

The Nervous System

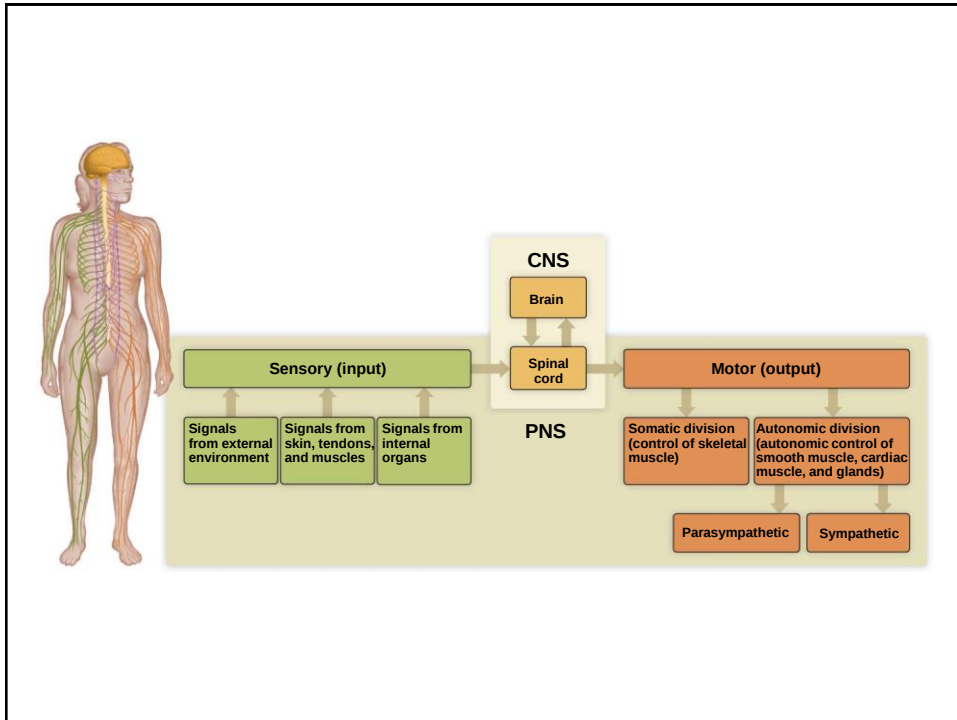


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Nervous System Has Two Principal Parts

- **Central nervous system (CNS)**
 - Components: brain and spinal cord
 - Functions: receives, processes, and transfers information
- **Peripheral nervous system (PNS)**
 - Components: nerves outside CNS
 - Sensory division: carries information toward the CNS
 - Motor division: carries information away from CNS

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Neurons: Communication Cells of the Nervous System

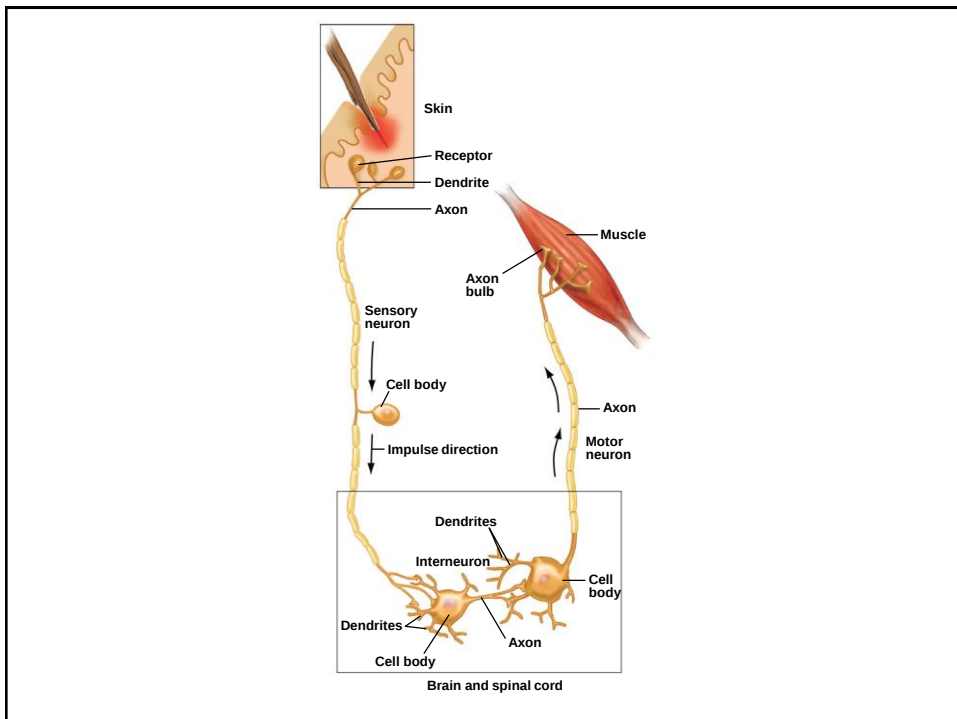
- Neurons are specialized cells for communication
 - Generate and conduct electrical impulses
- Types of neurons
 - **Sensory neurons**: neurons found in the PNS that receive stimuli and transmit information to the CNS
 - **Interneurons**: transmit information between components of the CNS
 - **Motor neurons**: neurons found in the PNS that transmit information away from the CNS

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Neurons: Cell Structure

- **Three parts of the neuron**
 - **Cell body:** main part of the cell, has the nucleus and most of the cytoplasm and organelles
 - **Dendrites:** small slender extensions of the cell body, receive incoming information
 - **Axon:** long slender extension, specialized to conduct electrical impulses away from the cell body

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Neurons Initiate Action Potentials

