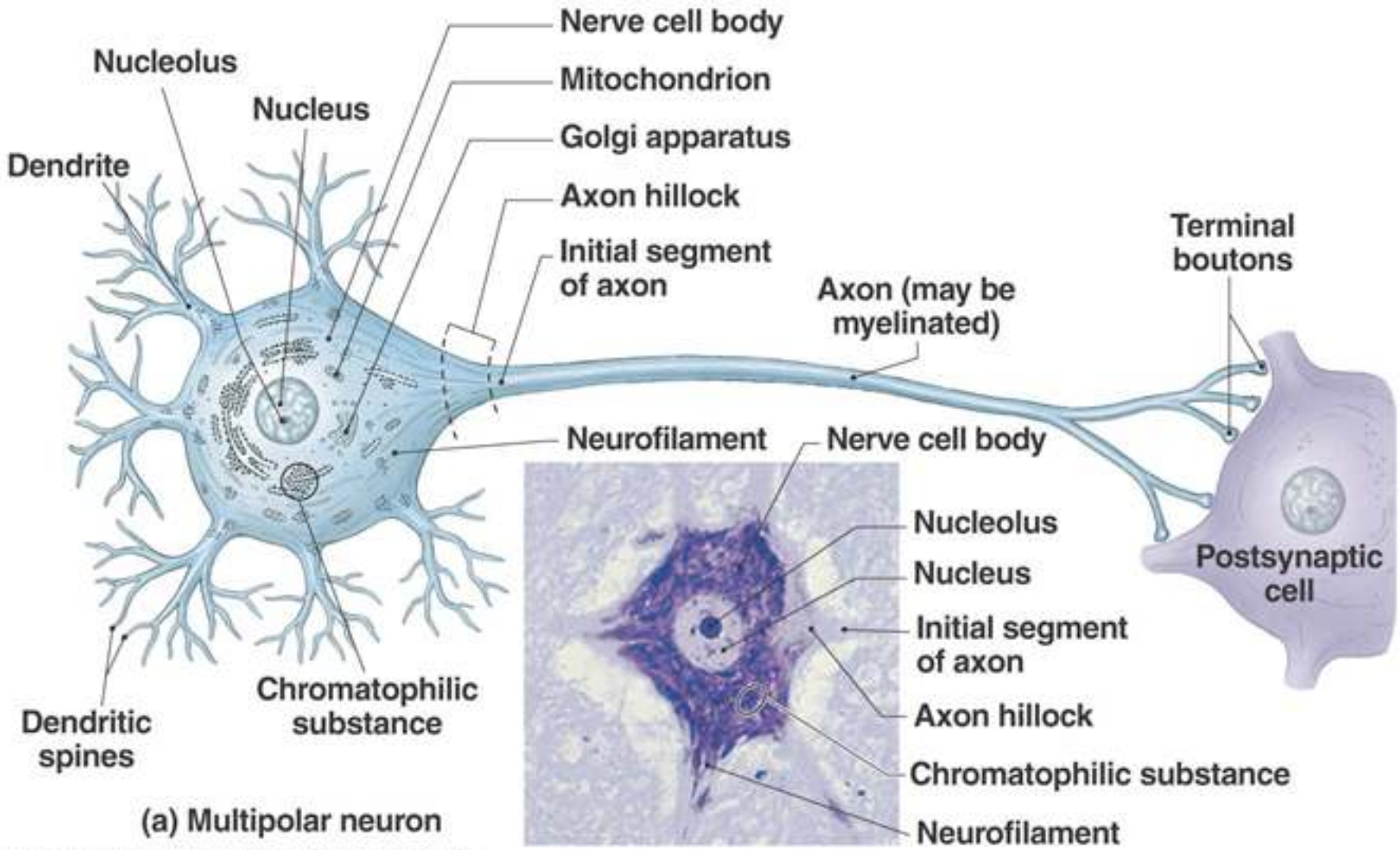
- Run through CNS in ***tracts*** of white matter

