7

The Nervous System

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KAIST

Functions of the Nervous System

- Sensory input—gathering information
  - To monitor changes occurring inside and outside the body
  - Changes = stimuli
- Integration
  - To process and interpret sensory input and decide if action is needed
- Motor output
  - A response to integrated stimuli
  - The response activates muscles or glands

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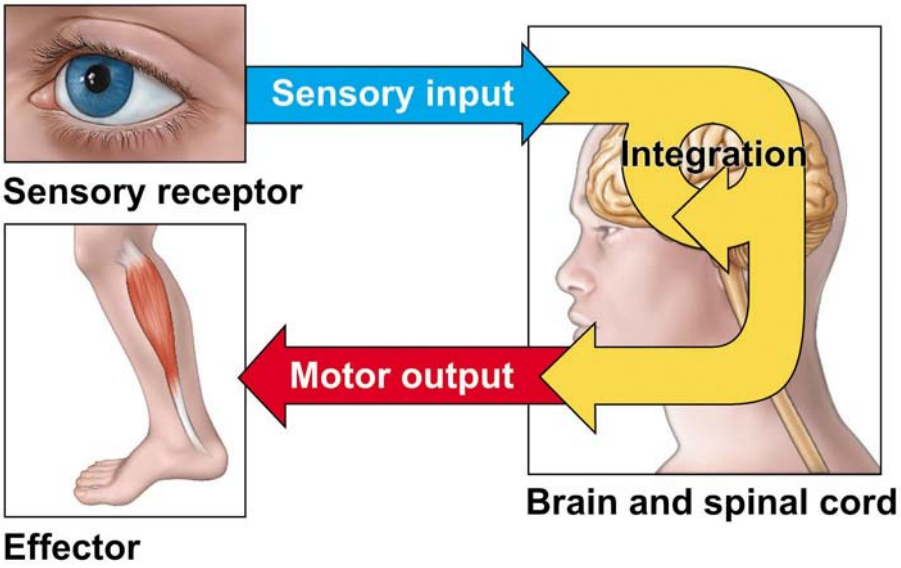

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Figure 7.1

Structural Classification of the Nervous System

- Central nervous system (CNS)
  - Organs
    - Brain
    - Spinal cord
  - Function
    - Integration; command center
    - Interpret incoming sensory information
    - Issues outgoing instructions

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Structural Classification of the Nervous System

- Peripheral nervous system (PNS)
  - Nerves extending from the brain and spinal cord
    - Spinal nerves—carry impulses to and from the spinal cord
    - Cranial nerves—carry impulses to and from the brain
  - Functions
    - Serve as communication lines among sensory organs, the brain and spinal cord, and glands or muscles

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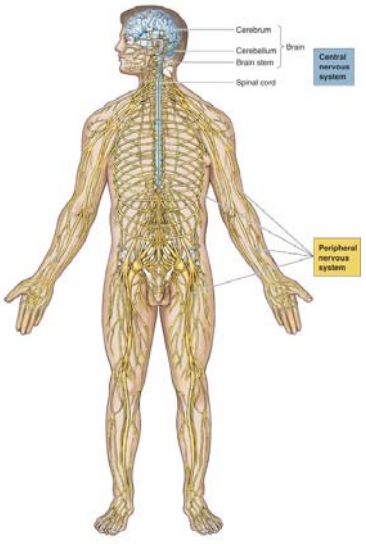
Structural Classification of the Nervous System

- Central nervous system (CNS)
  - Brain
  - Spinal cord
- Peripheral nervous system (PNS)
  - Nerves outside the brain and spinal cord
    - Spinal nerves
    - Cranial nerves



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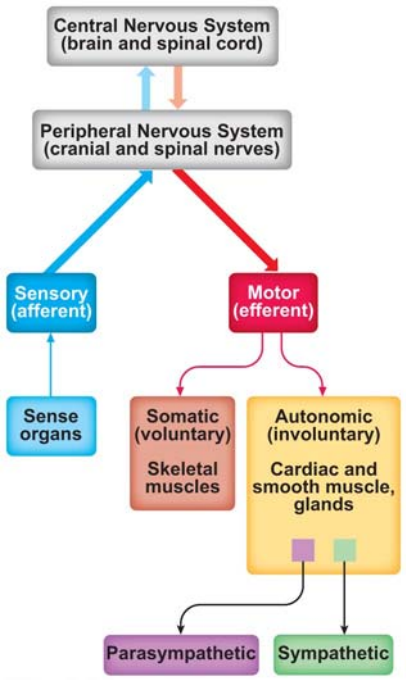

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Figure 7.2

Functional Classification of the Peripheral Nervous System

- Sensory (afferent) division
  - Nerve fibers that carry information to the central nervous system
- Motor (efferent) division
  - Nerve fibers that carry impulses away from the central nervous system

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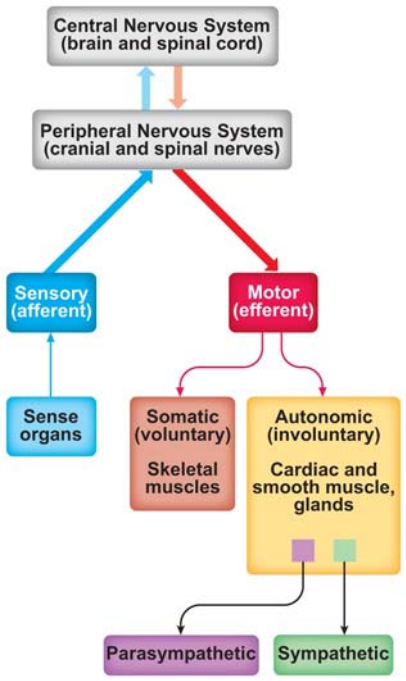

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Figure 7.2

Functional Classification of the Peripheral Nervous System

- Motor (efferent) division (continued)
  - Two subdivisions
    - Somatic nervous system = voluntary
      - Consciously controls skeletal muscles
    - Autonomic nervous system = involuntary
      - Automatically controls smooth and cardiac muscles and glands
      - Further divided into the sympathetic and parasympathetic nervous systems

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Nervous Tissue: Support Cells

- Support cells in the CNS are grouped together as “neuroglia”
- General functions
  - Support
  - Insulate
  - Protect neurons

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Nervous Tissue: Support Cells

- Astrocytes
  - Abundant, star-shaped cells
  - Brace neurons
  - Form barrier between capillaries and neurons
  - Control the chemical environment of the brain

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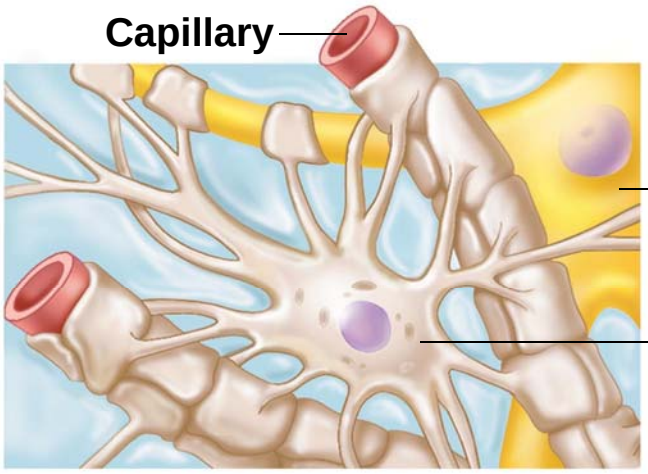

(a) Astrocytes are the most abundant and versatile neuroglia.

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Figure 7.3a

Nervous Tissue: Support Cells

- Microglia
  - Spiderlike phagocytes
  - Dispose of debris

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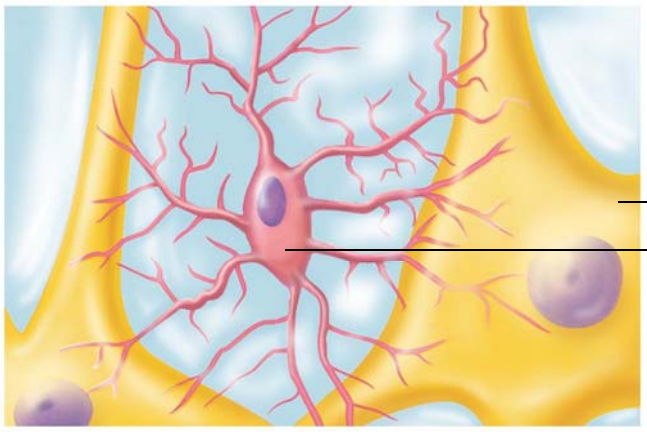

(b) Microglial cells are phagocytes that defend CNS cells.

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Figure 7.3b

Nervous Tissue: Support Cells

- Ependymal cells
  - Line cavities of the brain and spinal cord
  - Cilia assist with circulation of cerebrospinal fluid

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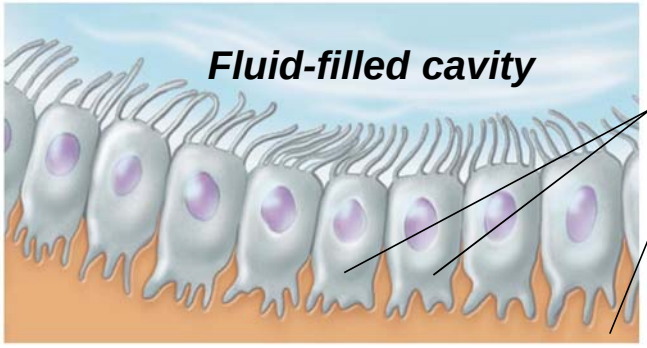

(c) Ependymal cells line cerebrospinal fluid-filled cavities.

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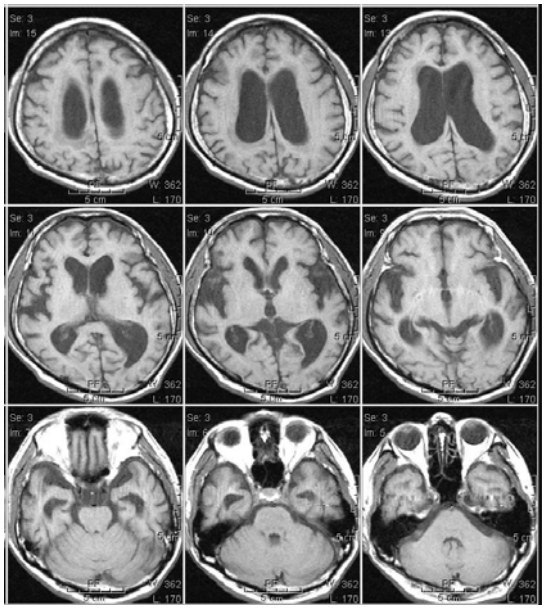
Figure 7.3c



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Nervous Tissue: Support Cells

- Oligodendrocytes
  - Wrap around nerve fibers in the central nervous system
  - Produce myelin sheaths

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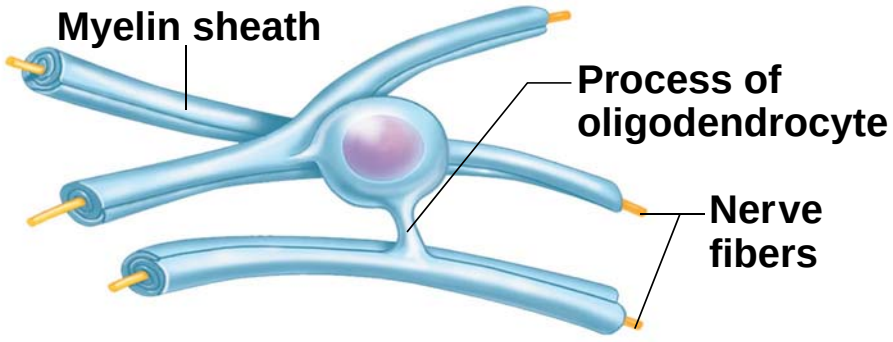

(d) Oligodendrocytes have processes that form myelin sheaths around CNS nerve fibers.

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Figure 7.3d

Nervous Tissue: Support Cells

- Satellite cells
  - Protect neuron cell bodies
- Schwann cells
  - Form myelin sheath in the peripheral nervous system

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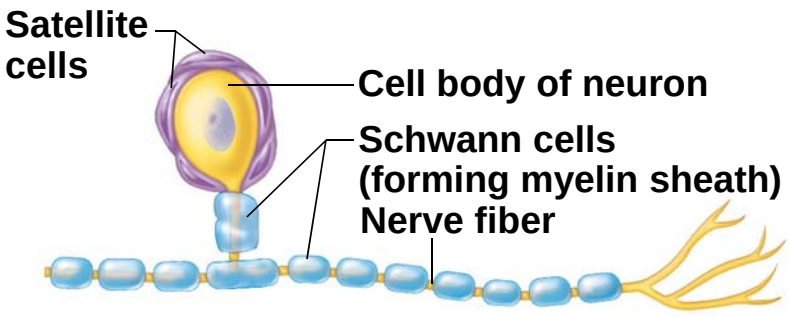

(e) Satellite cells and Schwann cells (which form myelin) surround neurons in the PNS.

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Figure 7.3e

Nervous Tissue: Neurons

- Neurons = nerve cells
  - Cells specialized to transmit messages
  - Major regions of neurons
    - Cell body—nucleus and metabolic center of the cell
    - Processes—fibers that extend from the cell body

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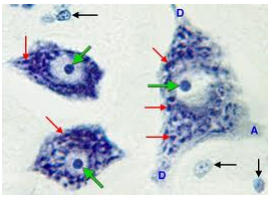
Nervous Tissue: Neurons

- Cell body
  - Nissl bodies
    - Specialized rough endoplasmic reticulum
  - Neurofibrils
    - Intermediate cytoskeleton
    - Maintains cell shape
  - Nucleus with large nucleolus



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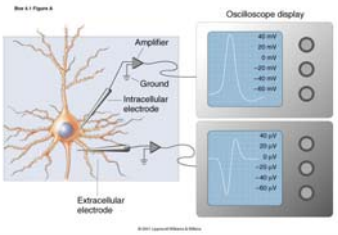
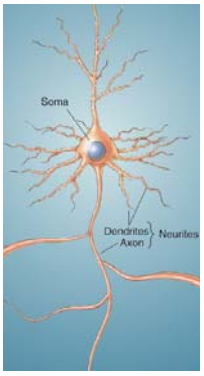
Neuron Specific Function and Structure

- Excitability: action potential
  - Ion channels
- Long axon
  - Cytoskeleton: microtubule etc.
  - Myeline sheath
- Signal transmission
  - Synapse
  - Neurotransmitter
  - Receptor





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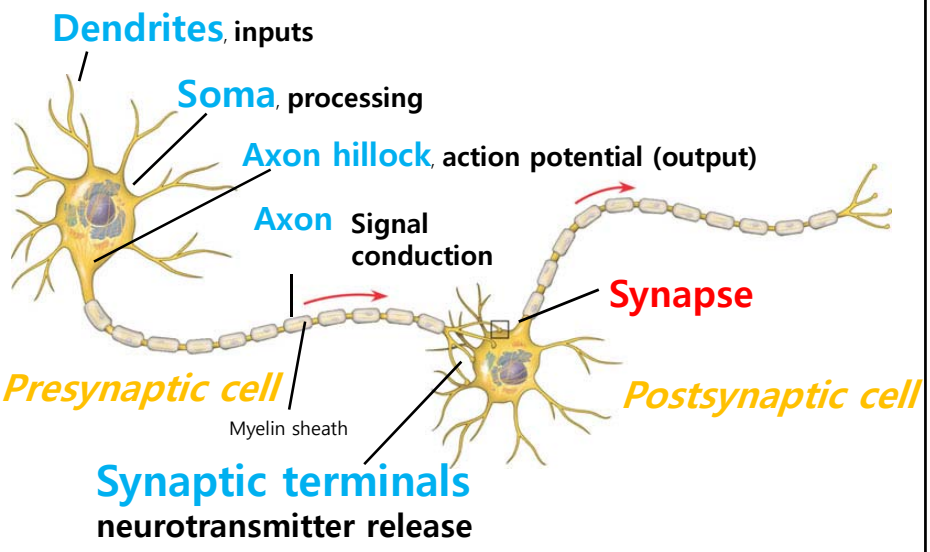
Structure of Neuron



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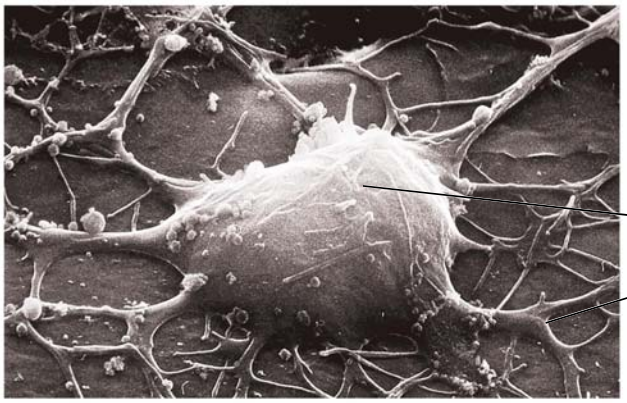