- Neurons generate and transmit action potentials
- An action potential is basically an electrical impulse
- Primary means of communication throughout the nervous system

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Neuroglial Cells Support/Protect Axons

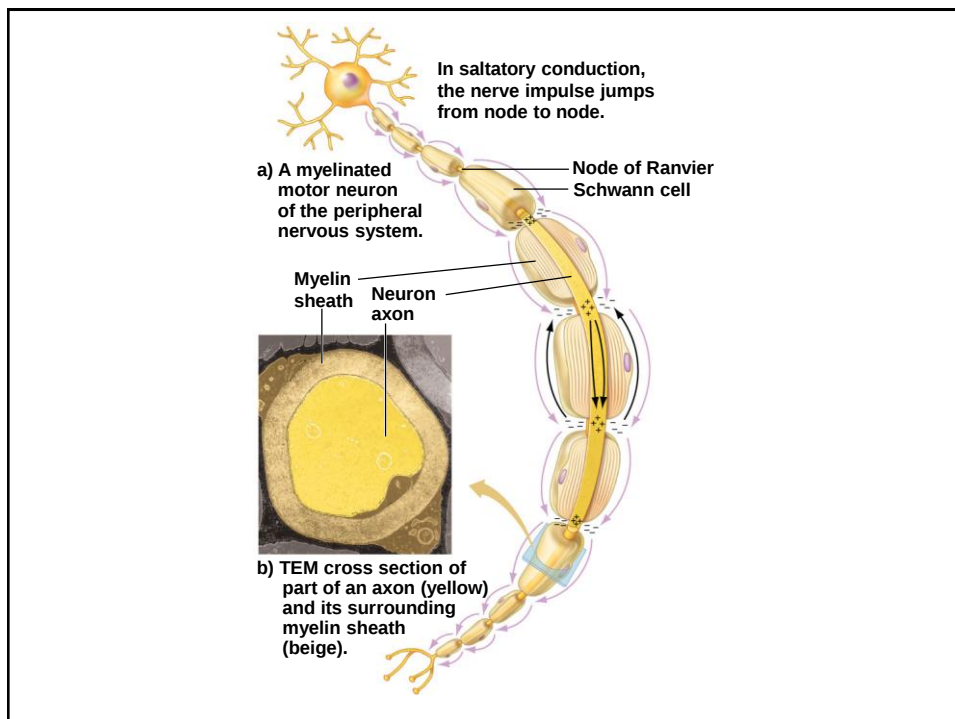
- Neuroglial cells make up 80% of nervous system
 - Function
 - Support
 - Protection
 - Do NOT transmit action potentials
 - Two types
 - Schwann cells
 - Oligodendrocytes

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Neuroglial Cells: Form Myelin Sheath on Neurons

- **Schwann cells**
 - Form myelin sheath in PNS
 - Save the neuron energy
 - Speed up the transmission of impulses
 - **Saltatory conduction:** leaping pattern of action potential conduction
 - Help damaged or severed axons regenerate
- **Oligodendrocytes**
 - Form myelin sheath in CNS

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Demyelinating Diseases

- Disorders associated with degeneration of myelin sheaths
 - **Multiple sclerosis (MS)**
 - Progressive damage to myelin sheaths in brain and spinal cord
 - Weakness, visual impairment, incontinence
 - **Amyotrophic lateral sclerosis (ALS)**
 - Lou Gehrig's disease
 - Progressive damage to myelin sheaths in motor area of spinal cord
 - Progressive weakening and wasting of skeletal muscle

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Information Is Transferred from Neuron to Target

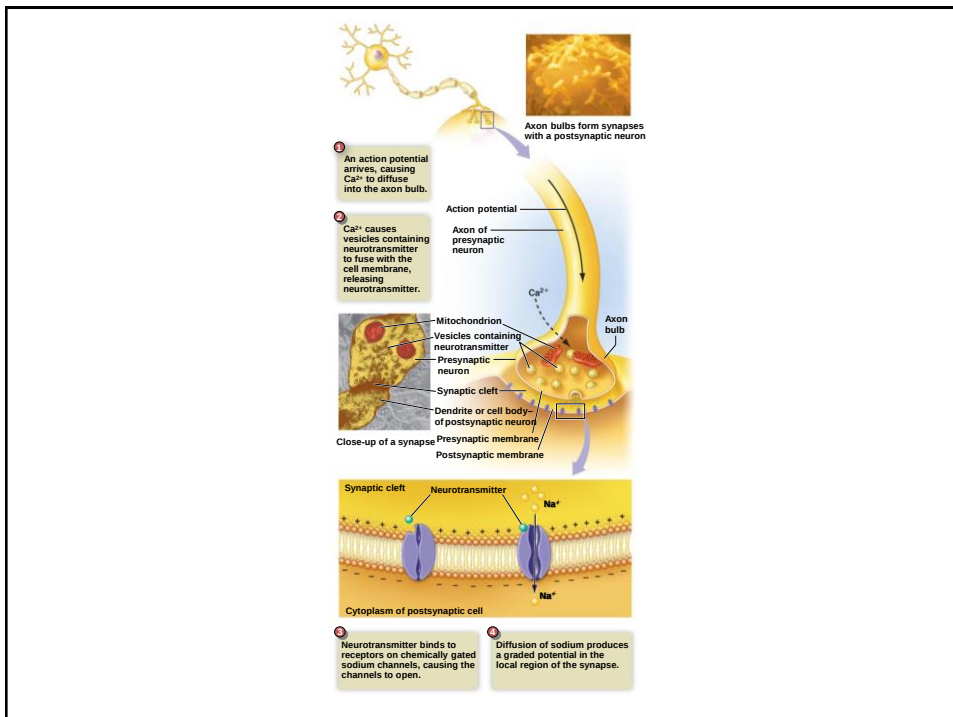
- Targets
 - another neuron, muscle cell, or gland
- **Synapse**
 - special junction between axon terminus and target cell
- Synaptic transmission
 - Process of transmission of impulse from sending (presynaptic neuron) across synaptic cleft to receiving (postsynaptic) target
 - Involves release and diffusion of chemical neurotransmitter

