Nerve Cells and Nerve Impulses

The Cells of the Nervous System

- The human nervous system is comprised of two kinds of cells:
  - Neurons
  - Glia
- The human brain contains approximately 100 billion individual neurons.
- Behavior depends upon the communication between neurons.

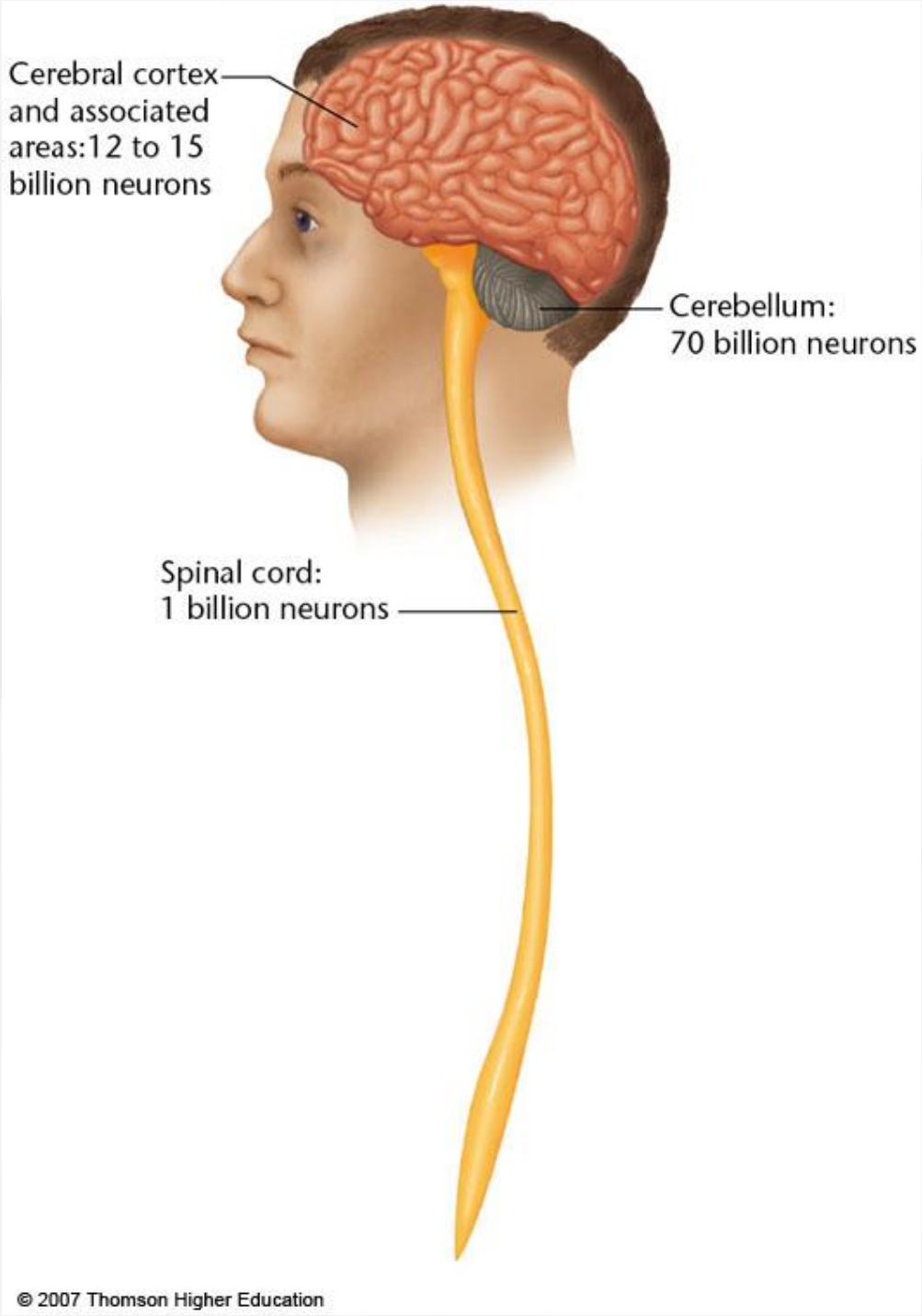

Cerebral cortex and associated areas:12 to 15 billion neurons
Cerebellum: 70 billion neurons
Spinal cord: 1 billion neurons
© 2007 Thomson Higher Education

Fig. 2-1, p. 30

Fig. 2-4, p. 32

The Cells of the Nervous System

- Spaniard Santiago Ramon y Cajal (1852-1934) was the first to demonstrate that the individual cells comprising the nervous system remained separate.
- He showed that they did not grow into each other as previously believed.

The Cells of the Nervous System

- Like other cells in the body, neurons contain the following structures:
  - Membrane
  - Nucleus
  - Mitochondria
  - Ribosomes
  - Endoplasmic reticulum

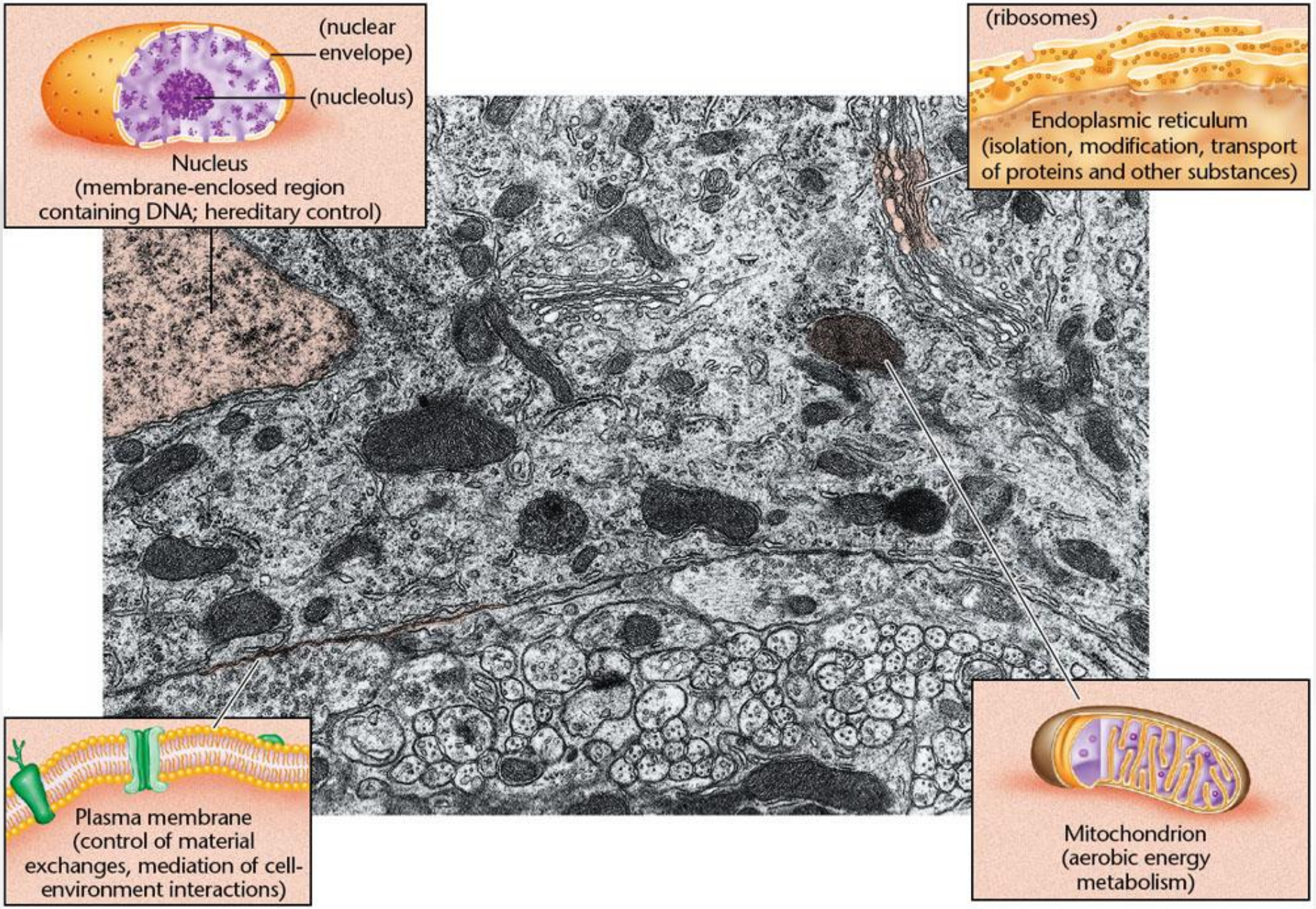


Fig. 2-2, p. 31

The Cells of the Nervous System

- The membrane refers to the structure that separates the inside of the cell from the outside environment.
- The nucleus refers to the structure that contains the chromosomes.
- The mitochondria are the strucures that perform metabolic activities and provides energy that the cells requires.
- Ribosomes are the sites at which the cell synthesizes new protein molecules

