Chapter 2:
Neuroscience and Behavior

Neurons and Synapses

Types of Neurons

Sensory — **Motor** — **Interneurons**

Glial Cells

•Outnumbering brain neurons by about 10 to 1, glial cells provide support and nutrition for neurons.

•*Astrocytes* are one type of glial cell that *provides connections* between neurons and blood vessels in the brain.

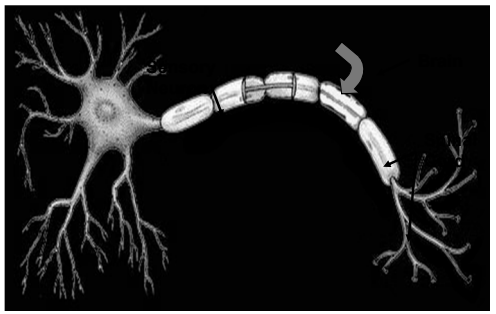
•Other types of glial cells form the *myelin sheath, a fatty insulating substance* wrapped around some neuron axons.

•Glial cells are much more actively involved in regulating neuronal communication and activity than previously believed.

Sensory Neurons

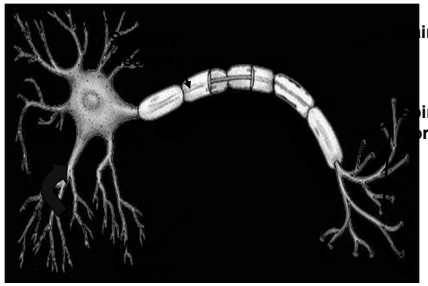
INPUT From sensory organs to the brain and spinal cord

Drawing shows a somatic neuron



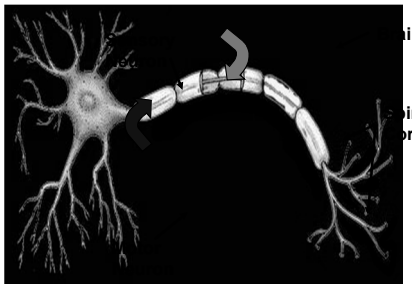
Motor Neurons

OUTPUT From the brain and spinal cord, to the muscles and glands

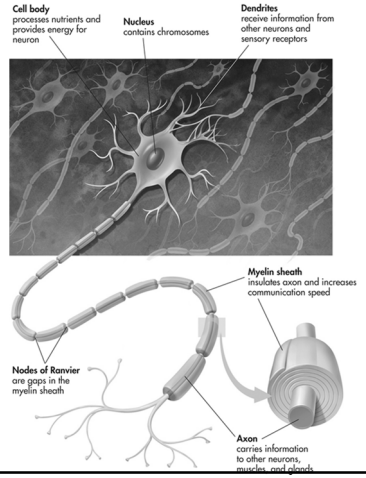


Interneurons

Interneurons carry information between other neurons only found in the brain and spinal cord



Parts of a Neuron



The Cell Body

Contains the cell's nucleus

- round, centrally located structure
- contains DNA
- controls protein manufacturing
- directs metabolism
- no role in neural signaling

Dendrites

- Information collectors
- Receive inputs from neighboring neurons
- Inputs may number in thousands
- If enough inputs, the cell's AXON may generate an output

Dendritic Growth

- Mature neurons generally can't divide
- But new dendrites can grow
- Provides room for more connections to other neurons
- New connections are basis for learning

Axon

- The cell's output structure
- One axon per cell, 2 distinct parts
  - tubelike structure
  - branches at end that connect to dendrites of other cells

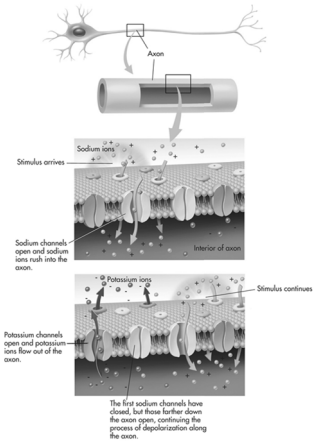
Myelin Sheath

- White fatty casing on axon
- Acts as an electrical insulator
- Not present on all cells
- When present, increases the speed of neural signals down the axon