(b)

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Figure 7.4b

Nervous Tissue: Neurons

- Processes outside the cell body
  - Dendrites—conduct impulses toward the cell body
    - Neurons may have hundreds of dendrites
  - Axons—conduct impulses away from the cell body
    - Neurons have only one axon arising from the cell body at the axon hillock

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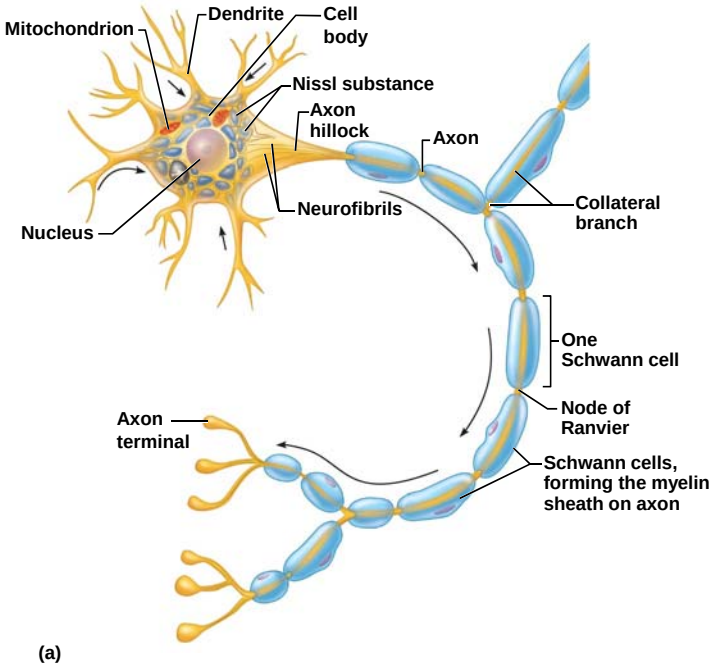

(a)

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Figure 7.4a

Nervous Tissue: Neurons

- Axons
  - End in axon terminals
  - Axon terminals contain vesicles with neurotransmitters
  - Axon terminals are separated from the next neuron by a gap
    - Synaptic cleft—gap between adjacent neurons
    - Synapse—junction between nerves

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Nervous Tissue: Neurons

- Myelin sheath—whitish, fatty material covering axons
  - Schwann cells—produce myelin sheaths in jelly roll-like fashion around axons (PNS)
    - Nodes of Ranvier—gaps in myelin sheath along the axon
  - Oligodendrocytes—produce myelin sheaths around axons of the CNS

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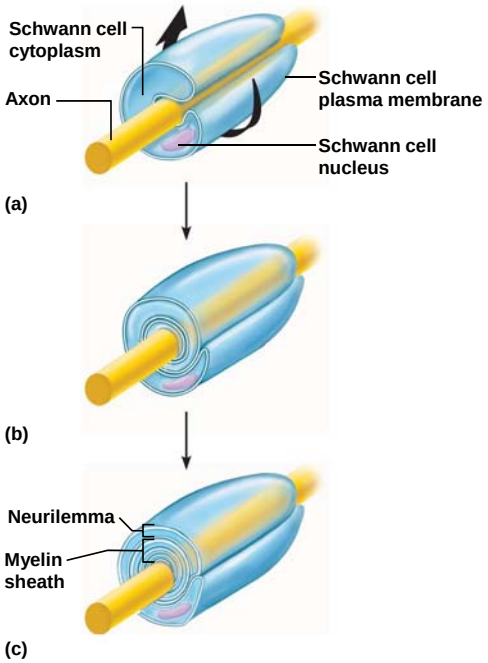

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Figure 7.5

Neuron Cell Body Location

- Most neuron cell bodies are found in the central nervous system
  - Gray matter—cell bodies and unmyelinated fibers
  - Nuclei—clusters of cell bodies within the white matter of the central nervous system
- Ganglia—collections of cell bodies outside the central nervous system

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Neuron Cell Body Location

- Tracts—bundles of nerve fibers in the CNS
- Nerves—bundles of nerve fibers in the PNS
- White matter—collections of myelinated fibers (tracts)
- Gray matter—collections of mostly unmyelinated fibers and cell bodies

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Functional Classification of Neurons

- Sensory (afferent) neurons
  - Carry impulses from the sensory receptors to the CNS
    - Cutaneous sense organs
    - Proprioceptors—detect stretch or tension
- Motor (efferent) neurons
  - Carry impulses from the central nervous system to viscera, muscles, or glands

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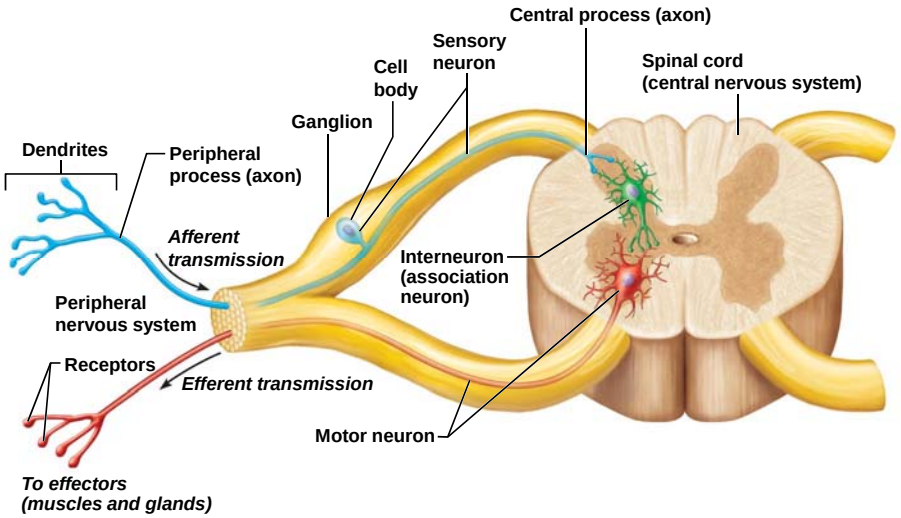

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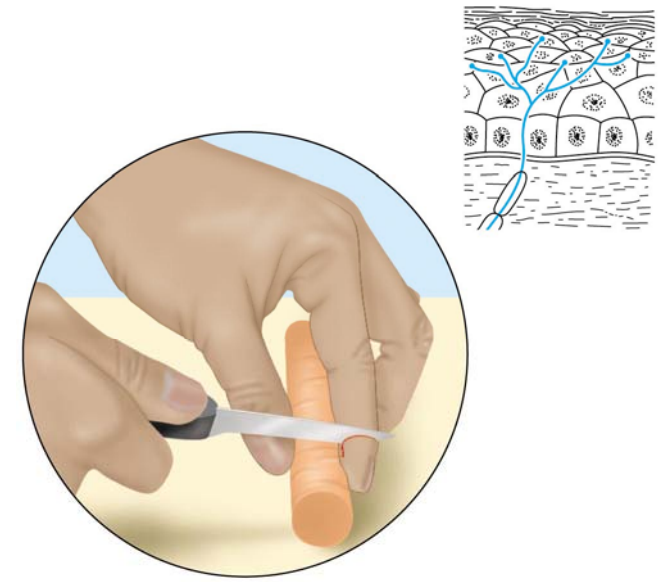
Figure 7.6



(a) Free nerve endings (pain and temperature receptors)

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Figure 7.7a

(b) Meissner's corpuscle (touch receptor)

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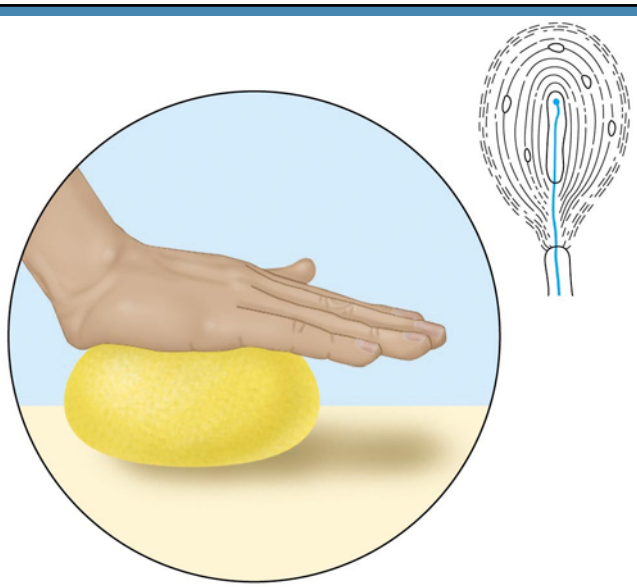
Figure 7.7b



(c) Lamellar corpuscle (deep pressure receptor)

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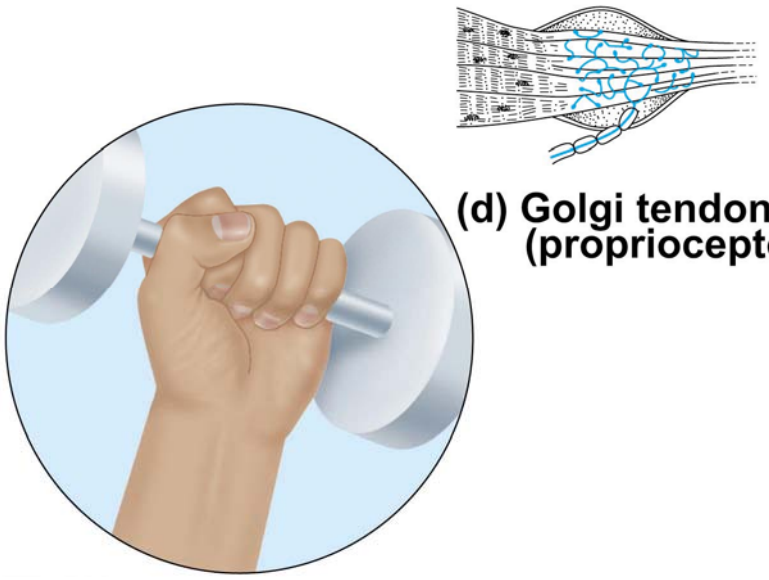
Figure 7.7c



(d) Golgi tendon organ (proprioceptor)

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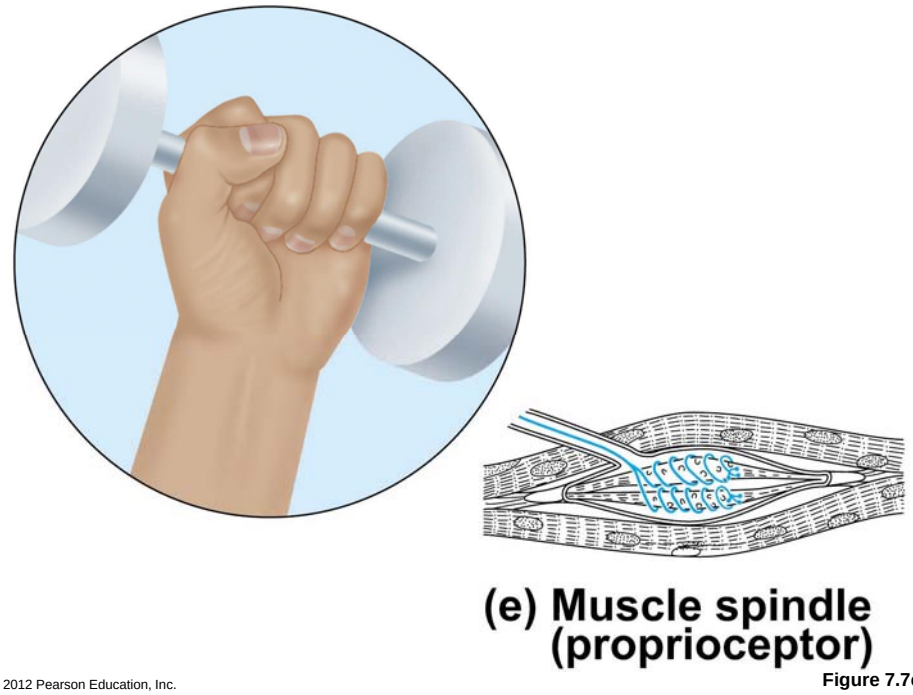
Figure 7.7d



(e) Muscle spindle (proprioceptor)

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Figure 7.7e

Functional Classification of Neurons

- Interneurons (association neurons)
  - Found in neural pathways in the central nervous system
  - Connect sensory and motor neurons

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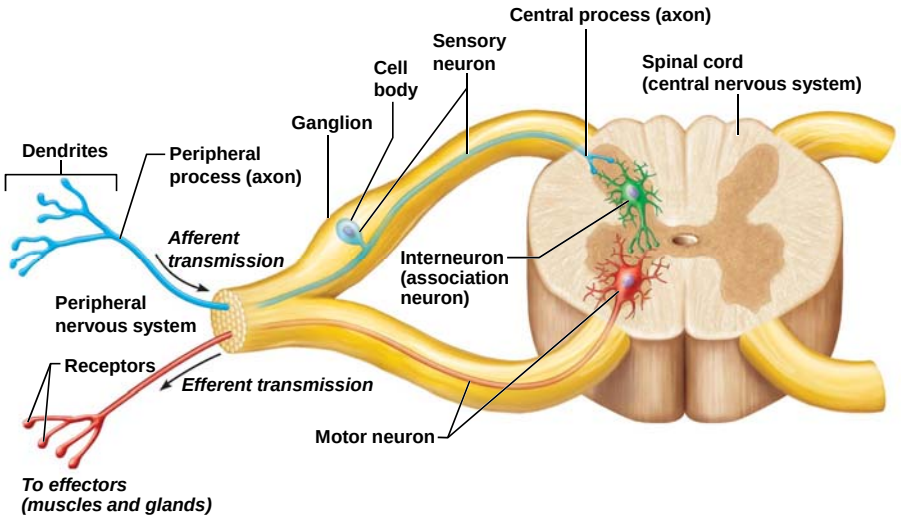

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Figure 7.6

Structural Classification of Neurons

- Multipolar neurons—many extensions from the cell body
  - All motor and interneurons are multipolar
  - Most common structure

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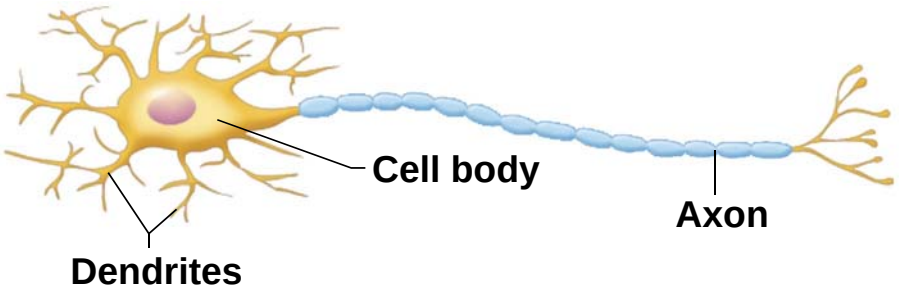

(a) Multipolar neuron

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Figure 7.8a

Structural Classification of Neurons

- Bipolar neurons—one axon and one dendrite
  - Located in special sense organs such as nose and eye
  - Rare in adults

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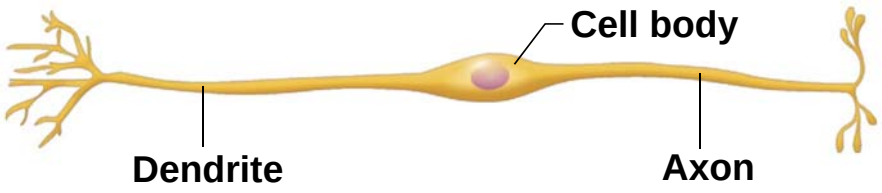

(b) Bipolar neuron

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Figure 7.8b

Structural Classification of Neurons

- Unipolar neurons—have a short single process leaving the cell body
  - Sensory neurons found in PNS ganglia

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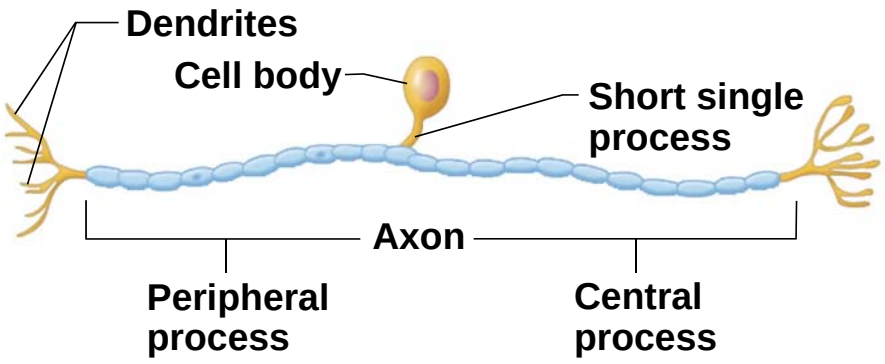

