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1 Neuroanatomy and Physiology

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1.1 Neuron Anatomy

- Basic components (**Table 1.1, Fig. 1.1**).
- Synaptic junction and signal transmission:
  - Mechanism of basic chemical synapses (**Fig. 1.3**).
    - Action potential (depolarization) reaches terminal branch of the presynaptic neuron.
    - N-type Ca^{2+} channels open, Ca^{2+} influx.
      - *Associated pathologies:* Lambert–Eaton myasthenic syndrome.
    - Ca^{2+} facilitates vesicle docking, neurotransmitter released into synaptic cleft.
      - *Associated pathologies:* botulism, tetanus (lockjaw).
    - Neurotransmitter binds neurotransmitter receptor (postsynaptic neuron).
      - *Associated pathologies:* myasthenia gravis.
    - Depending on its function, the neurotransmitter receptor creates either an excitatory postsynaptic potential (EPSP) or an inhibitory postsynaptic potential (IPSP).

Table 1.1 Basic anatomy of the neuron

Component	Function
Dendrites	Receive signals from other neurons for transfer toward the cell body
Cell body (soma)	Contains cell nucleus. Site of protein and ATP production
Axon hillock	Portion of cell body that connects to axon. Final site of action potential summation (trigger zone)
Axon	Carries action potential from cell body to terminal branches
Myelin sheath	Fatty insulating layer around axon that facilitates action potential through saltatory conduction. • Oligodendrocytes myelinate neurons of the central nervous system (CNS). A single oligodendrocyte myelinates multiple neurons (**Fig. 1.2a**). • Schwann's cells myelinate neurons of the peripheral nervous system (PNS). Multiple Schwann's cells myelinate a single neuron (**Fig. 1.2b**).
Nodes of Ranvier	Occasional interruptions in the myelin sheath that expose the axonal membrane. Contain a high density of voltage-gated Na^+ and K^+ channels and Na^+/K^+ ATPases, which act to regenerate the action potential.
Terminal branches (boutons) of axon	Branched terminal portion of an axon. Site of neurotransmitter release into the synaptic cleft. Often referred to as the presynaptic terminal.

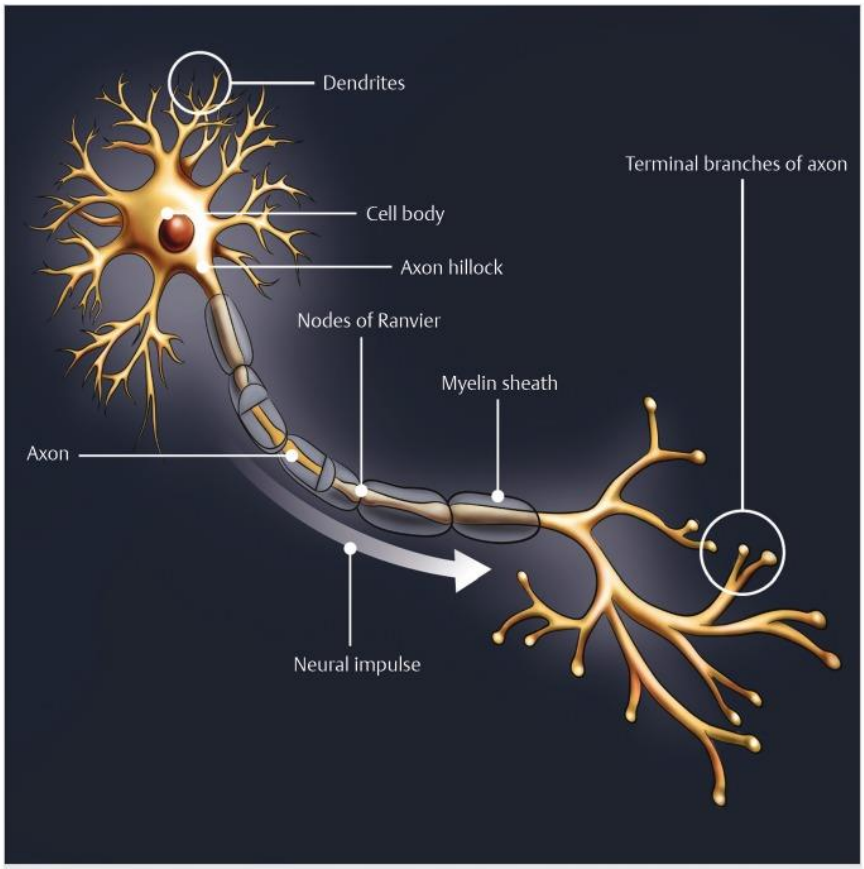


Fig. 1.1 Basic components of the neuron.

