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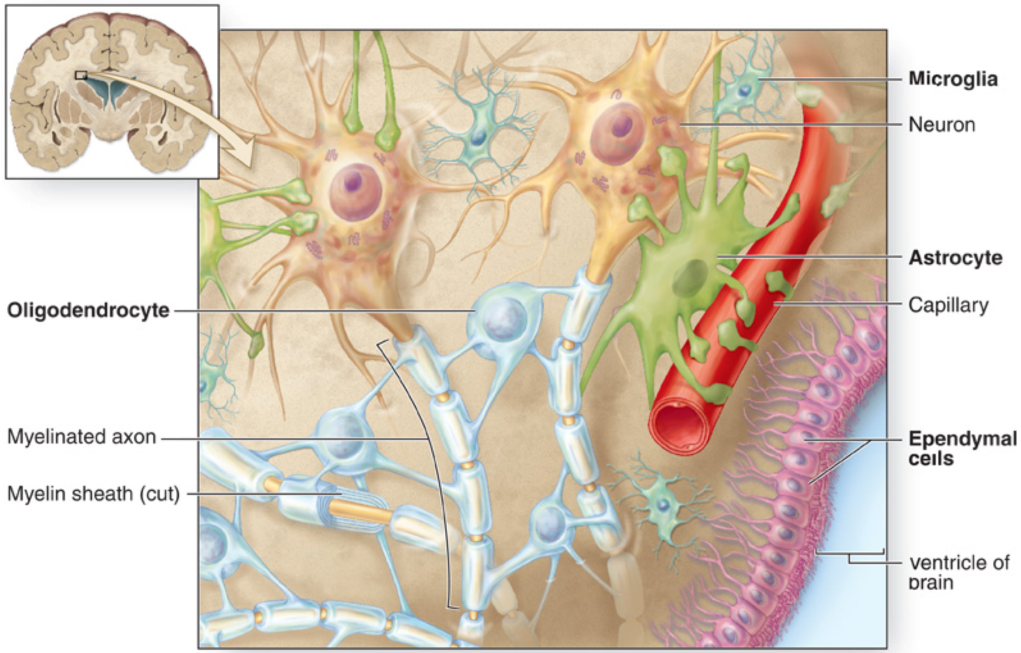
Human Anatomy



Nervous Tissue

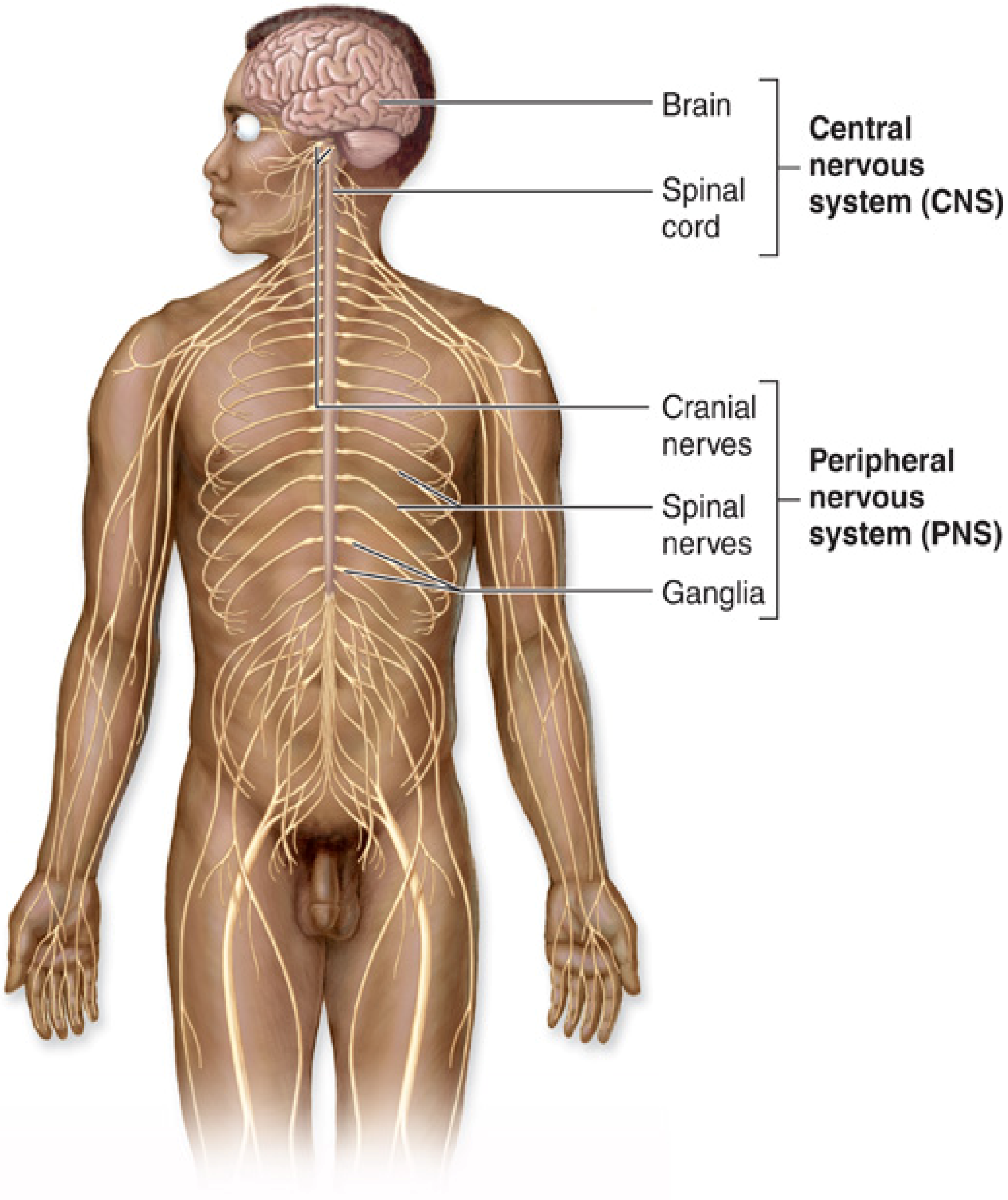
The Nervous System

- The body's primary communication and control system.
- Can be divided according to:
  - Structural categories
  - Functional categories.

Nervous System: Structural Organization

Structural subdivisions of the nervous system:

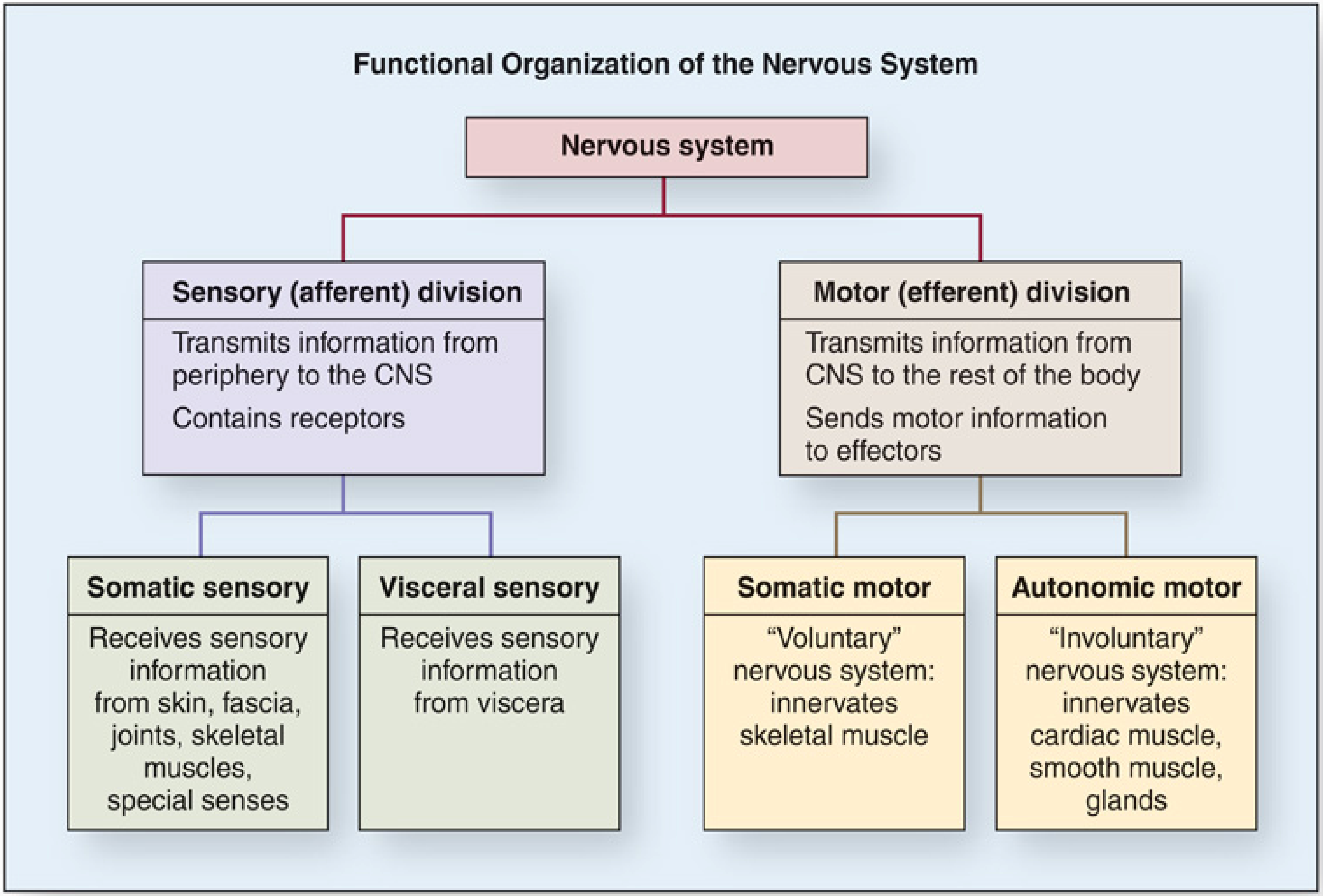
- Central nervous system (CNS)
  - brain and spinal cord
- Peripheral nervous system (PNS)
  - cranial nerves (nerves that extend from the brain)
  - spinal nerves (nerves that extend from the spinal cord)
  - ganglia (clusters of neuron cell bodies (somas) located outside the CNS)


Brain
Spinal cord
Central nervous system (CNS)
Cranial nerves
Spinal nerves
Ganglia
Peripheral nervous system (PNS)

Nervous System: Functional Organization

Functional divisions of the nervous system:

- Sensory afferent division:
  - receives sensory information (input) from receptors
  - transmits this information to the CNS.
- Motor efferent division:
  - transmits motor impulses (output) from the CNS
  - to muscles or glands (effector organs).


Functional Organization of the Nervous System
Nervous system
Sensory (afferent) division
Transmits information from periphery to the CNS
Contains receptors
Motor (efferent) division
Transmits information from CNS to the rest of the body
Sends motor information to effectors
Somatic sensory
Receives sensory information from skin, fascia, joints, skeletal muscles, special senses
Visceral sensory
Receives sensory information from viscera
Somatic motor
"Voluntary" nervous system: innervates skeletal muscle
Autonomic motor
"Involuntary" nervous system: innervates cardiac muscle, smooth muscle, glands

Sensory Division: two components

- Somatic sensory components:
  - General somatic senses:
    - touch
    - pain
    - pressure
    - vibration,
    - temperature
    - proprioception.
  - Special senses:
    - Taste
    - Vision
    - Hearing
    - Balance
    - smell

Sensory Division: two components

- Visceral sensory components
  - transmit nerve impulses from blood vessels and viscera to the CNS
  - visceral senses primarily include:
    - temperature
    - stretch (of the organ wall).

Motor Division: two components

- The somatic motor component (somatic nervous system; SNS):
  - conducts nerve impulses from the CNS to skeletal muscles
  - also known as the voluntary nervous system
- The autonomic motor component (autonomic nervous system; ANS): internal organs, regulates smooth muscle, cardiac muscle, and glands.
  - Innervates
    - Internal organs
    - Regulates smooth muscle
    - Regulates cardiac muscle
    - Regulates glands
  - also known as the visceral motor system or involuntary nervous system

Nerve Cells

- Nervous Tissue
  - Two distinct cell types
    - Neurons
      - excitable cells
      - initiate and transmit nerve impulses
    - Glial cells
      - nonexcitable cells
      - support and protect the neurons

Characteristics of Neurons

- Neurons have a high metabolic rate.
- Neurons have extreme longevity.
- Neurons typically are non-mitotic.