(c) Unipolar neuron

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Figure 7.8c

Functional Properties of Neurons

- Irritability
  - Ability to respond to stimuli
- Conductivity
  - Ability to transmit an impulse

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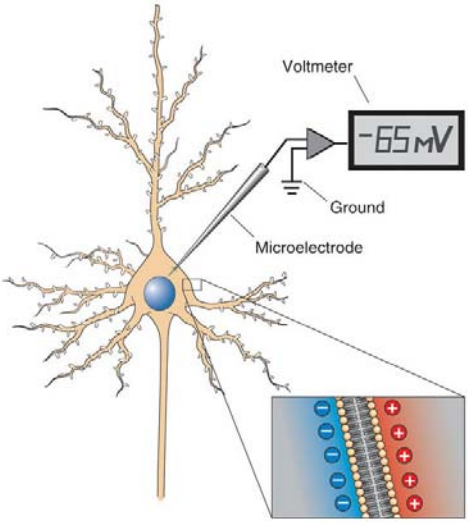
Nerve Impulses

- Resting neuron
  - The plasma membrane at rest is polarized
  - Fewer positive ions are inside the cell than outside the cell



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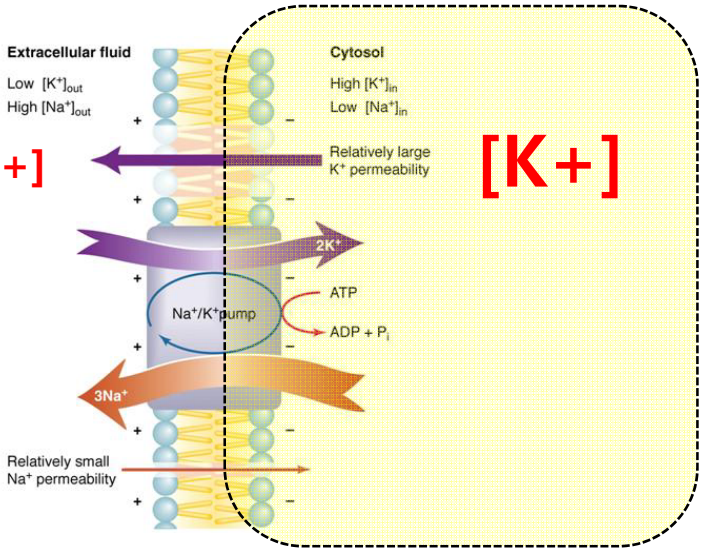
Resting Membrane Potential

[Na+]

[Ca2+]

[Cl-]



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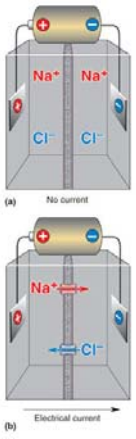
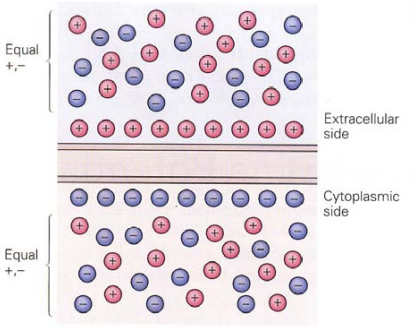
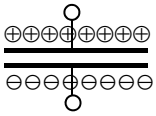
Equilibrium Potential: Selective Permeability







(Capacitance)

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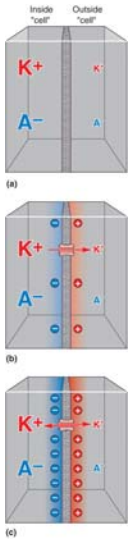
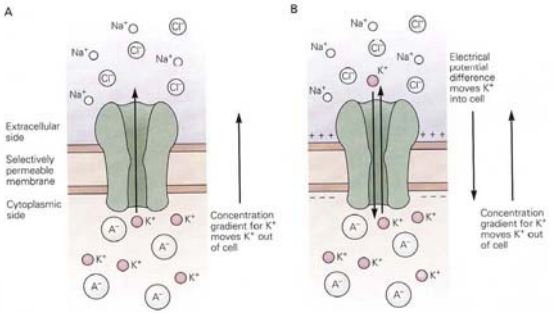
Equilibrium Potential





Equilibrium potential:
Chemical driving force = Electrical driving force

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Nernst Equation

(Equilibrium potential in Squid Giant Axon)

$$E_x = \frac{RT}{zF} \ln \frac{[X]_o}{[X]_i}$$

Ex) RT/F = 25mV at 25°C

$[K^+]_o$ = 20mM, $[K^+]_i$ = 400mM

$$E_K = \frac{58mV}{1} \log \frac{[20]}{[400]} = -75mv$$

E_{Na} = 55mV, $[Na^+]_o$ = 440mM, $[Na^+]_i$ = 50mM

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Goldman Equation

$$Vm = \frac{RT}{zF} \ln \frac{P_K[K]_o + P_{Na}[Na]_o + P_{Cl}[Cl]_i}{P_K[K]_i + P_{Na}[Na]_i + P_{Cl}[Cl]_o}$$

P: Permeability

Resting; P_K:P_{Na}:P_{Cl} = 1.0:0.04:0.45

= 1.0:20:0.45

(Action Potential)

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Nerve Impulses

- Resting neuron
  - The plasma membrane at rest is polarized
  - Fewer positive ions are inside the cell than outside the cell
- Depolarization
  - A stimulus depolarizes the neuron's membrane
  - A depolarized membrane allows sodium (Na+) to flow inside the membrane
- The exchange of ions initiates an action potential in the neuron

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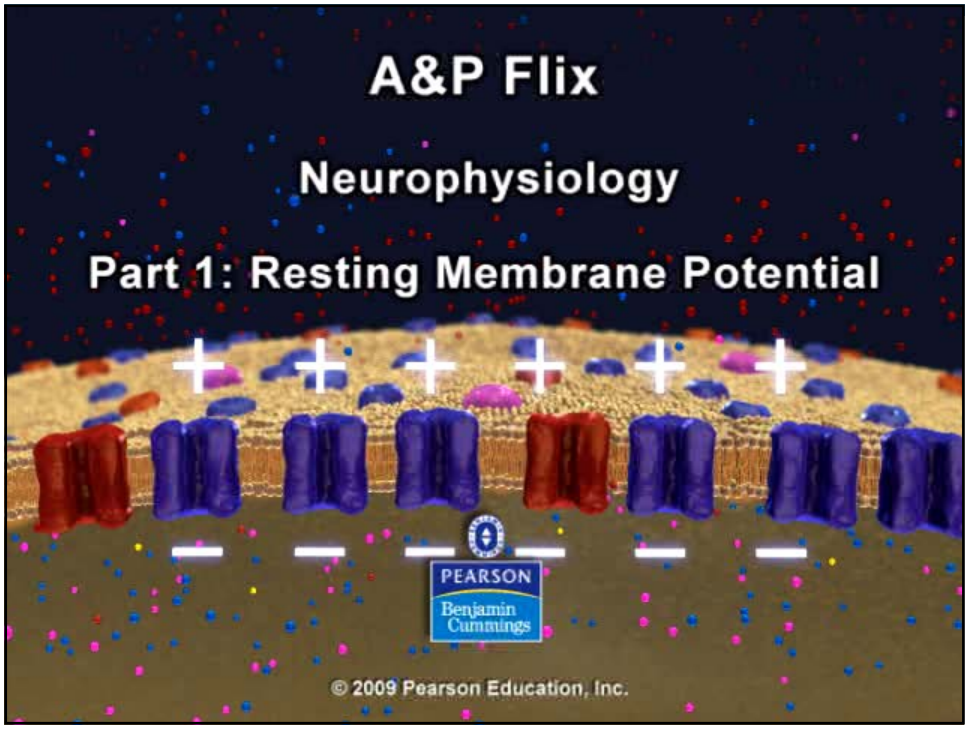

- Resting Membrane Potential
  http://bcs.whfreeman.com/thelifewire/content/chp44/4402001.html

- Action Potential
  http://bcs.whfreeman.com/thelifewire/content/chp44/4402002.html?v=chapter&i=44020.03&s=44000&n=00020&o=|00510|00570|00520|00530|00540|00550|00580|00130|00PRS|00560|00590|00030|00040|00050|00060|00070|00120|00080|00090|00100|00110|01000|02000|03000|04000|05000|06000|07000|08000|09000|10000|11000|12000|13000|14000|15000|16000|17000|18000|19000|20000|21000|22000|23000|24000|25000|26000|27000|28000|29000|30000|31000|32000|33000|34000|35000|36000|37000|38000|39000|40000|41000|42000|43000|44000|45000|46000|47000|48000|49000|50000|51000|52000|53000|54000|55000|56000|57000|58000|99000|00010|00020|

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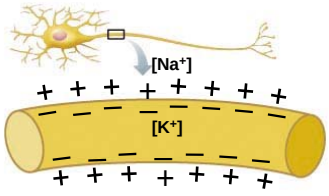

① Resting membrane is polarized. In the resting state, the external face of the membrane is slightly positive; its internal face is slightly negative. The chief extracellular ion is sodium (Na^+), whereas the chief intracellular ion is potassium (K^+). The membrane is relatively impermeable to both ions.

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Figure 7.9, step 1

Nerve Impulses

- Depolarization
  - A stimulus depolarizes the neuron's membrane
  - The membrane is now permeable to sodium as sodium channels open
  - A depolarized membrane allows sodium (Na^+) to flow inside the membrane

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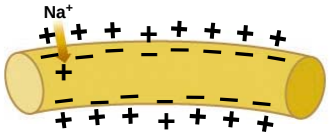

② Stimulus initiates local depolarization. A stimulus changes the permeability of a local "patch" of the membrane, and sodium ions diffuse rapidly into the cell. This changes the polarity of the membrane (the inside becomes more positive; the outside becomes more negative) at that site.

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Figure 7.9, step 2

Nerve Impulses

- Action potential
  - The movement of ions initiates an action potential in the neuron due to a stimulus
  - A graded potential (localized depolarization) exists where the inside of the membrane is more positive and the outside is less positive

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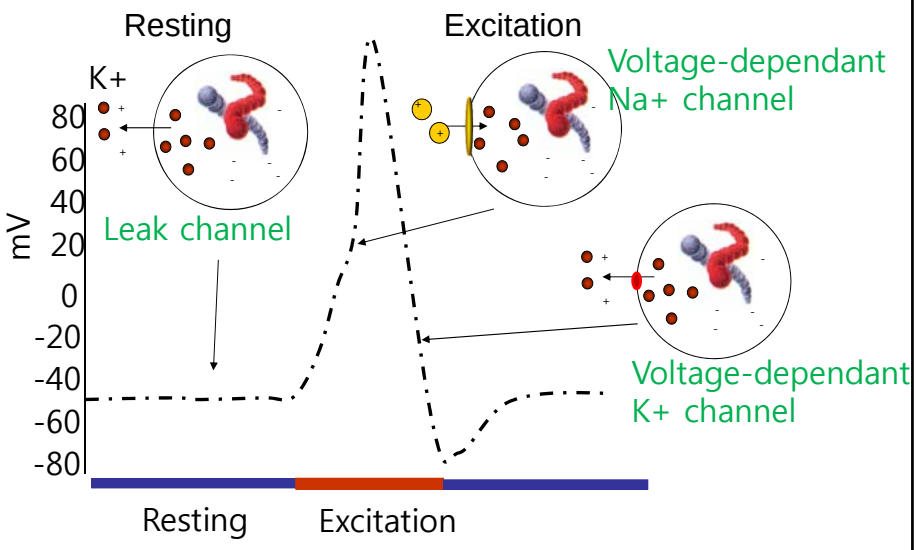
Neuronal Signal (= Action Potential)



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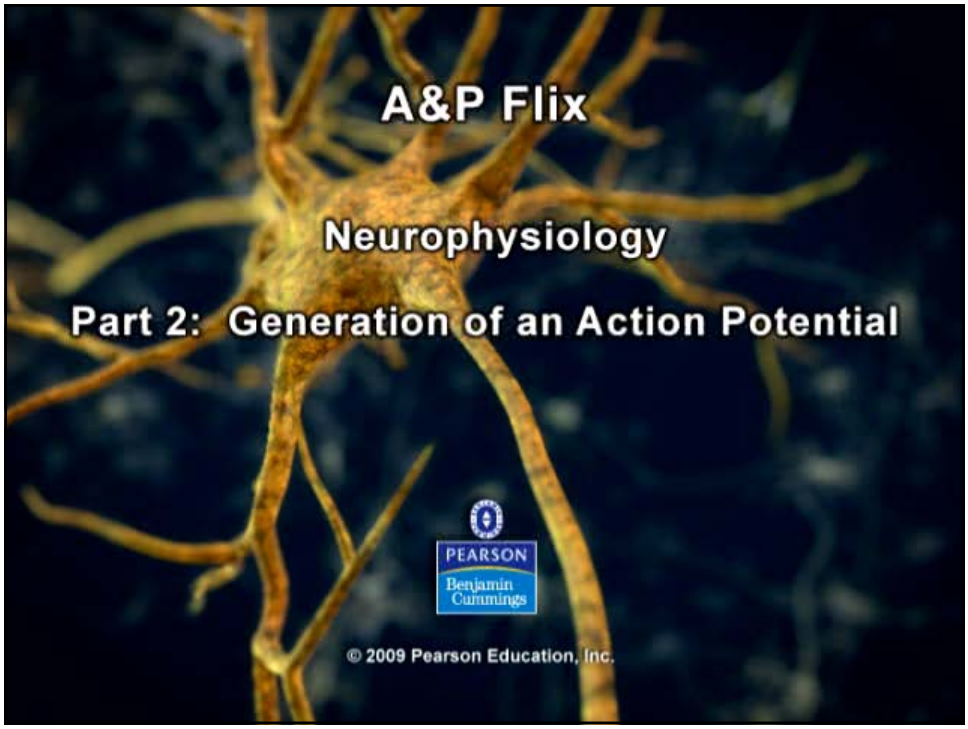

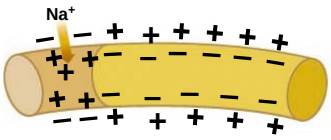

③ **Depolarization and generation of an action potential. If the stimulus is strong enough, depolarization causes membrane polarity to be completely reversed and an action potential is initiated.**

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Figure 7.9, step 3

Nerve Impulses

- Propagation of the action potential
  - If enough sodium enters the cell, the action potential (nerve impulse) starts and is propagated over the entire axon
  - Impulses travel faster when fibers have a myelin sheath

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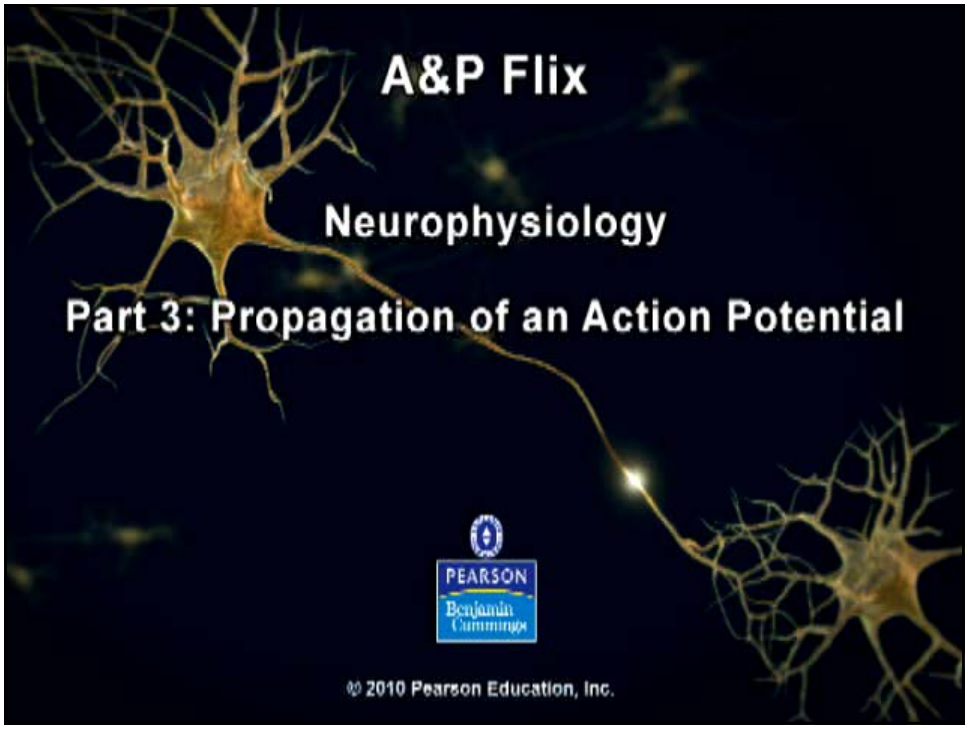

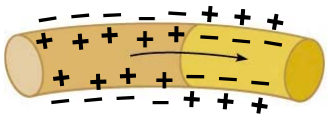

④ Propagation of the action potential. Depolarization of the first membrane patch causes permeability changes in the adjacent membrane, and the events described in step ② are repeated. Thus, the action potential propagates rapidly along the entire length of the membrane.