How Neurons Communicate

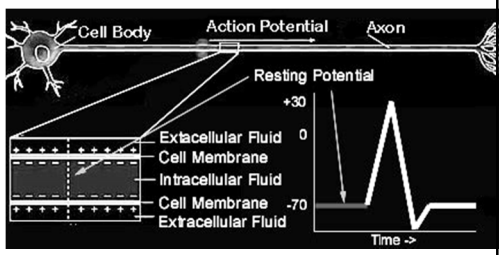
- Neurons communicate by means of an electrical signal called the **action potential**
- Action potentials are based on the movements of ions between the outside and inside of the cell
- When an action potential occurs, a molecular message is sent to neighboring neurons

Action Potential Within a Neuron



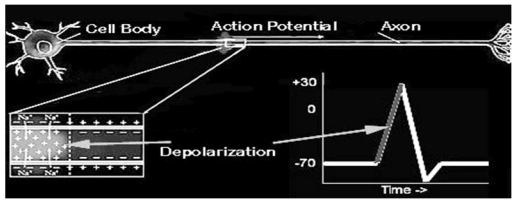
Resting Potential

- At rest, the inside of the cell is at -70 microvolts
- With inputs to dendrites, the inside becomes more positive
- If resting potential rises above threshold, an action potential starts to travel from cell body down the axon
- Figure shows resting axon being approached by an action potential



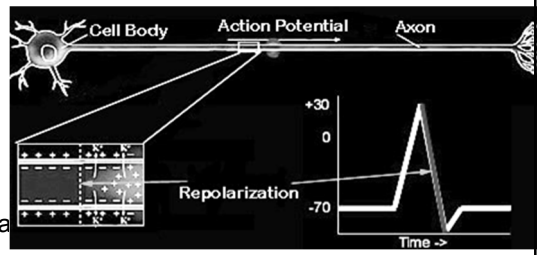
Depolarization Ahead of AP

- Action potential opens cell membrane to allow sodium (Na^+) in
- Inside of cell rapidly becomes more positive than outside
- This depolarization travels down the axon as leading edge of the action potential



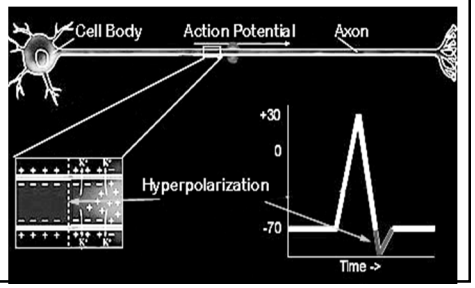
Repolarization Follows

- After depolarization potassium (K^+) moves out restoring the inside to a negative voltage
- This is called repolarization
- The rapid depolarization and repolarization produce a pattern called a spike discharge



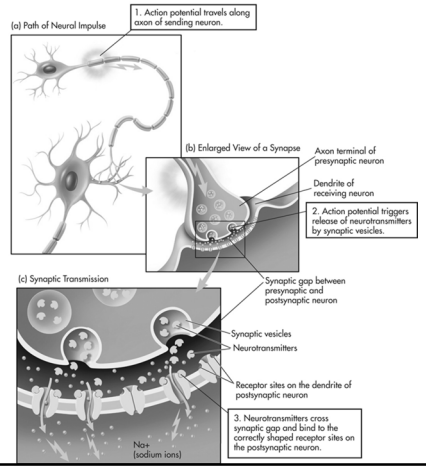
Finally, Hyperpolarization

- Repolarization leads to a voltage below the resting potential, called hyperpolarization
- Now, neuron cannot produce a new action potential
- This is the refractory period



Neuron to Neuron

- Axons branch out and end near dendrites of neighboring cells
- Axon terminals are the tips of the axon's branches
- A gap separates the axon terminals from dendrites
- Gap is called the synapse



Neurotransmitter Release

Action potential causes vesicle to open

- Neurotransmitter released into synapse
- Locks onto receptor molecule in postsynaptic membrane

Excitatory and Inhibitory Messages

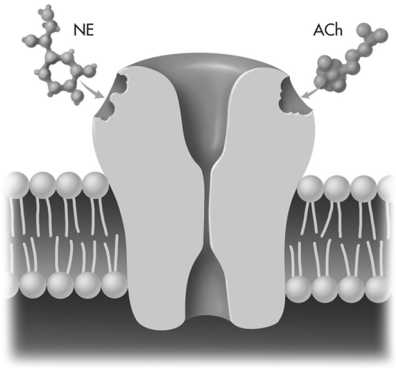
•Excitatory message—increases the likelihood that the postsynaptic neuron will activate