- Run through the PNS forming peripheral ***nerves***

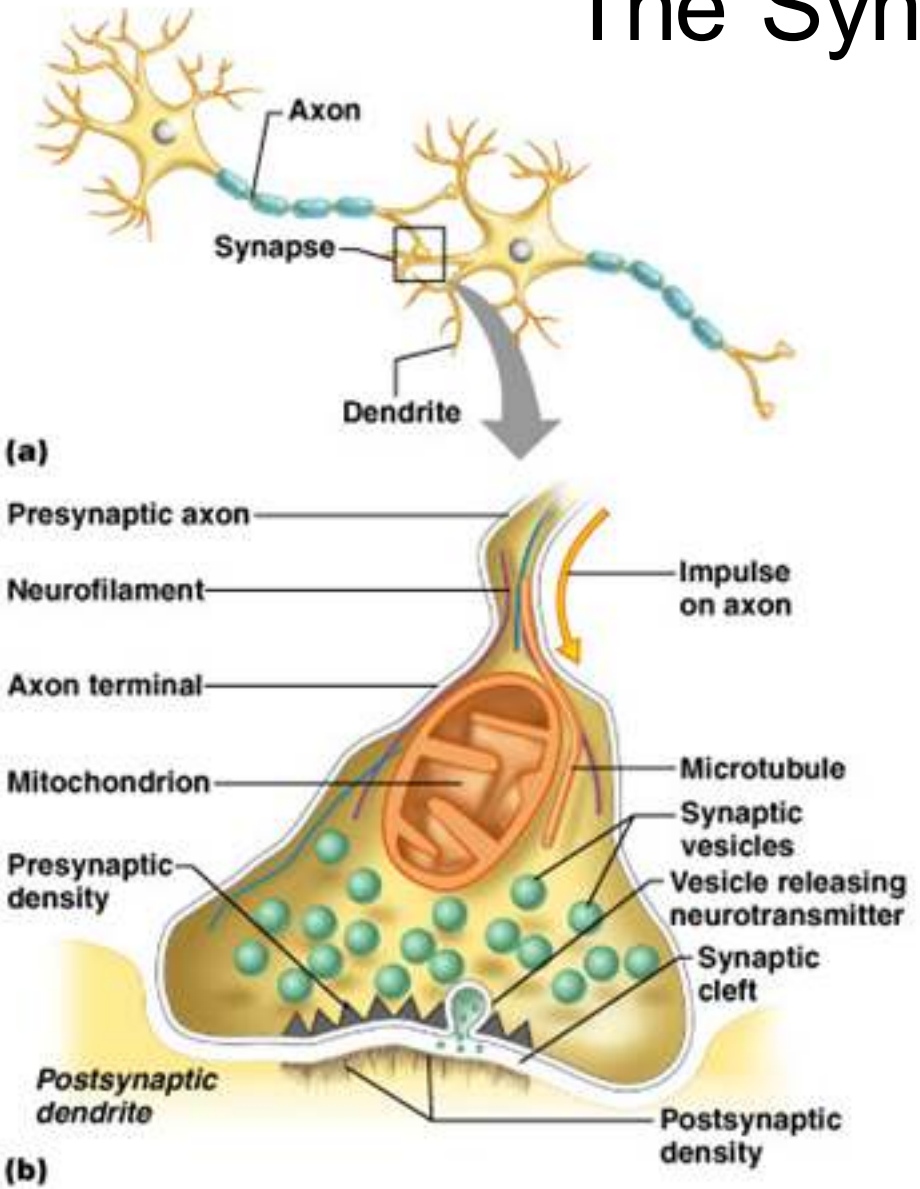
Synapses

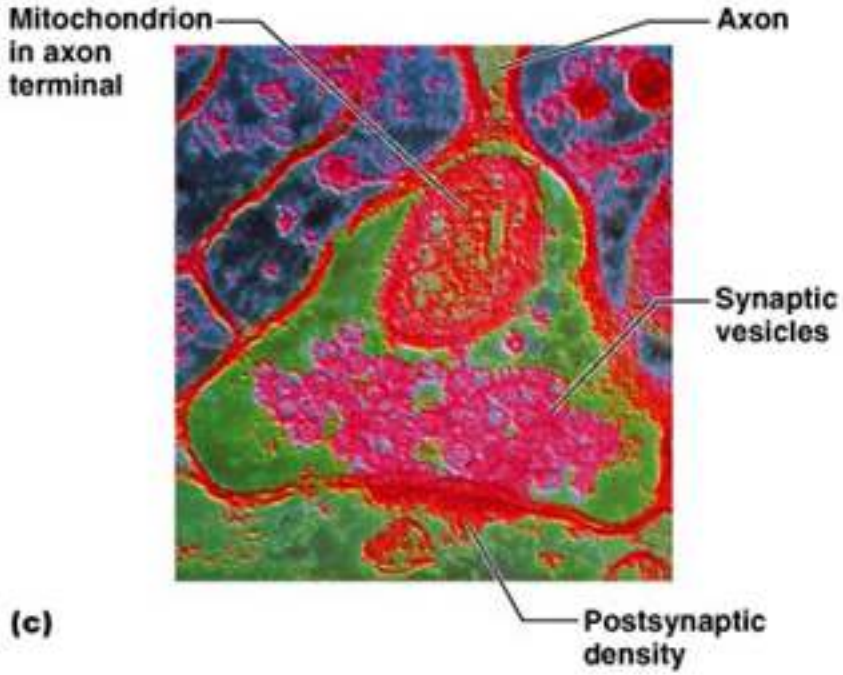


- Junctions between neurons
- Information is passed (usually chemically)
- Unidirectional
- Presynaptic (*toward* synapse) vs postsynaptic (*away from* synapse): most neurons function as both
- Synaptic cleft (tiny gap)



The Synapse



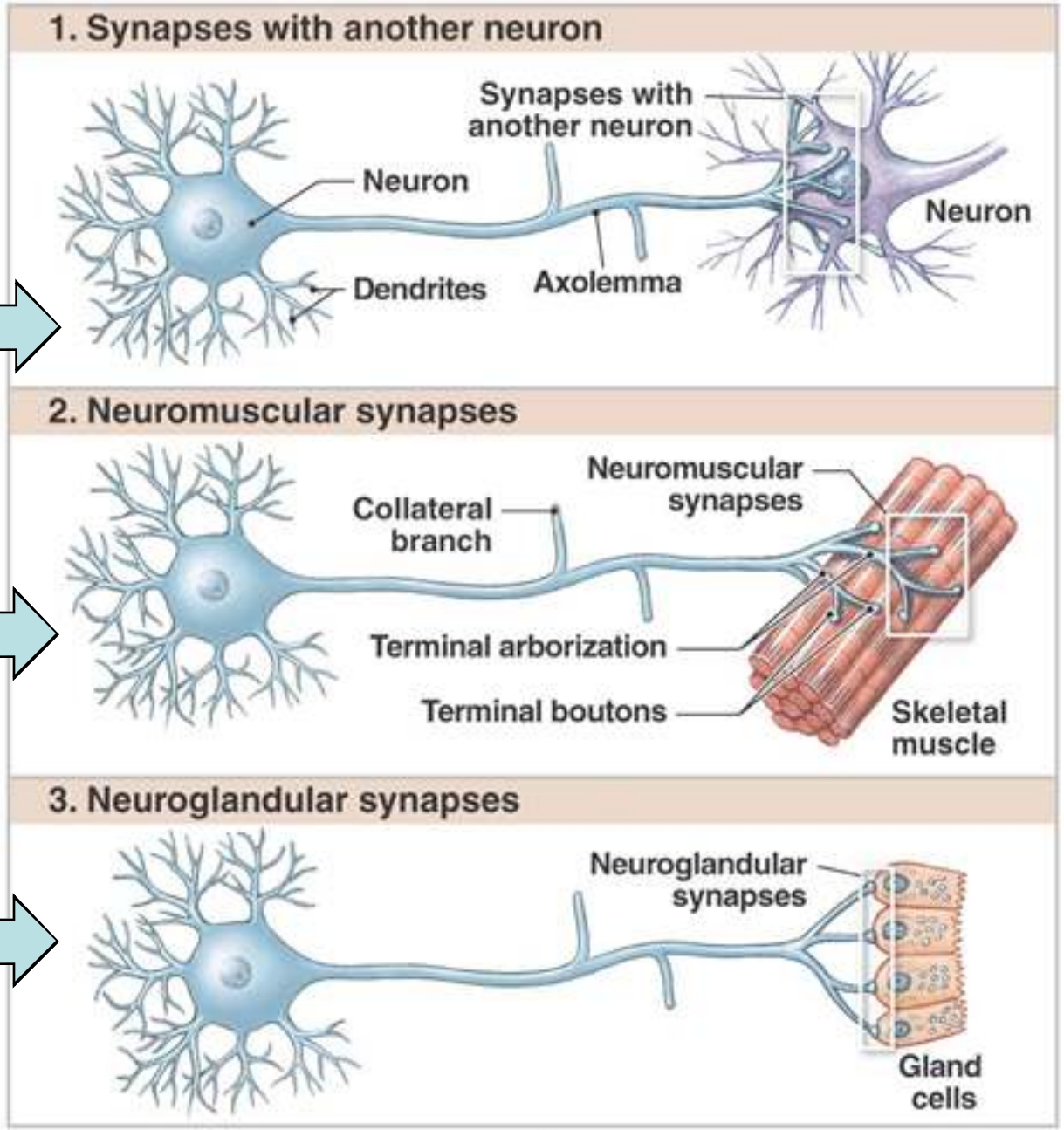


simplified

- Info passed between neurons by chemicals
  - Can be excitatory or inhibitory
- Along the axons, the information passes electrically