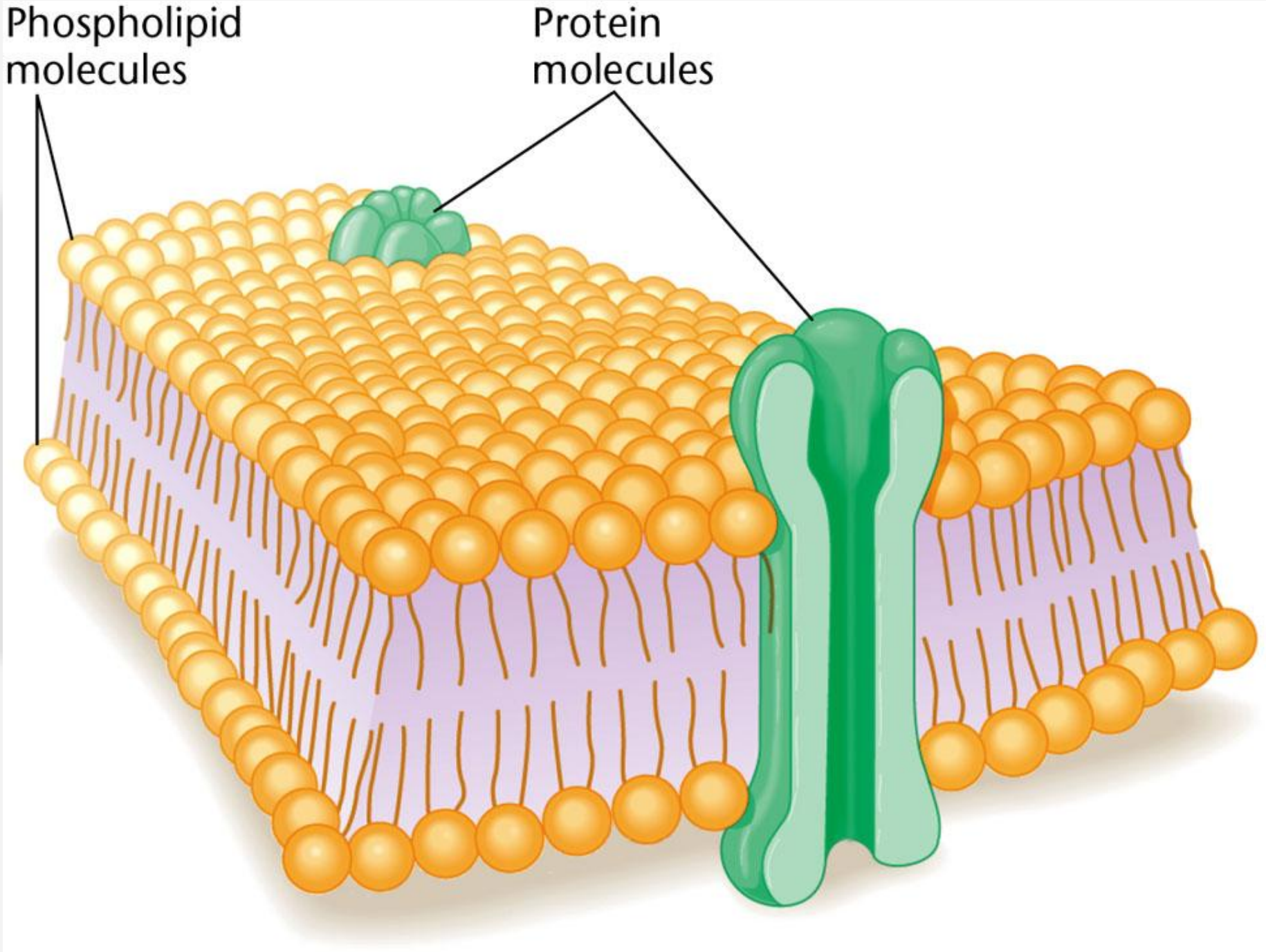


Fig. 2-3, p. 32

The Cells of the Nervous System

- Neuron cells are similar to other cells of the body but have a distinctive shape.
- A motor neuron has its soma in the spinal cord and receives excitation from other neurons and conducts impulses along it axon to a muscle.
- A sensory neuron is specialized at one end to be highly sensitive to a particular type of stimulation (touch, temperature, odor etc.)

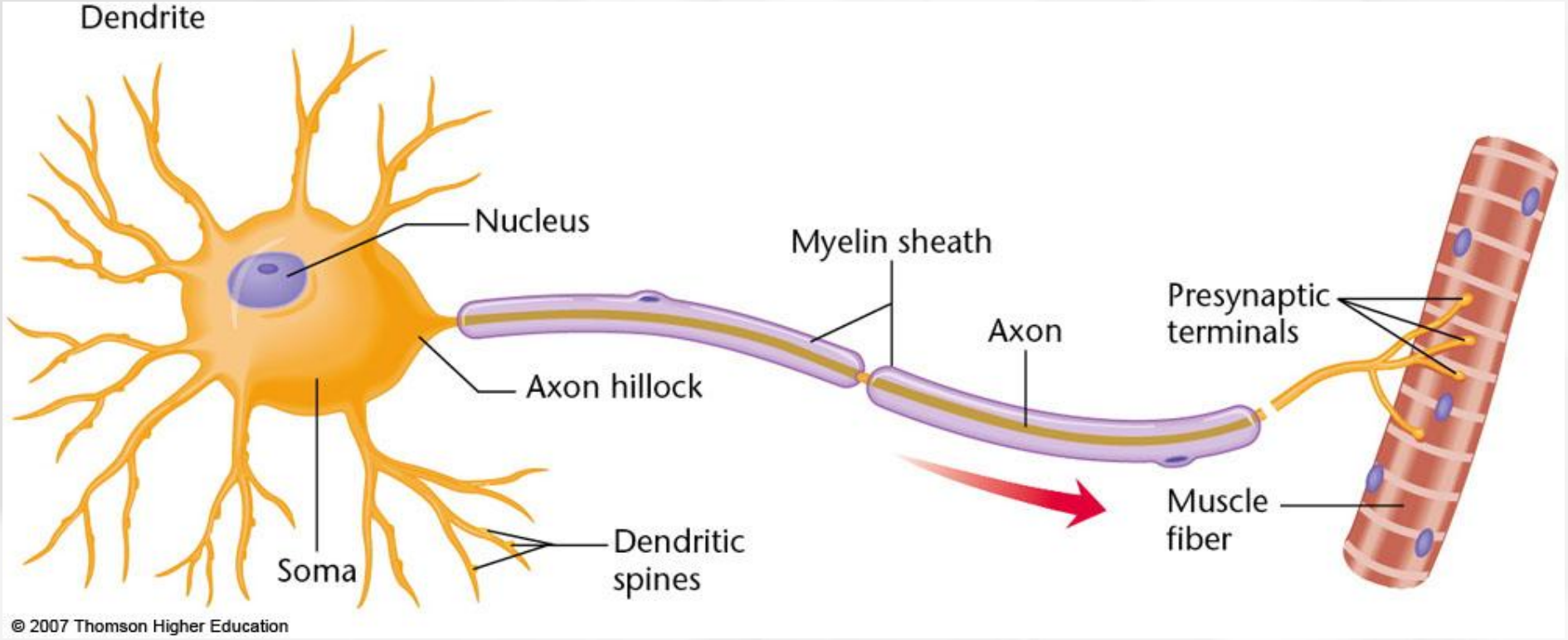

Dendrite
Nucleus
Myelin sheath
Axon
Presynaptic terminals
Axon hillock
Muscle fiber
Soma
Dendritic spines
© 2007 Thomson Higher Education

Fig. 2-5, p. 32

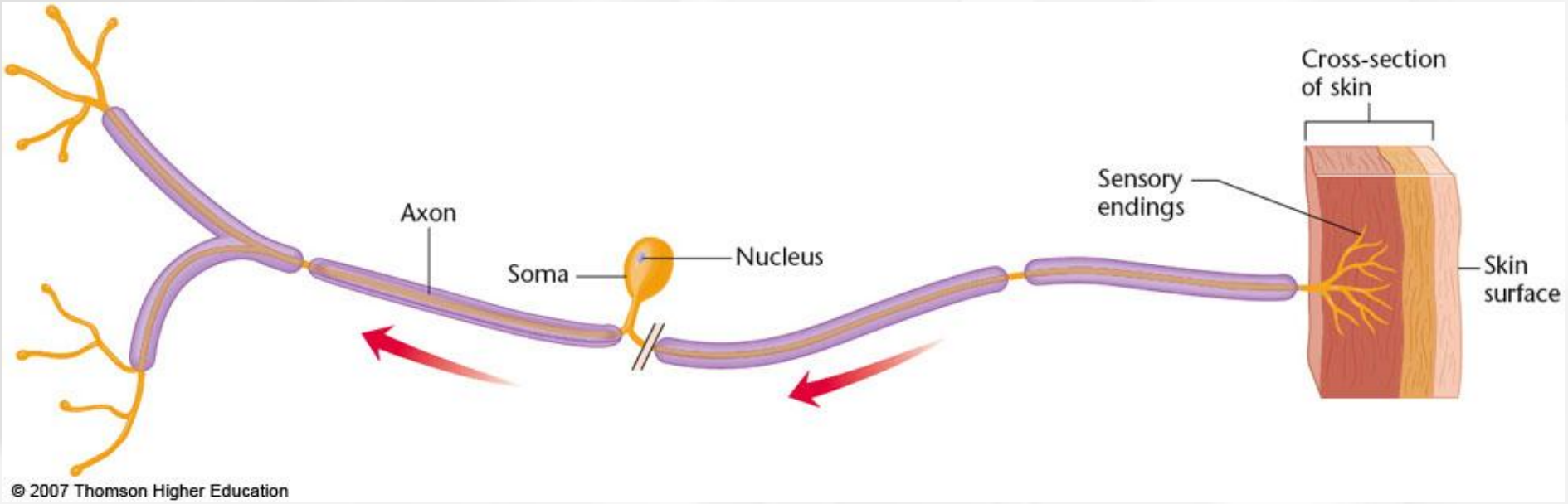


Fig. 2-6, p. 33

The Cells of the Nervous System

- All neurons have the following major components:
  - Dendrites.
  - Soma/ cell body.
  - Axon.
  - Presynaptic terminals.