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Synaptic Transmission: Neurotransmitter Release

- Action potential arrives at axon terminus, causing Ca^{2+} to diffuse into axon bulb
- Ca^{2+} causes release of neurotransmitter from vesicles
- Neurotransmitter diffuses across synaptic cleft
- Neurotransmitter binds to receptors on target (postsynaptic) membrane and opens gated channels

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Neurotransmitters Exert Excitatory or Inhibitory Effects

- Response of postsynaptic target cell depends on
 - Type of neurotransmitter (>50 types)
 - Type of receptors
 - Type of gated ion channels

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Table 11.1 Actions of common neurotransmitters

Neurotransmitter	Sites where released	Principal actions
Acetylcholine	Neuromuscular junctions, autonomic nervous systems, brain	Excitatory on skeletal muscles; excitatory or inhibitory at other sites, depending on receptors
Norepinephrine	Areas of brain and spinal cord, autonomic nervous system	Excitatory or inhibitory, depending on receptors; plays a role in emotions
Serotonin	Areas of brain, spinal cord	Usually inhibitory; involved in moods, sleep cycle, appetite
Dopamine	Areas of brain, parts of peripheral nervous system	Excitatory or inhibitory, depending on receptors; plays a role in emotions
Glutamate	Areas of brain, spinal cord	Usually excitatory; major excitatory neurotransmitter in brain
Endorphins	Many areas in brain, spinal cord	Natural opiates that inhibit pain; usually inhibitory
Gamma-aminobutyric acid	Areas of brain, spinal cord	Usually inhibitory; principal inhibitory neurotransmitter in brain
Somatostatin	Areas of brain, pancreas	Usually inhibitory; inhibits pancreatic release of growth hormone

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- This is just to show the names of some neurotransmitters
 - Do not worry about the 'site where released' or 'principal actions'

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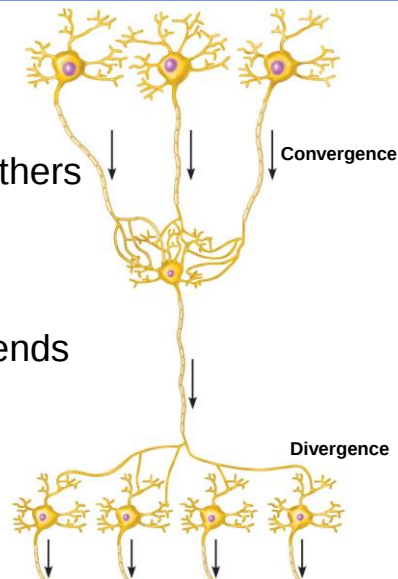
Postsynaptic Neurons Integrate and Process Information

- Response in postsynaptic cell depends on
 - How many neurons are forming synapses with it
 - Whether the neurons forming synapses with it are excitatory or inhibitory

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Postsynaptic Neurons Integrate and Process Information

- Convergence
 - occurs when one neuron receives input from many others
- Divergence
 - occurs when one neuron sends action potentials to multiple other neurons



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Peripheral Nervous System Relays Information Between Tissues and CNS

- Nerve
 - contains axons of many neurons wrapped together in a protective sheath
 - Carries information to and from the CNS
- Cranial nerves
 - 12 pairs
 - Connect directly to brain
- Spinal nerves
 - 31 pairs
 - Connect to spinal cord

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Sensory Neurons Provide Information to the CNS

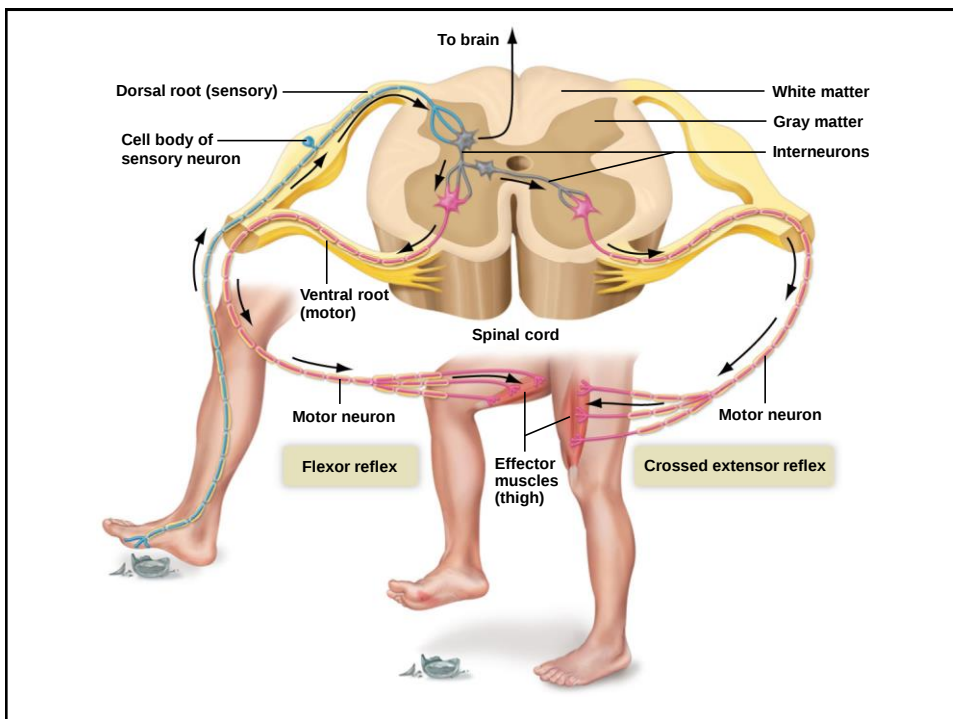
- Provide information for both the somatic and autonomic motor divisions of the PNS
- Incoming information arrives at the CNS as action potentials from sensory neurons located throughout the body