Neuron Structure

- Neurons come in all shapes and sizes
- All neurons share certain basic structural features.
- typical neuron:
  - Cell body (soma, perikaryon)
  - Dendrites
  - Axon
    - Collaterals: branches
    - axon terminals or telodendria
    - Synaptic knobs

Neuron Structure – Cell Body

- The cell body (perikaryon, soma)
  - the neuron's control center
    - responsible for:
      - receiving
      - integrating
      - sending nerve impulses.
  - Consists of:
    - Plasma membrane
    - Cytoplasm
    - Nucleus with prominent nucleolus
    - Chromatophobic substance (Nissil bodies): RER
    - Free ribosomes

Neuron Structure – Dendrites

- Shorter, smaller processes
- Branch off the cell body.
- Some neurons have only one dendrite, while others have many.
- Dendrites conduct nerve impulses toward the cell body
  - they receive input
  - transfer input to the cell body for processing.
- The more dendrites a neuron has, the more nerve impulses that neuron can receive from other cells.

Neuron Structure – Axon

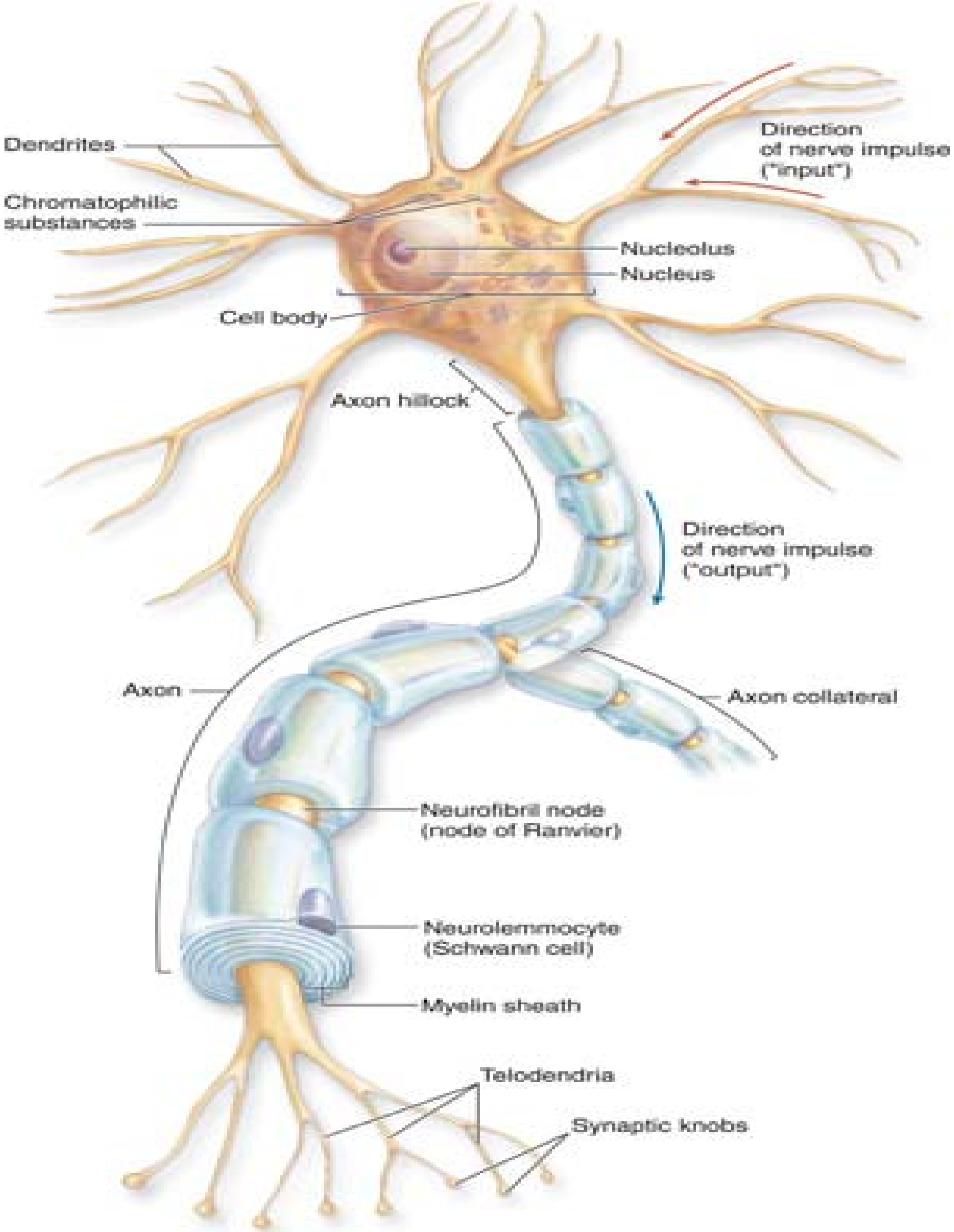
- larger, typically longer nerve cell process
- Extend from the cell body
  - Axon hillock
- also called a nerve fiber
- Most neurons have only one axon.
  - Anaxonic

Neuron Structure – Axon

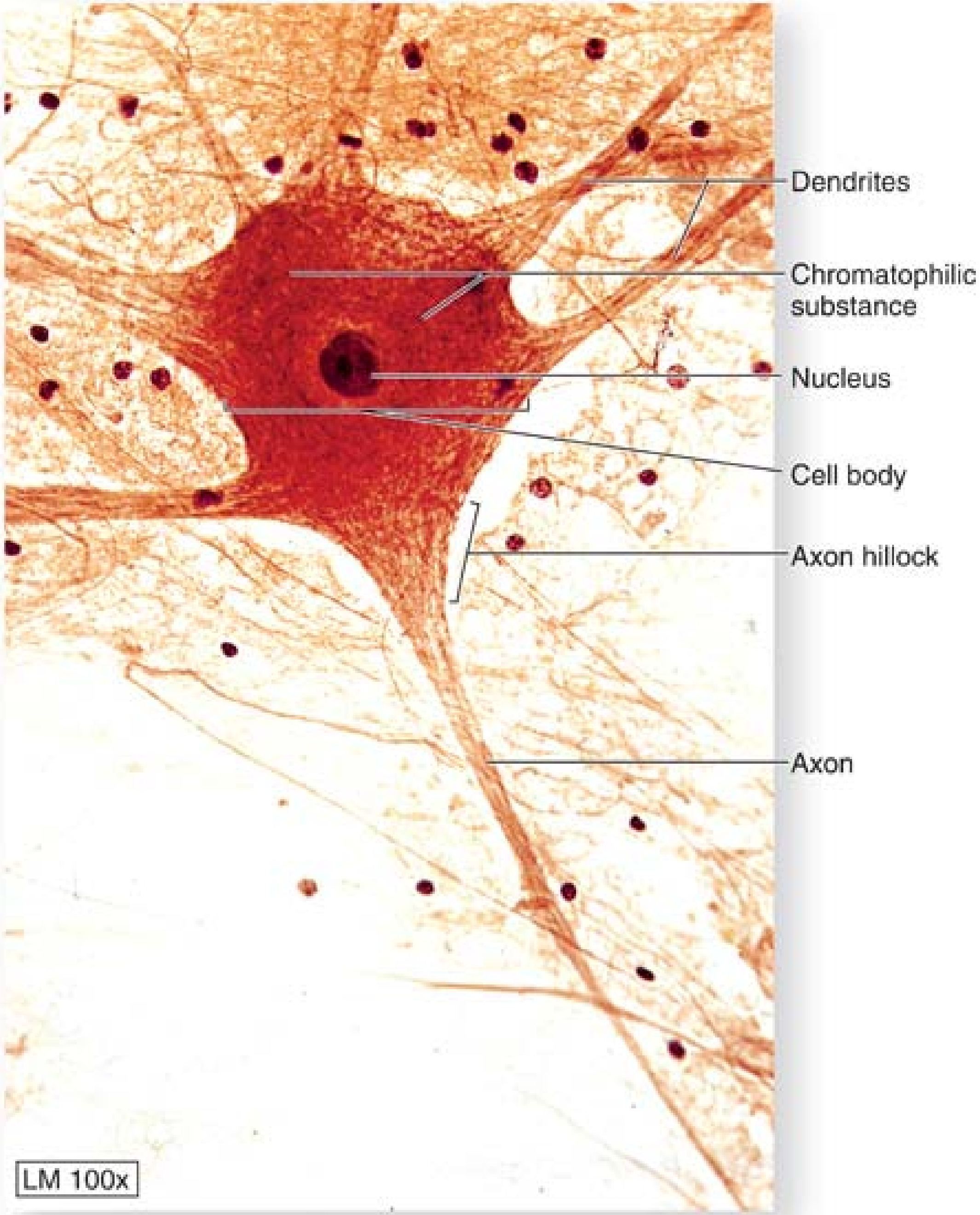
- Structures
  - Collaterals
  - Telodendria (axon terminals)
  - Synaptic knobs (terminal boutons)
- The axon transmits a nerve impulse away from the cell body toward another cell.

Neuron Structure

- Cytoskeleton
  - Neurotubules
    - microtubules
  - Neurofilaments
    - Intermediate fibers
  - Neurofibrils
    - Bundles of neurofibrils
    - In both dendrites and axons
    - Provide strength


Dendrites
Chromatophilic substances
Direction of nerve impulse ("input")
Nucleolus
Nucleus
Cell body
Axon hillock
Direction of nerve impulse ("output")
Axon
Axon collateral
Neurofibril node (node of Ranvier)
Neurolemmocyte (Schwann cell)
Myelin sheath
Telodendria
Synaptic knobs

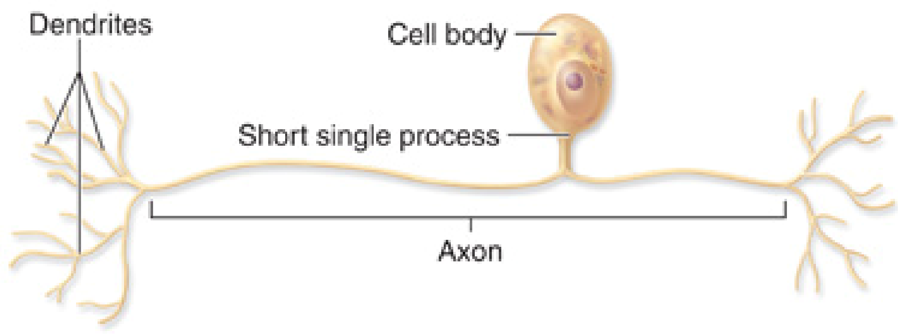
(a)


Dendrites
Chromatophilic substance
Nucleus
Cell body
Axon hillock
Axon
LM 100x

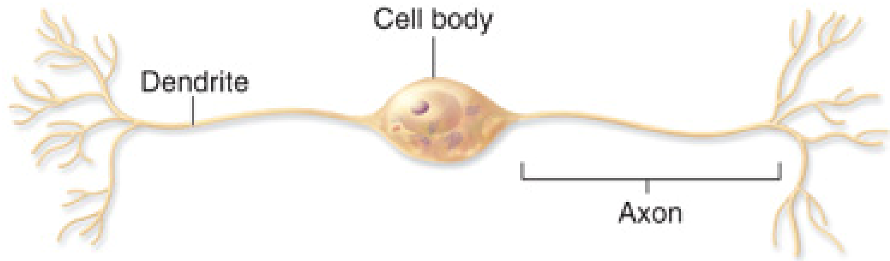
(b)

Classifications of Neurons

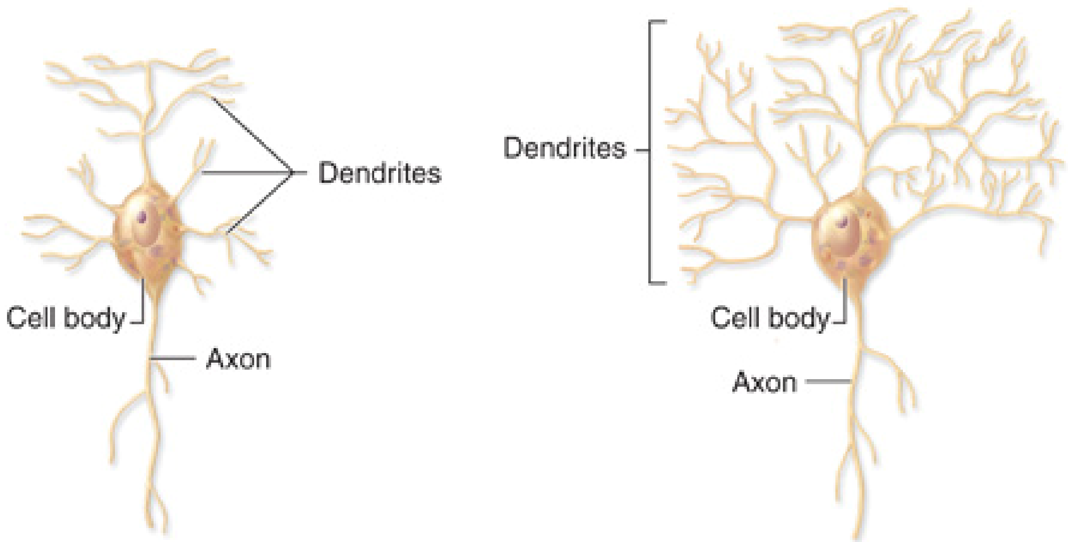
- Neurons vary widely in morphology and location.
  - classified based on
    - structure
    - function.
- Structural classification: number of processes extending from the cell body.
  - unipolar neuron has a single process
  - bipolar neurons have two processes
  - multipolar neurons have three or more processes