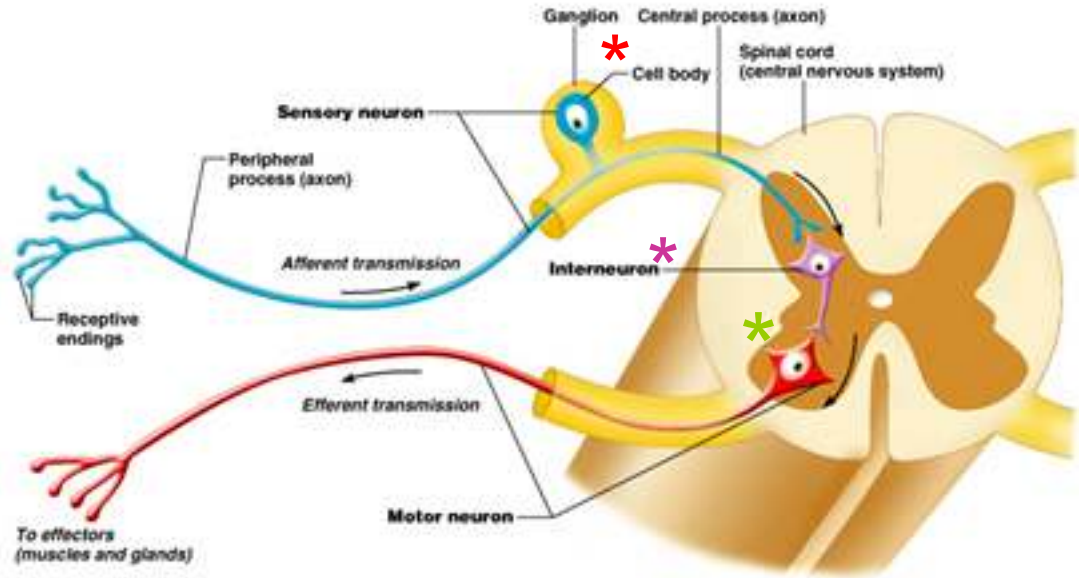
Neurons can synapse with:

1. Neurons
2. Muscle
3. Glands

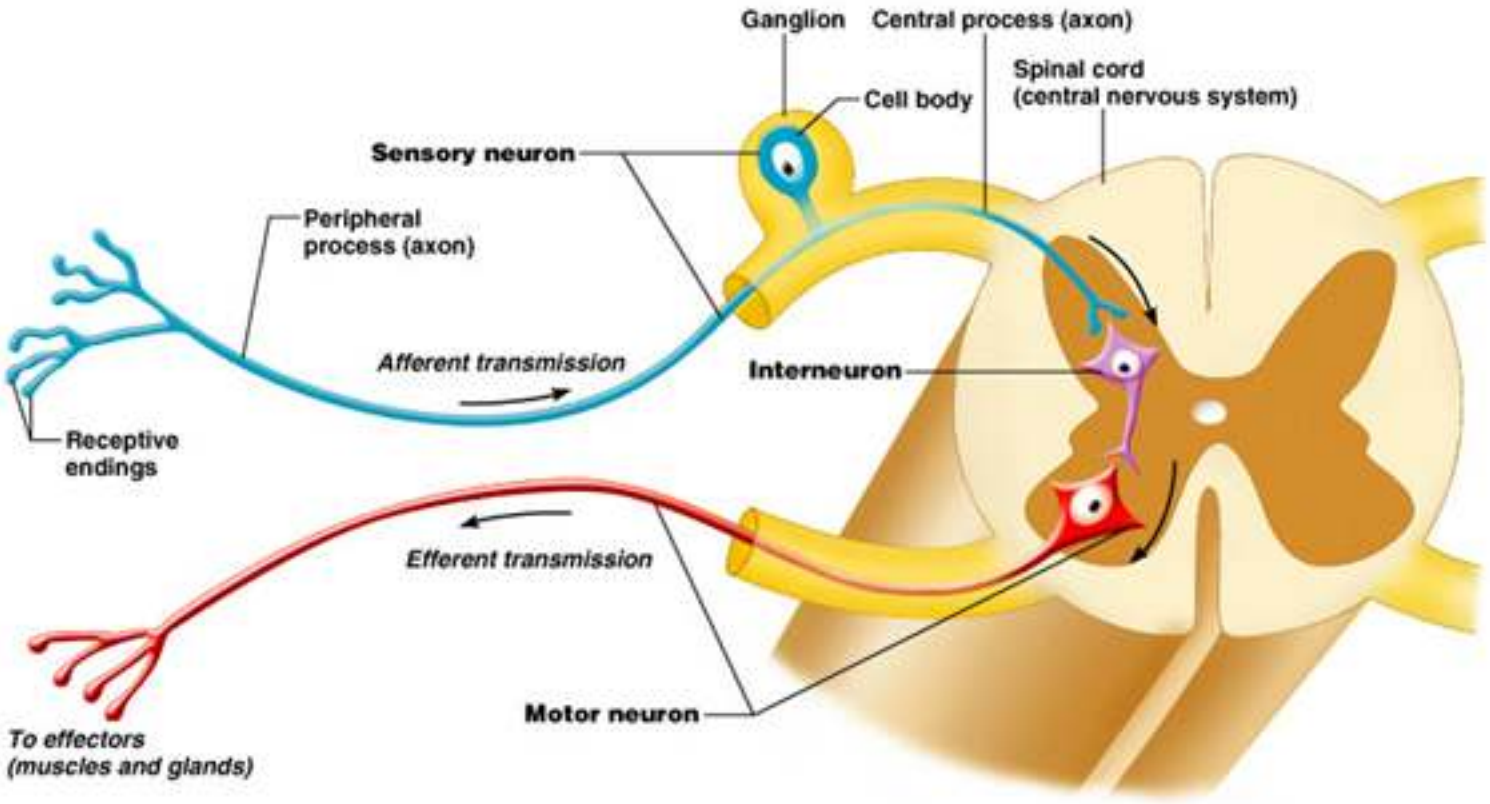


Neurons by function/direction *(relative to the CNS)*

- Sensory or afferent (toward CNS from sensory receptor in PNS)
  - Dendrites with specialized sensory receptors (in skin, muscles, viscera, etc)
  - Cell bodies **always** in ganglion* outside CNS
- Motor or efferent
  - From CNS to muscles, glands or viscera
  - Cell bodies almost always in CNS*
- Interneurons*: 99.98% of neurons (within CNS; can be long, e.g. travel down the spinal cord)



Learn this diagram!



From earlier…

Nervous tissue: 2 types of cells

1. (Neurons and their processes: we just did)
2. Supporting cells = neuroglia ("nerve glue") or just glial cells
   - CNS
     - Astrocytes
     - Oligodendrocytes
     - Microglia
     - Ependymal cells
   - PNS
     - Schwann cells
     - Satellite cells

Supporting cells

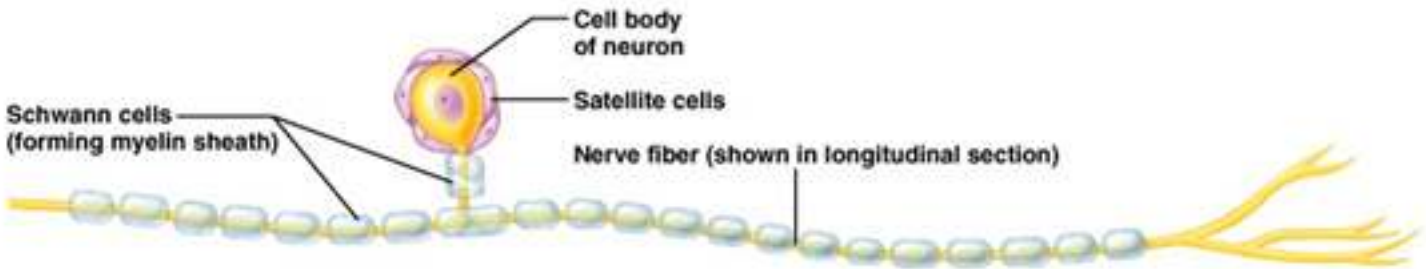
- Neuroglia usually refers to CNS ones
- Just “glia” to both
- Divide throughout life
- Smaller and darker than neurons
- Outnumber neurons 10 to 1

Neuroglia (CNS glial cells)