•Inhibitory message—decreases the likelihood that the postsynaptic neuron will activate

Locks and Keys

Neurotransmitter molecules have specific shapes

- Receptor molecules have binding sites
- When NT binds to receptor, ions enter



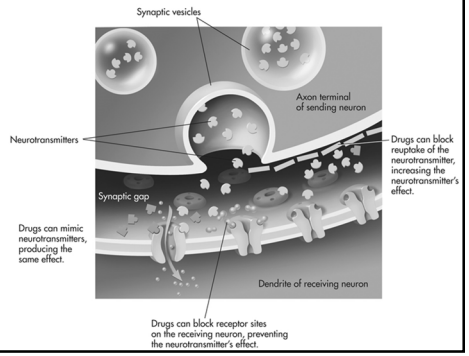
Some Drugs Work on Receptors

Some drugs are shaped like neurotransmitters

Antagonists: poorly fit the receptor and block the NT

- eg, beta blockers

- Agonists: fit receptor well and act like the NT
  - eg, nicotine



Types of Neurotransmitters

- Acetylcholine
- Dopamine
- Serotonin
- Norepinephrine
- GABA
- Endorphins

Acetylcholine (Ach)

- Found in neuromuscular junctions
- Involved in muscle movements
- Involved in learning and memory

Disruptions of Acetylcholine Functioning

- Curare—blocks ACh receptors
  - paralysis results
- Nerve gases and black widow spider venom; too much ACh leads to severe muscle spasms and possible death

Disruptions of Acetylcholine Functioning

Cigarettes—nicotine works on ACh receptors

- can artificially stimulate skeletal muscles, leading to slight trembling movements

Other uses of Acetylcholine

•Botulin, an extremely lethal substance produced by a bacteria, blocks the release of acetylcholine from motor neurons, causing muscle paralysis.

•Used to eliminate facial wrinkles through injections of minute amounts of this substance

•Used as a chemical weapon (nerve gas) by causing acetylcholine to be continuously released by the motor neurons. Excessive acetylcholine builds up in the synaptic gap, causing severe muscle spasms

Alzheimer's Disease

•Deterioration of memory, reasoning, and language skills

•Symptoms may be due a to loss of ACh neurons

Dopamine

•Involved in movement, attention, and learning

•Dopamine imbalance also involved in schizophrenia

•Parkinson's disease is caused by a loss of dopamine-producing neurons

Parkinson's Disease

Results from loss of dopamine-producing neurons in the substantia nigra

Symptoms include

- difficulty starting and stopping voluntary movements
- tremors at rest
- stooped posture
- rigidity
- poor balance

Parkinson's Disease

Treatments

- L-dopa
- transplants of fetal dopamine-producing substantia nigra cells
- adrenal gland transplants
- electrical stimulation of the thalamus has been used to stop tremors

Serotonin

- Involved in sleep
- Involved in depression
  - Prozac works by keeping serotonin in the synapse longer, giving it more time to exert an effect

Norepinephrine

- Arousal
- "Fight or flight" response

Endorphins

- Control pain and pleasure
- Released in response to pain
- Morphine and codeine work on endorphin receptors; involved in healing effects of acupuncture
- Runner's high— feeling of pleasure after a long run is due to heavy endorphin release

GABA

- Inhibition of brain activity
- Huntington's disease involves loss of neurons in striatum that use GABA
  - Symptoms:
    - jerky, involuntary movements
    - mental deterioration

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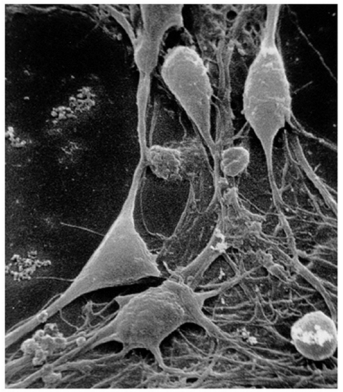
Summary

- Neuron structure
- Action potentials
- Synapses
- Neurotransmitters
- Receptors and ions
- Agonists and antagonists