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Figure 7.9, step 4

Nerve Impulses

- Repolarization
  - Potassium ions rush out of the neuron after sodium ions rush in, which repolarizes the membrane
  - Repolarization involves restoring the inside of the membrane to a negative charge and the outer surface to a positive charge

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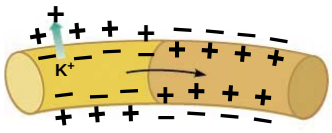

⑤ **Repolarization. Potassium ions diffuse out of the cell as the membrane permeability changes again, restoring the negative charge on the inside of the membrane and the positive charge on the outside surface. Repolarization occurs in the same direction as depolarization.**

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Figure 7.9, step 5

Nerve Impulses

- Repolarization
  - Initial ionic conditions are restored using the sodium-potassium pump.
  - This pump, using ATP, restores the original configuration
  - Three sodium ions are ejected from the cell while two potassium ions are returned to the cell

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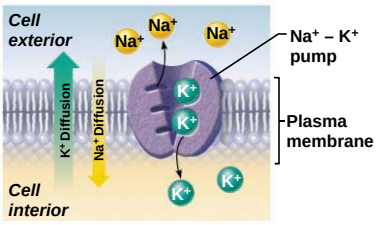

⑥ **Initial ionic conditions restored. The ionic conditions of the resting state are restored later by the activity of the sodium-potassium pump. Three sodium ions are ejected for every two potassium ions carried back into the cell.**

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Figure 7.9, step 6

Transmission of a Signal at Synapses

- When the action potential reaches the axon terminal, the electrical charge opens calcium channels

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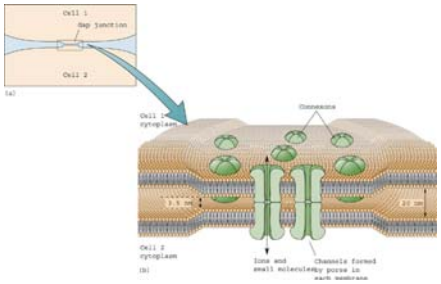
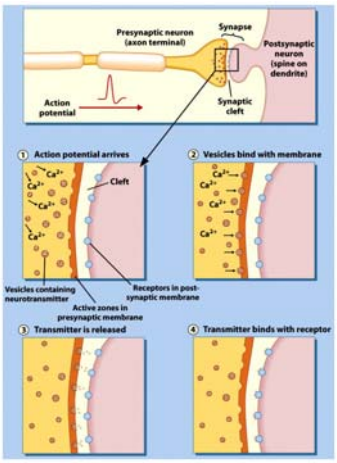
SYNAPTIC TRANSMISSION

- **Electrical: gap junction**
- **Chemical**





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Electrical synapse

- Gap junction
- Cytoplasmic continuity
- Bidirectional
- Instantaneous signal transmission
- Gap junction channel: connexon (6 connexin)

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Chemical synapse

- Amplify signal
- Cytoplasmic discontinuity
- Unidirectional ?
- Synaptic delay
- Active zone
- Neurotransmitter

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- Synaptic transmission

http://bcs.whfreeman.com/thelifewire/content/chp44/4402003.html?v=chapter&i=44020.04&s=44000&n=00020&o=|00510|00570|00520|00530|00540|00550|00580|00130|00PRS|00560|00590|00030|00040|00050|00060|00070|00120|00080|00090|00100|00110|01000|02000|03000|04000|05000|06000|07000|08000|09000|10000|11000|12000|13000|14000|15000|16000|17000|18000|19000|20000|21000|22000|23000|24000|25000|26000|27000|28000|29000|30000|31000|32000|33000|34000|35000|36000|37000|38000|39000|40000|41000|42000|43000|44000|45000|46000|47000|48000|49000|50000|51000|52000|53000|54000|55000|56000|57000|58000|99000|00010|00020|

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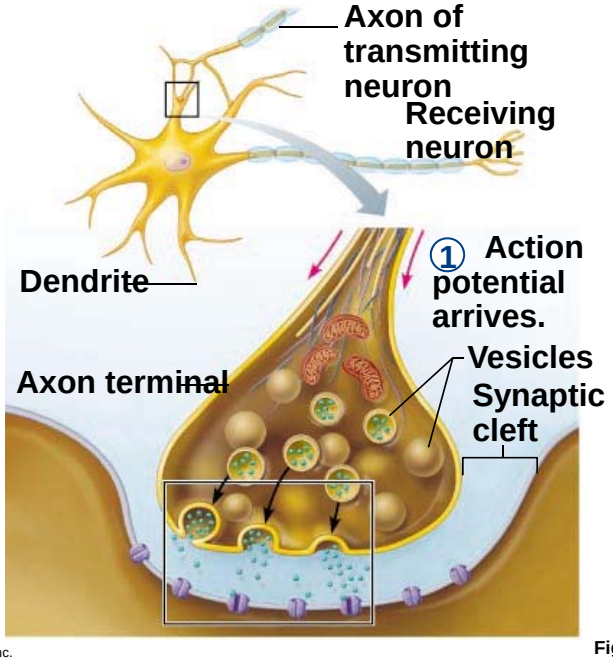

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Figure 7.10, step 1

Transmission of a Signal at Synapses

- Calcium, in turn, causes the tiny vesicles containing the neurotransmitter chemical to fuse with the axonal membrane

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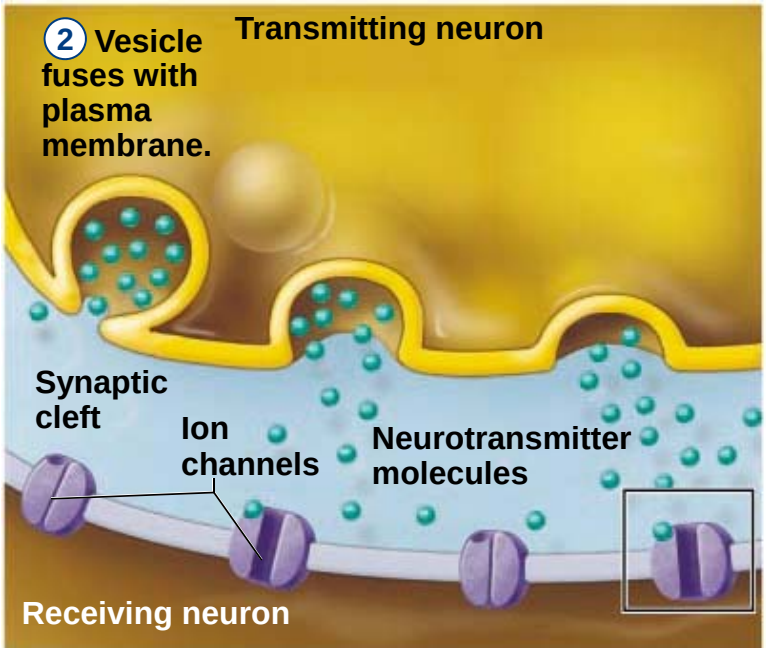

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Figure 7.10, step 2

Transmission of a Signal at Synapses

- The entry of calcium into the axon terminal causes porelike openings to form, releasing the transmitter

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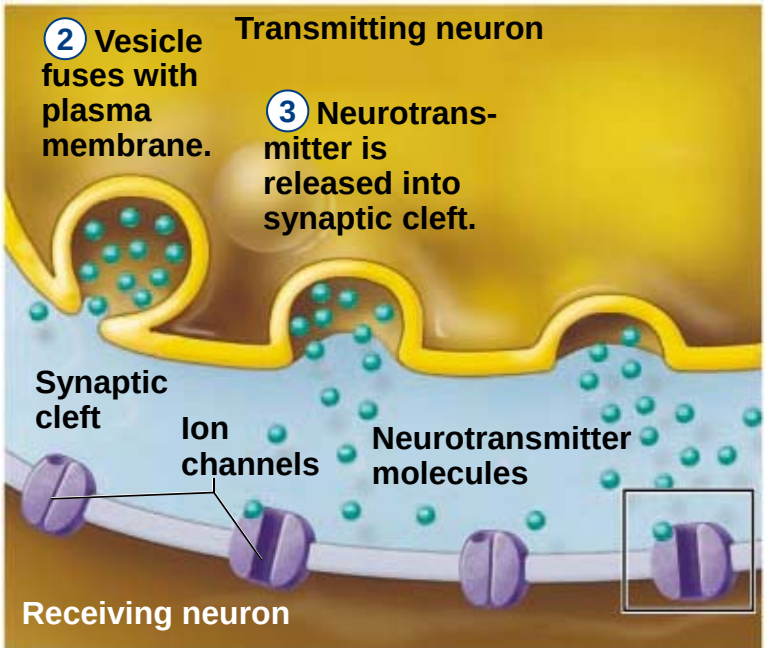

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Figure 7.10, step 3

Transmission of a Signal at Synapses

- The neurotransmitter molecules diffuse across the synapse and bind to receptors on the membrane of the next neuron

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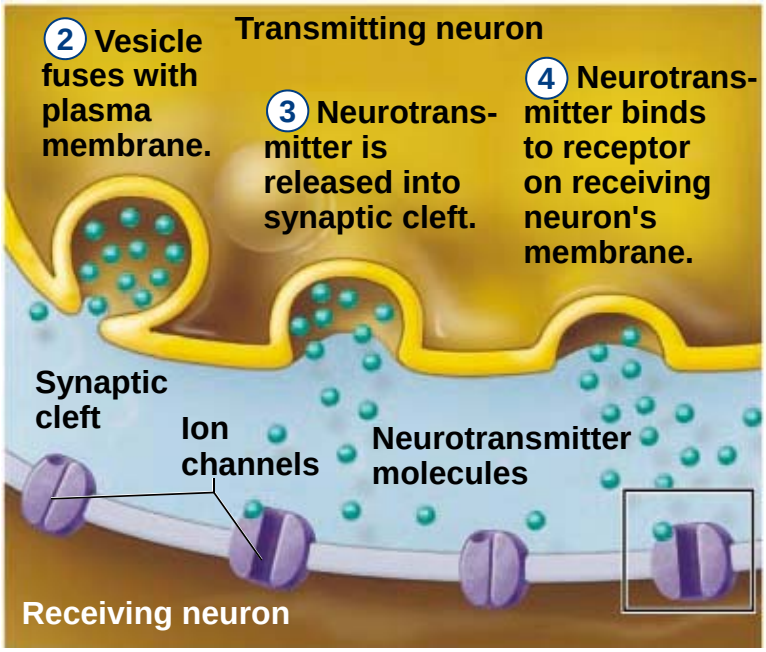

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Figure 7.10, step 4

Transmission of a Signal at Synapses

- If enough neurotransmitter is released, graded potential will be generated
- Eventually an action potential (nerve impulse) will occur in the neuron beyond the synapse

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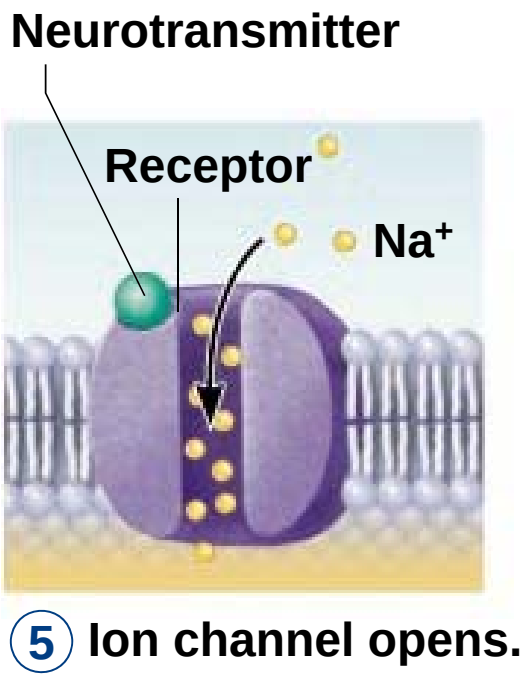

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Figure 7.10, step 5

Transmission of a Signal at Synapses

- The electrical changes prompted by neurotransmitter binding are brief
- The neurotransmitter is quickly removed from the synapse

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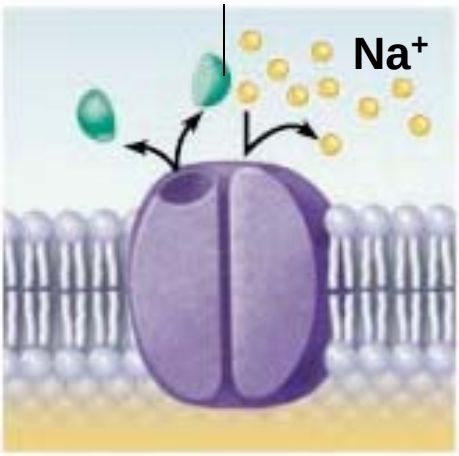
Neurotransmitter is broken down and released.



6 Ion channel closes.

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Figure 7.10, step 6

The Reflex Arc

- Reflex—rapid, predictable, and involuntary response to a stimulus
  - Occurs over pathways called reflex arcs
- Reflex arc—direct route from a sensory neuron, to an interneuron, to an effector

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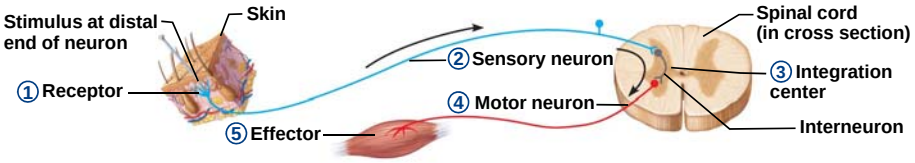

(a) Five basic elements of reflex arc

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Figure 7.11a

The Reflex Arc

- Somatic reflexes
  - Reflexes that stimulate the skeletal muscles
  - **Example:** pull your hand away from a hot object
- Autonomic reflexes
  - Regulate the activity of smooth muscles, the heart, and glands
  - **Example:** Regulation of smooth muscles, heart and blood pressure, glands, digestive system

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The Reflex Arc

- Five elements of a reflex:
  - Sensory receptor–reacts to a stimulus
  - Sensory neuron–carries message to the integration center
  - Integration center (CNS)–processes information and directs motor output
  - Motor neuron–carries message to an effector
  - Effector organ–is the muscle or gland to be stimulated

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Two-Neuron Reflex Arc

- Two-neuron reflex arcs
  - Simplest type
  - **Example:** Patellar (knee-jerk) reflex

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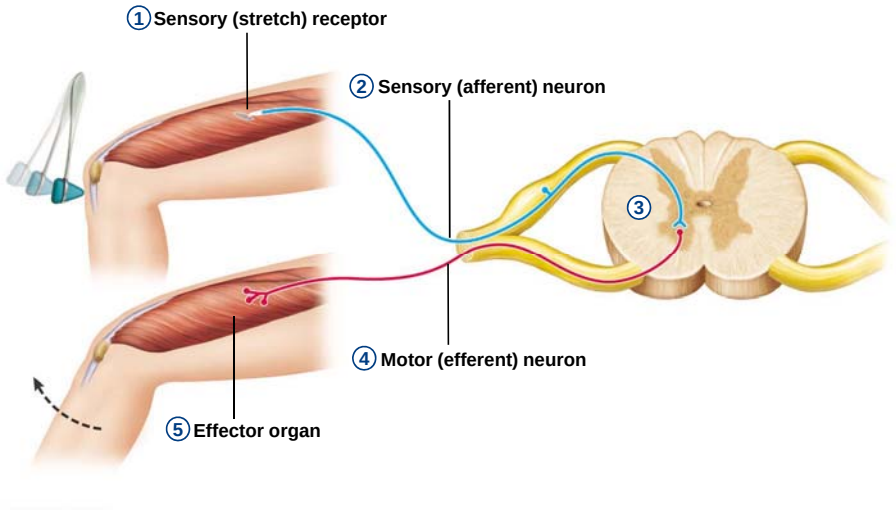

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Figure 7.11b

Three-Neuron Reflex Arc

- Three-neuron reflex arcs
  - Consists of five elements: receptor, sensory neuron, interneuron, motor neuron, and effector
  - **Example:** Flexor (withdrawal) reflex