- Astrocytes
  - Star shaped; the most numerous
  - Involved in metabolism & synapse formation
- Microglia
  - Phagocytes
- Ependymal cells
  - Line the cavities of CNS and spinal cord; cilia
- Oligodendrocytes
  - Produce myelin sheaths in CNS (see later slide)

PNS supporting cells

- Satellite cells
  - Surround neuron cell body
- Schwann cells
  - Form myelin (see next slide) in PNS

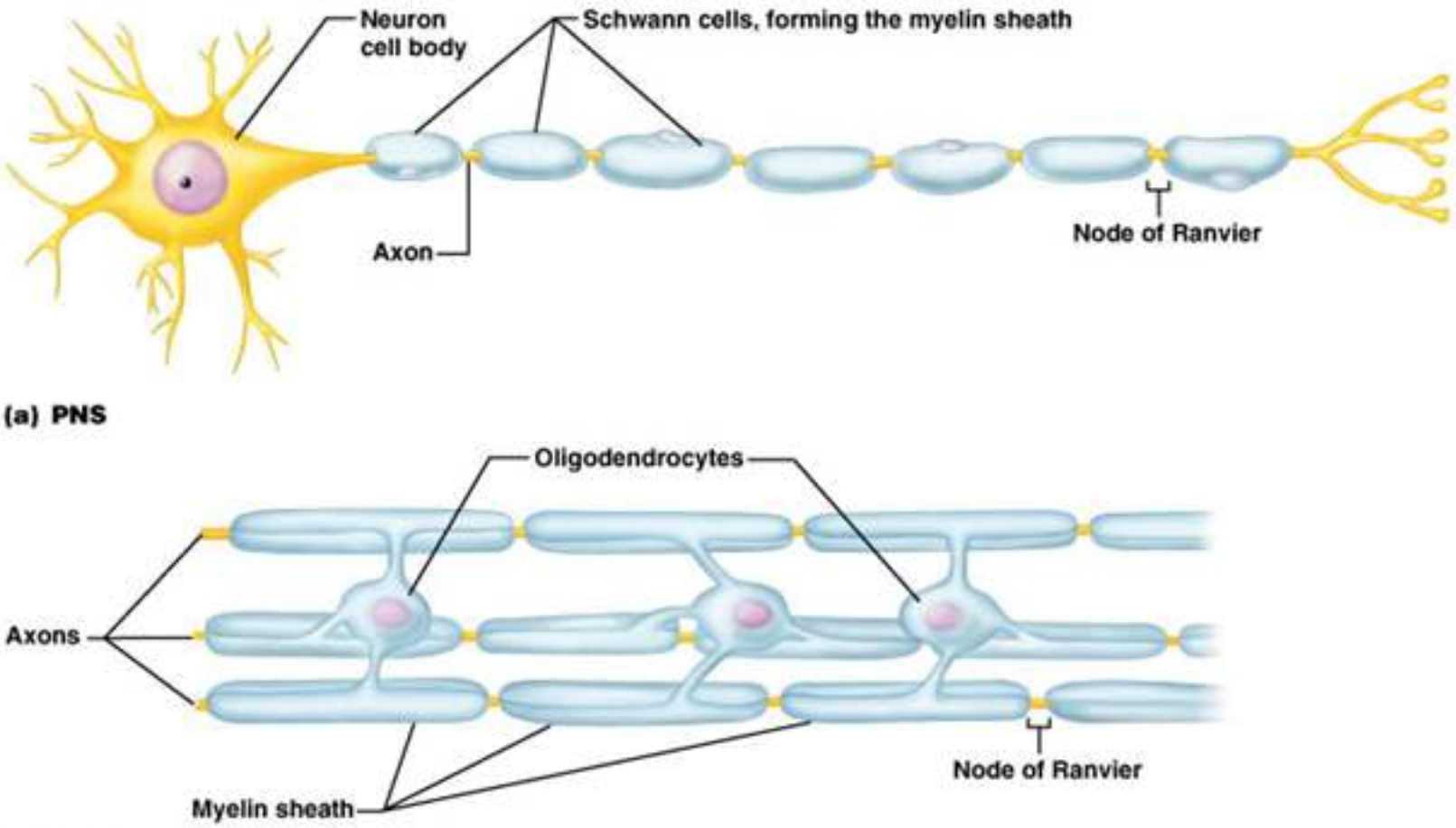


Sensory neuron with Schwann cells and satellite cells

Myelin

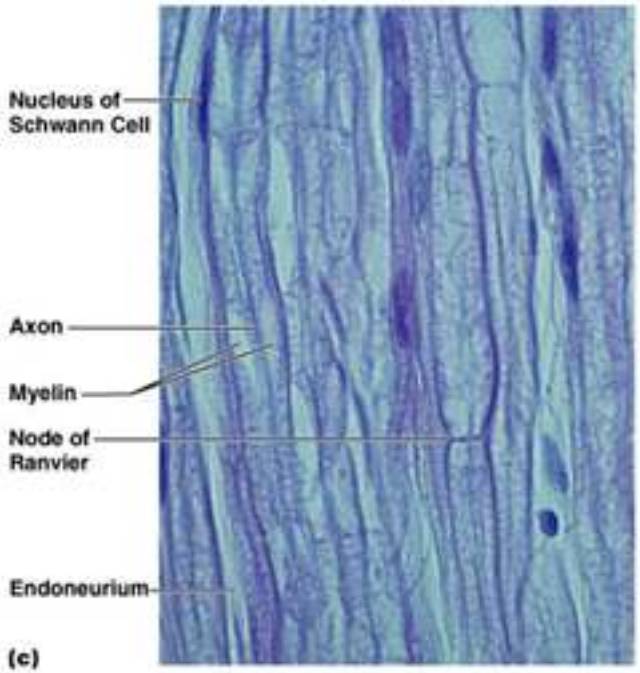
- Lipoprotein
- Increases speed of conduction, large axons
  - Are “insulation”
  - Prevent leakage of electric current
- Layers with spaces (nodes of Ranvier) between cells
- Impulse “jumps” from node to node
- “Unmyelinated” axons – smaller, slower

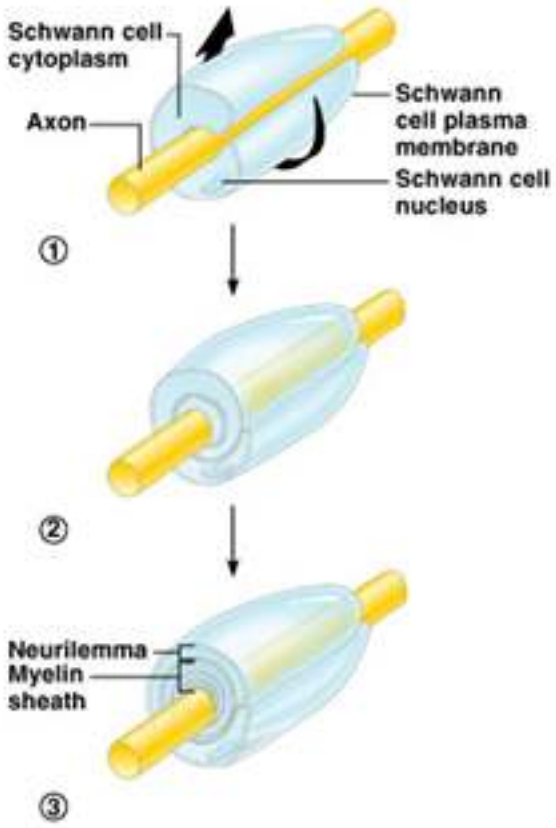
Myelin in the Peripheral and Central Nervous Systems