The Cells of the Nervous System

- Dendrites- branching fibers with a surface lined with synaptic receptors responsible for bringing in information from other neurons.
- Some dendrites also contain dendritic spines that further branch out and increase the surface area of the dendrite.

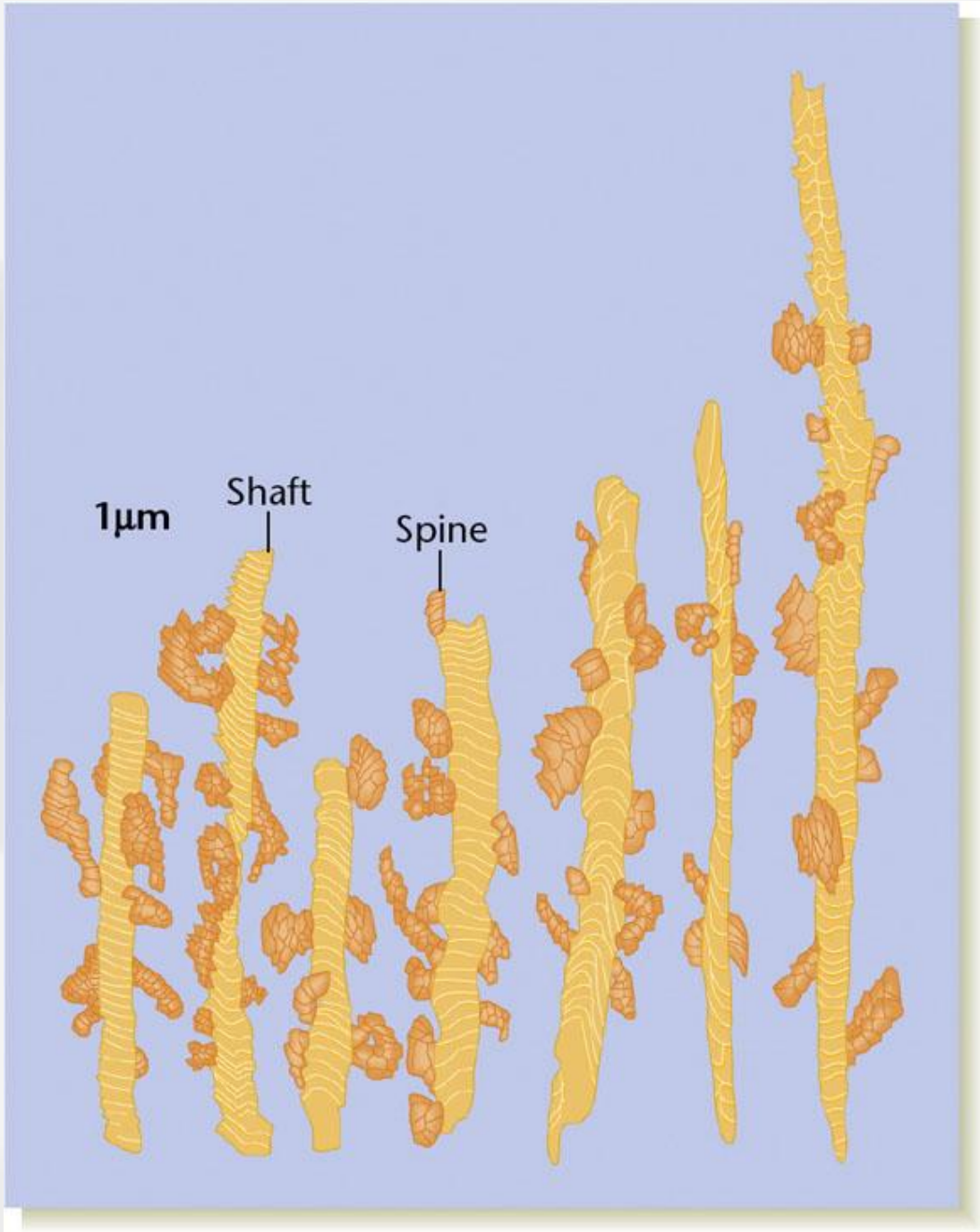


Fig. 2-7, p. 33

The Cells of the Nervous System

- Soma - contains the nucleus, mitochondria, ribosomes, and other structures found in other cells.
  - Also responsible for the metabolic work of the neuron.

The Cells of the Nervous System

- Axon - thin fiber of a neuron responsible for transmitting nerve impulses away to other neurons, glands, or muscles.
- Some neurons are covered with an insulating material called the myelin sheath with interruptions in the sheath known as nodes of Ranvier.

The Cells of the Nervous System

- Presynaptic terminals refer to the end points of an axon responsible for releasing chemicals to communicate with other neurons.

The Cells of the Nervous System

- Terms used to describe the neuron include the following:
  - Afferent axon - refers to bringing information into a structure.
  - Efferent axon - refers to carrying information away from a structure.
  - Interneurons or Intrinsic neurons are those whose dendrites and axons are completely contained within a structure.

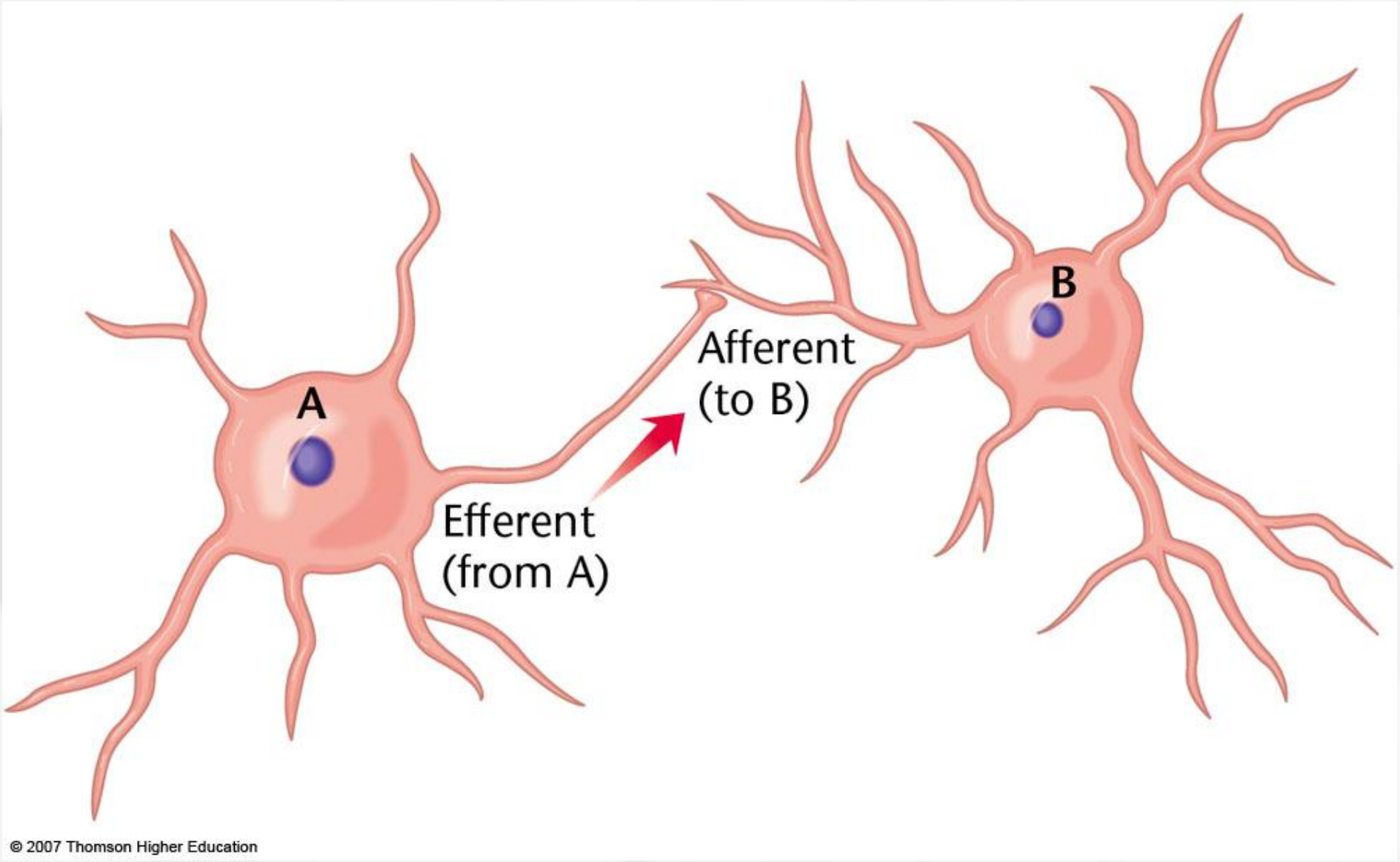


Fig. 2-8, p. 34

The Cells of the Nervous System

- Neurons vary in size, shape, and function.
- The shape of a neuron determines it connection with other neurons and its connections with other neurons.
- The function is closely related to the shape of a neuron.
  - Example: Pukinje cells of the cerebellum branch extremely widely within a single plane

