**Nervous System Cells**

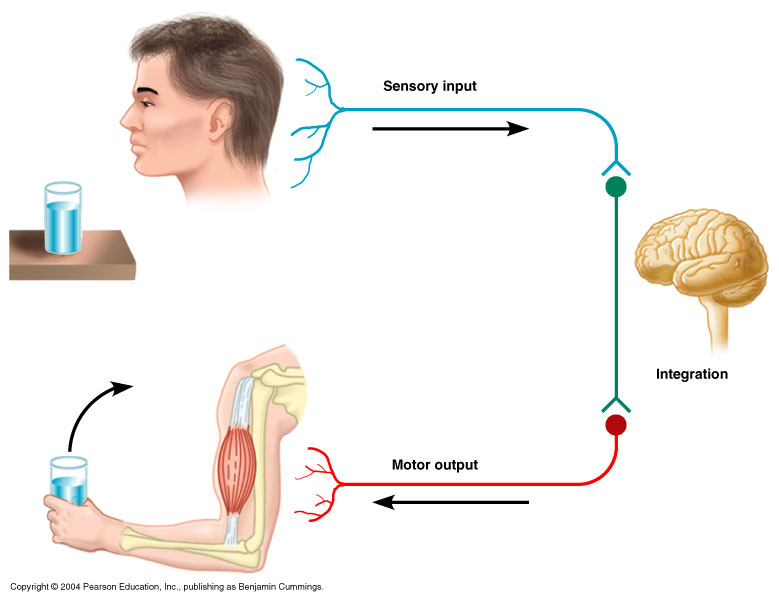
**Dr. Gary Mumaugh – Campbellsville University**

**Introduction**

* The function of the nervous system, along with the endocrine system, is to communicate
  + Communication makes possible control
  + Control makes possible integration
  + Integration makes possible homeostasis
  + Homeostasis makes possible survival
* The nervous system consists of the brain, spinal cord, and nerves

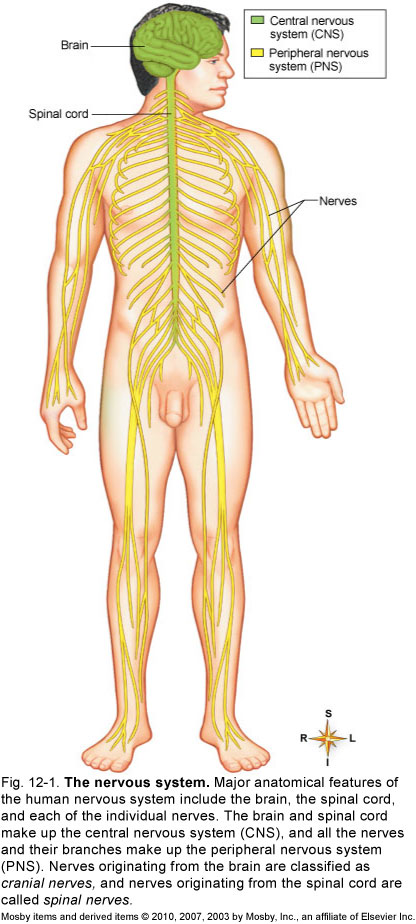
**Overview of Nervous System**

* endocrine and nervous system maintain internal coordination
  + endocrine system - communicates by means of chemical messengers (hormones) secreted into to the blood
  + nervous system - employs electrical and chemical means to send messages from cell to cell
* nervous system carries out its task in three basic steps:
  + sense organs receive information about changes in the body and the external environment, and transmits coded messages to the spinal cord and the brain
  + brain and spinal cord processes this information, relates it to past experiences, and determine what response is appropriate to the circumstances
  + brain and spinal cord issue commands to muscles and gland cells to carry out such a response

****

**Two Major Anatomical Subdivisions of Nervous System**

* central nervous system (CNS)
  + brain and spinal cord enclosed in bony coverings
  + enclosed by cranium and vertebral column
* peripheral nervous system (PNS)
  + all the nervous system outside the brain and spinal cord
  + composed of nerves and ganglia
    - nerve – a bundle of nerve fibers (axons) wrapped in fibrous connective tissue
    - ganglion – a knot-like swelling in a nerve where neuron cell bodies are concentrated

****

**Sensory (afferent) division**

* carries sensory signals from various receptors to the CNS
* informs the CNS of stimuli within or around the body
* somatic sensory division – carries signals from receptors in the skin, muscles, bones, and joints
* visceral sensory division – carries signals from the viscera of the thoracic and abdominal cavities
  + heart, lungs, stomach, and urinary bladder