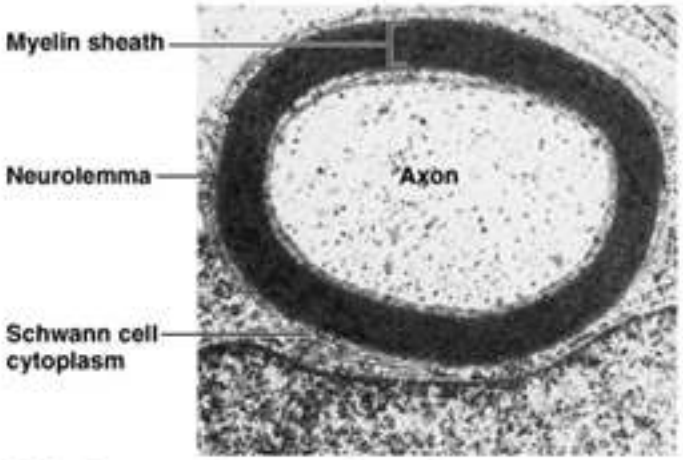


In multiple sclerosis (MS), patches of myelin are destroyed in the brain and spinal cord

- Schwann cells
  - Myelin sheath
  - Neurolemma (nucleus and most of cytoplasm squeezed to outside)







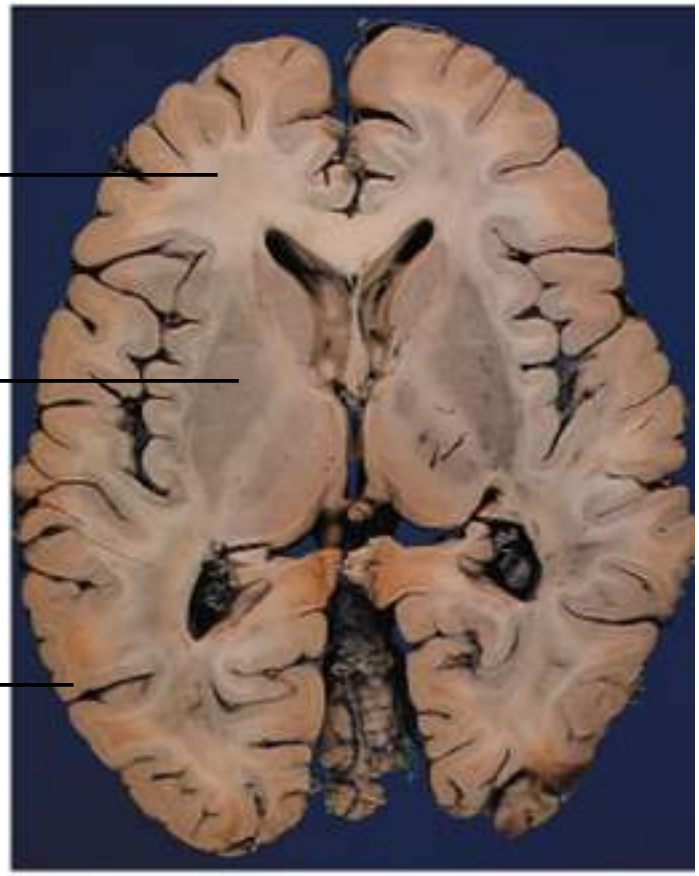
(a) Schwann cells on myelinated axon

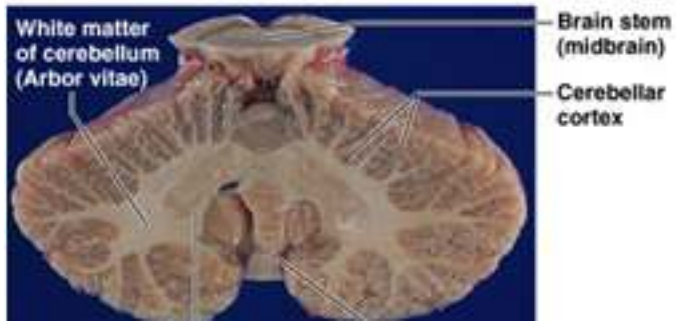
Gray and White Matter of the CNS
(GROSS ANATOMY OF THE CNS)

- Gray matter: gray-colored
  - Where neuron cell bodies are clustered
- White matter: white-colored
  - Where millions of axons are running between different part of CNS, in bundles of “tracts”
    - Remember, *tracts* are in CNS, vs *nerves* in PNS
  - White is from the myelin sheaths

Usual pattern of gray/white in CNS

- White exterior to gray
- Gray surrounds hollow central cavity
- Two regions with additional gray called "cortex"
  - Cerebrum: "cerebral cortex"
  - Cerebellum: "cerebellar cortex"



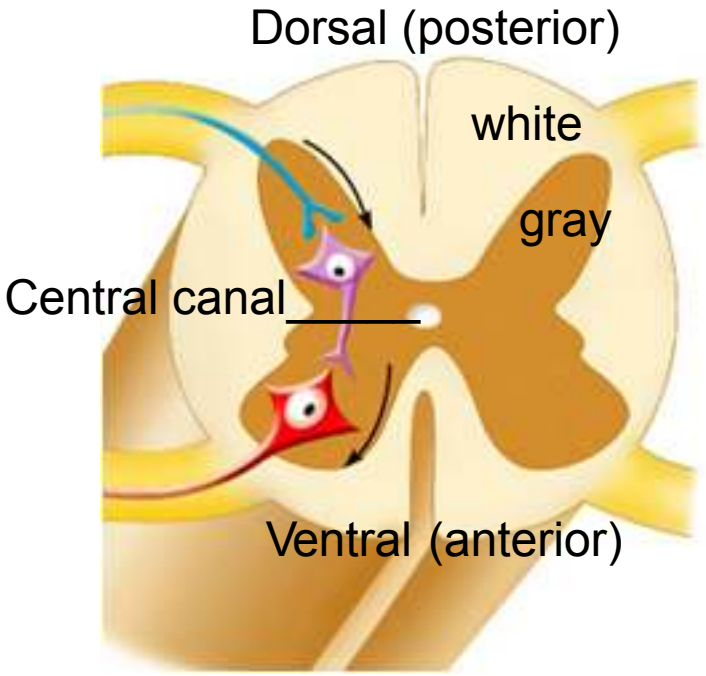


(pic from Marieb lab book p 263)

Gray/White in spinal cord

- Hollow central cavity ("central canal")
- Gray matter surrounds cavity
- White matter surrounds gray matter (white: ascending and descending tracts of axons)
- "H" shaped on cross section
- Dorsal half of "H": cell bodies of interneurons
- Ventral half of "H": cell bodies of motor neurons
- No cortex

Same pattern



From earlier: neuron processes

- Run through CNS in ***tracts*** of white matter

- Run through the PNS forming peripheral ***nerves***

Nerves are bundles of nerve fibers (long axons) in connective tissue

- To or from CNS to periphery
- Classified according to direction, like neurons
- ***Mixed***: carry both sensory (afferent) and motor (efferent) fibers
  - All spinal nerves are mixed
- ***Sensory*** or afferent nerves: ***to*** CNS
- ***Motor*** or efferent nerves: ventral roots of spinal cord