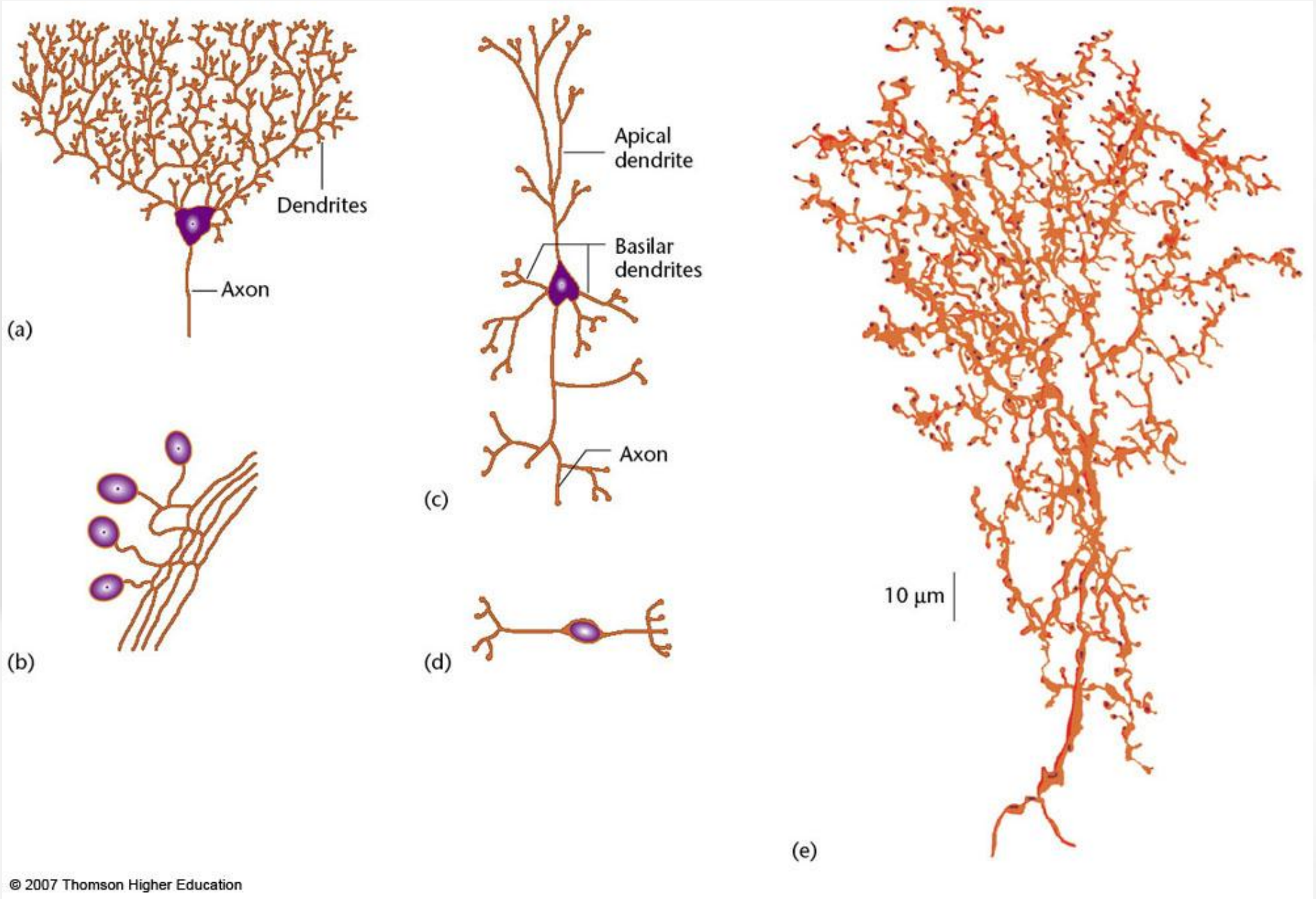


Fig. 2-9, p. 34

The Cells of the Nervous System

- Glia are the other major component of the nervous system and include the following:
  - Astrocytes helps synchronize the activity of the axon by wrapping around the presynaptic terminal and taking up chemicals released by the axon.
  - Microglia - remove waste material and other microorganisms that could prove harmful to the neuron.