(a) Unipolar neuron



(b) Bipolar neuron



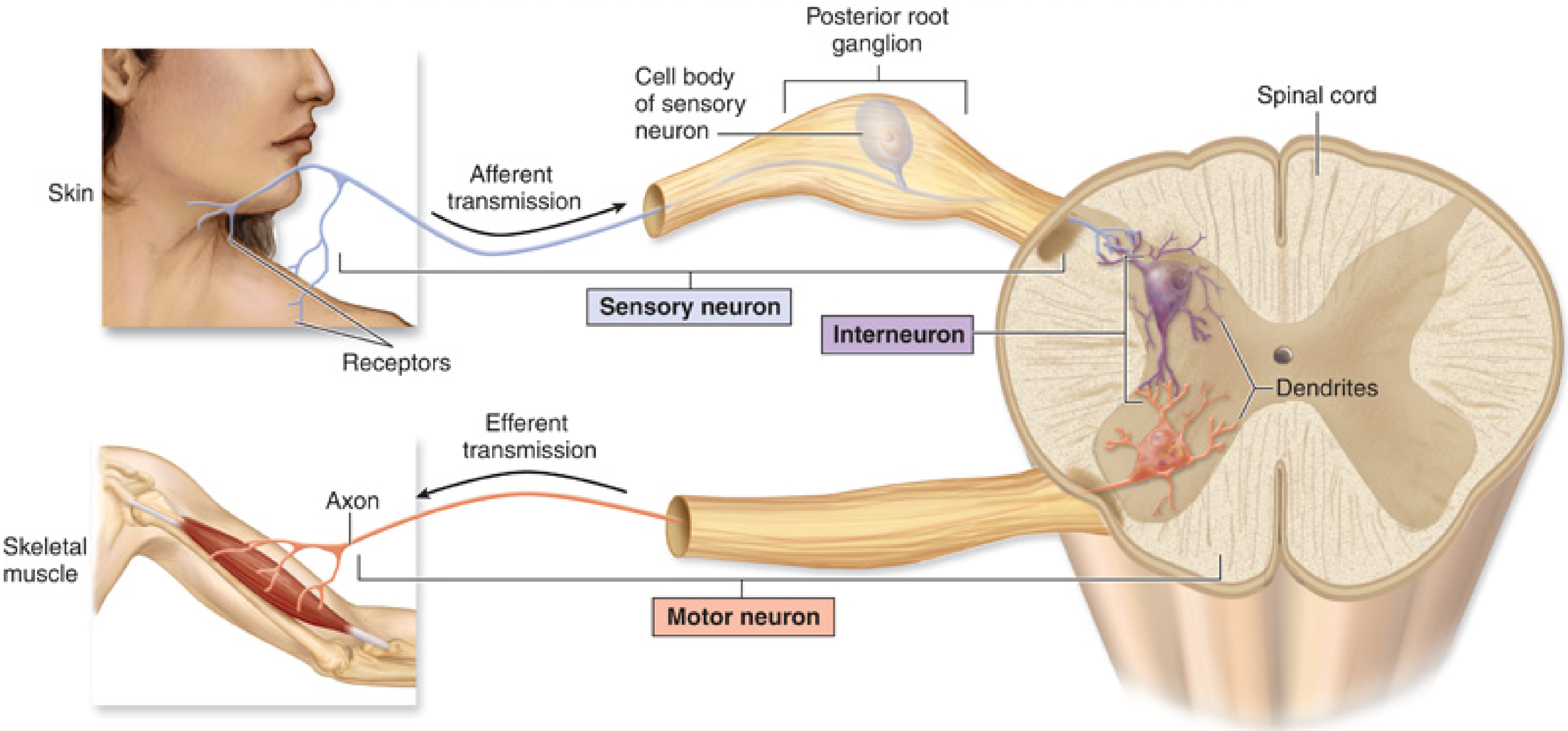
(c) Multipolar neurons

Functional Classification

- Sensory afferent neurons: receptor to CNS
- Motor efferent neurons: CNS to effector
- Interneurons (association neurons): facilitate communication between sensory and motor neurons.

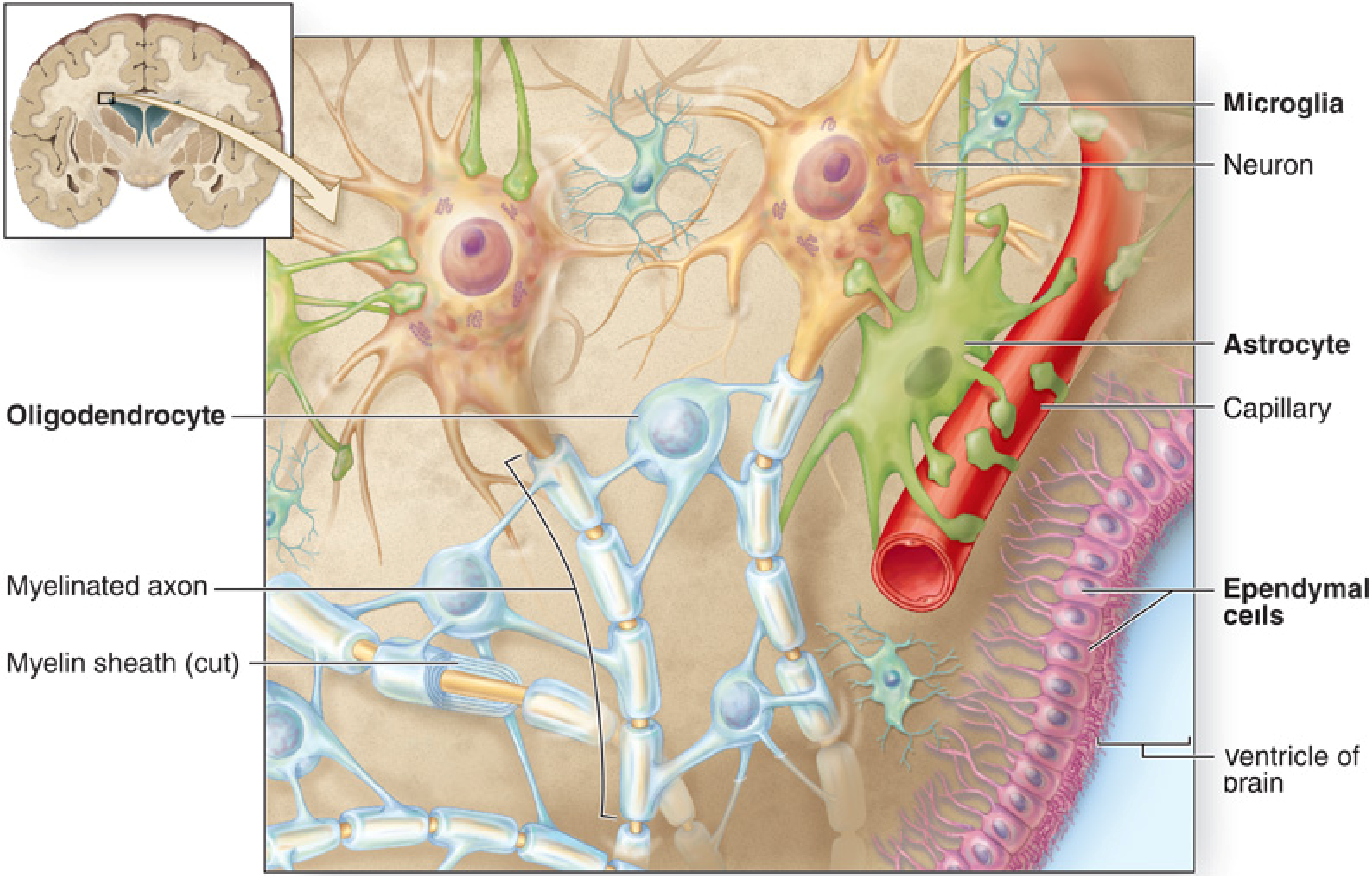
Interneurons

- Interneurons, or association neurons
  - lie entirely within the CNS
  - multipolar.
- They receive nerve impulses from many other neurons
- They carry out the integrative function of the nervous system.
- Interneurons facilitate communication between sensory and motor neurons.

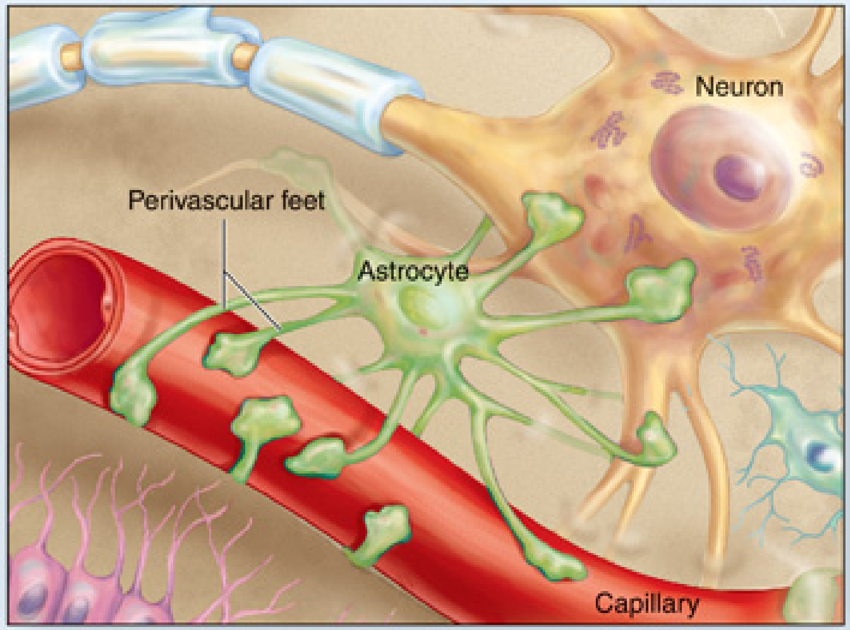

Posterior root ganglion
Cell body of sensory neuron
Spinal cord
Skin
Afferent transmission
Sensory neuron
Interneuron
Receptors
Dendrites
Efferent transmission
Axon
Skeletal muscle
Motor neuron

Glial Cells

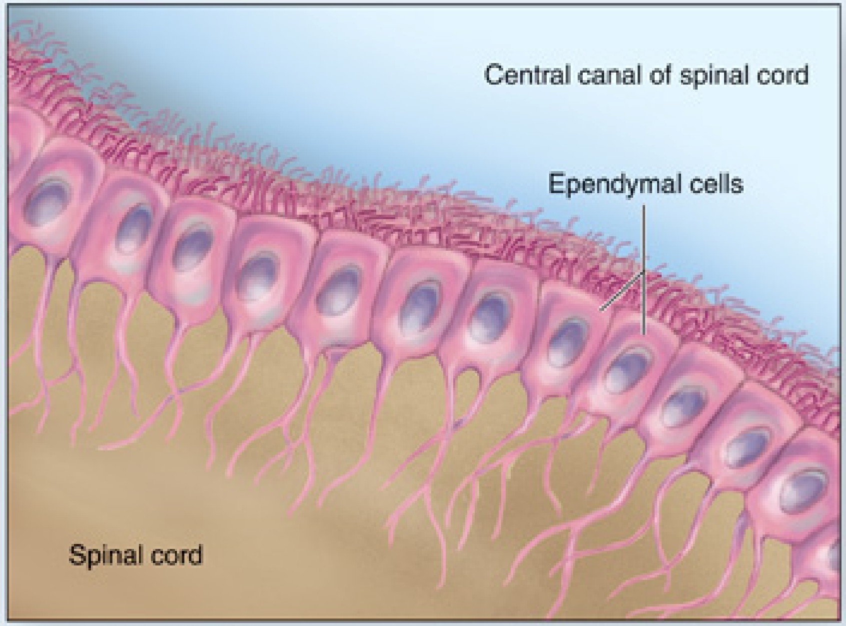
- Also called neuroglia
- Occur within both the CNS and the PNS.
- are smaller than neurons
- are capable of mitosis.
- do not transmit nerve impulses.
- Glial cells
  - physically protect neurons
  - help nourish neurons
  - provide a supporting framework for all the nervous tissue.
- Glial cells far outnumber neurons.
- Glial cells account for about half the volume of the nervous system.