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Somatic Division Controls Skeletal Muscles

- Functions
 - Voluntary
 - Conscious control of skeletal muscles
 - Involuntary (Reflexes)
 - **Spinal reflexes:** Involuntary responses mediated primarily by spinal cord and spinal nerves, with little brain involvement
 - flexor (withdrawal) reflex
 - crossed extensor reflex
 - stretch reflex: important in maintaining upright posture, movement

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The Autonomic Division

- Part of the motor output of the PNS
- Controls automatic body functions of many internal organs
- Consists of two divisions
 - Sympathetic division
 - Parasympathetic division
- Both sympathetic and parasympathetic neurons enervate each organ

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The Sympathetic and Parasympathetic Autonomic Divisions Oppose Each Other

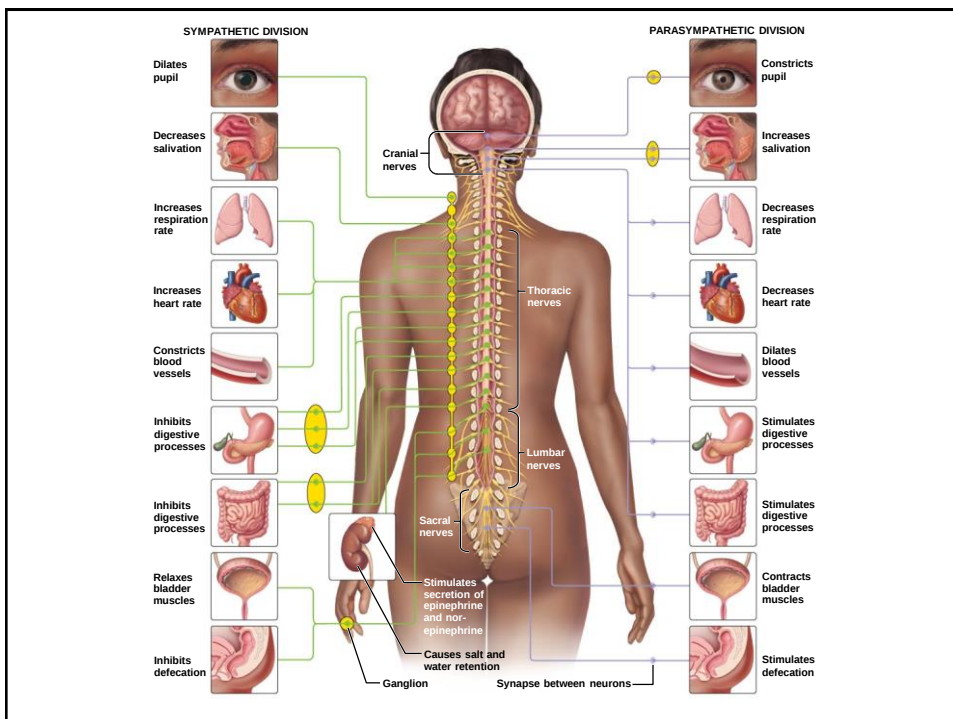
- Sympathetic division
 - Prepares the body for emergencies
 - Norepinephrin is the key neurotransmitter
 - Produces fight-or-flight response
 - Increases heart rate and respiration
 - Raises blood pressure
 - Dilates pupils
 - Slows digestion and urine production
 - Generally produces a unified response in all organs at once
 - Opposes parasympathetic division

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The Sympathetic and Parasympathetic Autonomic Divisions Oppose Each Other

- Parasympathetic division
 - Relaxes the body
 - Opposes sympathetic division
 - Acetylcholine is the key neurotransmitter
 - Actions:
 - lowers heart rate and respiration
 - increases digestion
 - permits defecation and urination
- Sympathetic and parasympathetic divisions work antagonistically to maintain homeostasis

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Table 11.2 The somatic and autonomic divisions of the PNS

	Somatic division	Autonomic division	
		<i>Sympathetic</i>	<i>Parasympathetic</i>
Functions	Serves skeletal muscles	Fight or flight; arouses body to deal with situations involving physical activity, mental alertness	Relaxes body; promotes digestion and other basic functions
Neurotransmitter	Acetylcholine	Norepinephrine	Acetylcholine
Number of neurons required to reach the target cell	One	Two (preganglionic and postganglionic)	Two (preganglionic and postganglionic)