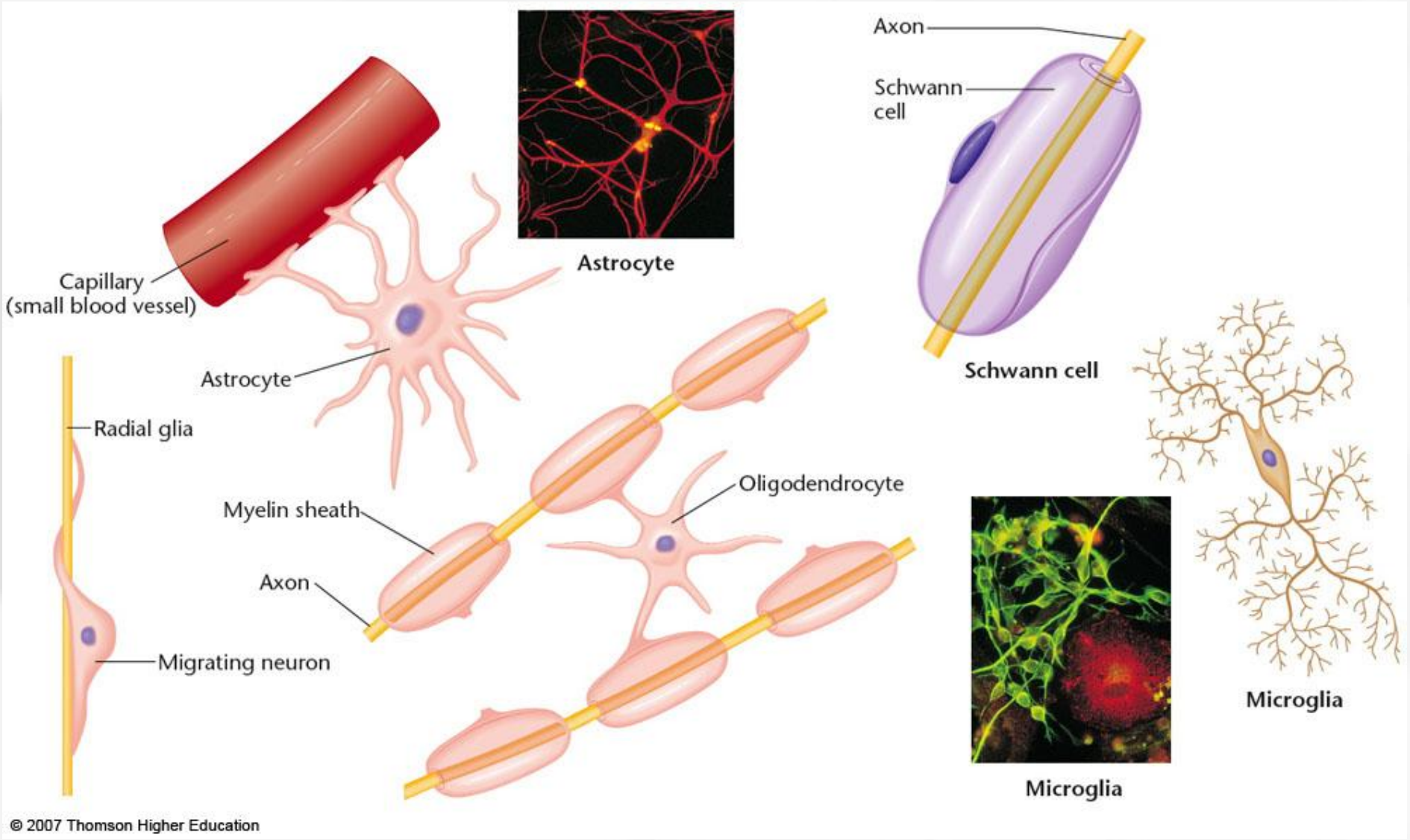


Fig. 2-10, p. 35

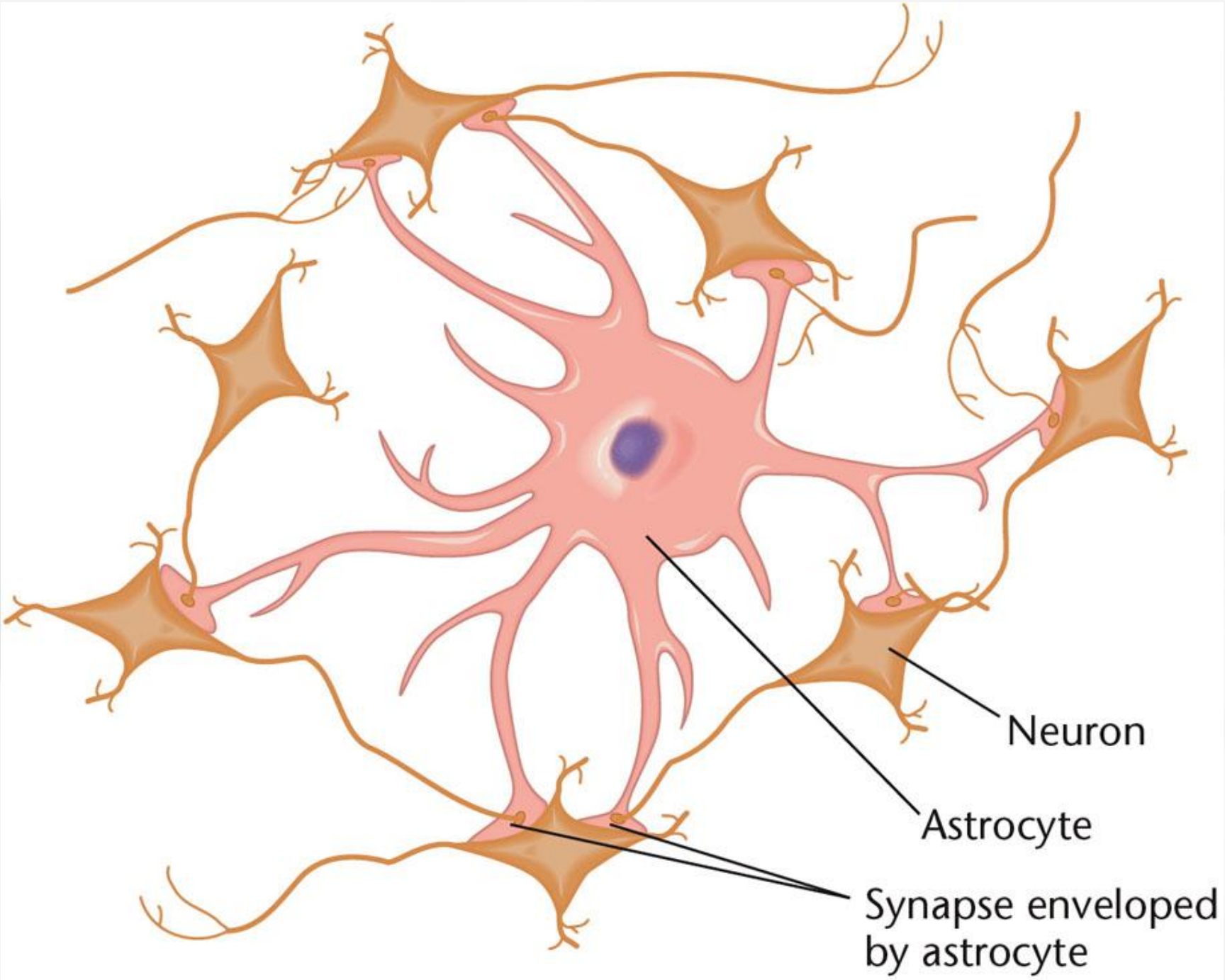


Fig. 2-11, p. 36

The Cells of the Nervous System

- (Types of glia continued)
  - Oligdendrocytes & Schwann cells- build the myelin sheath that surrounds the axon of some neurons.
  - Radial glia- guide the migration of neurons and the growth of their axons and dendrites during embryonic development.

The Cells of the Nervous System

- The blood-brain barrier is a mechanism that surrounds the brain and blocks most chemicals from entering.
- Our immune system destroys damaged or infected cells throughout the body.
- Because neurons in the brain generally do not regenerate, it is vitally important for the blood brain barrier to block incoming viruses, bacteria or other harmful material from entering.

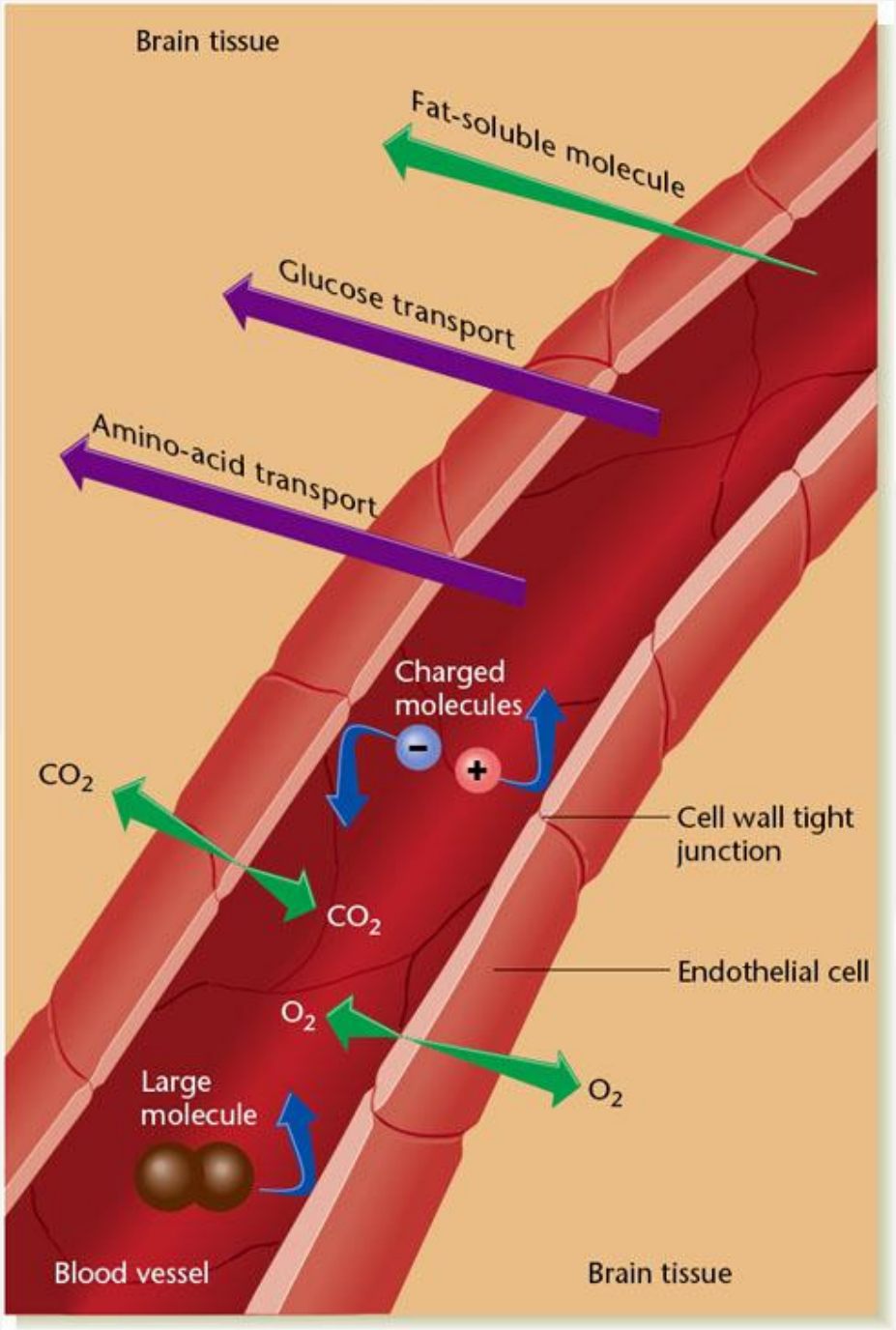


Fig. 2-12, p. 37

The Cells of the Nervous System

- Active transport is the protein mediated process by which useful chemicals are brought into the brain.
- Glucose, hormones, amino acids, and vitamins are brought into the brain via active transport.
- Glucose is a simple sugar that is the primary source of nutrition for neurons.
  - Thiamine is a chemical that is necessary for the use of glucose.

The Nerve Impulse

- A nerve impulse is the electrical message that is transmitted down the axon of a neuron.
- The impulse does not travel directly down the axon but is regenerated at points along the axon.
- The speed of nerve impulses ranges from approximately 1 m/s to 100 m/s.

The Nerve Impulse

- The resting potential of a neuron refers to the state of the neuron prior to the sending of a nerve impulse.
- The membrane of a neuron maintains an electrical gradient which is a difference in the electrical charge inside and outside of the cell.