Microglia
Neuron
Astrocyte
Capillary
Oligodendrocyte
Ependymal cells
Myelinated axon
Myelin sheath (cut)
Ventricle of brain

CNS Glial Cells



(a) Astrocyte



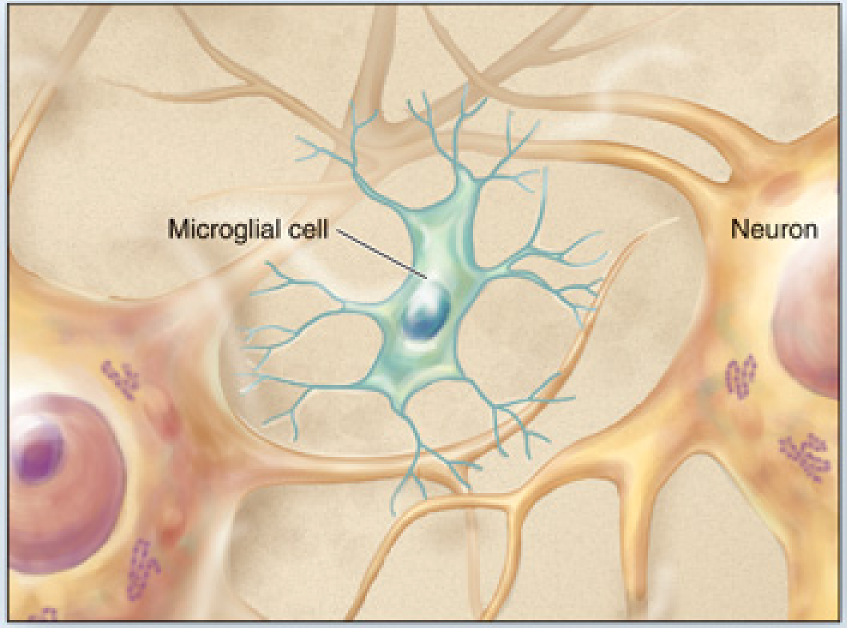
(b) Ependymal cells

Glial Cells of the CNS: astrocytes

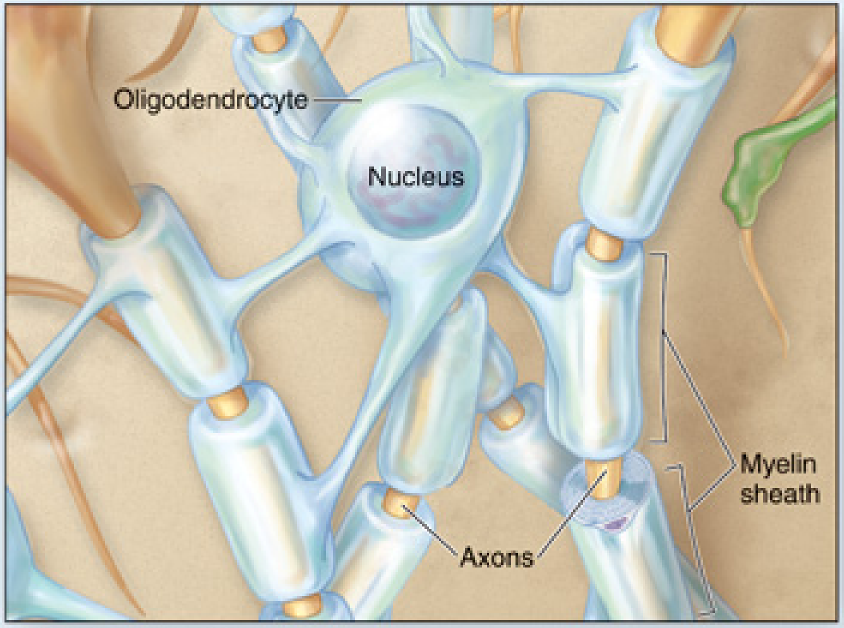
- Exhibit a starlike shape due to projections from their surface.
- The most abundant glial cells in the CNS
  - constitute over 90% of the tissue in some areas of the brain.
- Help form the blood-brain barrier (BBB):
  - strictly controls substances entering the nervous tissue in the brain from the bloodstream.
- Regulate tissue fluid composition.
- Provide structural support
- Replace damaged neurons
- Assist neuronal development

Glial Cells of the CNS: ependymal cells

- Cuboid ET
  - Cilia on apical surface
    - Circulates CSF.
- Line internal cavities
- Processes make contact with other glial cells
- Help form the choroid plexus
  - CSF: cerebral spinal fluid



(c) Microglia



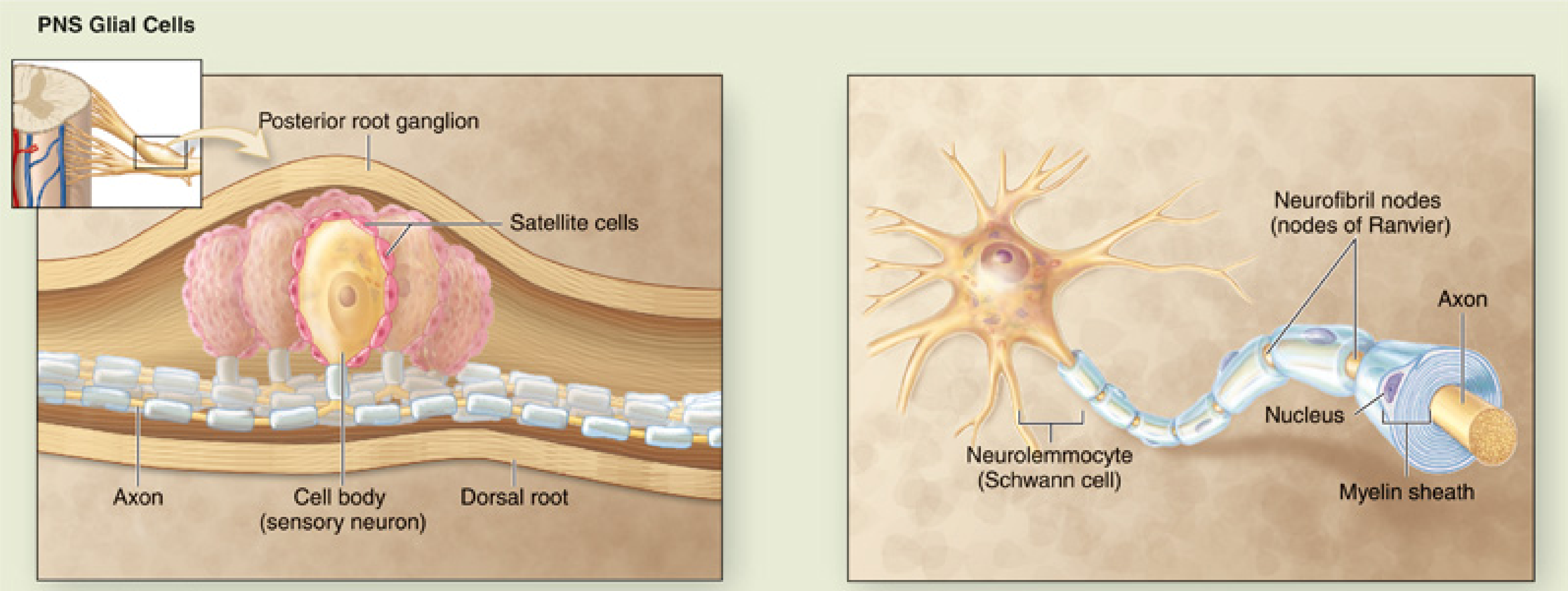
(d) Oligodendrocyte

Glial Cells of the CNS: microglia

- Smallest % of CNS glial cells.
- Phagocytic
  - Move through the tissue in response to infection
  - Remove debris.
  - Like macrophages

Glial Cells of the CNS: oligodendrocytes

- Large, with big body and processes.
- Processes form myelin sheaths
  - Speeds up transmission



(e) Satellite cells

(f) Neurolemmocytes

Glial Cells of the PNS

- Satellite cells:
  - Flattened cells
  - Cover somas in ganglia
  - Separate soma from surrounding tissue fluid
    - Regulate exchange.
- Neurolemmocytes (Schwann cells)
  - Myelination in the PNS

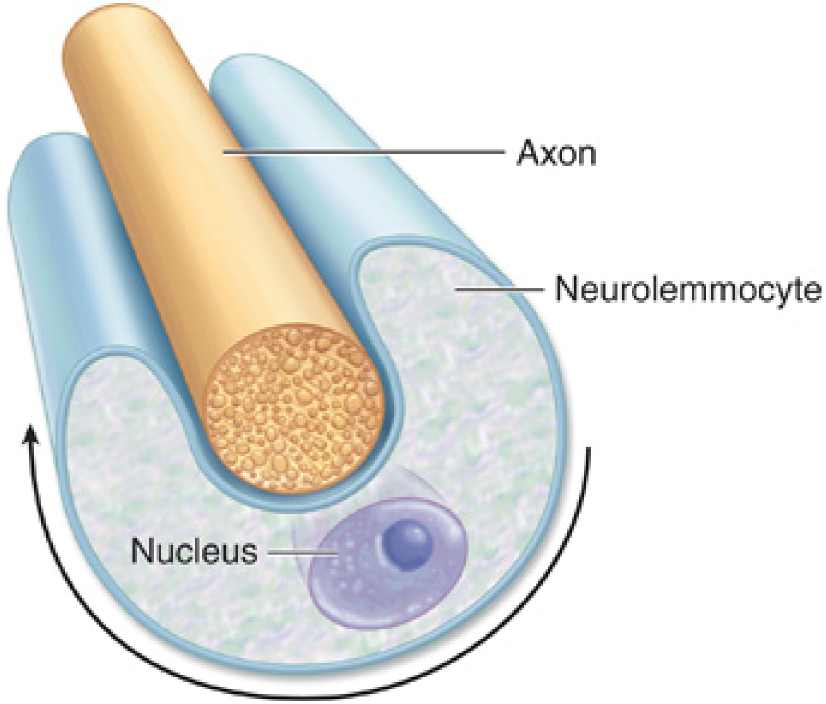
Myelination

- Process by which part of an axon is wrapped with a myelin sheath
  - Forms a protective fatty coating
  - Has a glossy-white appearance.
- The myelin sheath:
  - supports the axon
  - protects the axon
  - insulates an axon

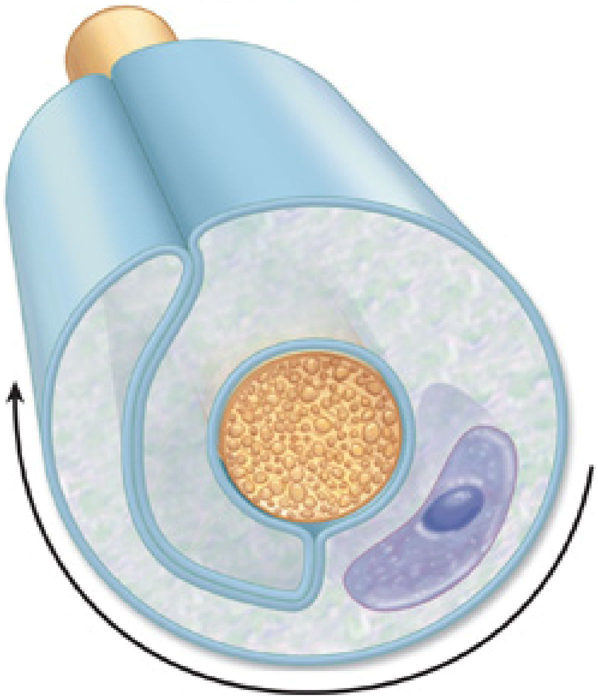
Myelination

- No change in voltage can occur across the membrane in the insulated portion of an axon.
- Voltage change occurs at the nodes
- Neurolemmocytes: form myelin sheaths in PNS
- Oligodendrocytes: form myelin sheaths in the CNS

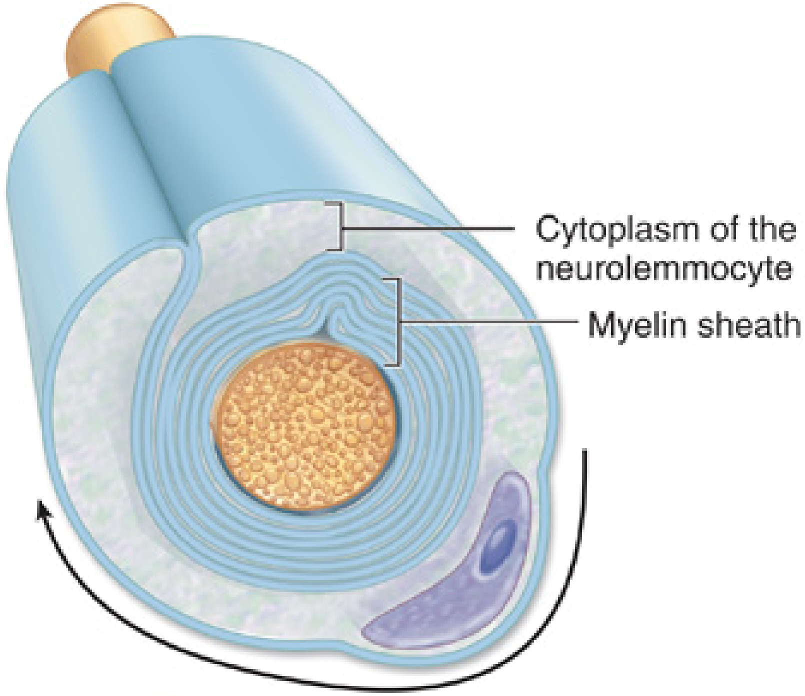
1. Neurolemmocyte starts to wrap around a portion of an axon.