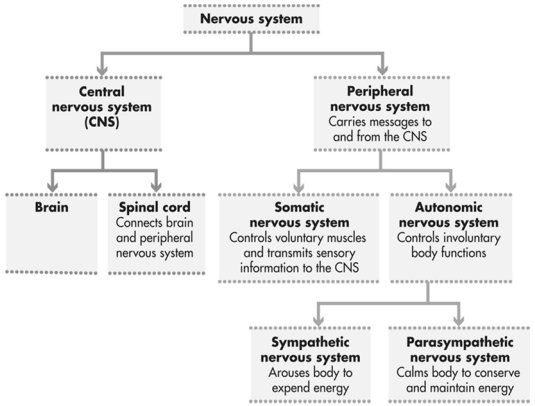
Parts of the Nervous System

Central nervous system (CNS)
- Brain and spinal cord

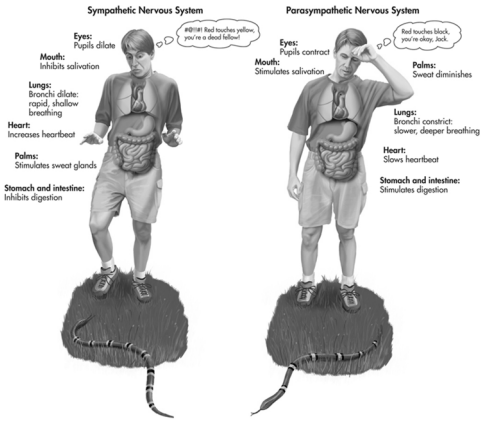
Peripheral nervous system (PNS)
- Carries messages to and from CNS

Central nervous system

Peripheral nervous system



Sympathetic and parasympathetic divisions of the nervous system



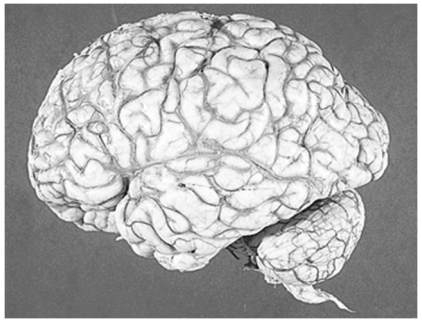
Endocrine System

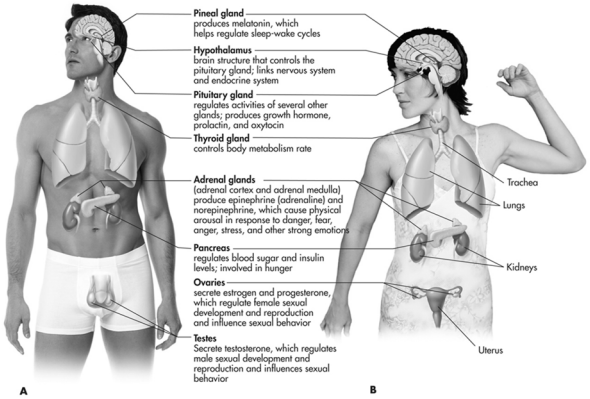
- Pituitary gland—attached to the base of the brain, hormones affect the function of other glands
- Adrenal glands—hormones involved in human stress response
- Gonads—hormones regulate sexual characteristics and reproductive processes; testes in males, ovaries in females