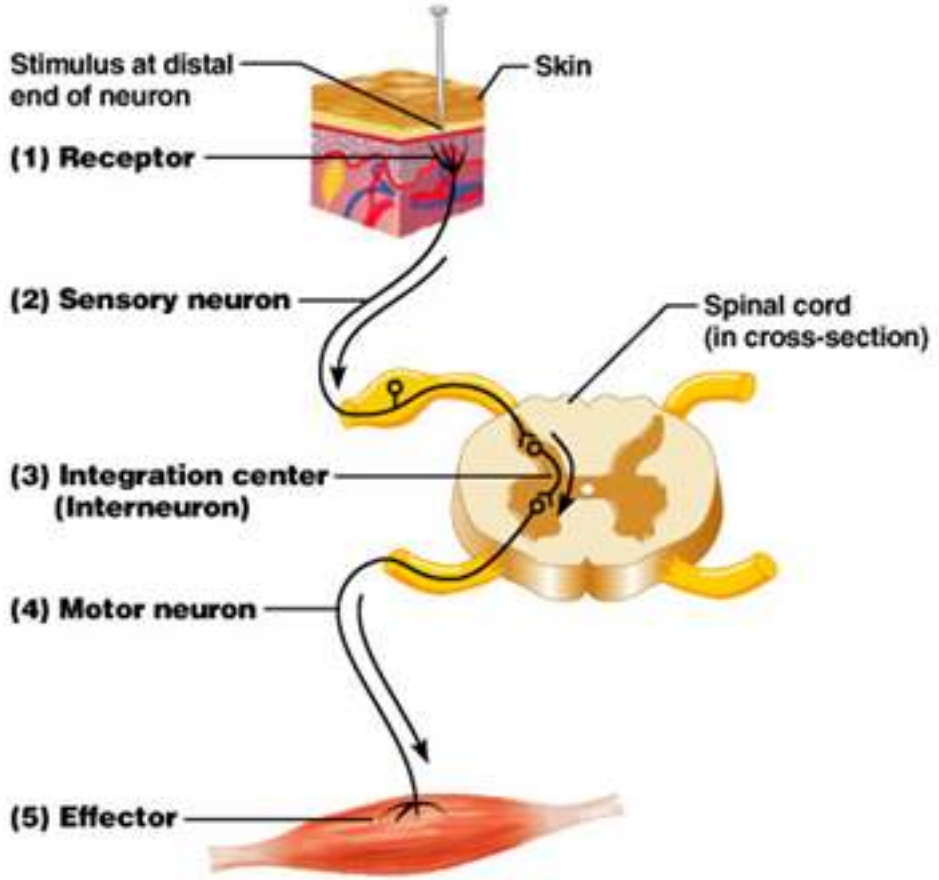
Interneurons
(99% of all neurons)

- In gray matter:
  - They process received sensory information
  - They direct this info to specific regions of the CNS
  - They initiate the appropriate motor response
- Via axons in white matter
  - They transmit info (sensory and motor) from one region of the CNS to another

The structural link between the PNS and CNS occurs in the gray matter of the CNS
The simplest example of neuronal integration is the reflex arc (see next slide)

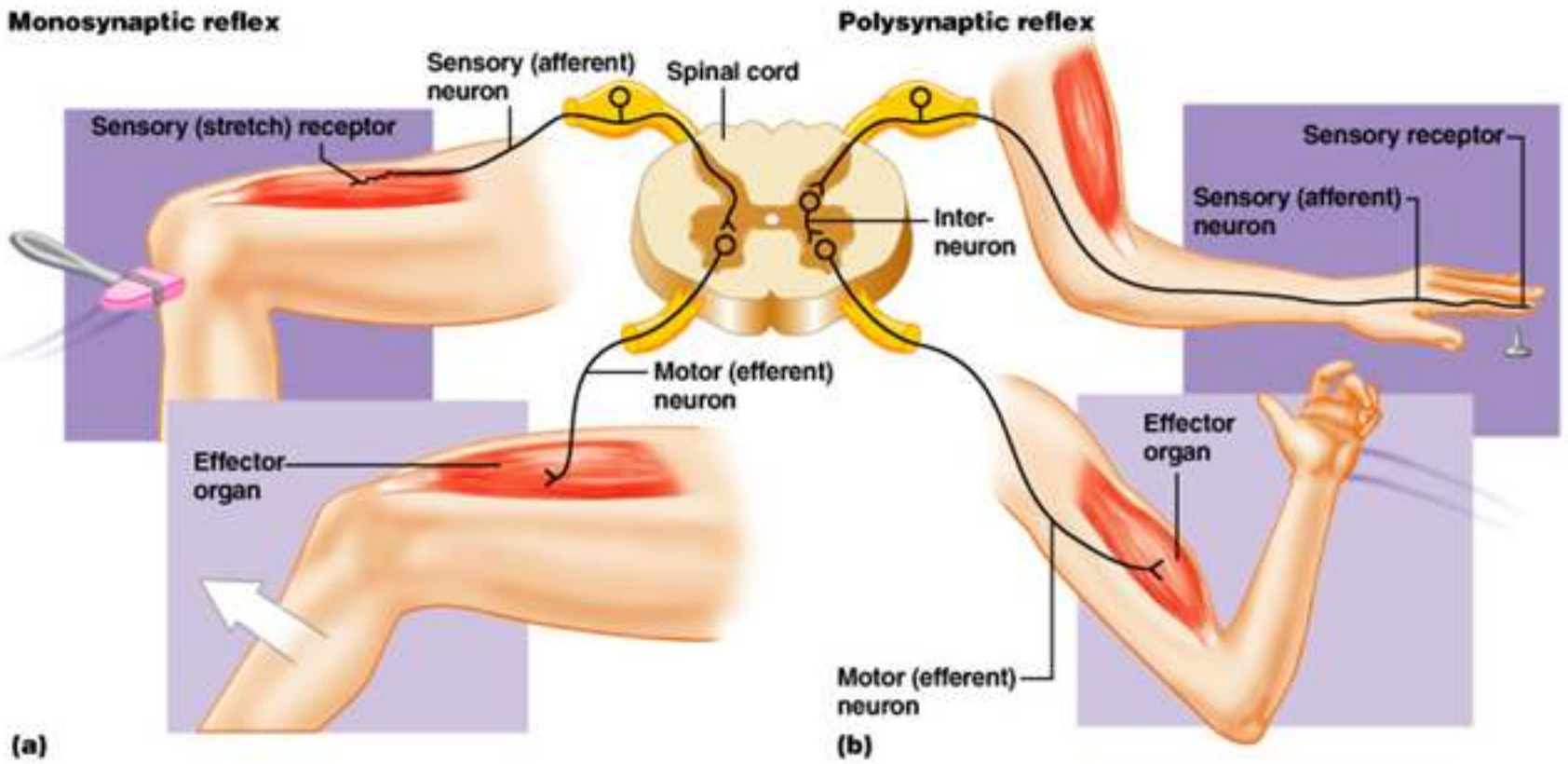
Reflex arcs: our “reflexes”