  - EPSPs depolarize the postsynaptic neuron and increase the probability of action potential formation.
  - IPSPs either hyperpolarize or resist depolarization of the postsynaptic neuron and decrease the probability of action potential formation.
- The potentials across all dendrites are integrated in the cell body and axon hillock, determining whether or not an action potential will fire in the postsynaptic neuron.
- A variety of mechanisms, including enzymatic degradation (i.e., acetylcholine) and presynaptic reuptake (i.e., serotonin), remove neurotransmitters from the synaptic cleft to end the postsynaptic stimulus.

- Neuromuscular junction:
  - Specialized chemical synapse between motor neuron and muscle fiber.
  - Cholinergic synapse containing mainly nicotinic acetylcholine receptors.
  - Nerve impulse results in contraction of muscle fiber(s).

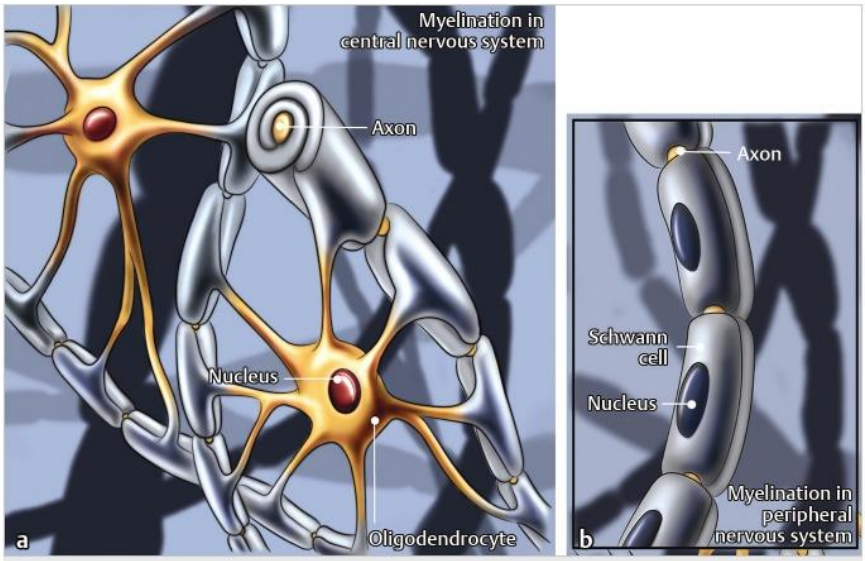


Fig. 1.2 (a) Oligodendrocyte (central nervous system). **(b)** Schwann's cell (peripheral nervous system).

- Motor unit:
  - A *single* motor neuron and all muscle fibers that it innervates.
    - A small motor unit contains three to six muscle fibers and controls muscles of fine control.
    - A large motor unit contains 100 to 1,000 muscle fibers and controls muscles of crude control and strength (i.e., biceps, quadriceps).
  - All muscle fibers of a single motor unit are of the same fiber type (types 1, 2a, and 2b).

- Neuron types (**Table 1.2**).
- Nerve fiber organization (**Table 1.3, Fig. 1.4**).
- Nervous system organization (**Fig. 1.5**).
- Afferent and efferent nerves (**Table 1.4, Fig. 1.6**):
  - Afferent nerve fibers carry sensory information and arrive at the spinal cord through dorsal roots.
  - Efferent nerve fibers carry motor information and exit the spinal cord through ventral roots.
  - Efferent motor neurons (**Table 1.5, Fig. 1.7**):
    - Upper motor neurons (UMNs)
      - Cell bodies originate within the primary motor cortex or brainstem nuclei.
      - Convey motor information by synapsing with lower motor neurons (LMNs, or interneurons) in the brainstem or spinal cord.