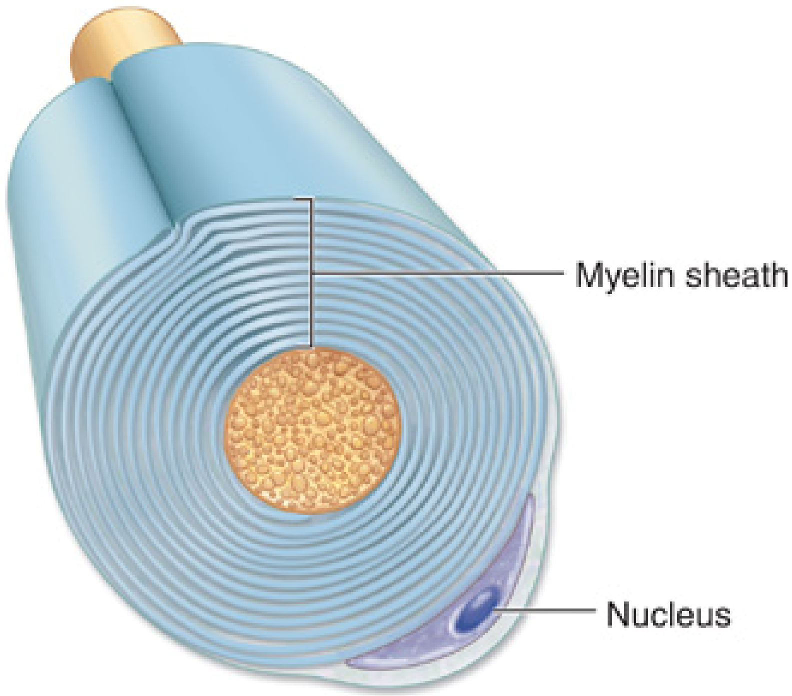
2. Neurolemmocyte cytoplasm and plasma membrane form consecutive layers around axon.



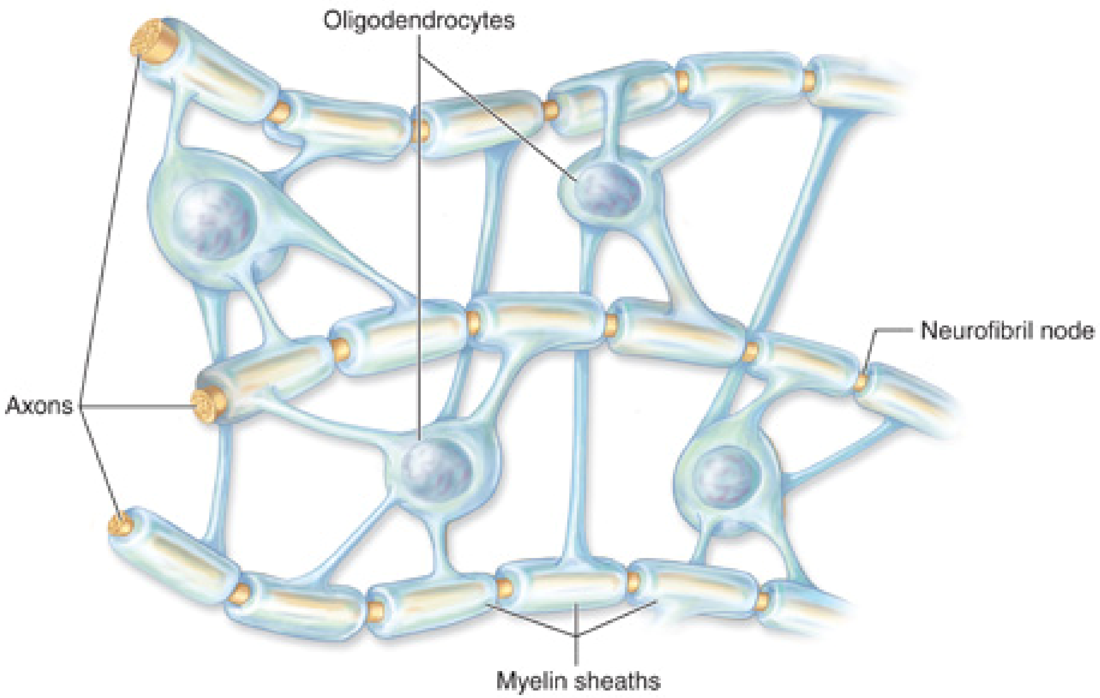
3 The overlapping inner layers of the plasma membrane form the myelin sheath.



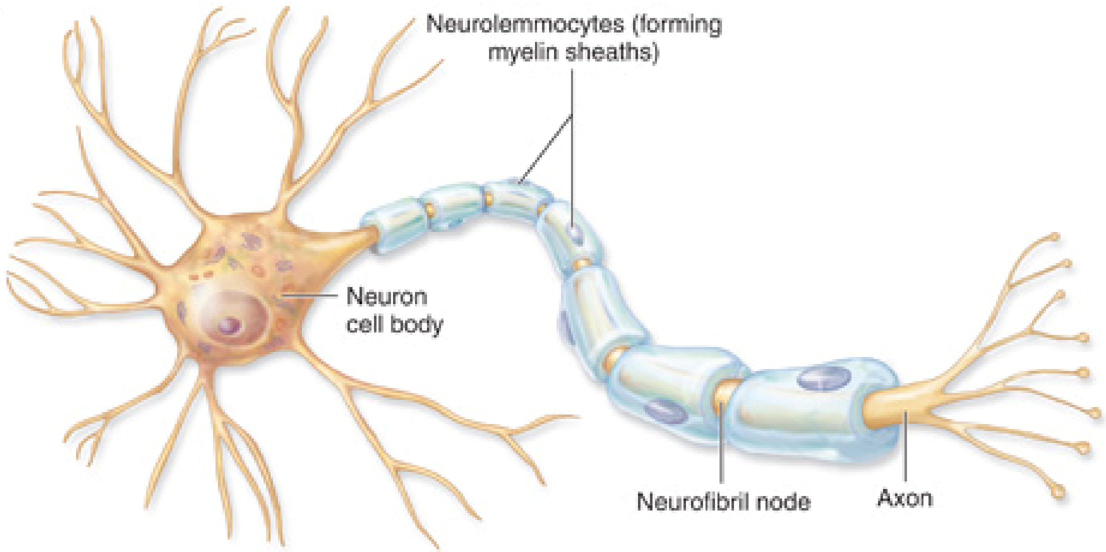
4 The neurolemmocyte cytoplasm and nucleus are pushed to the periphery of the cell as the myelin sheath is formed.



CNS

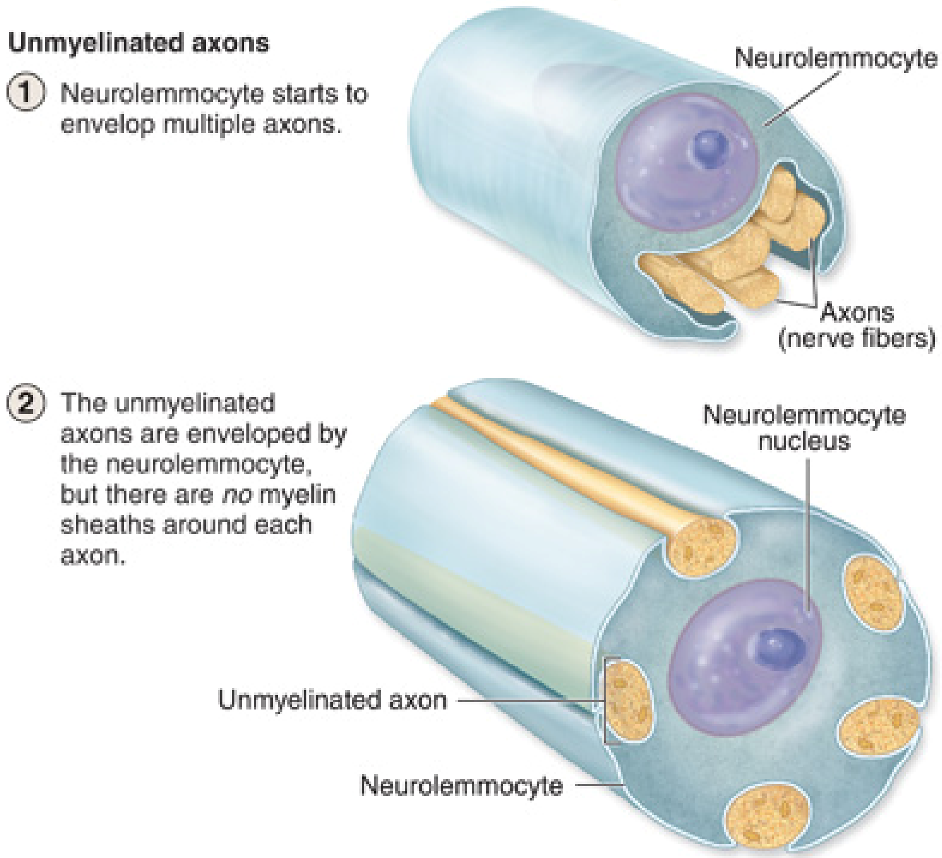

Oligodendrocytes
Neurofibril node
Axons
Myelin sheaths

PNS


Neurolemmocytes (forming myelin sheaths)
Neuron cell body
Neurofibril node
Axon

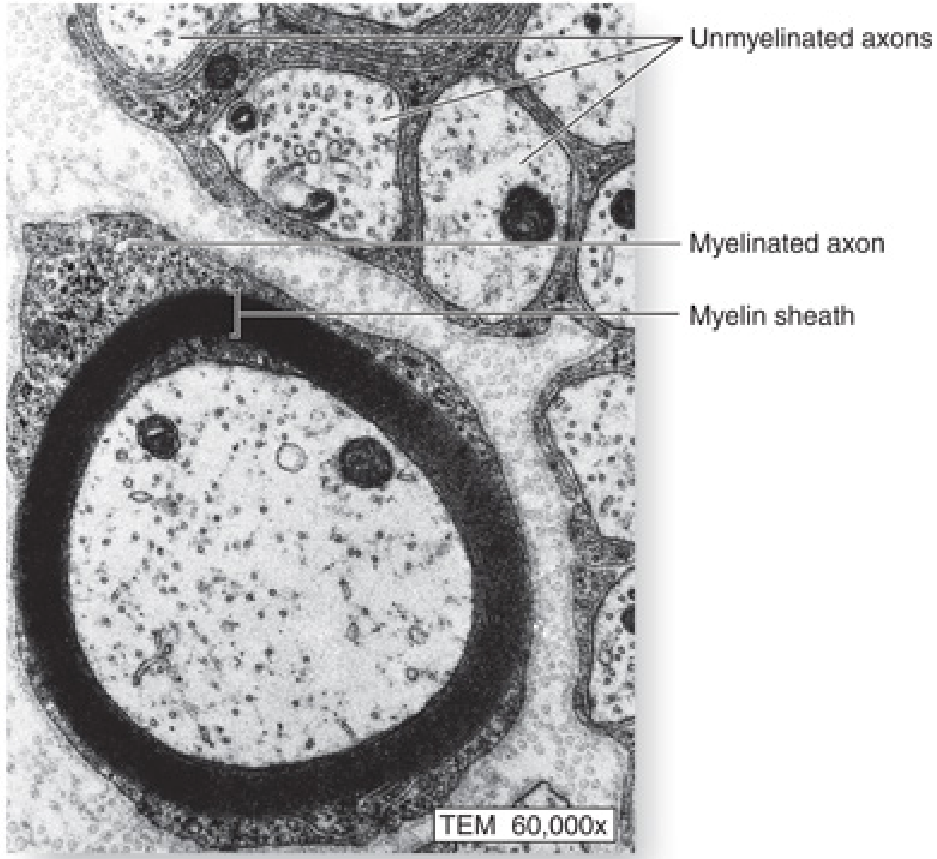
Mylenated vs. Unmylenated Axons

- myelinated axon
  - nerve impulse “jumps” from neurofibril node to neurofibril node
  - known as saltatory conduction
  - requires less energy (ATP) than does an unmyelinated axon
- unmyelinated axon
  - nerve impulse must travel the entire length of the axon
  - known as continuous conduction
  - nerve impulse takes longer to reach the end of the axon
  - Using continuous conduction, unmyelinated axons conduct nerve impulses from pain stimuli
- A myelinated axon produces a faster nerve impulse.