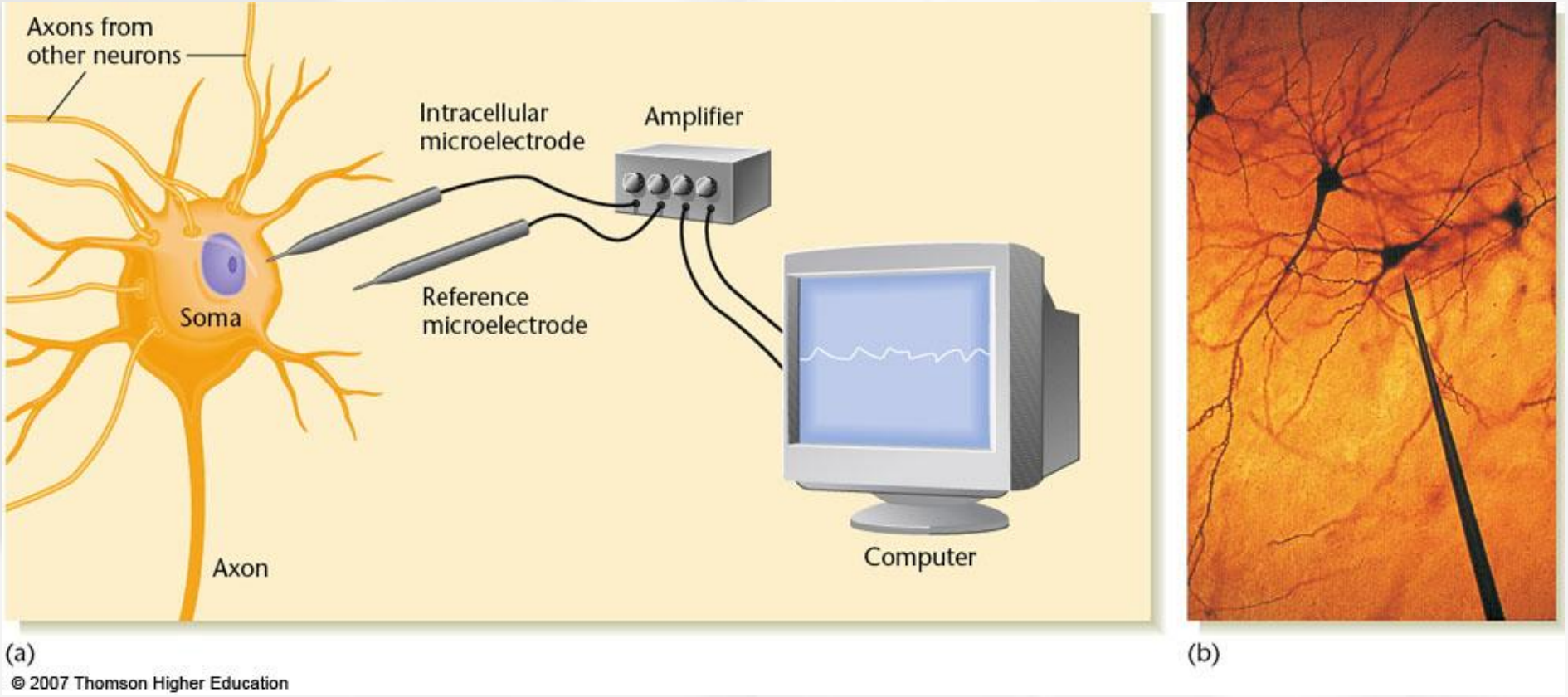


Fig. 2-13, p. 40

The Nerve Impulse

- At rest, the membrane maintains an electrical polarization or a difference in the electrical charge of two locations.
  - the inside of the membrane is slightly negative with respect to the outside. (approximately -70 millivolts)

The Nerve Impulse

- The membrane is selectively permeable, allowing some chemicals to pass more freely than others.
- Sodium, potassium, calcium, and chloride pass through channels in the membrane.
- When the membrane is at rest:
  - Sodium channels are closed.
  - Potassium channels are partially closed allowing the slow passage of sodium.

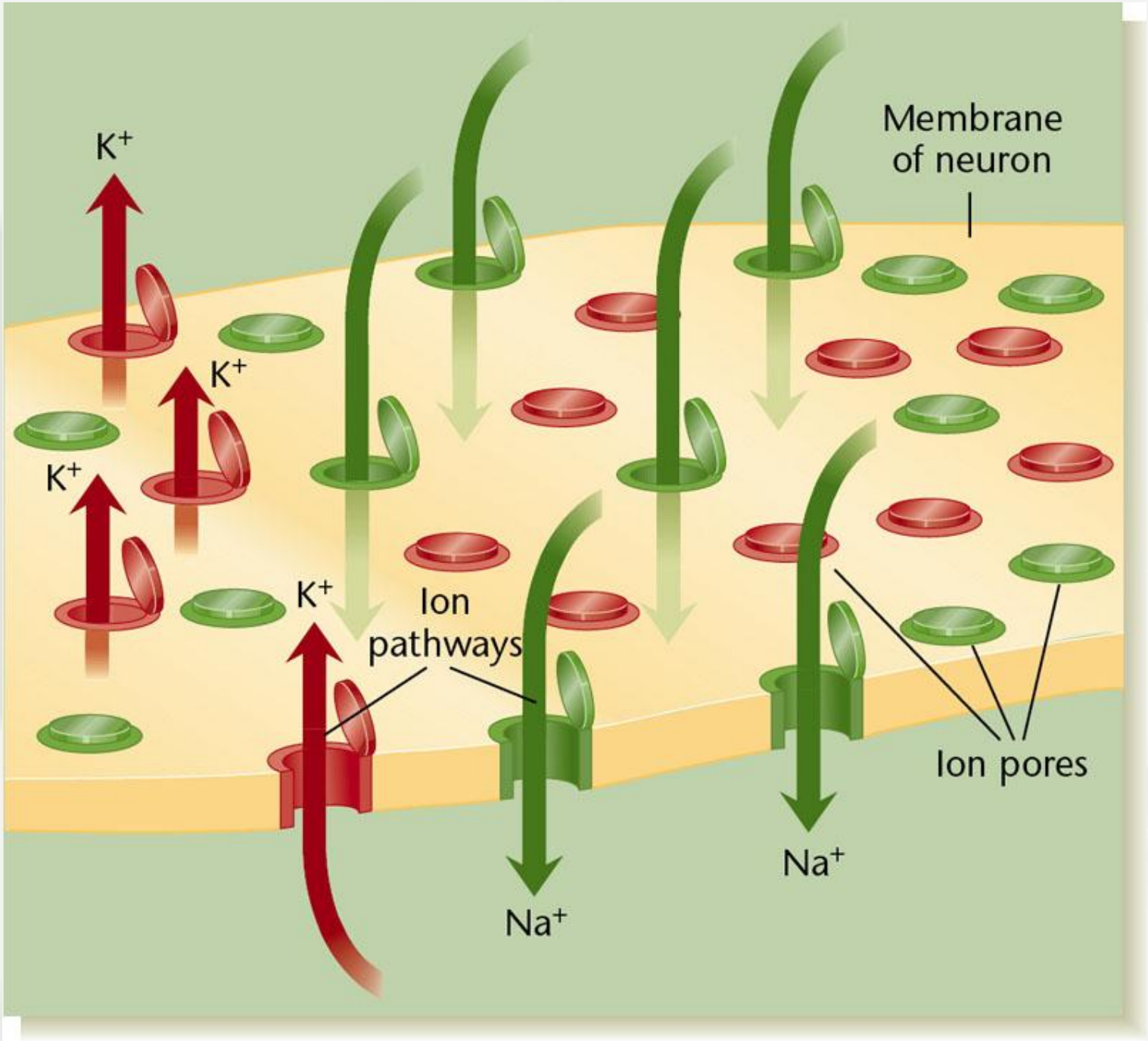


Fig. 2-14, p. 40

The Nerve Impulse

- The sodium-potassium pump is a protein complex that continually pumps three sodium ions out of the cells while drawing two potassium ions into the cell.
  - helps to maintain the electrical gradient.
- The electrical gradient and the concentration gradient work to pull sodium ions into the cell.
- The electrical gradient tends to pull potassium ions into the cells.

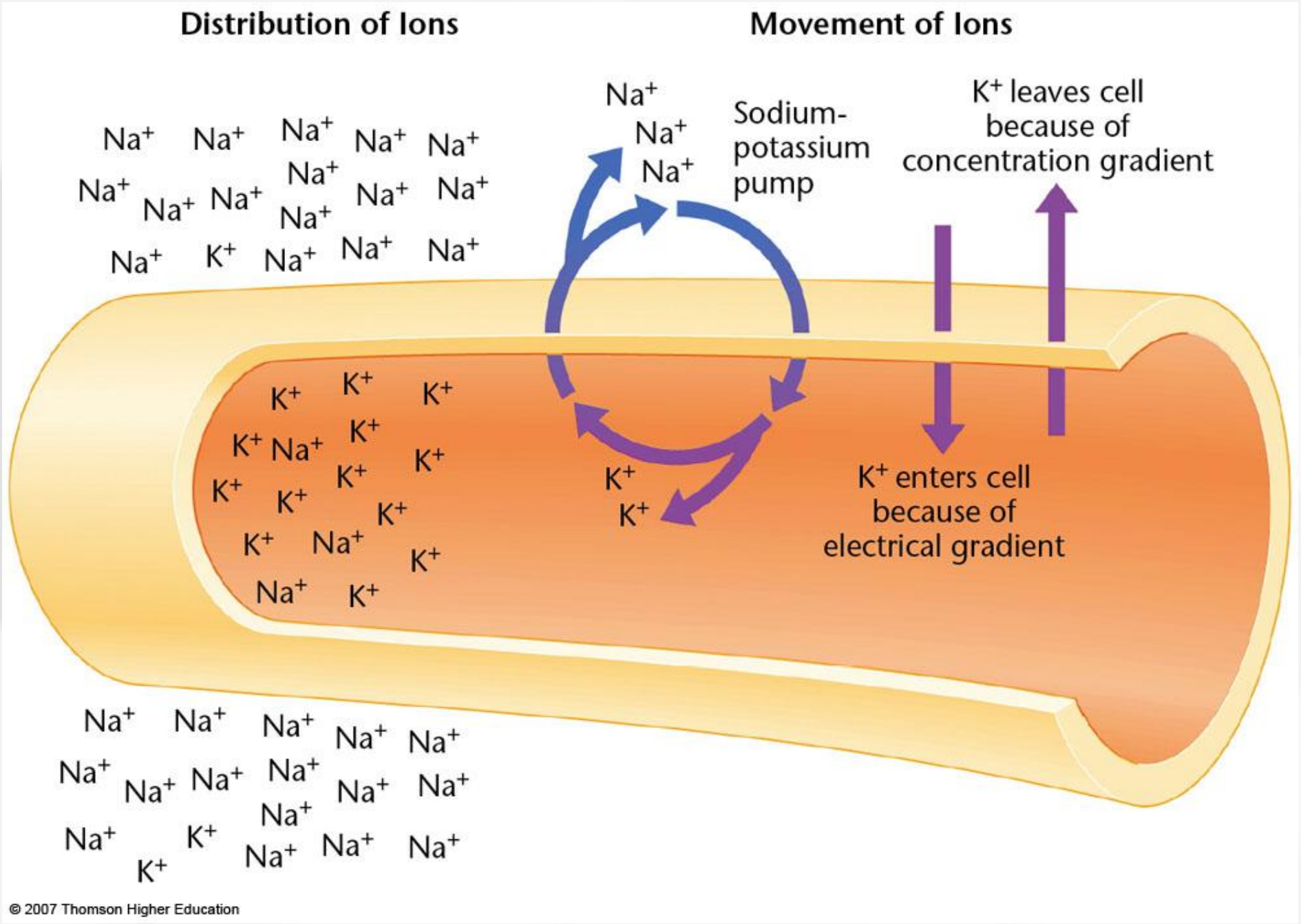


Fig. 2-15, p. 41

The Nerve Impulse

- The resting potential remains stable until the neuron is stimulated.
- Hyperpolarization refers to increasing the polarization or the difference between the electrical charge of two places.
- Depolarization refers to decreasing the polarization towards zero.
- The threshold of excitement refers any stimulation beyond a certain level and results in a massive depolarization.