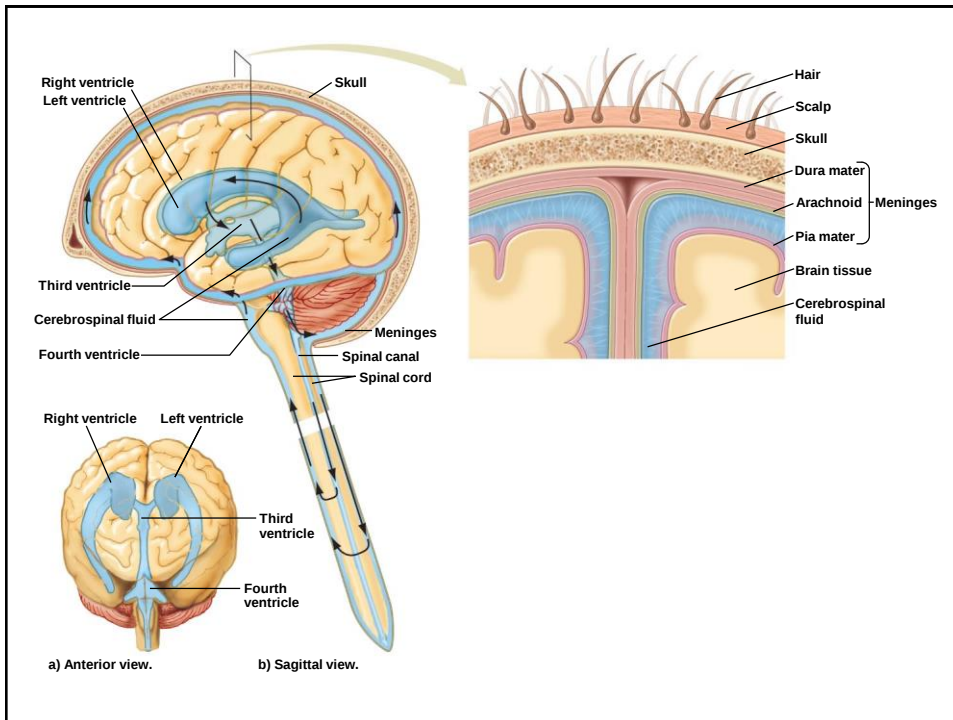
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Brain and Spinal Cord Constitute the CNS

- CNS protection
 - **Bone:** skull and vertebrae
 - **Meninges:** protective membranes
 - Dura mater, arachnoid, and pia mater
 - **Cerebrospinal fluid:** bathes the brain, spinal cord
 - Shock absorber
 - Produced within the ventricles of the brain
 - **Blood-brain barrier:** prevents entry of certain chemicals and pathogens

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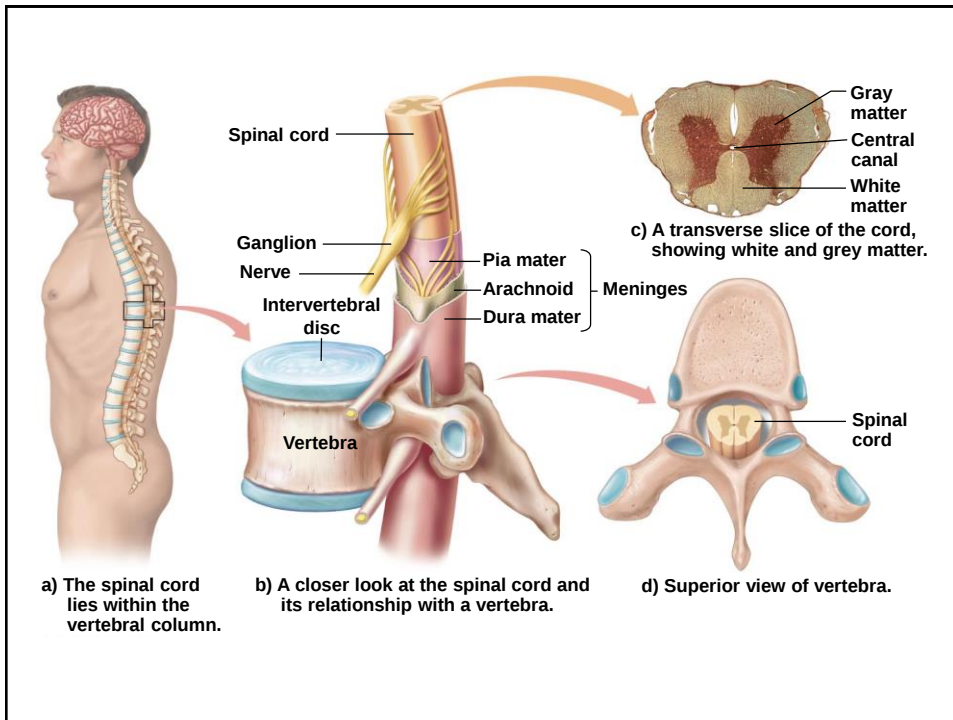


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The Spinal Cord Relays Information

- Spinal cord is a superhighway for action potentials between the brain and the rest of the body
- White matter
 - Outer portion of spinal cord
 - Consists of myelinated ascending (sensory) and descending (motor) nerve tracts
- Gray matter
 - Center portion of spinal cord
 - Contains cell bodies, dendrites