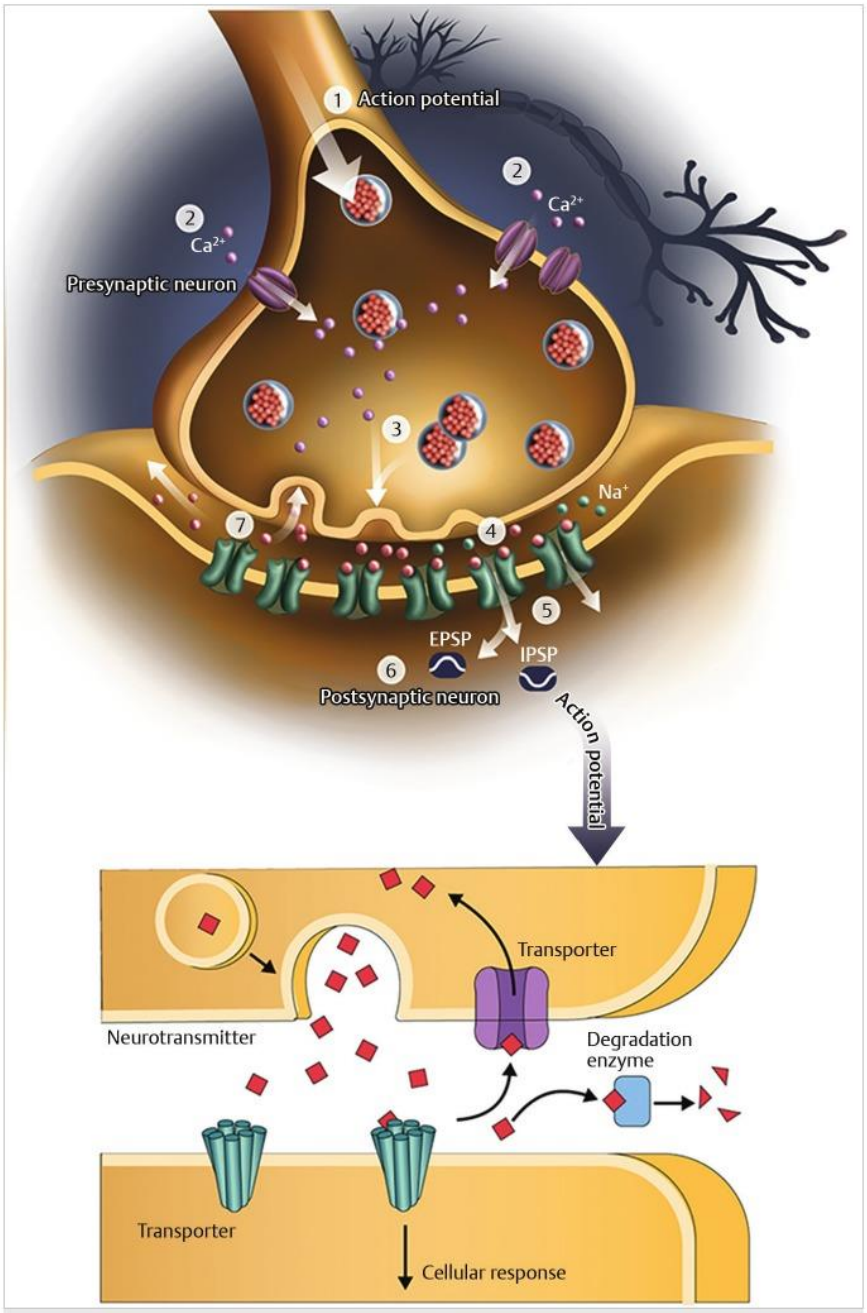
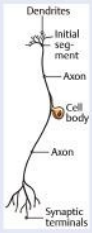
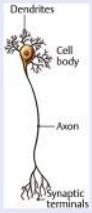


Fig. 1.3 Synaptic transmission at a chemical synapse.