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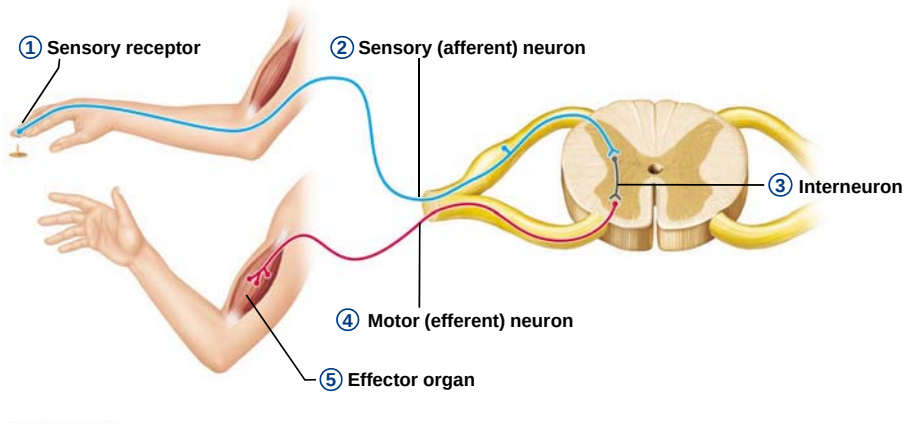

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Figure 7.11c, step 5

Central Nervous System (CNS)

- CNS develops from the embryonic neural tube
  - The neural tube becomes the brain and spinal cord
  - The opening of the neural tube becomes the ventricles
    - Four chambers within the brain
    - Filled with cerebrospinal fluid

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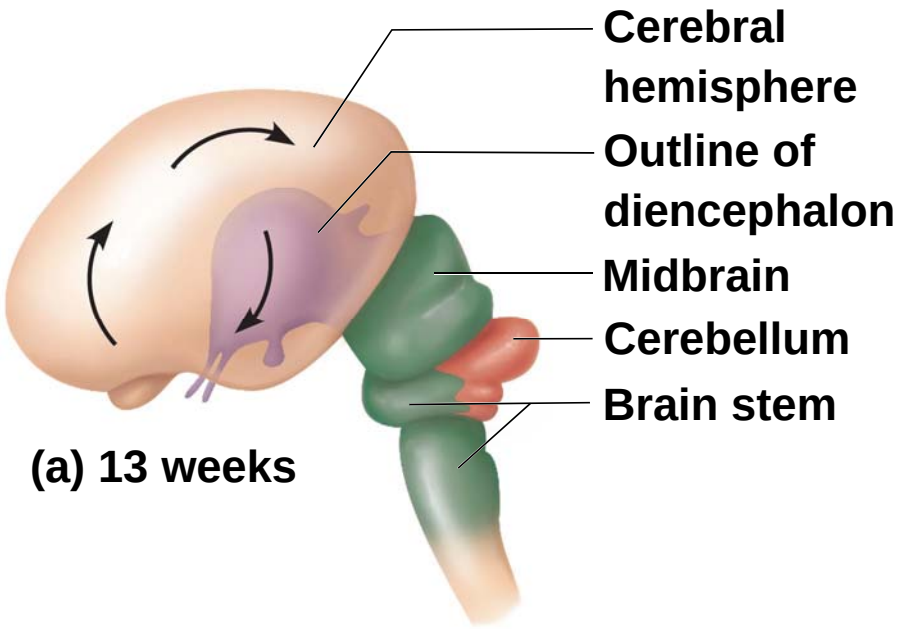

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Figure 7.12a

Regions of the Brain

- Cerebral hemispheres (cerebrum)
- Diencephalon
- Brain stem
- Cerebellum

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Figure AB-26: Build A Brain, Step 1

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Figure AB-27: Build A Brain, Step 2

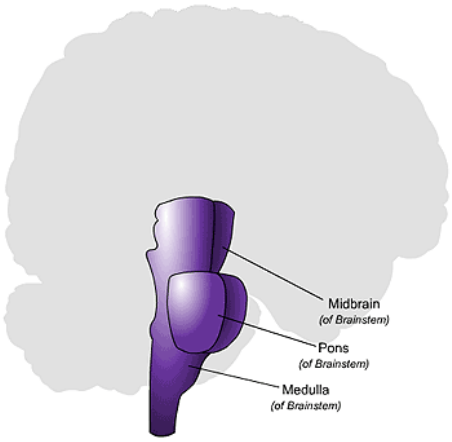

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Figure AB-28: Build A Brain, Step 3

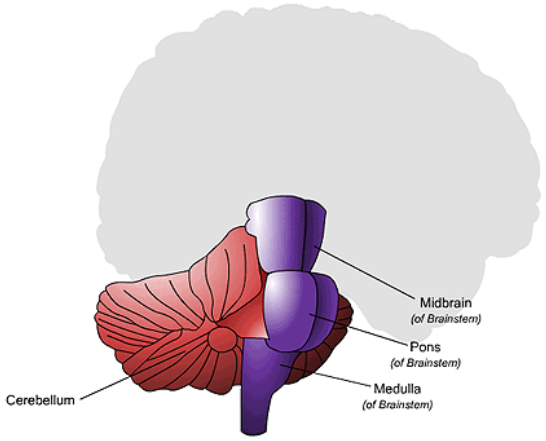

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Figure AB-29: Build A Brain, Step 4

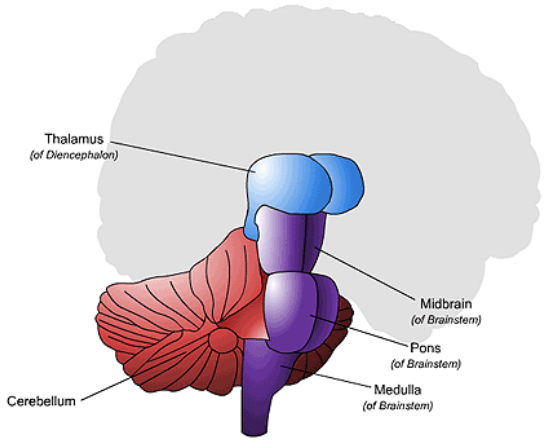

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Figure AB-30: Build A Brain, Step 5

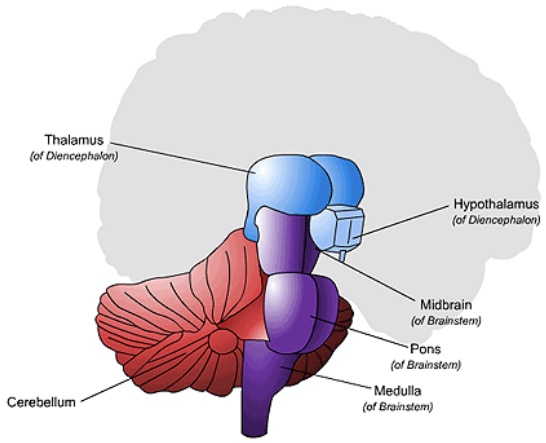

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Figure AB-31: Build A Brain, Step 6

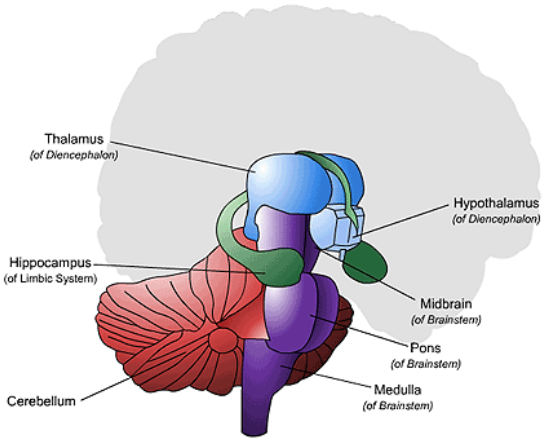

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Figure AB-32: Build A Brain, Step 7

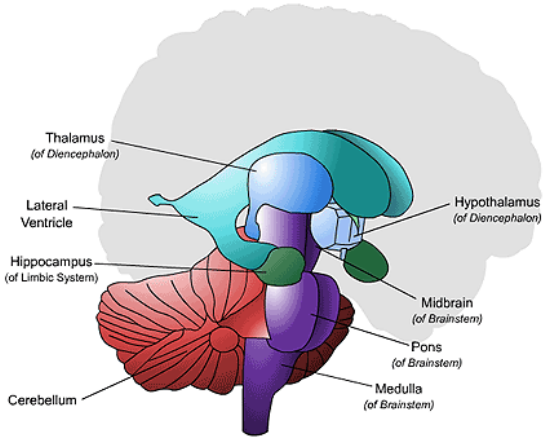

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Figure AB-33: Build A Brain, Step 8

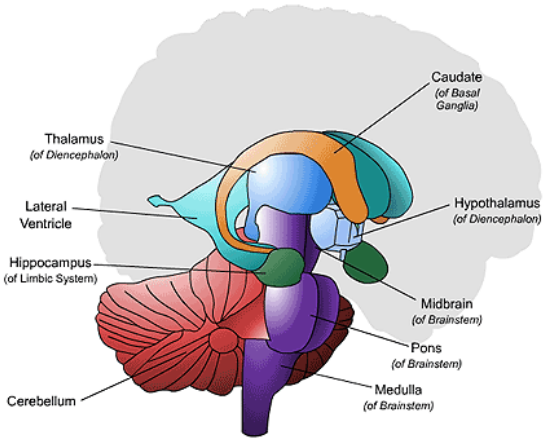

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Figure AB-34: Build A Brain, Step 9

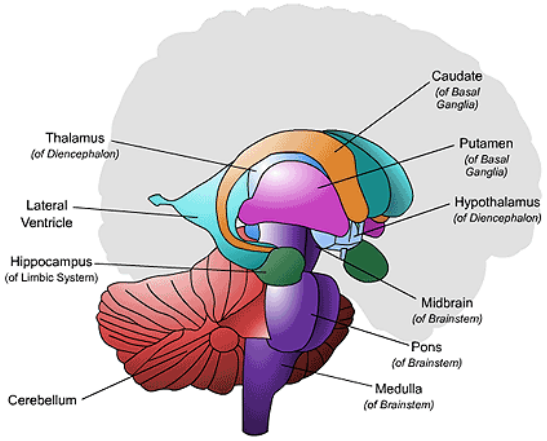

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Figure AB-34: Build A Brain, Step 9

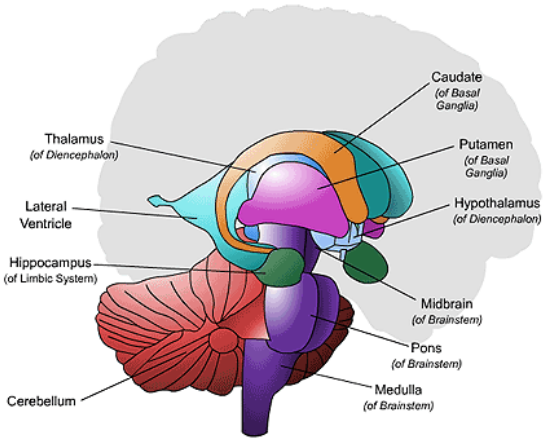

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Figure AB-35: Build A Brain, Step 10

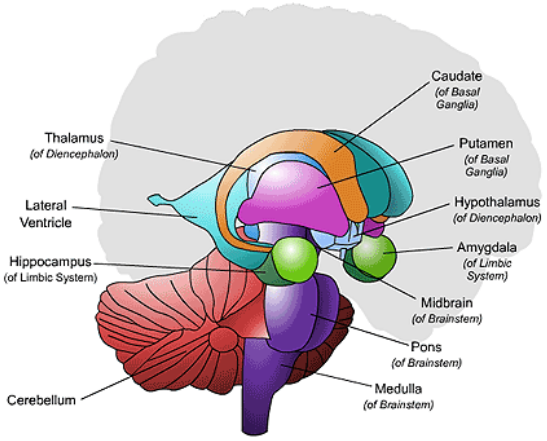

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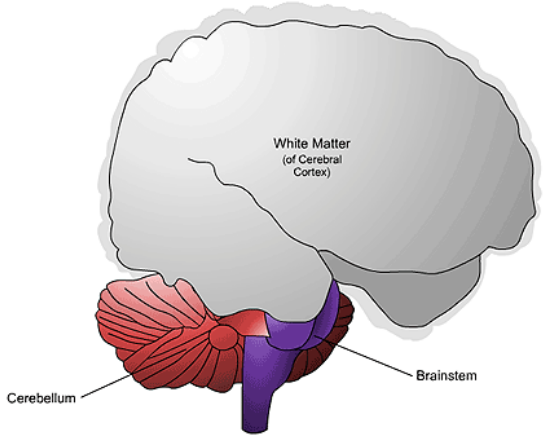
Figure AB-36: Build A Brain, Step 11



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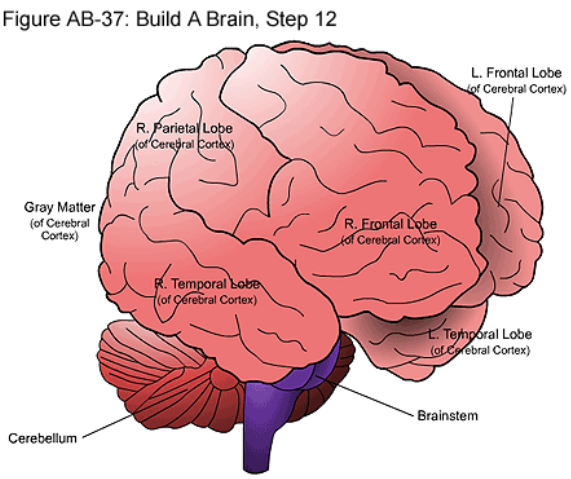

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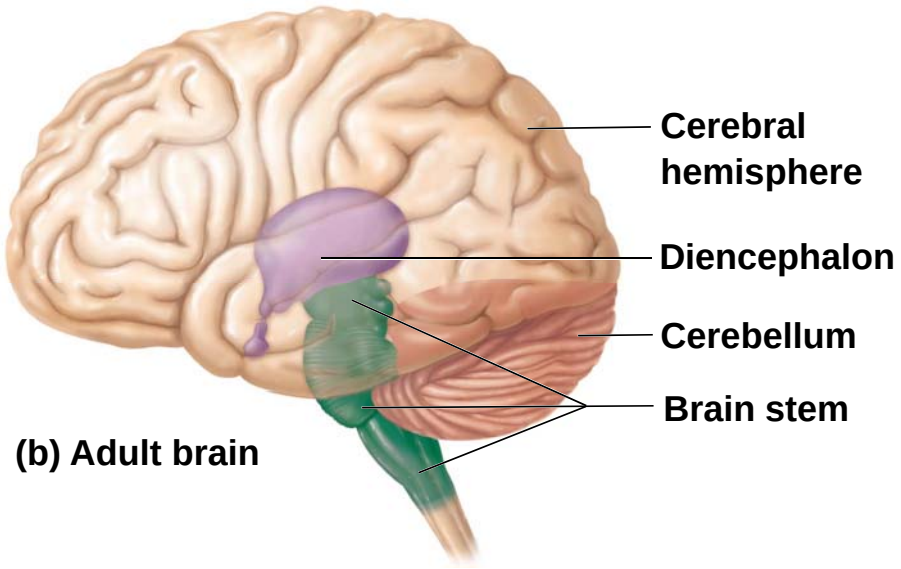

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Figure 7.12b

Regions of the Brain: Cerebrum

- Cerebral Hemispheres (Cerebrum)
  - Paired (left and right) superior parts of the brain
  - Includes more than half of the brain mass
  - The surface is made of ridges (gyri) and grooves (sulci)

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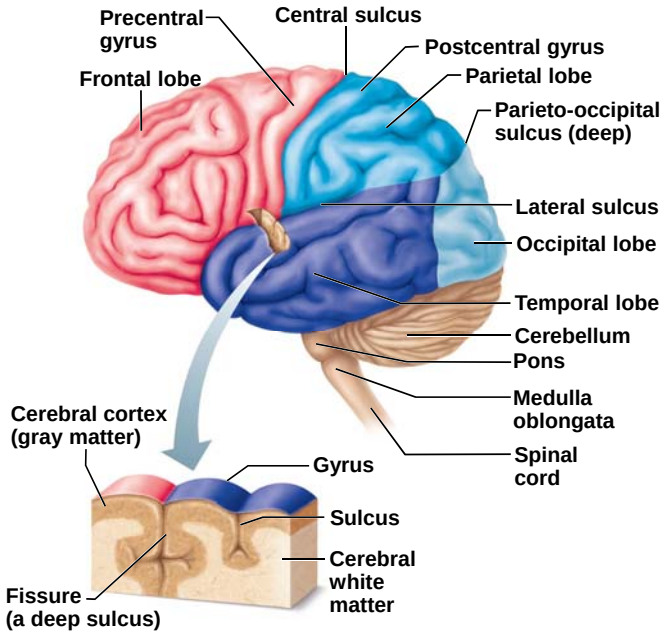

(a)