Unmyelinated axons
1 Neurolemmocyte starts to envelop multiple axons.
Neurolemmocyte
Axons (nerve fibers)
2 The unmyelinated axons are enveloped by the neurolemmocyte, but there are *no* myelin sheaths around each axon.
Neurolemmocyte nucleus
Unmyelinated axon
Neurolemmocyte

(a)



Unmyelinated axons
Myelinated axon
Myelin sheath
TEM 60,000x

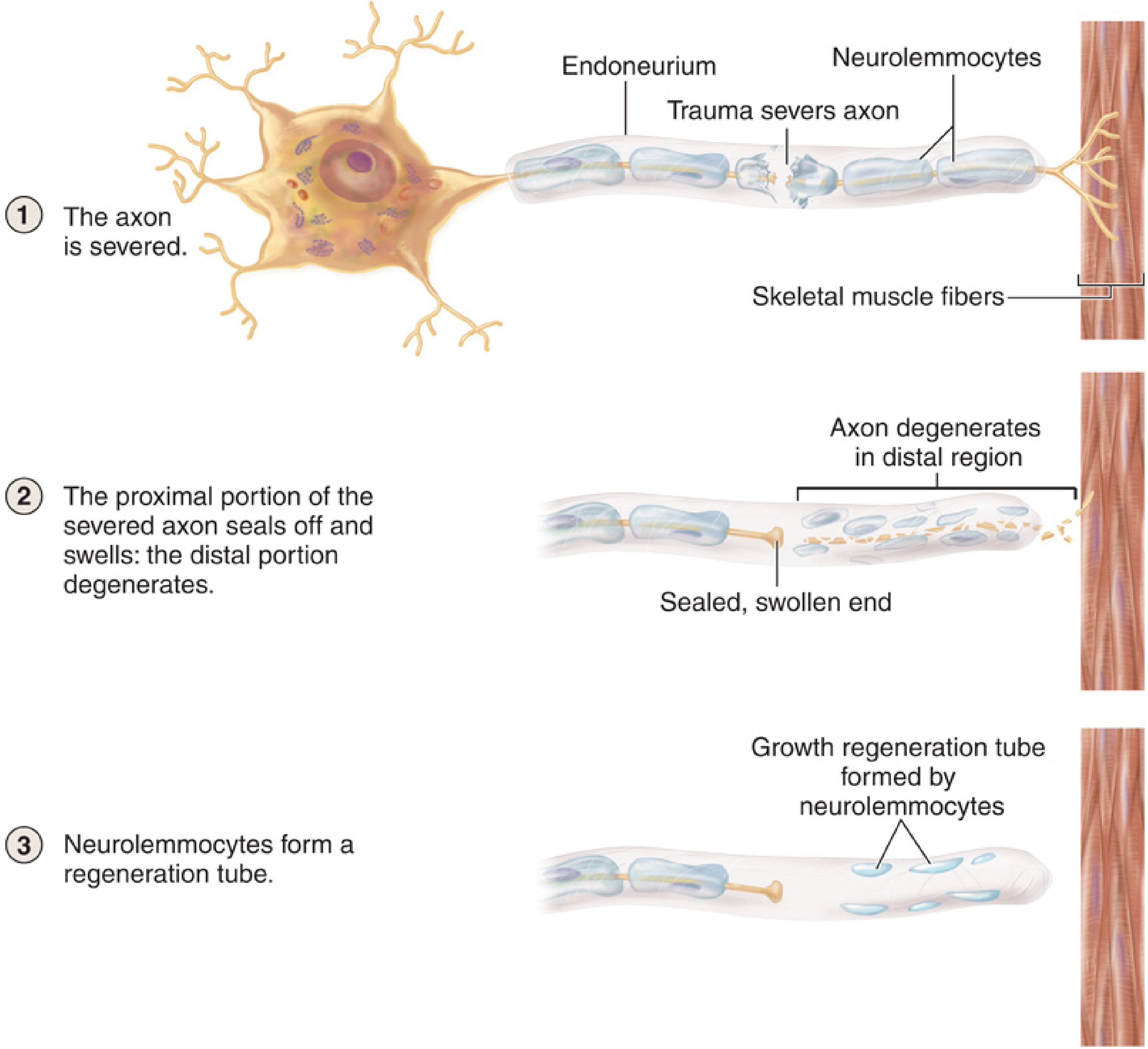
(b)

Regeneration of PNS Axons

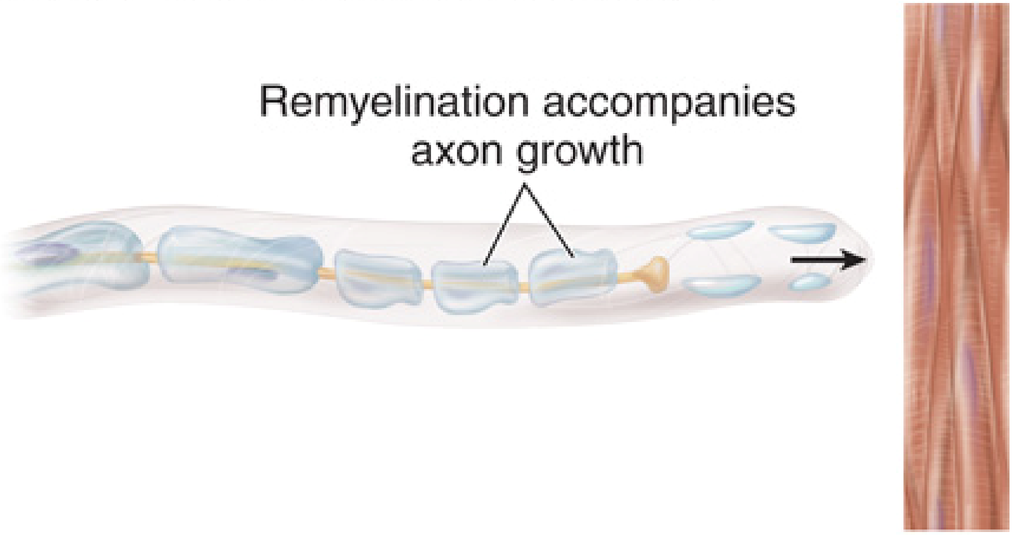
- PNS axons are vulnerable to cuts and trauma.
- A damaged axon can regenerate
  - if some neurilemma remains.
- PNS axon regeneration depends upon three factors.
  - amount of damage
  - neurolemmocyte secretion of nerve growth factors
    - stimulates outgrowth of severed axons
  - distance between the site of the damaged axon and the effector organ

Regeneration of PNS Axons

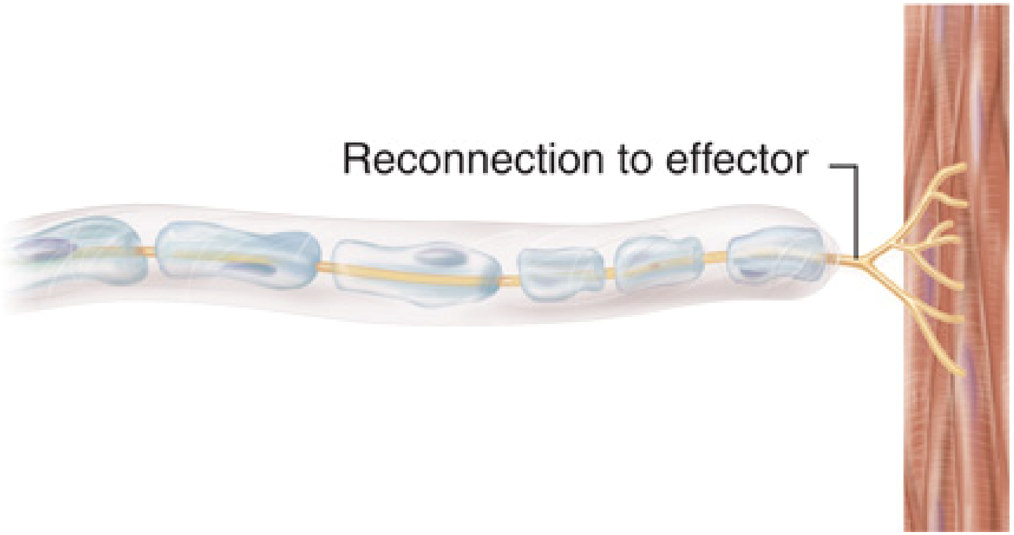
- Wallerian degeneration.
  - Axon damaged
  - Proximal end seals, and swells.
  - Distal end degenerates, macrophages clean up
  - Distal neurolemmocytes survive
  - Neurolemmocytes form regeneration tube (with endoneurinum)
  - Axon regenerates, remyelinates
  - Axon reestablishes contact with effector


1 The axon is severed.
Endoneurium
Neurolemmocytes
Trauma severs axon
Skeletal muscle fibers
2 The proximal portion of the severed axon seals off and swells: the distal portion degenerates.
Axon degenerates in distal region
Sealed, swollen end
3 Neurolemmocytes form a regeneration tube.
Growth regeneration tube formed by neurolemmocytes

(4) Axon regenerates and remyelination occurs.

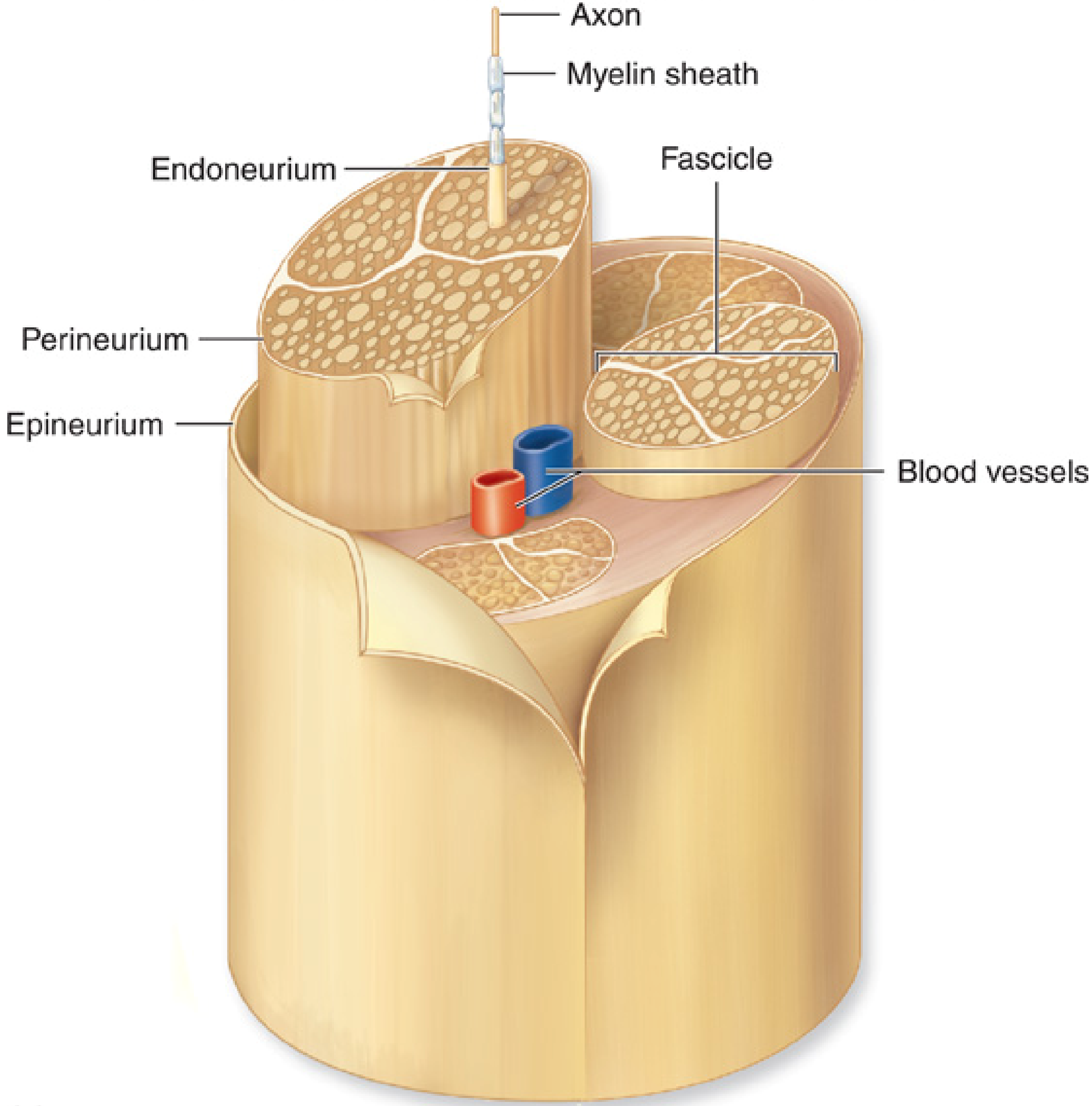


(5) Reinnervation of the effector (skeletal muscle fibers) by the axon.