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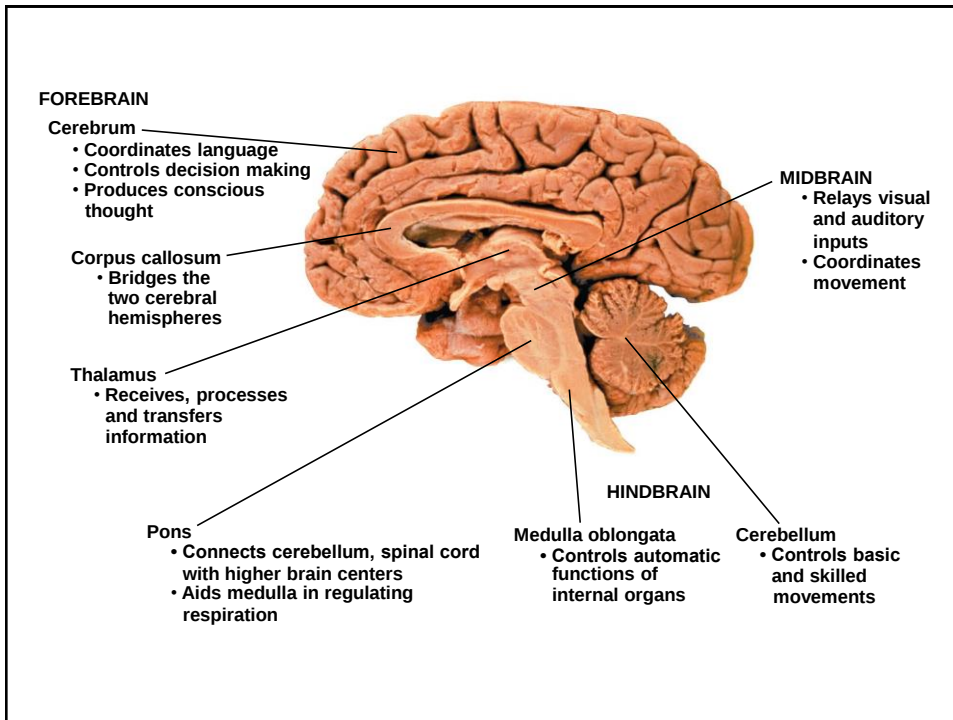


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The Brain Processes and Acts on Information

- Brain: command center of the body
- Three major anatomical/functional divisions
 - **Hindbrain:** coordinates basic, automatic, and vital tasks
 - **Midbrain:** coordinates muscle groups and responses to sight and sound
 - **Forebrain:** receives, integrates sensory input, determines complex behavior

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Hindbrain: Medulla Oblongata

- Connects to spinal cord
- Controls vital automatic functions of internal organs
 - Cardiovascular center: regulates heart rate and blood pressure
 - Respiratory center: adjusts respiration in response to CO₂ and O₂ levels
- Motor nerves cross over in medulla oblongata
 - Right forebrain controls left side of body
 - Left forebrain controls right side of body

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Hindbrain: Cerebellum

- Coordinates basic body movements
- Stores and replicates sequences of skilled movements
 - Examples
 - Tying a shoe
 - Swinging a bat
 - Using a keyboard

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Hindbrain: Pons

- Connects higher brain centers and the spinal cord
- Coordinates the flow of information between the cerebellum and higher brain centers
- Aids medulla oblongata in regulating respiration

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Midbrain: Vision and Hearing

- Coordinates movements of the head related to vision and hearing
- Controls movement of eyes and size of pupils

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Forebrain: Emotions and Conscious Thought

- Receives and integrates information concerning emotions and conscious thought
- **Hypothalamus**
 - Helps regulate homeostasis
- **Thalamus** (“Grand Central Station”)
 - Receiving, processing, and transfer center
- **Limbic system**
 - Pathways involved in emotions and memory
- **Cerebrum**
 - Language, decision making, conscious thought

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Forebrain: Cerebrum

- **Structure**
 - Right and left **hemispheres**
 - Hemispheres connected by **corpus callosum**
 - Nerve tracts in corpus callosum allow two hemispheres to share information
 - Cerebral cortex
 - gray matter, the outer layer of the cerebrum

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A Closer Look at the Cerebral Cortex

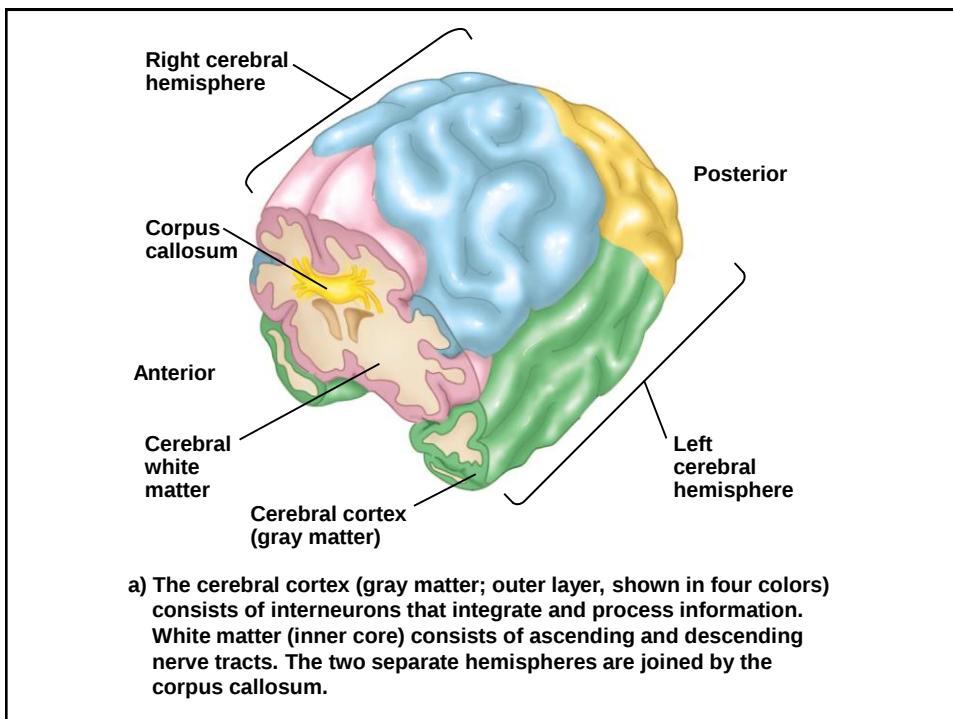
- **Functions**
 - memory storage
 - abstract thought
 - conscious awareness
 - conscious control of skeletal muscle