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Figure 7.13a

Regions of the Brain: Cerebrum

- Lobes of the cerebrum
  - Fissures (deep grooves) divide the cerebrum into lobes
  - Surface lobes of the cerebrum
    - Frontal lobe
    - Parietal lobe
    - Occipital lobe
    - Temporal lobe

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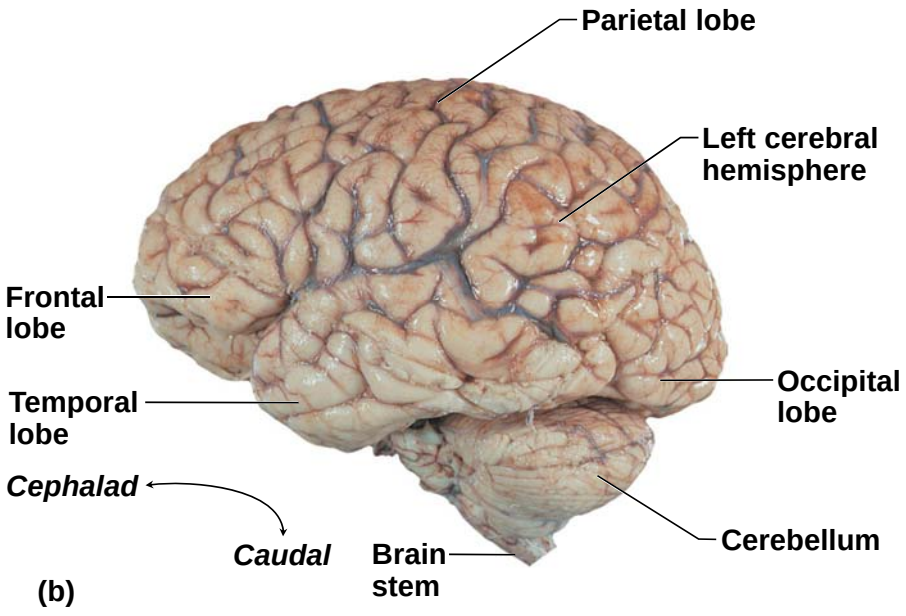

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Figure 7.13b

Regions of the Brain: Cerebrum

- Specialized areas of the cerebrum
  - Primary somatic sensory area
    - Receives impulses from the body's sensory receptors
    - Located in parietal lobe
  - Primary motor area
    - Sends impulses to skeletal muscles
    - Located in frontal lobe
  - Broca's area
    - Involved in our ability to speak

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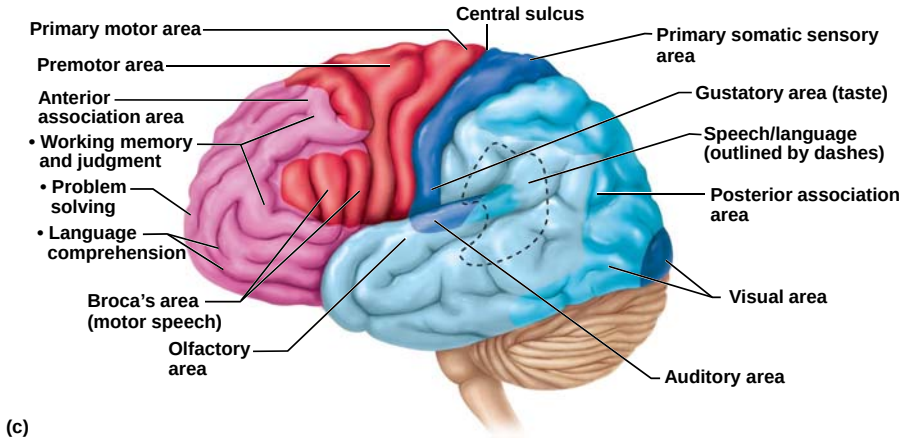

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Figure 7.13c

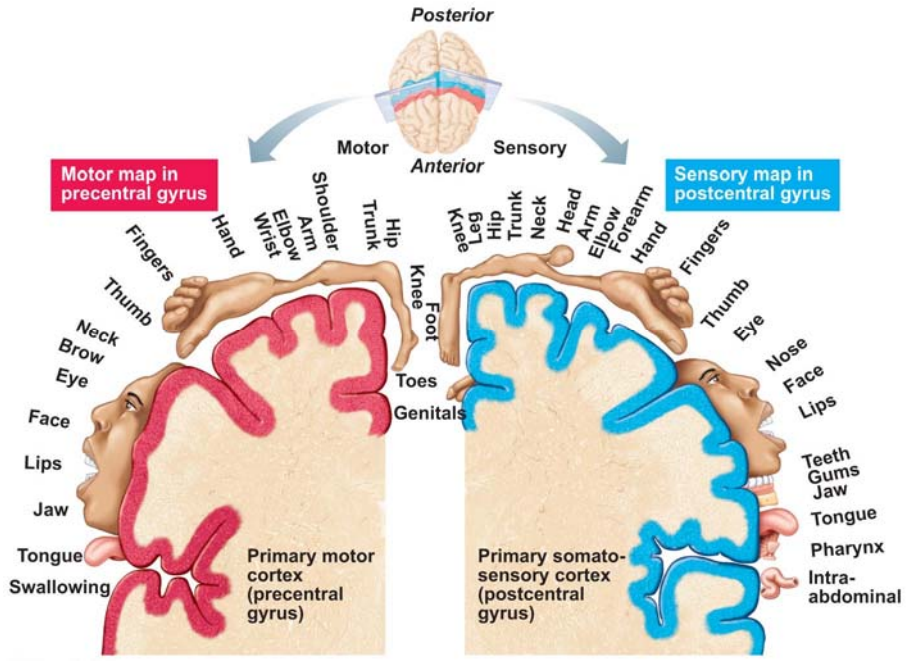

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Figure 7.14

Regions of the Brain: Cerebrum

- Cerebral areas involved in special senses
  - Gustatory area (taste)
  - Visual area
  - Auditory area
  - Olfactory area

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Regions of the Brain: Cerebrum

- Interpretation areas of the cerebrum
  - Speech/language region
  - Language comprehension region
  - General interpretation area

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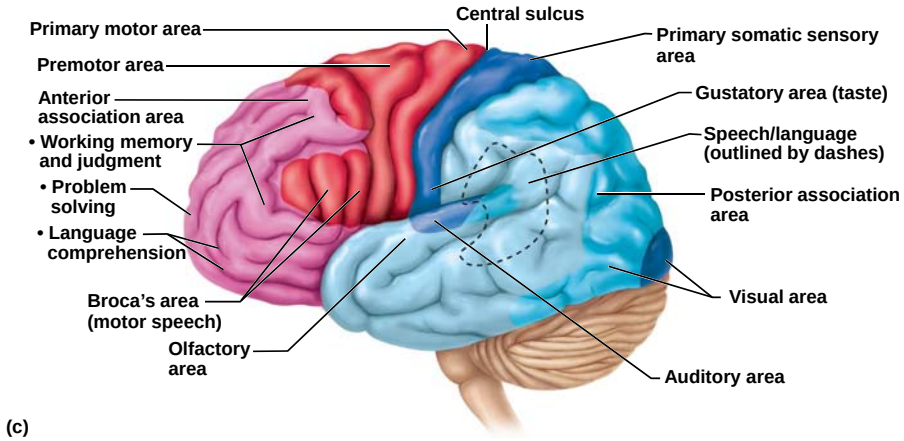

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Figure 7.13c

Regions of the Brain: Cerebrum

- Layers of the cerebrum
  - Gray matter—outer layer in the cerebral cortex composed mostly of neuron cell bodies
  - White matter—fiber tracts deep to the gray matter
    - Corpus callosum connects hemispheres
- Basal nuclei—islands of gray matter buried within the white matter

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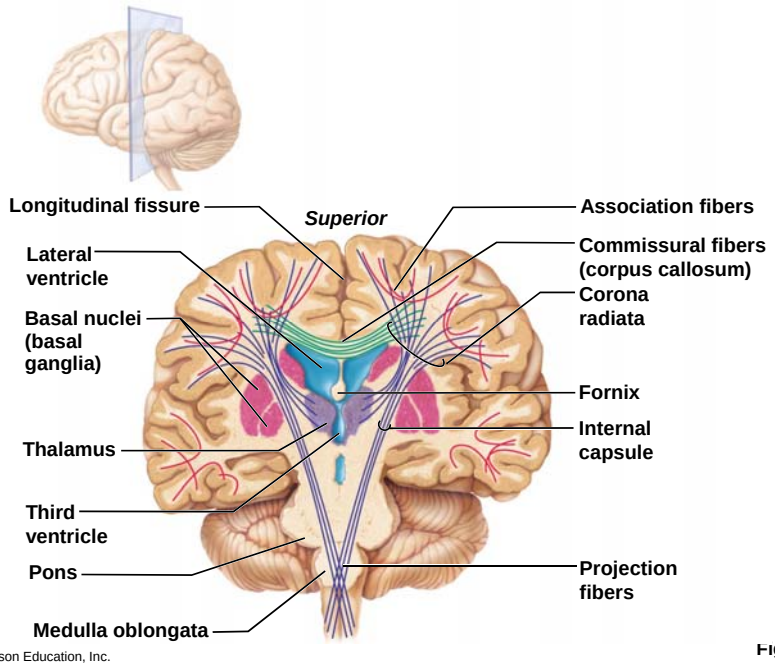

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Figure 7.15

Regions of the Brain: Diencephalon

- Sits on top of the brain stem
- Enclosed by the cerebral hemispheres
- Made of three parts
  - Thalamus
  - Hypothalamus
  - Epithalamus

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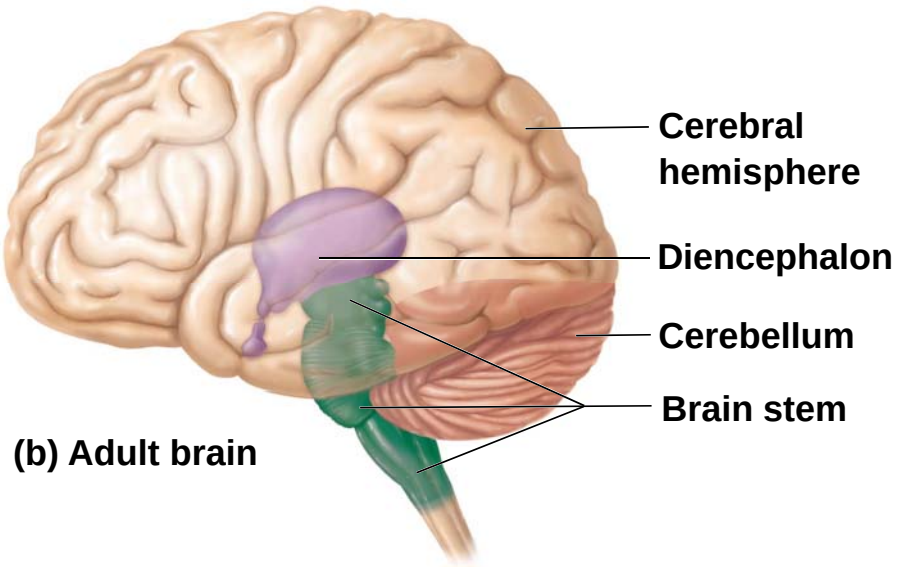

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Figure 7.12b

Regions of the Brain: Diencephalon

- Thalamus
  - Surrounds the third ventricle
  - The relay station for sensory impulses
  - Transfers impulses to the correct part of the cortex for localization and interpretation

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Regions of the Brain: Diencephalon

- Hypothalamus
  - Under the thalamus
  - Important autonomic nervous system center
    - Helps regulate body temperature
    - Controls water balance
    - Regulates metabolism
  - Houses the limbic center for emotions
  - Regulates the nearby pituitary gland
    - Produces two hormones of its own

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Regions of the Brain: Diencephalon

- Epithalamus
  - Forms the roof of the third ventricle
  - Houses the pineal body (an endocrine gland)
  - Includes the choroid plexus—forms cerebrospinal fluid

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Regions of the Brain: Brain Stem

- Attaches to the spinal cord
- Parts of the brain stem
  - Midbrain
  - Pons
  - Medulla oblongata

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Regions of the Brain: Brain Stem

- Midbrain
  - Mostly composed of tracts of nerve fibers
  - Has two bulging fiber tracts—cerebral peduncles
  - Has four rounded protrusions—corpora quadrigemina
    - Reflex centers for vision and hearing

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Regions of the Brain: Brain Stem

- Pons
  - The bulging center part of the brain stem
  - Mostly composed of fiber tracts
  - Includes nuclei involved in the control of breathing

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Regions of the Brain: Brain Stem

- Medulla oblongata
  - The lowest part of the brain stem
  - Merges into the spinal cord
  - Includes important fiber tracts
  - Contains important control centers
    - Heart rate control
    - Blood pressure regulation
    - Breathing
    - Swallowing
    - Vomiting

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Regions of the Brain: Brain Stem

- Reticular Formation
  - Diffuse mass of gray matter along the brain stem
  - Involved in motor control of visceral organs
  - Reticular activating system (RAS) plays a role in awake/sleep cycles and consciousness

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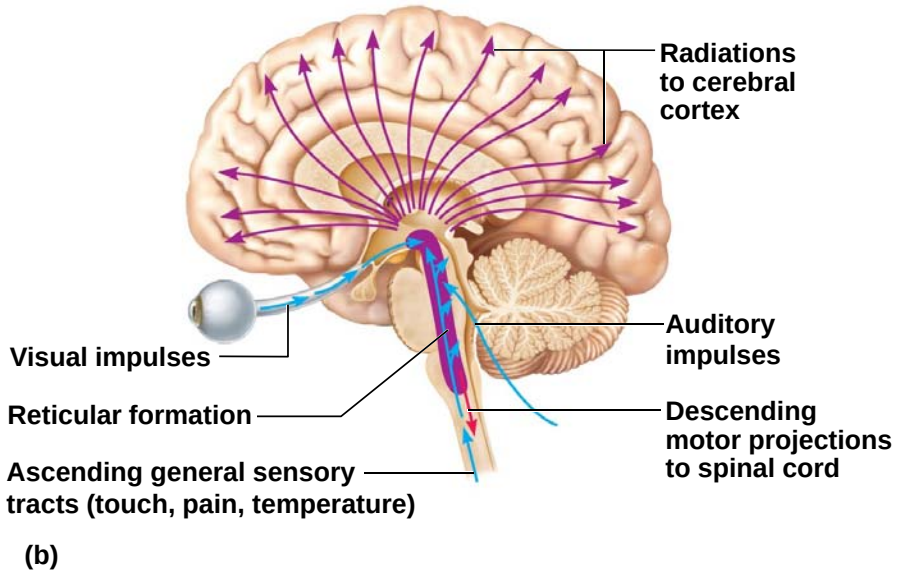

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Figure 7.16b

Regions of the Brain: Cerebellum

- Two hemispheres with convoluted surfaces
- Provides involuntary coordination of body movements

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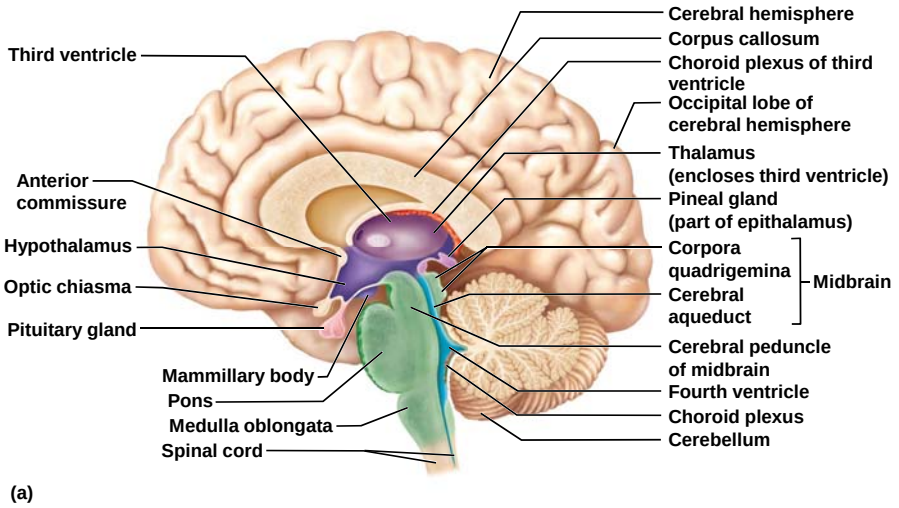

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Figure 7.16a

Protection of the Central Nervous System

- Scalp and skin
- Skull and vertebral column
- Meninges
- Cerebrospinal fluid (CSF)
- Blood-brain barrier