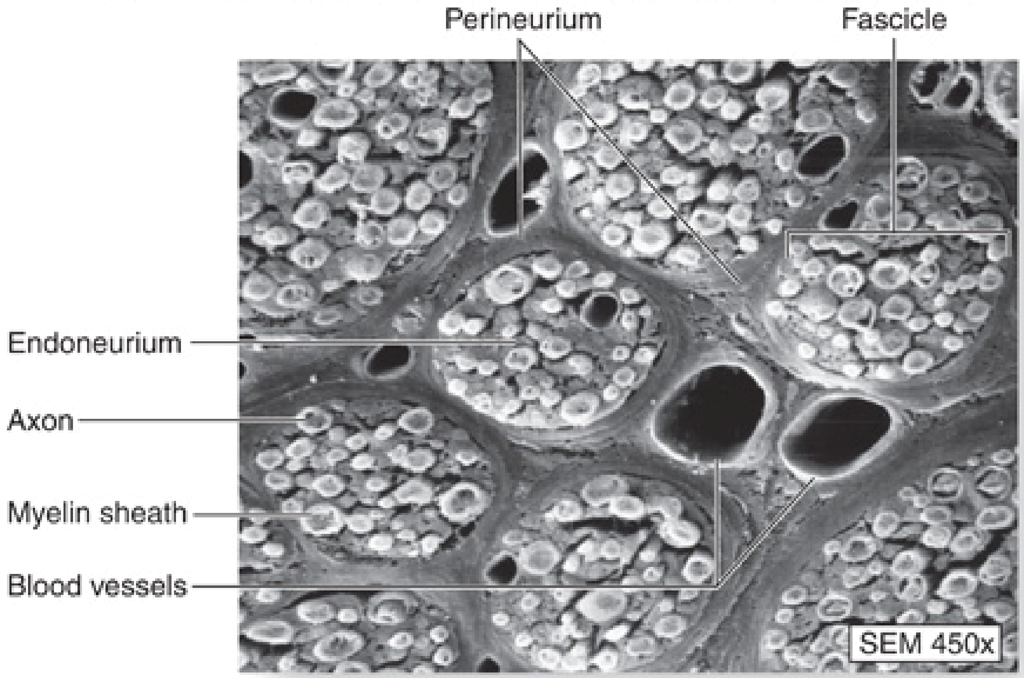


Structure of a Nerve

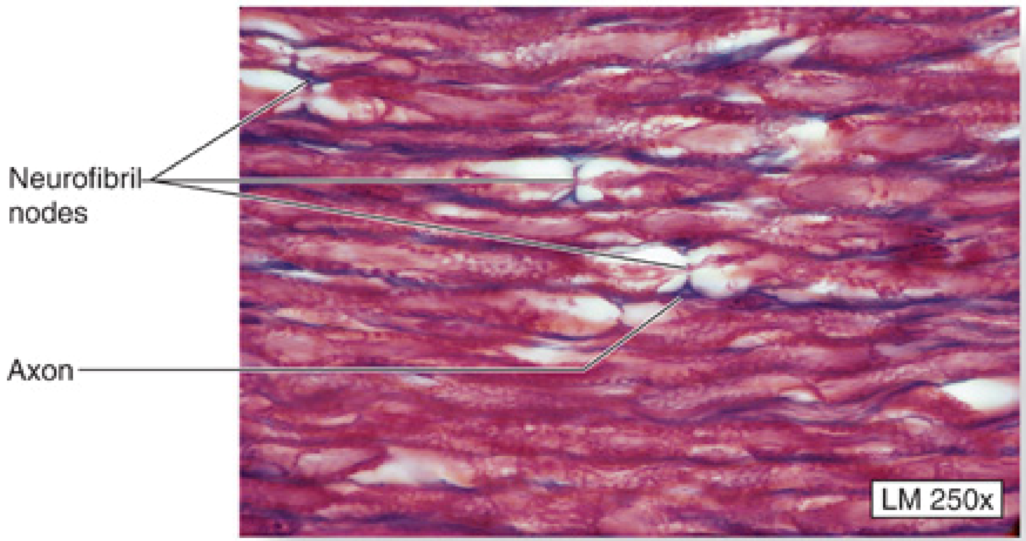
- A nerve is a cable-like bundle of parallel axons.
- three connective tissue wrappings.
  - Endoneurium
    - delicate layer of loose connective tissue
  - Perineurium
    - a cellular and fibrous connective tissue layer
    - wraps groups of axons into fascicles
  - Epineurium - a superficial connective tissue covering
    - This thick layer of dense irregular fibrous connective tissue
    - encloses entire nerve
    - provides support and protection


Axon
Myelin sheath
Endoneurium
Fascicle
Perineurium
Epineurium
Blood vessels

(a)


Perineurium
Fascicle
Endoneurium
Axon
Myelin sheath
Blood vessels
SEM 450x

(b)


Neurofibril nodes
Axon
LM 250x

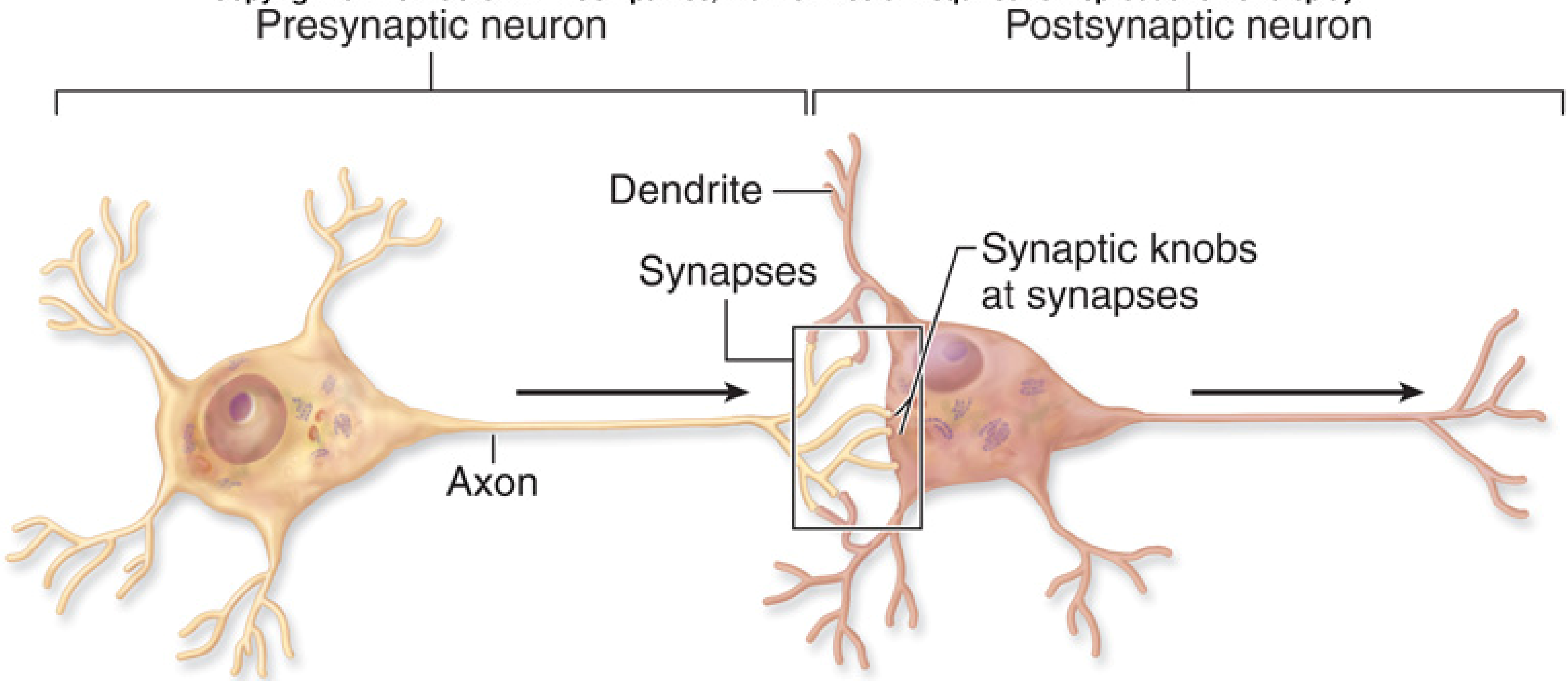
(c)

Nerves

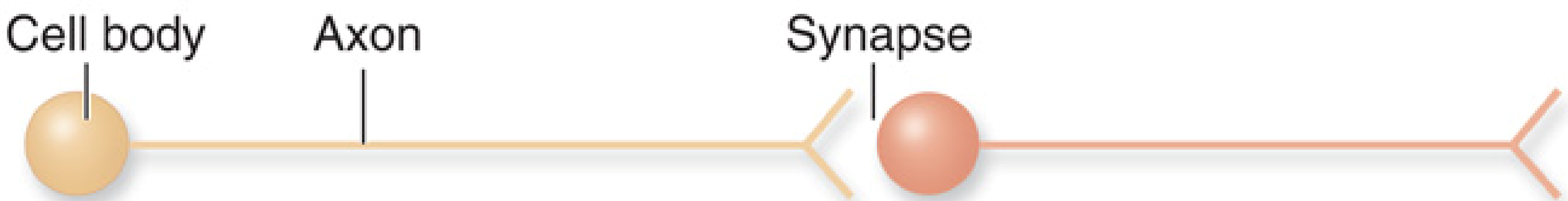
- Nerves are organs of the PNS.
- Sensory (afferent) nerves convey sensory information to the CNS.
- Motor (efferent) nerves convey motor impulses from the CNS to the muscles and glands.
- Mixed nerves: both sensory and motor
- Axons terminate as they contact other neurons, muscle cells, or gland cells.
- An axon transmits a nerve impulse at a specialized junction with another neuron called synapse.

Synapses

- Presynaptic neurons
  - transmit nerve impulses toward a synapse.
- Postsynaptic neurons
  - conduct nerve impulses away from the synapse.
- Axons may establish synaptic contacts with any portion of the surface of another neuron
  - except those regions that are myelinated.