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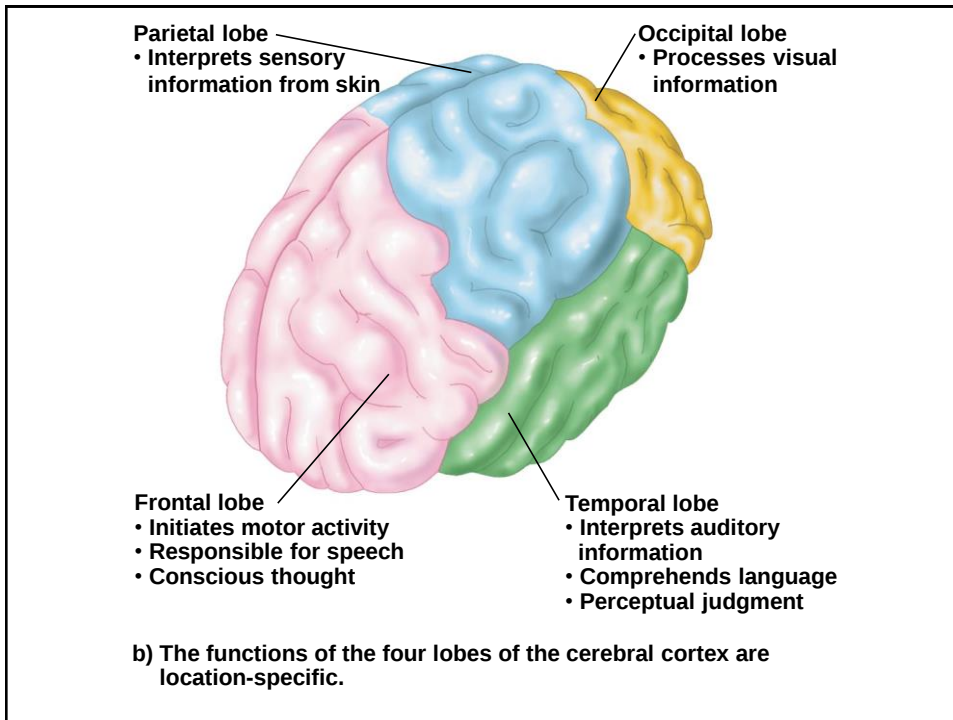
A Closer Look at the Cerebral Cortex

- Divided into four lobes
 - **Occipital lobe**
 - processes visual information
 - **Temporal lobe**
 - interprets auditory information, comprehends spoken/written language
 - **Parietal lobe**
 - receives and interprets sensory information from the skin
 - **Frontal lobe**
 - initiates motor activity, responsible for speech, conscious thought
- All four lobes: memory storage

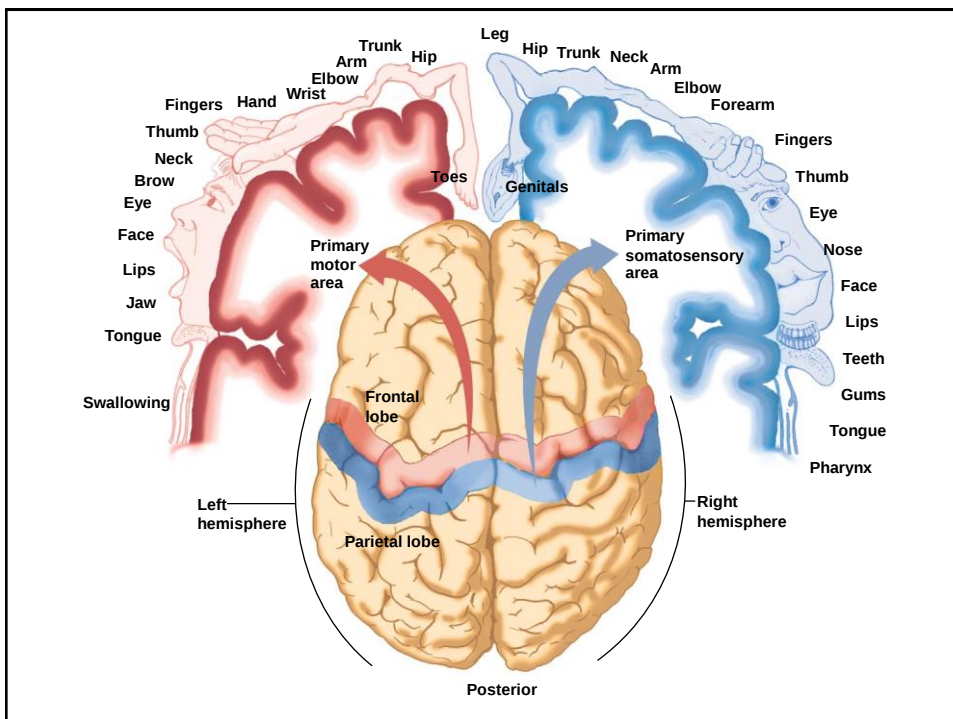
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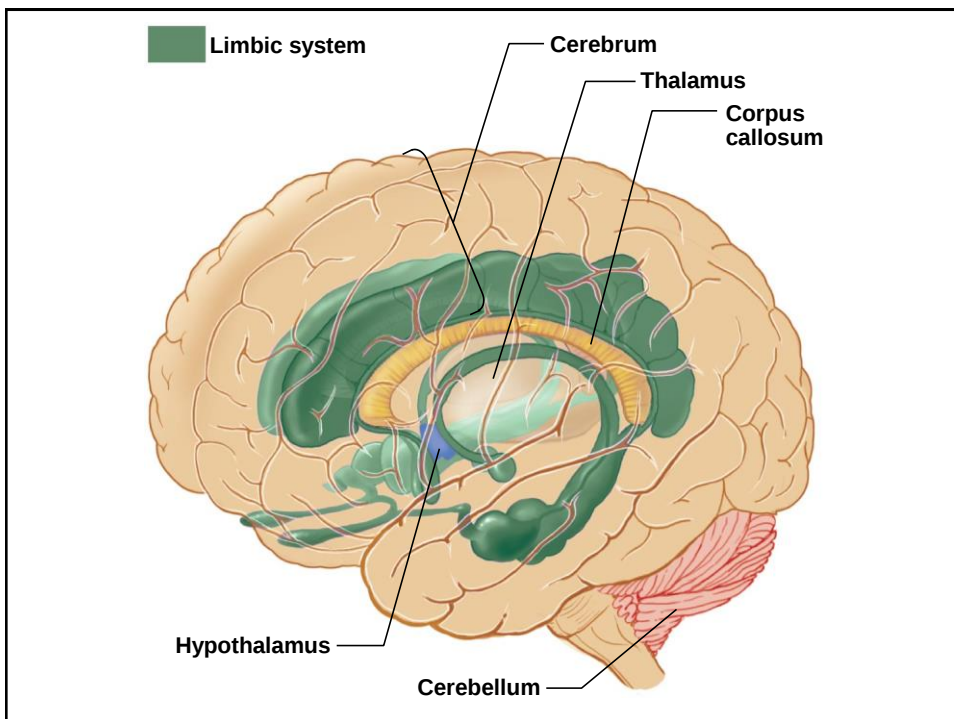