Brain

Brainstem
- Hindbrain
- Midbrain

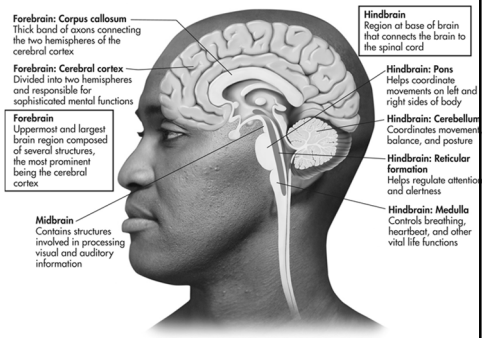
Forebrain
- Limbic system
- Cortex





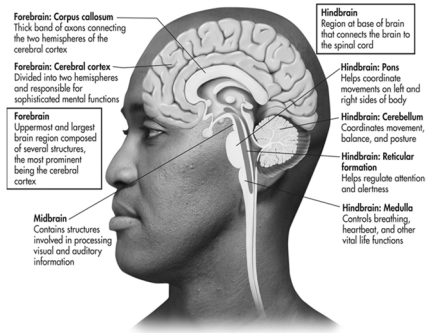
Hindbrain Structures

- Cerebellum
- Brainstem
  - medulla
  - reticular formation
  - pons



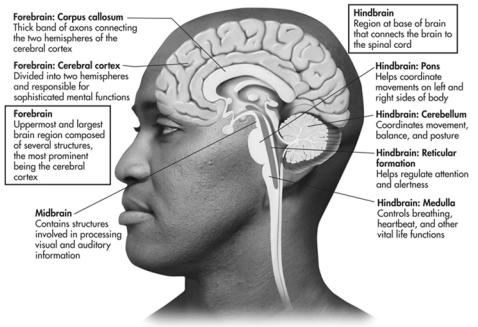
Cerebellum

- Coordinated,rapid voluntary movements
  - playing the piano, kicking, throwing, etc.
- Lesions to cerebellum
  - jerky, exaggerated movements
  - difficulty walking
  - loss of balance
  - shaky hands



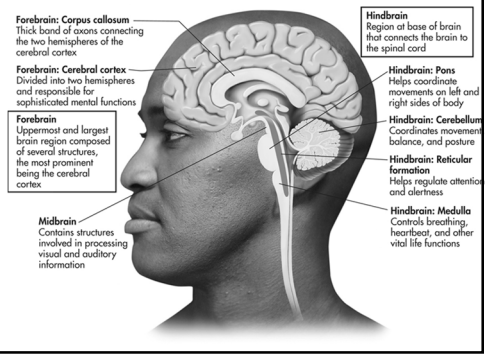
Medulla

- Breathing
- Heart rate
- Digestion
- Other vital reflexes
  - swallowing
  - coughing
  - vomiting
  - sneezing



Reticular Formation

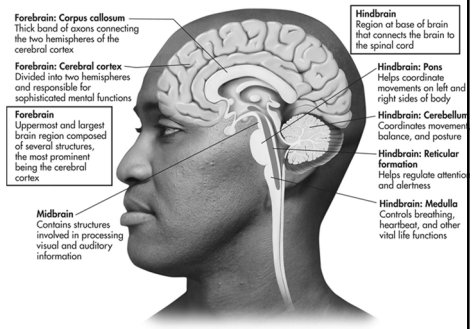
- Network of neurons in the brainstem (and thalamus)
- Sleep and arousal
- Attention



Pons

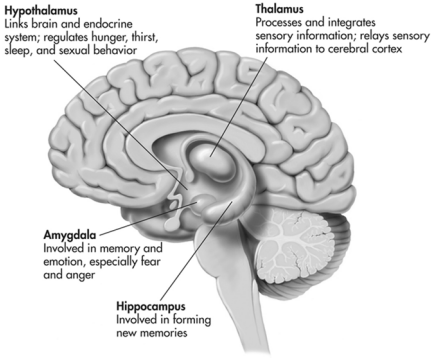
Helps coordinate movements on left and right sides of the body

- eg, postural reflexes that help you maintain balance while standing or moving



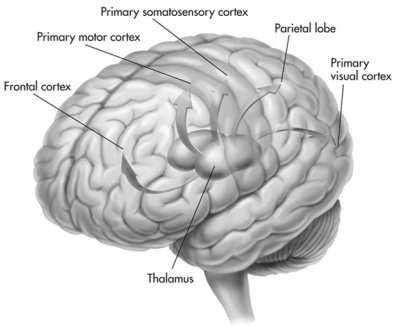
Forebrain Structures

- Thalamus
- Limbic System
- Cortex



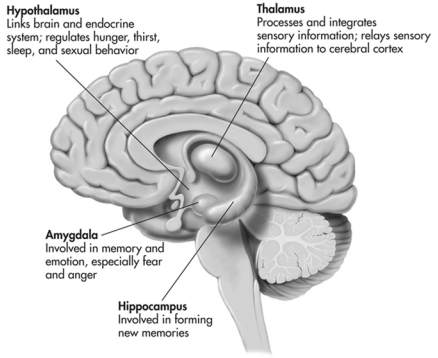
Thalamus

- Relay station in brain
- Processes most information to and from higher brain centers



The Limbic System

- Hypothalamus
- Amygdala
- Hippocampus



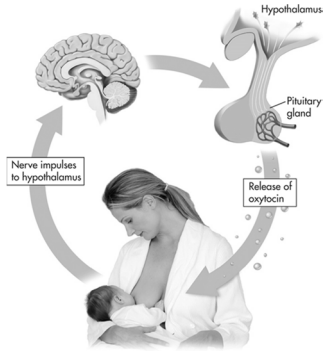
Hypothalamus

Contains nuclei involved in a variety of behaviors

- sexual behavior
- hunger and thirst
- sleep
- water and salt balance
- body temperature regulation
- circadian rhythms
- role in hormone secretion

Hypothalamus and Hormones

Hypothalamus releases hormones or releasing factors, which in turn cause pituitary gland to release its hormones



Amygdala and Emotion

Identify emotion from facial expressions

Amygdala damage makes this task difficult.