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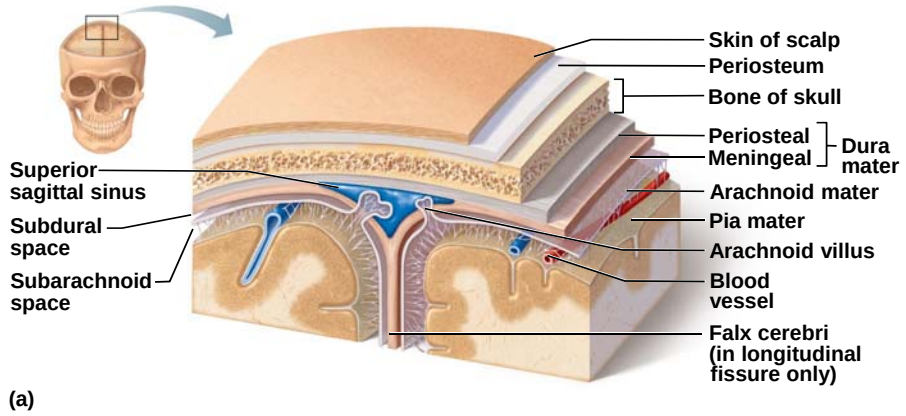

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Figure 7.17a

Meninges

- Dura mater
  - Tough outermost layer
  - Double-layered external covering
    - Periosteum—attached to inner surface of the skull
    - Meningeal layer—outer covering of the brain
  - Folds inward in several areas
    - Falx cerebri
    - Tentorium cerebelli

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Meninges

- Arachnoid layer
  - Middle layer
  - Web-like extensions span the subarachnoid space
  - Arachnoid villi reabsorb cerebrospinal fluid
- Pia mater
  - Internal layer
  - Clings to the surface of the brain

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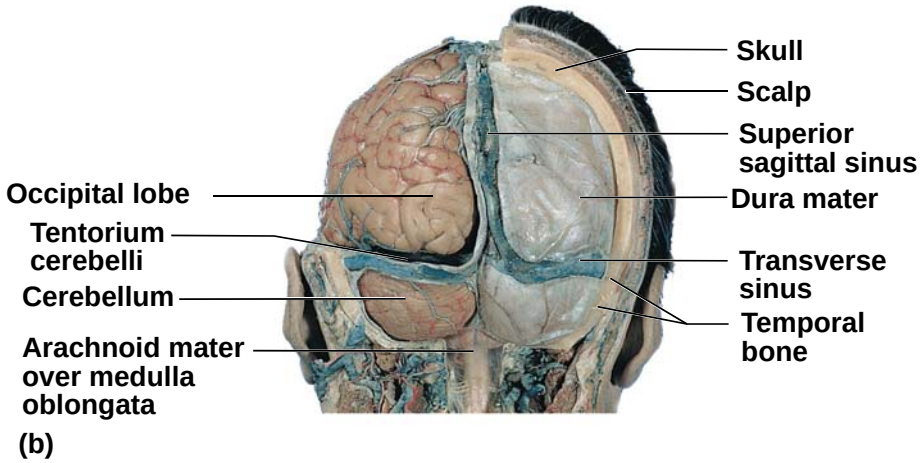

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Figure 7.17b

Cerebrospinal Fluid (CSF)

- Similar to blood plasma composition
- Formed by the choroid plexus
  - Choroid plexuses–capillaries in the ventricles of the brain
- Forms a watery cushion to protect the brain
- Circulated in arachnoid space, ventricles, and central canal of the spinal cord

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Cerebrospinal Fluid (CSF) Pathway of Flow

1. CSF is produced by the choroid plexus of each ventricle.
2. CSF flows through the ventricles and into the subarachnoid space via the median and lateral apertures. Some CSF flows through the central canal of the spinal cord.
3. CSF flows through the subarachnoid space.
4. CSF is absorbed into the dural venous sinuses via the arachnoid villi.

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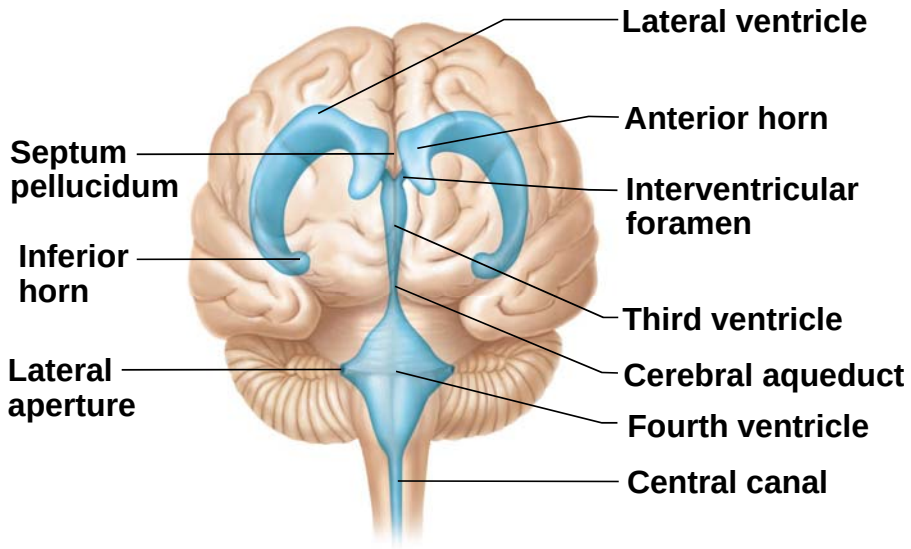

(a) Anterior view

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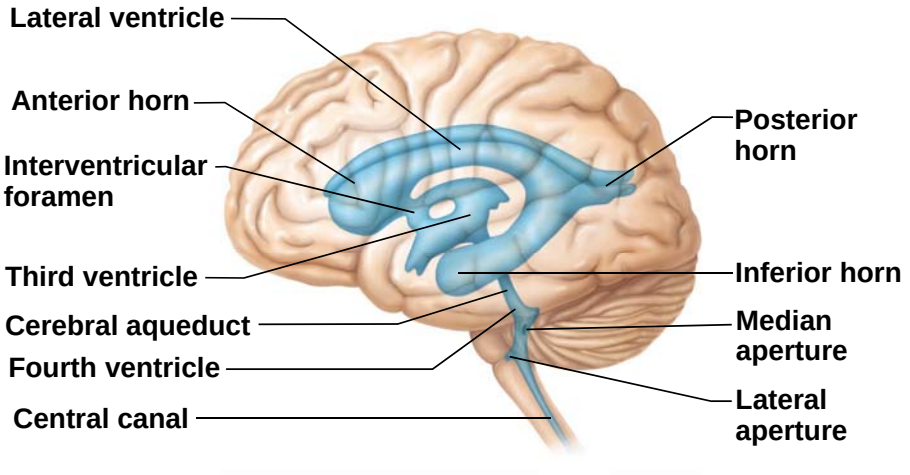
Figure 7.18a



(b) Left lateral view

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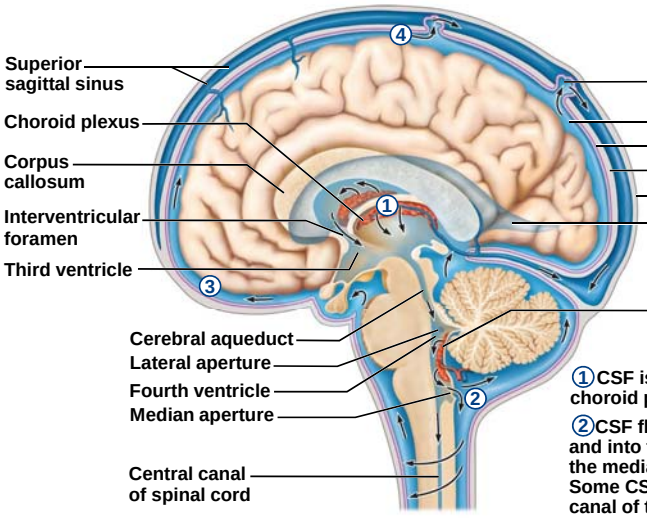
Figure 7.18b



(c) CSF circulation

①CSF is produced by the choroid plexus of each ventricle.

②CSF flows through the ventricles and into the subarachnoid space via the median and lateral apertures. Some CSF flows through the central canal of the spinal cord.

③CSF flows through the subarachnoid space.

④CSF is absorbed into the dural venous sinuses via the arachnoid villi.

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Figure 7.18c

Hydrocephalus in a Newborn

- Hydrocephalus
  - CSF accumulates and exerts pressure on the brain if not allowed to drain
  - Possible in an infant because the skull bones have not yet fused
  - In adults, this situation results in brain damage

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Figure 7.19

Blood-Brain Barrier

- Includes the least permeable capillaries of the body
- Excludes many potentially harmful substances
- Useless as a barrier against some substances
  - Fats and fat soluble molecules
  - Respiratory gases
  - Alcohol
  - Nicotine
  - Anesthesia

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Traumatic Brain Injuries

- Concussion
  - Slight brain injury
  - No permanent brain damage
- Contusion
  - Nervous tissue destruction occurs
  - Nervous tissue does not regenerate
- Cerebral edema
  - Swelling from the inflammatory response
  - May compress and kill brain tissue

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Cerebrovascular Accident (CVA) or Stroke

- Result from a ruptured blood vessel supplying a region of the brain
- Brain tissue supplied with oxygen from that blood source dies
- Loss of some functions or death may result
  - Hemiplegia–One-sided paralysis
  - Aphasis–Damage to speech center in left hemisphere
- Transischemia-attack (TIA)–temporary brain ischemia (restriction of blood flow)
  - Warning signs for more serious CVAs

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Alzheimer's Disease

- Progressive degenerative brain disease
- Mostly seen in the elderly, but may begin in middle age
- Structural changes in the brain include abnormal protein deposits and twisted fibers within neurons
- Victims experience memory loss, irritability, confusion, and ultimately, hallucinations and death

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Spinal Cord

- Extends from the foramen magnum of the skull to the first or second lumbar vertebra
- Provides a two-way conduction pathway from the brain to and from the brain
- 31 pairs of spinal nerves arise from the spinal cord
- Cauda equina is a collection of spinal nerves at the inferior end

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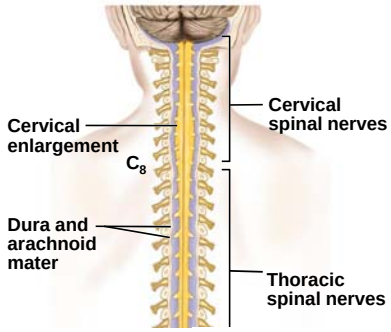

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Figure 7.20 (1 of 2)

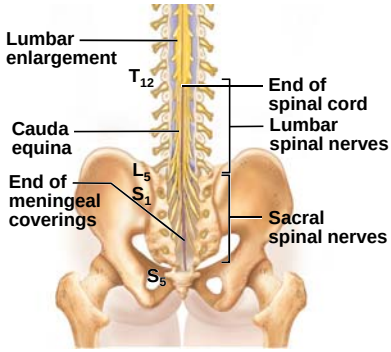

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Figure 7.20 (2 of 2)

Spinal Cord Anatomy

- Internal gray matter is mostly cell bodies
  - Dorsal (posterior) horns
  - Anterior (ventral) horns
  - Gray matter surrounds the central canal
    - Central canal is filled with cerebrospinal fluid
- Exterior white mater—conduction tracts
  - Dorsal, lateral, ventral columns

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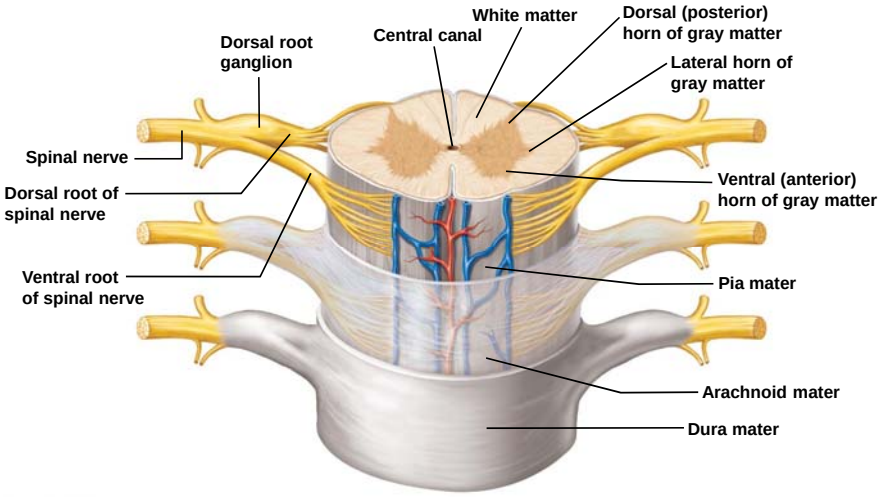

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Figure 7.21

Spinal Cord Anatomy

- Meninges cover the spinal cord
- Spinal nerves leave at the level of each vertebrae
  - Dorsal root
    - Associated with the dorsal root ganglia—collections of cell bodies outside the central nervous system
  - Ventral root
    - Contains axons

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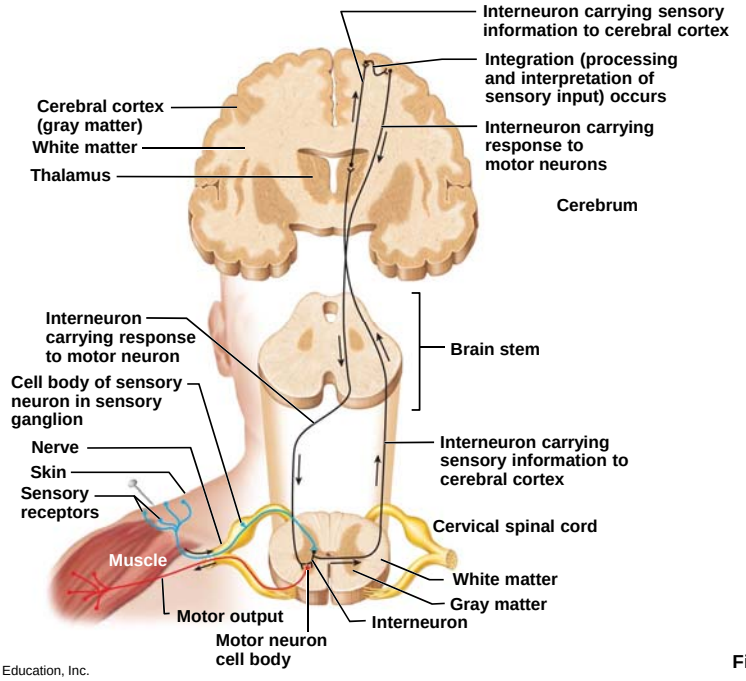

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Figure 7.22

Peripheral Nervous System (PNS)

- Nerves and ganglia outside the central nervous system
- Nerve = bundle of neuron fibers
- Neuron fibers are bundled by connective tissue

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PNS: Structure of a Nerve

- Endoneurium surrounds each fiber
- Groups of fibers are bound into fascicles by perineurium
- Fascicles are bound together by epineurium

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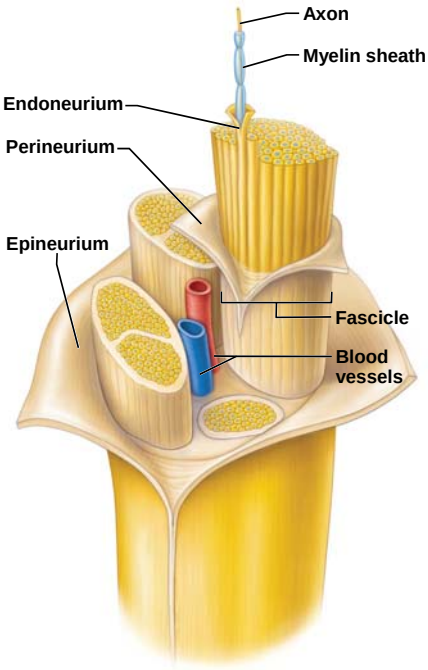

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Figure 7.23

PNS: Classification of Nerves

- Mixed nerves
  - Both sensory and motor fibers
- Sensory (afferent) nerves
  - Carry impulses toward the CNS
- Motor (efferent) nerves
  - Carry impulses away from the CNS

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PNS: Cranial Nerves

- Twelve pairs of nerves that mostly serve the head and neck
- Only the pair of vagus nerves extend to thoracic and abdominal cavities
- Most are mixed nerves, but three are sensory only

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PNS: Cranial Nerves Device

- Oh – Olfactory
- Oh – Optic
- Oh – Oculomotor
- To – Trochlear
- Touch – Trigeminal
- And – Abducens
- Feel – Facial
- Very – Vestibulocochlear
- Green – Glossopharyngeal
- Vegetables – Vagus
- A – Accessory
- H – Hypoglossal

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PNS: Cranial Nerves

- I Olfactory nerve—sensory for smell
- II Optic nerve—sensory for vision
- III Oculomotor nerve—motor fibers to eye muscles
- IV Trochlear—motor fiber to one eye muscle