Table 1.2 Basic neuron types

Type	Image	Description	Examples
Pseudounipolar		A single axon split into two branches with an *adjacent* cell body: • *Peripheral branch*: periphery to cell body (contains dendrites) • *Central branch*: cell body to spinal cord (contains synaptic terminals) Transmits sensory information from the periphery to the CNS	• Sensory neurons of dorsal root ganglia • Sensory ganglia of cranial nerves V, VII, IX, and X
Bipolar		Cell body centrally located between a: • *Dendrite:* transmits signals toward cell body • *Axon:* transmits signals away from cell body Specialized sensory neurons for the transmission of special senses (i.e., vision, hearing)	• Bipolar cells, ganglion cells, horizontal cells, and amacrine cells of the retina • Cochlear and vestibular ganglia of the inner ear
Multipolar		Cell body contains multiple dendrites and a single axon Able to receive and integrate abundant nerve impulses	• Motor neurons (ventral horn of spinal cord) • Interneurons (spinal cord gray matter) • Purkinje's cells (cerebellum) • Pyramidal cells (cerebral cortex)

Abbreviation: CNS, central nervous system.

Table 1.3 Hierarchical organization of nerve fibers

Component	Covering
Deep	
Axon (of individual neuron)	Endoneurium
Fascicle (bundle of axons)	Perineurium
Nerve (bundle of fascicles)	Epineurium
Superficial	

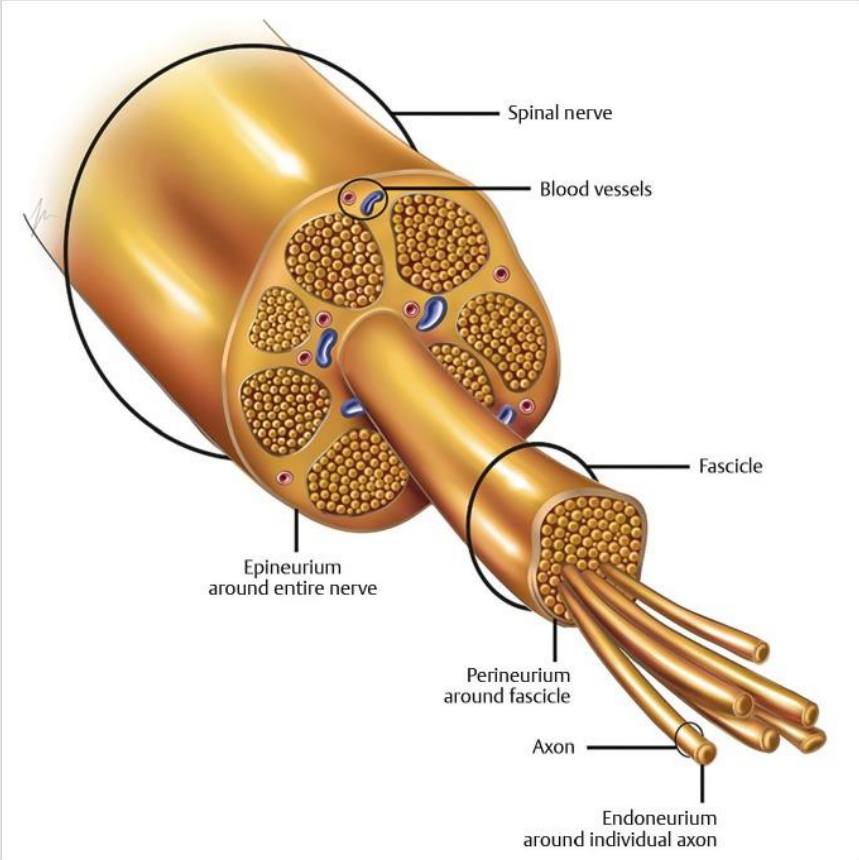


Fig. 1.4 Nerve fiber structure.

- LMNs:
  - Cell bodies originate in brainstem nuclei or the ventral horn of spinal cord gray matter.
  - Convey motor information from UMNs by synapsing with skeletal muscle in the periphery via neuromuscular junctions.

- Afferent sensory receptors (**Table 1.6**).
- Afferent sensory neurons (**Table 1.7**).

• Reflex arcs (**Table 1.8**):

- General principles:
  - A reflex arc is a neural pathway that controls a reflex action.
  - It involves the spinal cord only, allowing for a fast, subconscious response.
  - Sensory information is processed by the brain *after* the reflex has occurred.