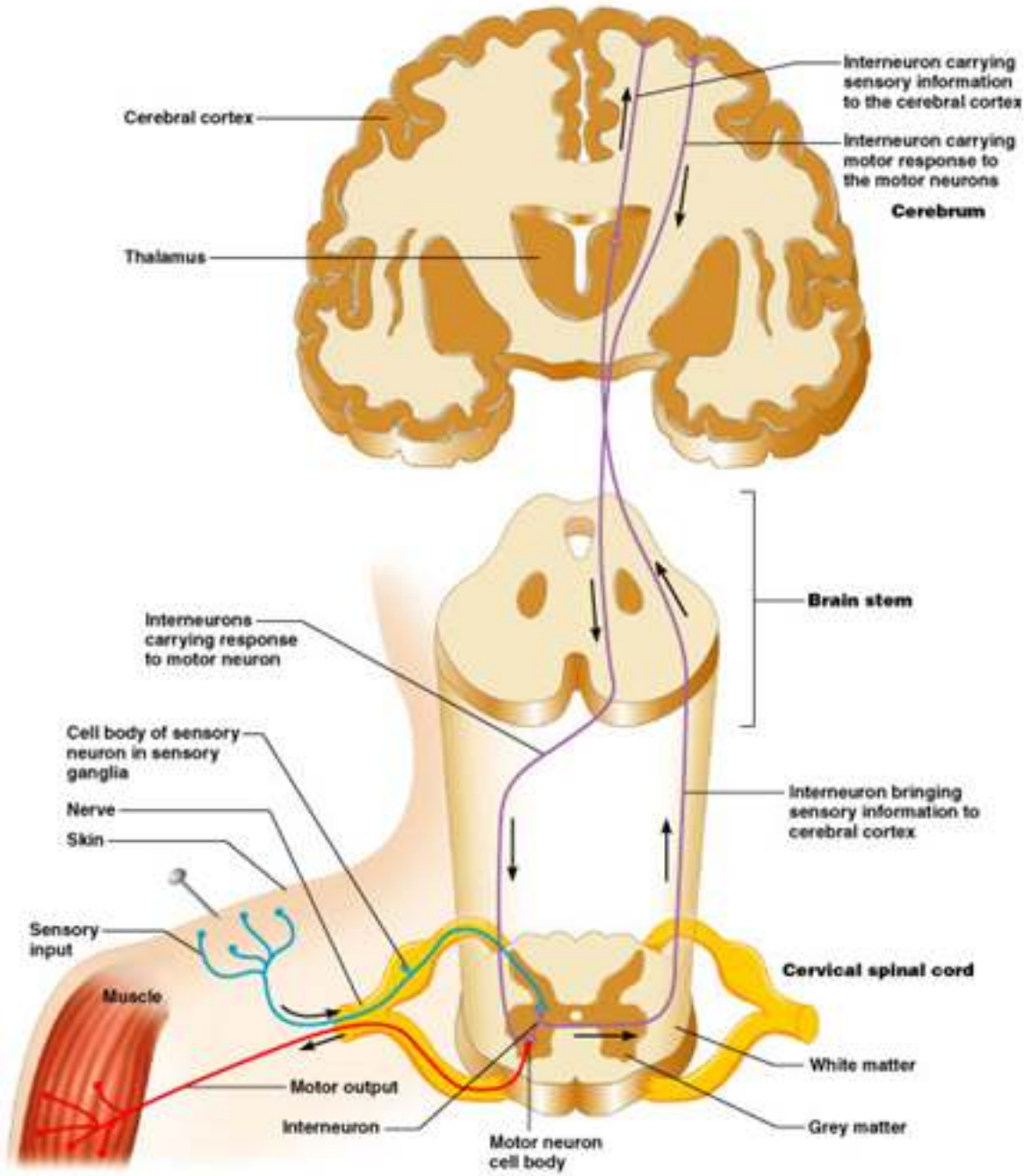
- Fast, automatic, involuntary
- Somatic or visceral
- Motor responses to stimuli
- Monosynaptic or polysynaptic
- 5 components: see right



Example of simplest, *monosynapatic* reflex

Reflex arcs: monosynaptic or polysynaptic





Anterior view

Basic neuronal organization

- Coronal section of cerebrum
- Cross sections of spinal cord and brains stem
- Note gray matter (brown) and white matter (tan)
- Reflex arc and information processing are shown

Terminology for quiz

- ***Neuron*** = nerve cell
- ***Neuroglia*** = supporting cell
- ***Nerve fiber*** = long axon
- ***Nerve*** = collection of nerve fibers (axons) in ***PNS***
- ***Tract*** = collections of nerve fibers (axons) in ***CNS***
- ***Nucleus*** = cluster of cell bodies in CNS
- ***Ganglia*** = cluster of cell bodies in PNS

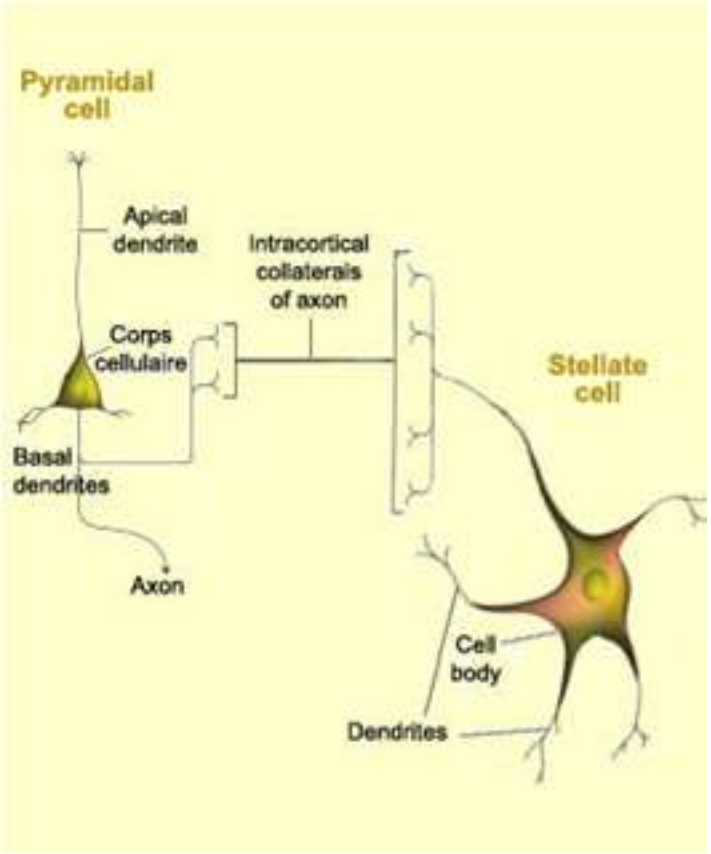
New:

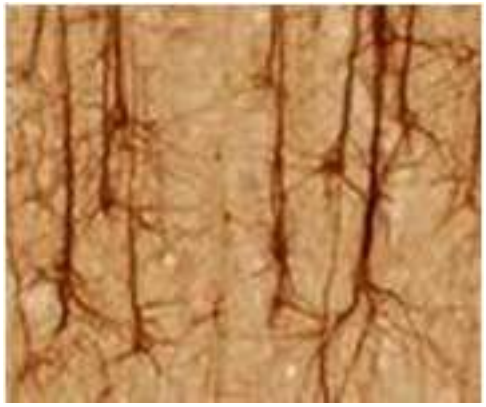
- ***Unilateral:*** on ***one*** side
- ***Ipsilateral:*** on the ***same*** side
- ***Contralateral:*** on the ***opposite*** side