Cortical Specialization

•Localization—notion that different functions are located in different areas of the brain

•Lateralization—notion that different functions are processed primarily on one side of the brain or the other

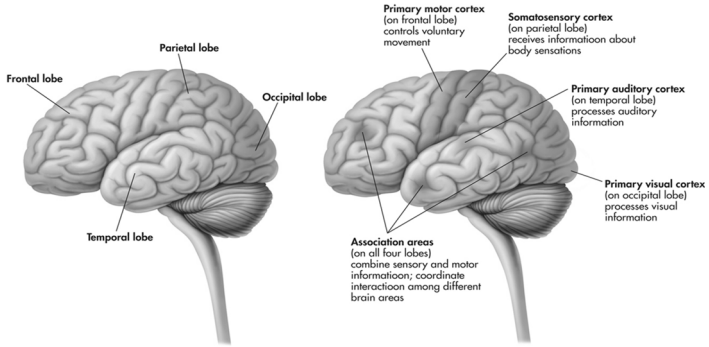
Lobes of the Cortex

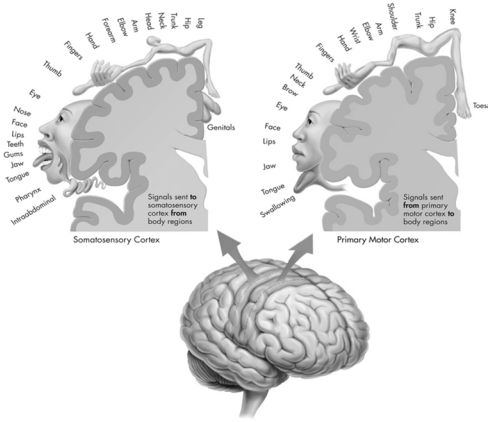
•Frontal lobe—largest lobe, produces voluntary muscle movements; involved in thinking, planning, and emotional control

•Temporal lobe—primary receiving area for auditory information

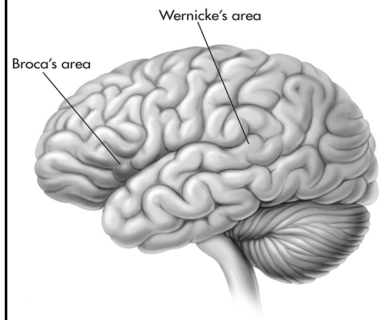
•Occipital lobe—primary receiving area for visual information

•Parietal lobe—processes somatic information

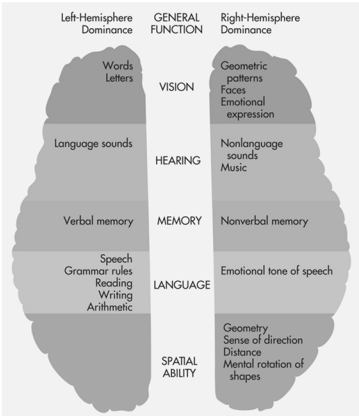


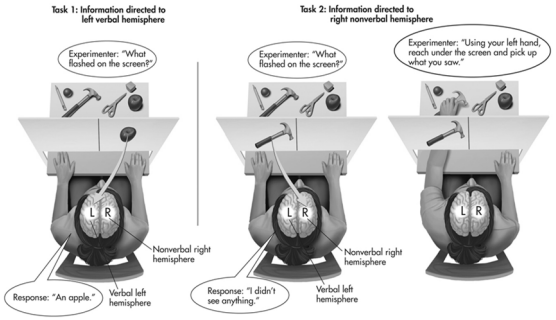


Language and the Brain



- Aphasia—partial or complete inability to articulate ideas or understand language because of brain injury or damage
- Broca's area—plays role in speech production
- Wernicke's area—plays role in understanding and meaningful speech





- Split-brain operation—procedure used to reduce recurrent seizures in severe cases of epilepsy
- Corpus callosum—thick band of axons that connects the two cerebral hemispheres