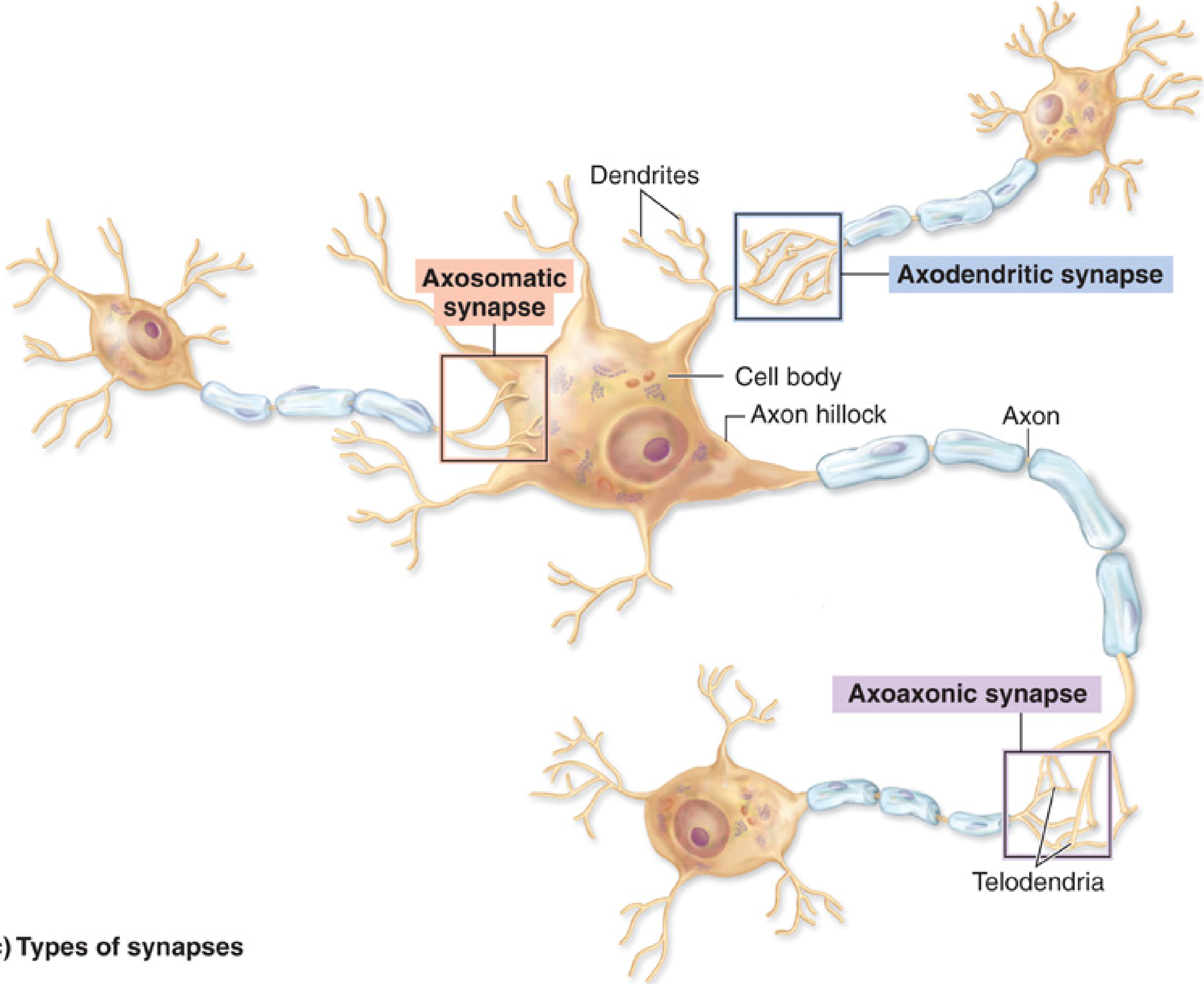
(a) Synapse



(b) Simplified representation of a synapse

Types of synapses: based on contacts

- axodendritic
- axosomatic
- axoaxonic



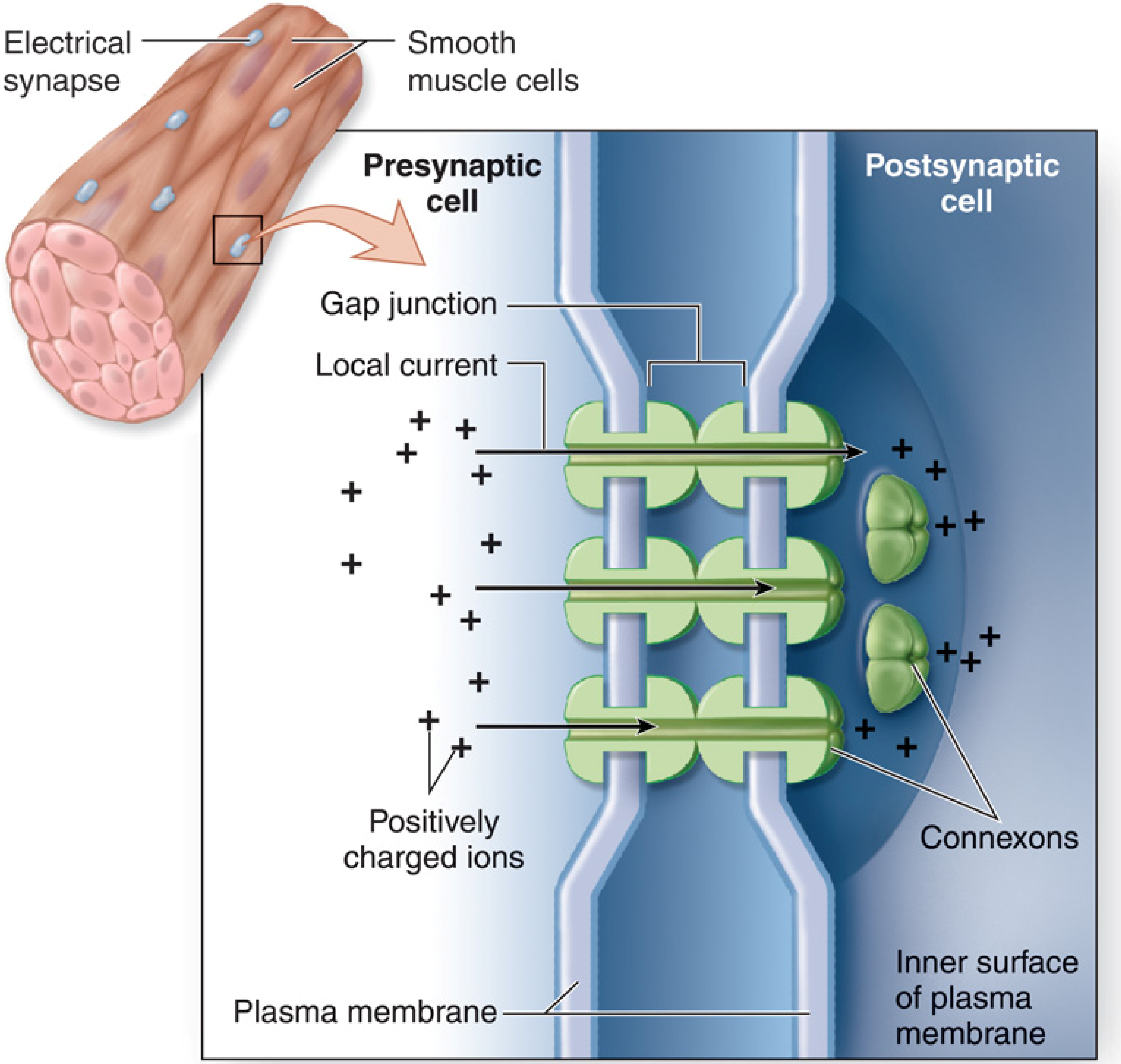
(c) Types of synapses

Main types of synapses

- Electrical synapses
  - Gap junctions
- Chemical synapses
  - Use neurotransmitters

Electrical Synapses

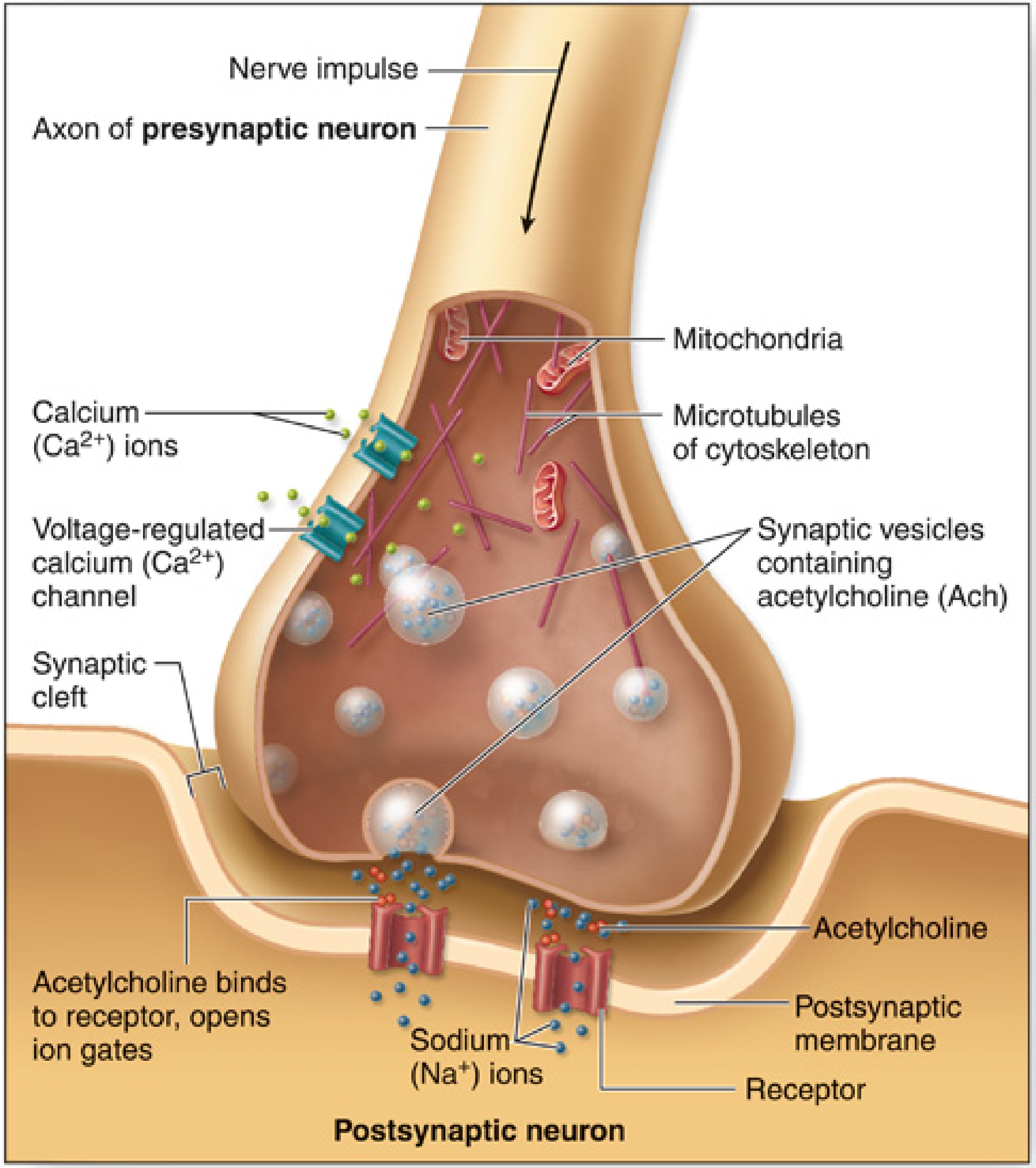
- Electrical synapses are not very common in mammals.
- In humans, these synapses occur primarily between smooth muscle cells where quick, uniform innervation is essential.
- Electrical synapses are also located in cardiac muscle.



(a) Electrical synapse

Chemical Synapses

- Most numerous type of synapse
- Facilitates interactions
  - between neurons
  - between neurons and effectors.
- These are cell junctions
- Presynaptic membrane:
  - releases a signaling molecule called a neurotransmitter, such as acetylcholine (ACh).
  - Other types of neurons use other neurotransmitters.
- Postsynaptic membrane:
  - Contains receptors for neurotransmitters



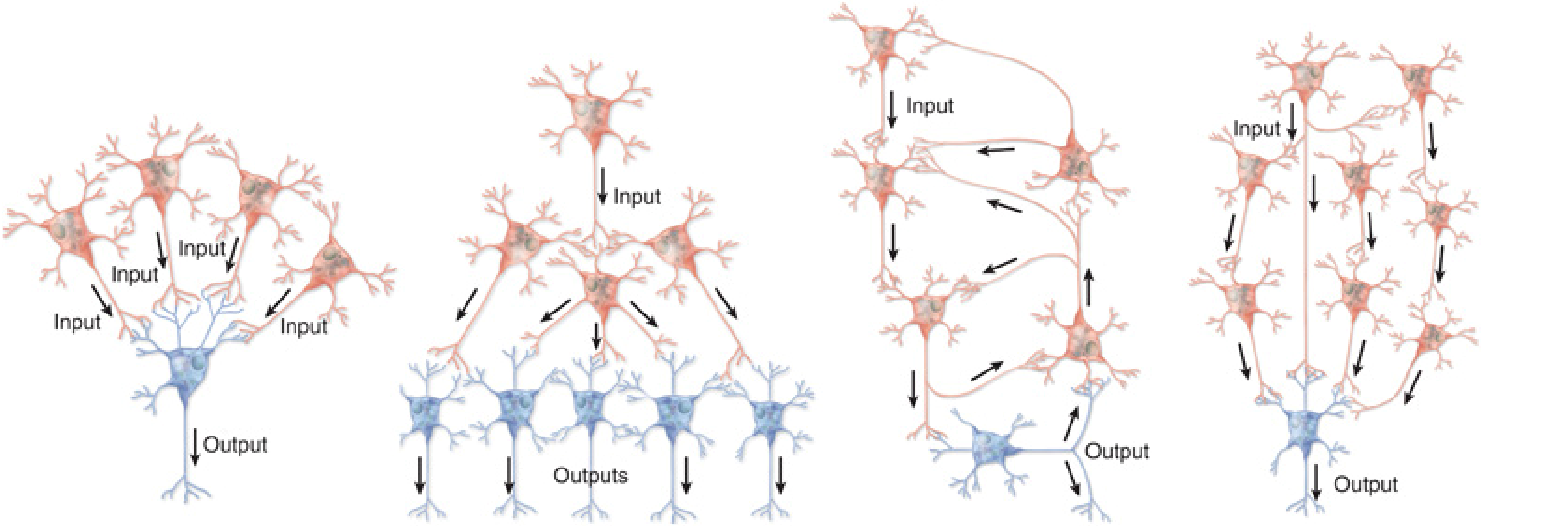
(b) Chemical synapse

Neurotransmitters

- Released from the plasma membrane of the presynaptic cell.
- Then binds to receptor proteins on the plasma membrane of the postsynaptic cell.
- A unidirectional flow of information and communication
- Two factors influence the rate of conduction of the impulse:
  - axon’s diameter
  - presence (or absence) of a myelin sheath.

Neuronal Pools (or Neuronal Circuits or Pathways)

- Billions of interneurons within the CNS are grouped in complex patterns called neuronal pools (or neuronal circuits or pathways).
- Neuronal pools are defined based upon function, not anatomy, into four types of circuits:
  - converging
  - diverging
  - reverberating
  - parallel-after-discharge
- A pool may be localized, or its neurons may be distributed in several different regions of the CNS.



(a) Converging circuit

(b) Diverging circuit

(c) Reverberating circuit

(d) Parallel after-discharge circuit