Remember also:

- ***CNS vs PNS***
- ***Input: sensory: afferent: to brain***
- ***Output: motor : efferent: from brain***

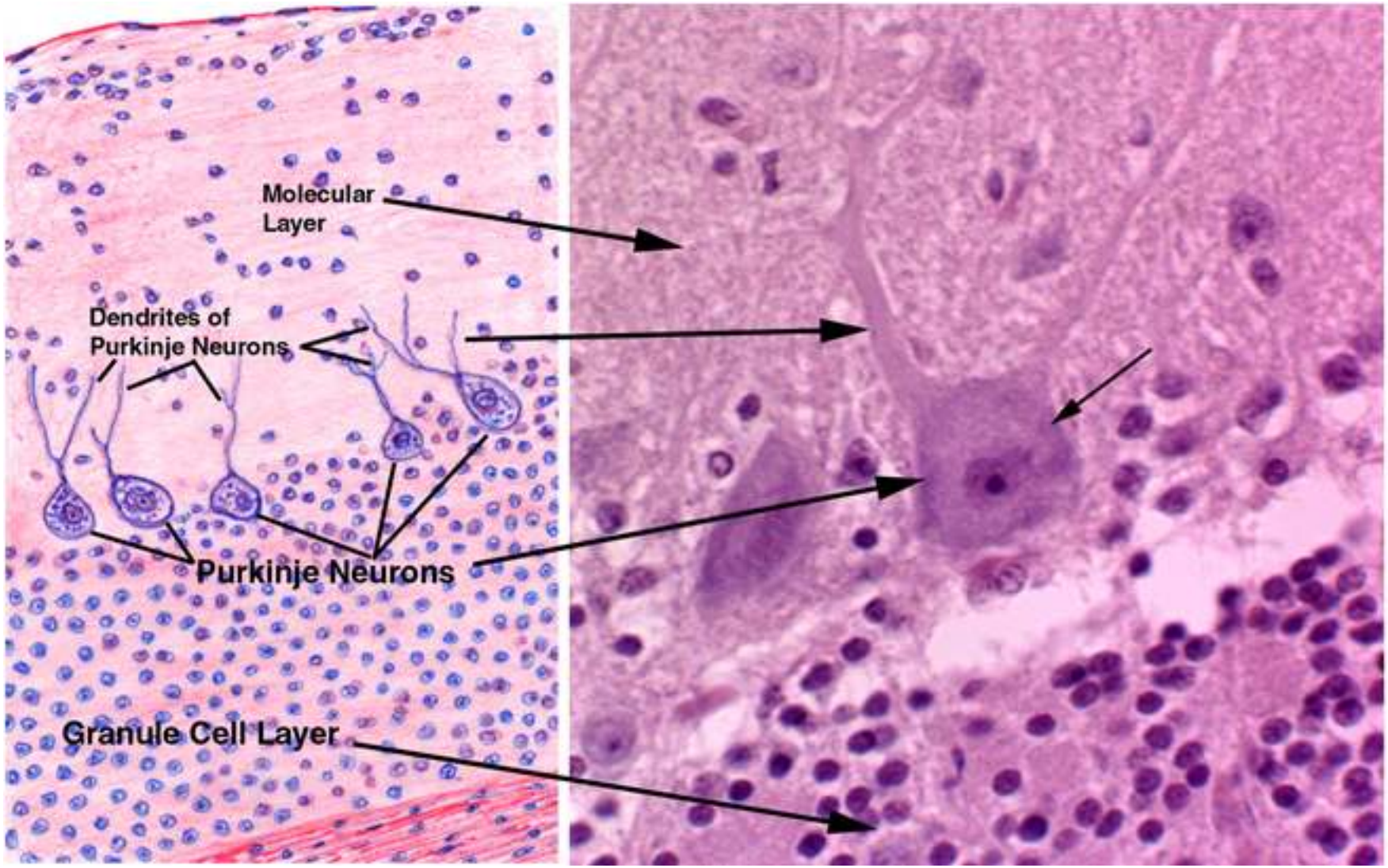
Pyramidal cells of cerebral cortex



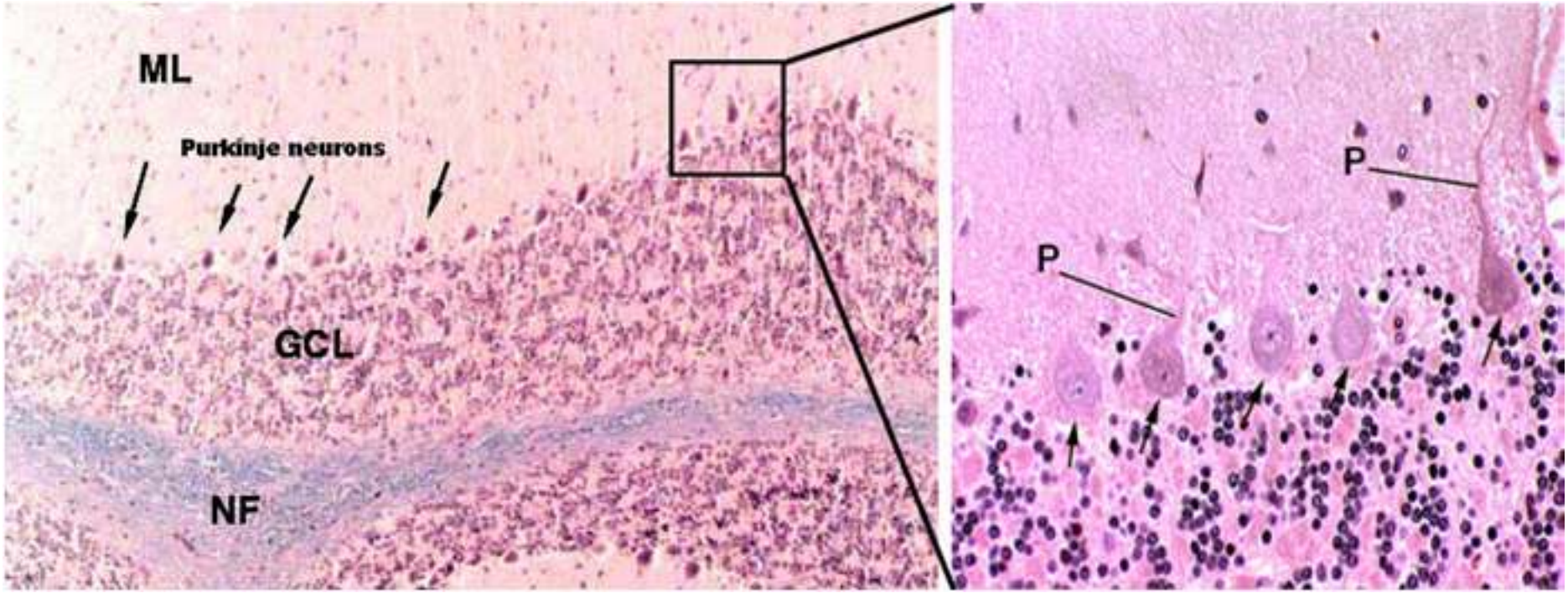


- This is where the “pyramidal” tract gets its name (the main motor tract from the cerebral cortex); also pyramids of medulla, pyramidal decussation

Cerebellar purkinje cells



Purkinje cells



Spinal cord cross section