The Nerve Impulse

- An action potential is a rapid depolarization of the neuron.
- Stimulation of the neuron past the threshold of excitation triggers a nerve impulse or action potential.

The Nerve Impulse

- Voltage-activated channels are membrane channels whose permeabililty depends upon the voltage difference across the membrane.
  - Sodium channels are voltage activated channels.
- When sodium channels are opened, positively charged sodium ions rush in and a subsequent nerve impulse occurs.

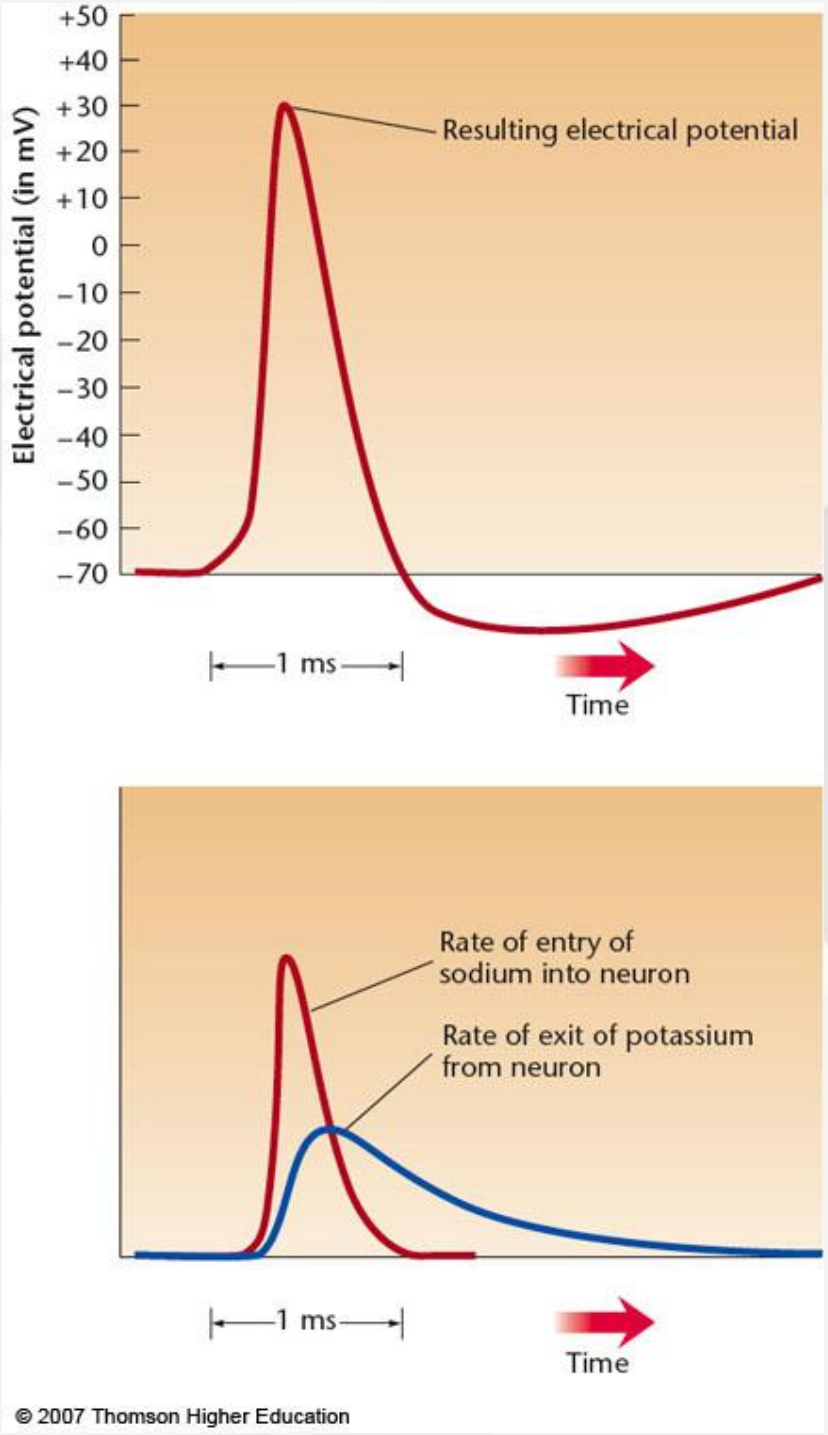


Fig. 2-16, p. 43

The Nerve Impulse

- After an action potential occurs, sodium channels are quickly closed.
- The neuron is returned to its resting state by the opening of potassium channels.
  - potassium ions flow out due to the concentration gradient and take with them their positive charge.
- The sodium-potassium pump later restores the original distribution of ions.

The Nerve Impulse

- Local anesthetic drugs block sodium channels and therefore prevent action potentials from occurring.
  - Example: Novocain

The Nerve Impulse

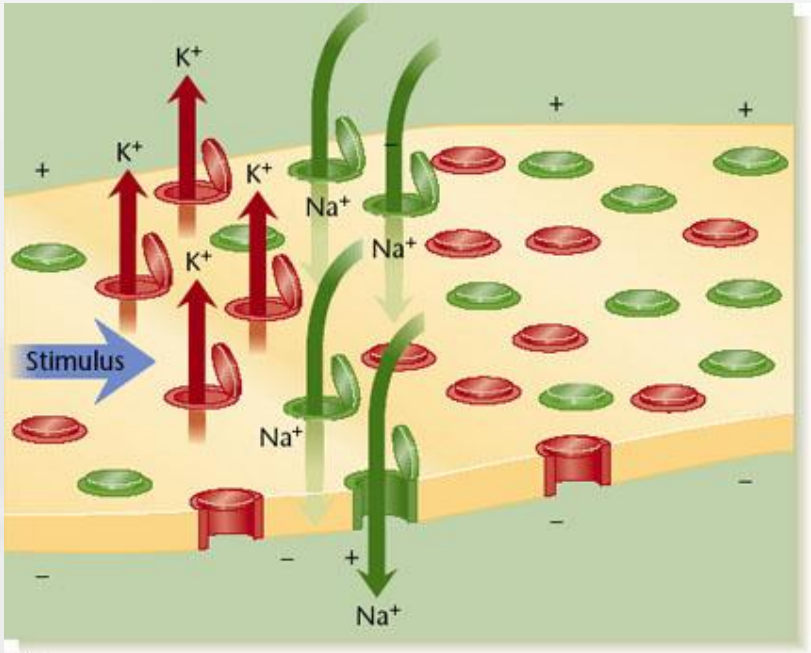
- The all-or-none law states that the amplitude and velocity of an action potential are independent of the intensity of the stimulus that initiated it.
  - Action potentials are equal in intensity and speed within a given neuron.

The Nerve Impulse

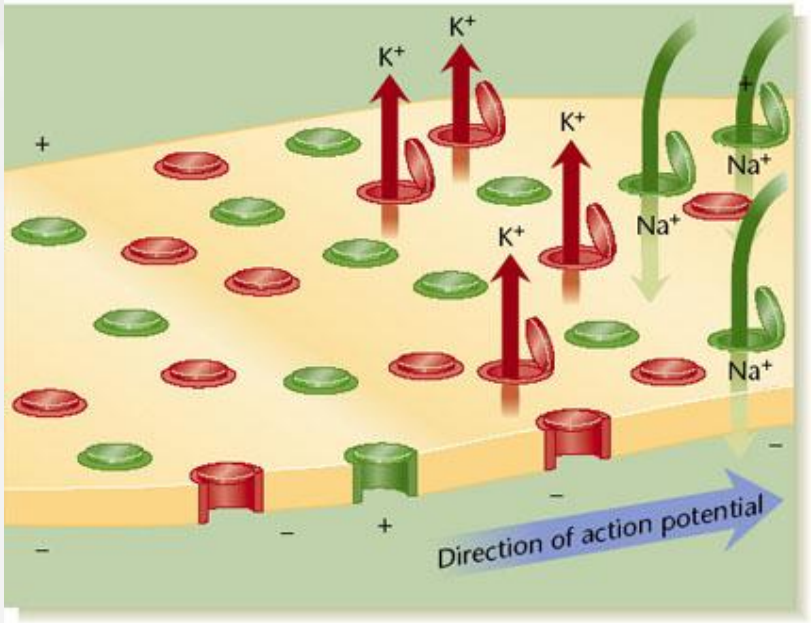
- After an action potential, a neuron has a refractory period during which time the neuron resists another action potential.
- The absolute refractory period is the first part of the period in which the membrane can not produce an action potential.
- The relative refractory period is the second part in which it take a stronger than usual stimulus to trigger an action potential.