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Limbic System: Site of Emotions and Basic Behaviors

- Includes all neuronal structures that together control emotional behavior and motivational drives
- Hypothalamus serves as a gateway to and from limbic system
- Emotions
 - Fear, anger, sorrow, love, etc.
- Basic behavior
 - Seeking food, satisfying thirst
 - Sexual gratification
- Behaviors modified by cerebrum
- Short-term memory

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Memory: Storing and Retrieving Information

- Short-term
 - Working memory
 - Information from previous few hours
 - Stored in the limbic system
- Long-term
 - Information from previous days to years
 - Involves permanent changes in neurons and synapses in the cerebral cortex

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Psychoactive Drugs Affect Higher Brain Functions

- Psychoactive drugs
 - Affect states of consciousness, emotions, or behavior
- Action
 - Able to cross blood-brain barrier
 - Influence concentrations or actions of neurotransmitters
 - Affect higher brain functions

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Psychoactive Drugs

- Psychological dependence
 - User craves the feeling associated with the drug
- Tolerance
 - Requires more of the substance to achieve the same effect
- Addiction
 - The need to continue obtaining and using a substance
 - No free choice
- Withdrawal
 - Physical symptoms that occur upon stopping the drug

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Disorders of the Nervous System

- Trauma
 - Physical injury to brain or spinal cord
 - Concussion
 - Blow to the head may lead to unconsciousness
 - Disruption of electrical activity in the brain
 - Risk of subdural hematoma
 - Spinal cord injuries
 - Impairment of sensation and function below site of injury

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Disorders of the Nervous System

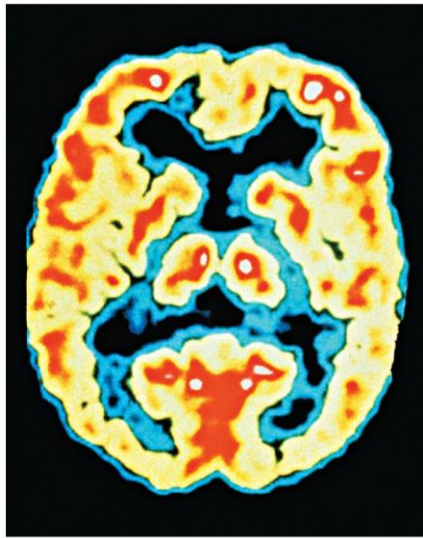
- **Infections:** Caused by viruses or bacteria that manage to pass through the blood-brain barrier
 - **Encephalitis**
 - Inflammation of the brain caused by viral infection
 - **Meningitis**
 - Inflammation of the meninges caused by viral or bacterial infection
 - **Rabies**
 - Infectious viral disease
 - Spread by bite or saliva of infected animal
 - Virus spreads from bite to brain via sensory neurons
- **Brain tumors:** abnormal growth in or on the brain

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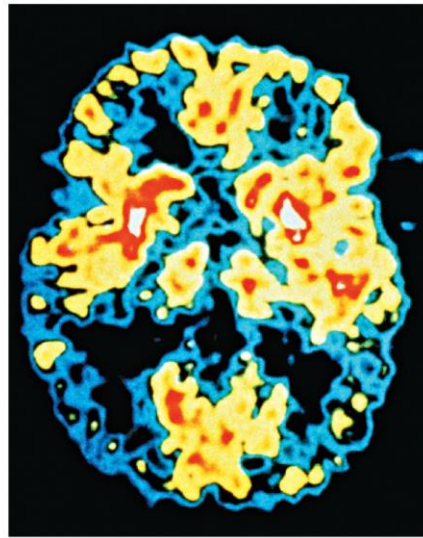
Disorders of the Nervous System

- Disorders of neural and synaptic transmission
 - **Epilepsy**
 - Recurring episodes of abnormal electrical activity (seizures)
 - **Alzheimer's disease**
 - Shortage of acetylcholine
 - Accumulation of abnormal protein, beta amyloid
 - Progressive memory lapses and dementia
 - **Parkinson's disease**
 - Loss of dopamine-releasing neurons
 - Progressive degenerative disorder affecting motor activity

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a) A PET scan of a healthy brain.



b) A PET scan of a patient with Alzheimer's disease, showing decreased activity and an irregular pattern.