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PNS: Cranial Nerves

- V Trigeminal nerve—sensory for the face; motor fibers to chewing muscles
- VI Abducens nerve—motor fibers to eye muscles
- VII Facial nerve—sensory for taste; motor fibers to the face
- VIII Vestibulocochlear nerve—sensory for balance and hearing

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PNS: Cranial Nerves

- IX Glossopharyngeal nerve—sensory for taste; motor fibers to the pharynx
- X Vagus nerves—sensory and motor fibers for pharynx, larynx, and viscera
- XI Accessory nerve—motor fibers to neck and upper back
- XII Hypoglossal nerve—motor fibers to tongue

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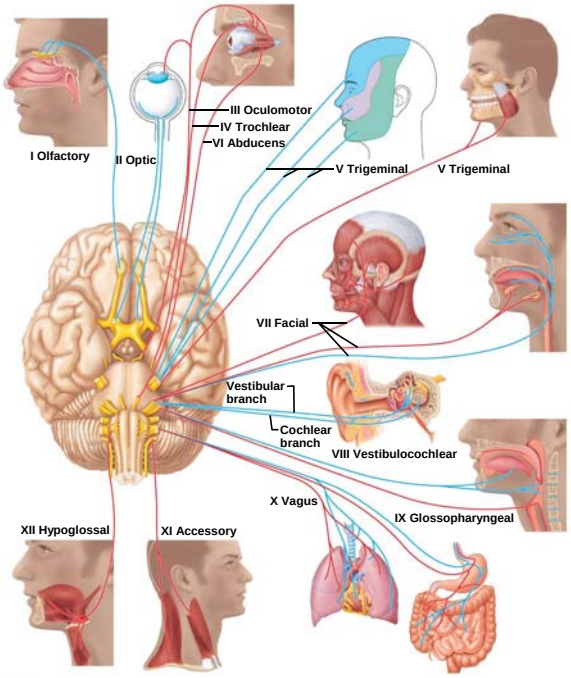

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Figure 7.24

PNS: Spinal Nerves

- There is a pair of spinal nerves at the level of each vertebrae for a total of 31 pairs
- Formed by the combination of the ventral and dorsal roots of the spinal cord
- Named for the region from which they arise

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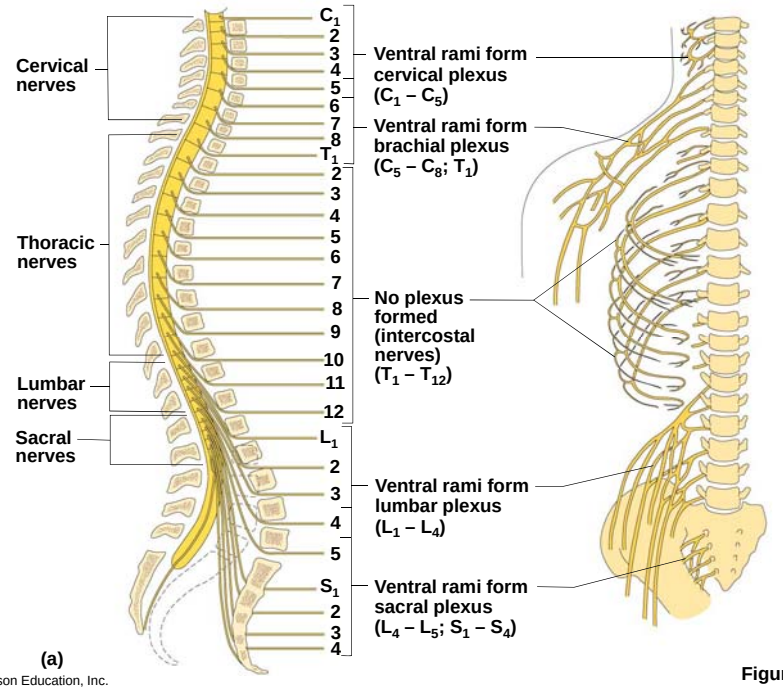

(a)

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Figure 7.25a

PNS: Anatomy of Spinal Nerves

- Spinal nerves divide soon after leaving the spinal cord
- Ramus—branch of a spinal nerve; contains both motor and sensory fibers
  - Dorsal rami—serve the skin and muscles of the posterior trunk
  - Ventral rami—form a complex of networks (plexus) for the anterior

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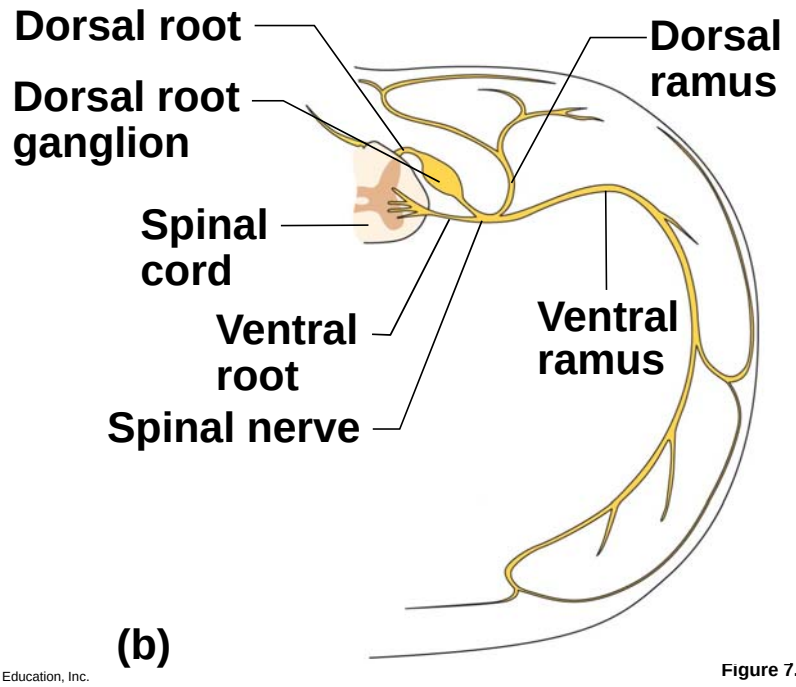

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Figure 7.25b

PNS: Spinal Nerve Plexuses

- Plexus–networks of nerves serving motor and sensory needs of the limbs
- Form from ventral rami of spinal nerves in the cervical, lumbar, and sacral regions
- Four plexuses:
  - Cervical
  - Brachial
  - Lumbar
  - Sacral

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PNS: Spinal Nerve Plexuses

- Cervical Plexus
  - Originates from ventral rami in C_1 – C_5
  - Important nerve is the phrenic nerve
  - Areas served:
    - Diaphragm
    - Shoulder and neck

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PNS: Spinal Nerve Plexuses

- Brachial Plexus
  - Originates from ventral rami in C_5 – C_8 and T_1
  - Important nerves:
    - Axillary
    - Radial
    - Median
    - Musculocutaneous
    - Ulnar
  - Areas served: shoulder, arm, forearm, and hand

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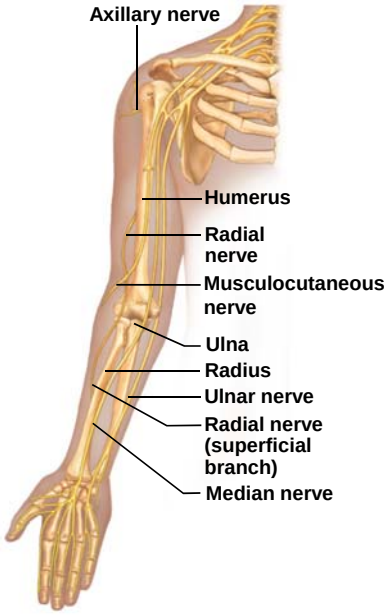

(a) The major nerves of the upper limb

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Figure 7.26a

PNS: Spinal Nerve Plexuses

- Lumbar Plexus
  - Originates from ventral rami in L_1 through L_4
  - Important nerves:
    - Femoral
    - Obturator
  - Areas served:
    - Lower abdomen
    - Anterior and medial thighs

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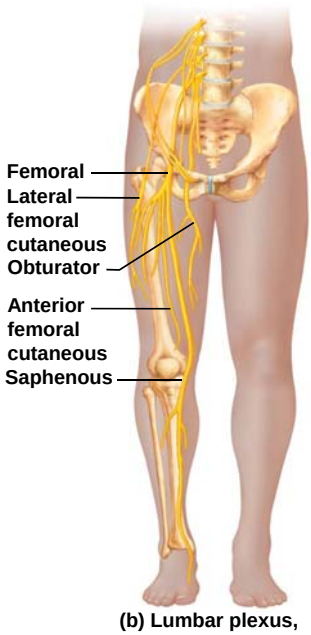

(b) Lumbar plexus, anterior view

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Figure 7.26b

PNS: Spinal Nerve Plexuses

- Sacral Plexus
  - Originates from ventral rami in L_4 – L_5 and S_1 – S_4
  - Important nerves:
    - Sciatic
    - Superior and inferior gluteal
  - Areas served:
    - Lower trunk and posterior thigh
    - Lateral and posterior leg and foot
    - Gluteal muscles of hip area

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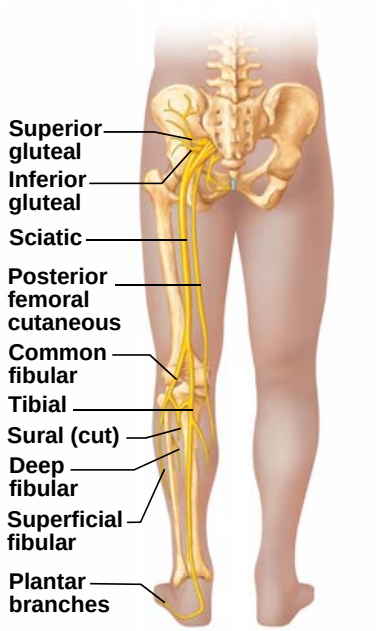

(c) Sacral plexus, posterior view

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Figure 7.26c

PNS: Autonomic Nervous System

- Motor subdivision of the PNS
  - Consists only of motor nerves
- Also known as the involuntary nervous system
  - Regulates activities of cardiac and smooth muscles and glands
- Two subdivisions
  - Sympathetic division
  - Parasympathetic division

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PNS: Differences Between Somatic and Autonomic Nervous Systems

	Somatic Nervous System	Autonomic Nervous System
Nerves	**One-neuron; it originates in the CNS and axons extend to the skeletal muscles served**	**Two-neuron system consisting of preganglionic and postganglionic neurons**
Effector organ	**Skeletal muscle**	**Smooth muscle, cardiac muscle, glands**
Subdivisions	**None**	**Sympathetic and parasympathetic**
Neurotransmitter	**Acetylcholine**	**Acetylcholine, epinephrine, norepinephrine**

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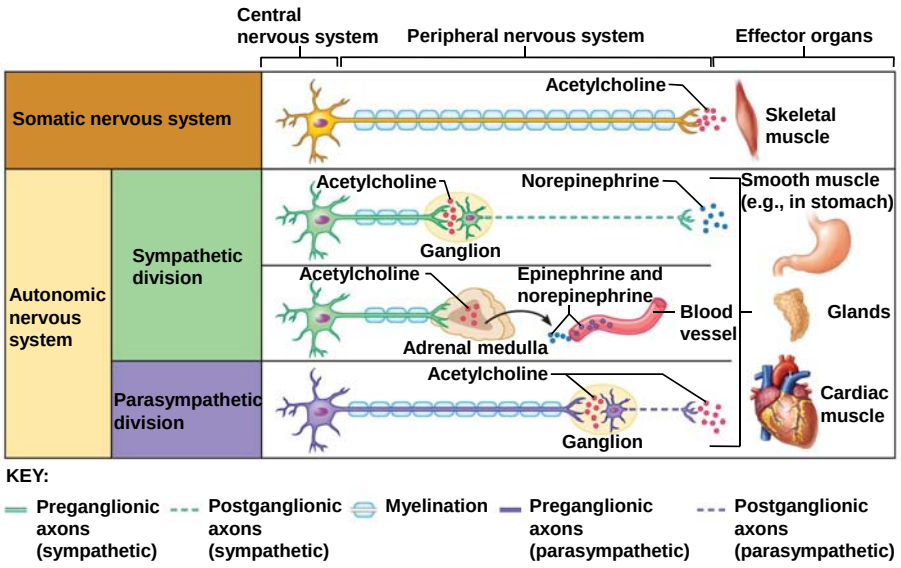

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Figure 7.27

PNS: Anatomy of the Parasympathetic Division

- Preganglionic neurons originate from the craniosacral regions:
  - The cranial nerves III, VII, IX, and X
  - S_2 through S_4 regions of the spinal cord
- Due to site of preganglionic neuron origination, the parasympathetic division is also known as the *craniosacral division*
- Terminal ganglia are at the effector organs
- Neurotransmitter: acetylcholine

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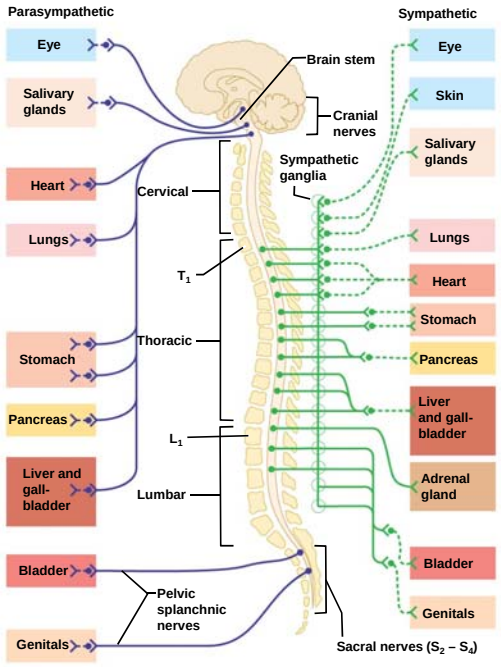

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Figure 7.28

PNS: Anatomy of the Sympathetic Division

- Preganglionic neurons originate from T_1 through L_2
- Ganglia are at the sympathetic trunk (near the spinal cord)
- Short pre-ganglionic neuron and long post-ganglionic neuron transmit impulse from CNS to the effector
- Neurotransmitters: norepinephrine and epinephrine (effector organs)

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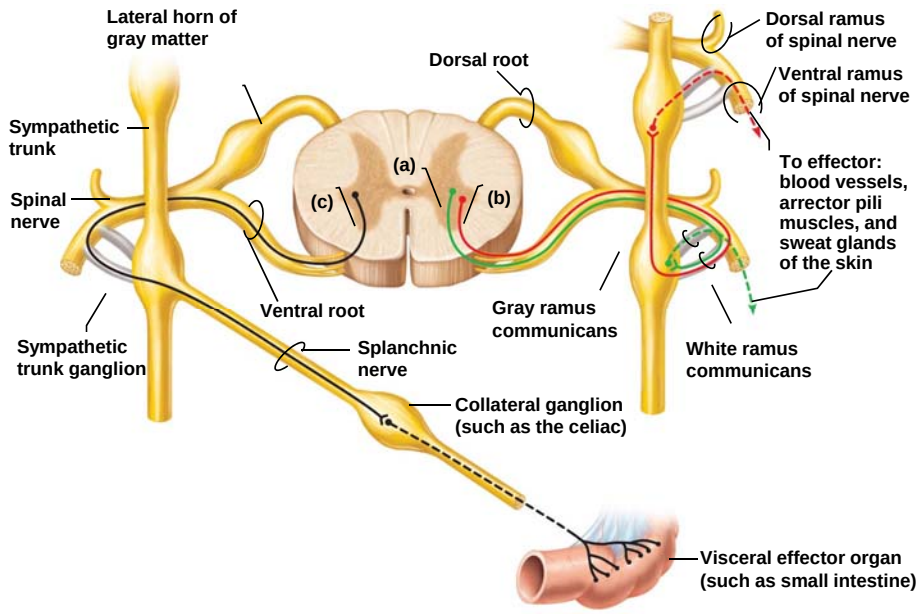

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Figure 7.29

PNS: Autonomic Functioning

- Sympathetic—"fight or flight"
  - Response to unusual stimulus
  - Takes over to increase activities
  - Remember as the "E" division
    - Exercise, excitement, emergency, and embarrassment

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PNS: Autonomic Functioning

- Parasympathetic—“housekeeping” activites
  - Conserves energy
  - Maintains daily necessary body functions
  - Remember as the “D” division
    - digestion, defecation, and diuresis

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Development Aspects of the Nervous System

- The nervous system is formed during the first month of embryonic development
- Any maternal infection can have extremely harmful effects
- The hypothalamus is one of the last areas of the brain to develop

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Development Aspects of the Nervous System

- No more neurons are formed after birth, but growth and maturation continues for several years
- The brain reaches maximum weight as a young adult

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