The Nerve Impulse

- In a motor neuron, the action potential begins at the axon hillock (a swelling where the axon exits the soma).
- Propagation of the action potential is the term used to describe the transmission of the action potential down the axon.
  - the action potential does not directly travel down the axon.



(a)

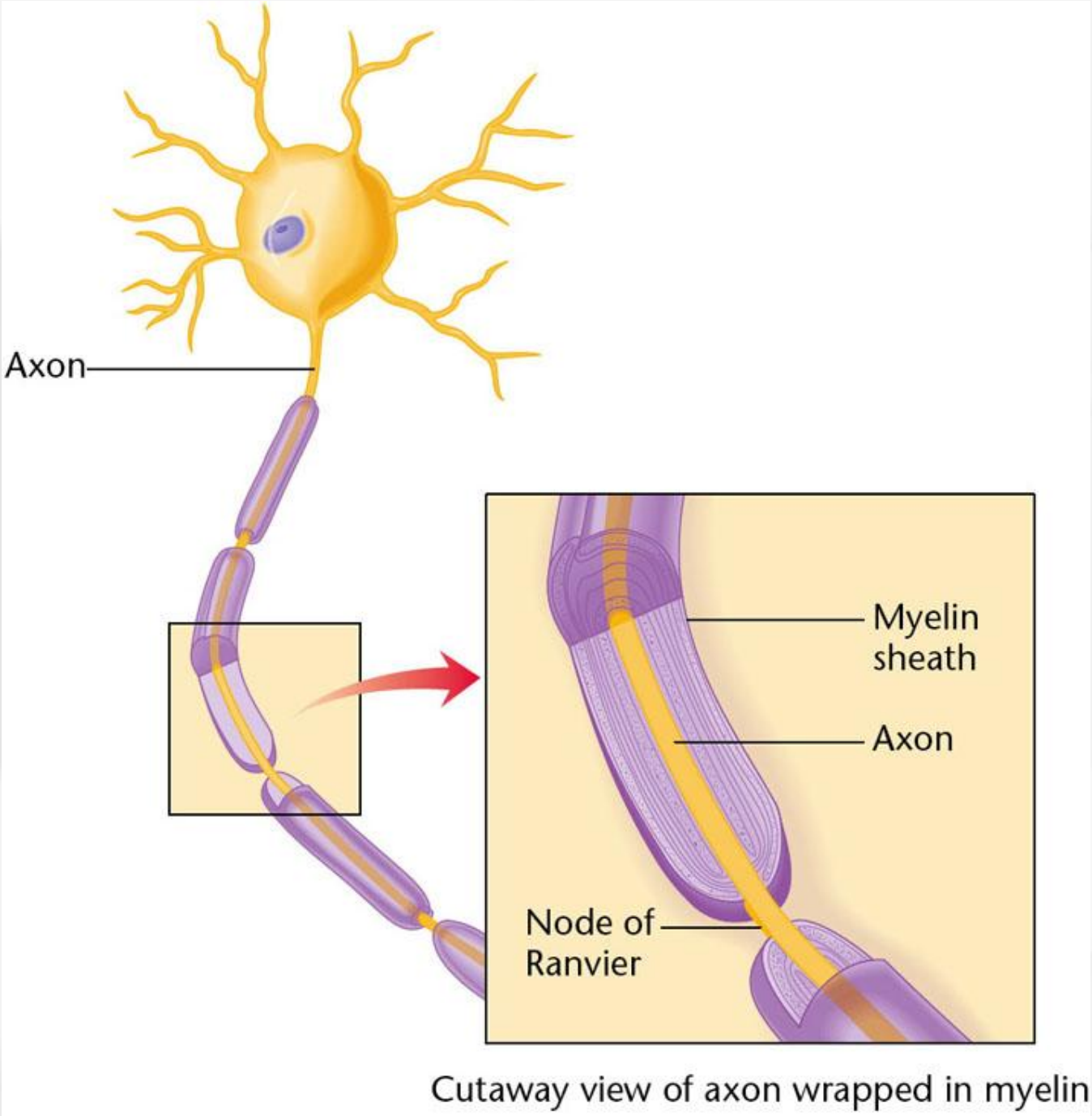


(b)

Fig. 2-17, p. 45

The Nerve Impulse

- The myelin sheath of axons are interrupted by short unmyelinated sections called nodes of Ranvier.
- At each node of Ranvier, the action potential is regenerated by a chain of positively charged ion pushed along by the previous segment.



Cutaway view of axon wrapped in myelin

Fig. 2-18, p. 46

The Nerve Impulse

- Saltatory conduction is the word used to describe this “jumping” of the action potential from node to node.
  - Provides rapid conduction of impulses
  - Conserves energy for the cell
- Multiple sclerosis is disease in which the myelin sheath is destroyed and associated with poor muscle coordination.

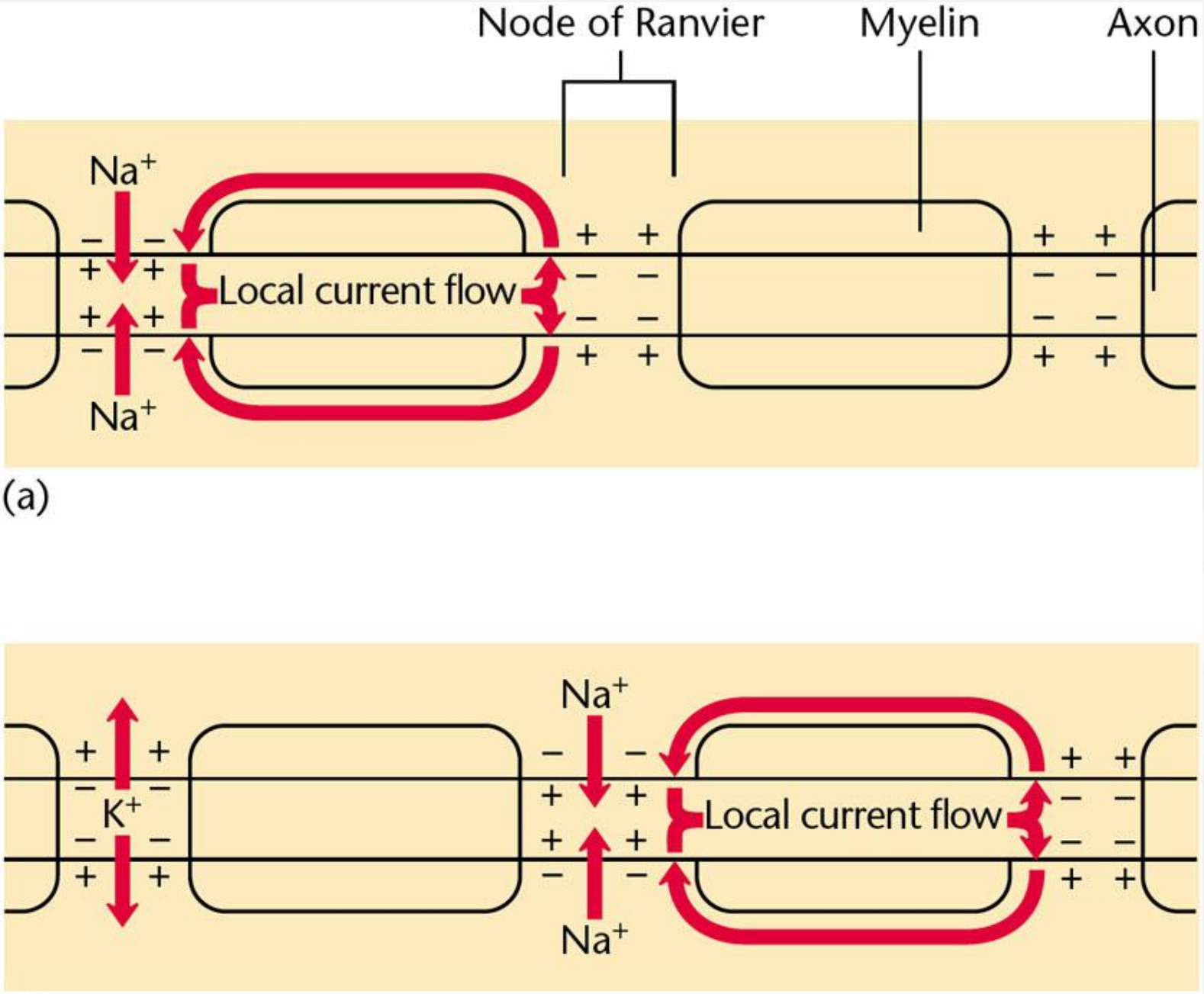


Fig. 2-19, p. 46

The Nerve Impulse

- Not all neurons have lengthy axons.
- Local neurons have short axons, exchange information with only close neighbors, and do not produce action potentials.
- When stimulated, local neurons produce graded potentials which are membrane potentials that vary in magnitude and do not follow the all-or-none law,.
- A local neuron depolarizes or hyperpolarizes in proportion to the stimulation.