**Motor (efferent) division**

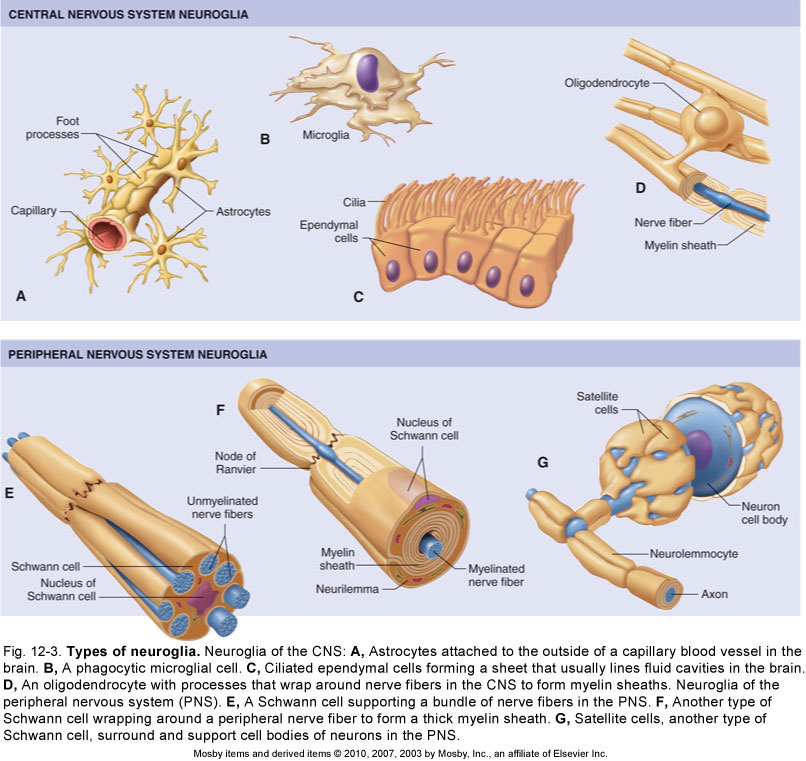
* carries signals from the CNS to gland and muscle cells that carry out the body’s response
  + effectors – cells and organs that respond to commands from the CNS
* somatic motor division – carries signals to skeletal muscles
  + output produces muscular contraction as well as somatic reflexes – involuntary muscle contractions
* visceral motor division (autonomic nervous system) - carries signals to glands, cardiac muscle, and smooth muscle
  + involuntary, and responses of this system and its receptors are visceral reflexes
  + Visceral Motor Division = Autonomic Nervous System
    - sympathetic division
      * tends to arouse body for action
      * accelerating heart beat and respiration, while inhibiting digestive and urinary systems
    - parasympathetic division
      * tends to have calming effect
      * slows heart rate and breathing
      * stimulates digestive and urinary systems

**Organization of the Nervous System**

* Organized to detect changes in internal and external environments, evaluate the information, and initiate an appropriate response
* Subdivided into smaller “systems” by location
  + Central nervous system (CNS)
    - Structural and functional center of the entire nervous system
    - Consists of the brain and spinal cord
    - Integrates sensory information, evaluates it, and initiates an outgoing response
  + Peripheral nervous system (PNS)
    - Nerves that lie in the “outer regions” of the nervous system
    - Cranial nerves originate from the brain
    - Spinal nerves originate from the spinal cord

**Organization of the Nervous System - continued**

* Afferent and efferent divisions
  + Afferent division consists of all incoming sensory pathways
  + Efferent division consists of all outgoing motor pathways
* “Systems” according to organs innervated
  + Somatic nervous system
    - Somatic motor division carries information to the somatic effectors (skeletal muscles)
    - Somatic sensory division carries feedback information to somatic integration centers in the CNS
  + Autonomic nervous system (ANS)
    - Efferent division of ANS carries information to the autonomic or visceral effectors (smooth and cardiac muscles and glands)
      * Sympathetic division: prepares the body to deal with immediate threats to the internal environment; produces fight-or-flight response
      * Parasympathetic division: coordinates the body’s normal resting activities; sometimes called the *rest-and-repair* division
    - Visceral sensory division carries feedback information to autonomic integrating centers in the CNS

****

**Cells of the Nervous System**

* Glia (neuroglia) - Glial cells support the neurons
* Five major types of glia
  + Astrocytes (in CNS)
    - Star shaped; largest and most numerous type of glia
    - Cell extensions connect to both neurons and capillaries
    - Astrocytes transfer nutrients from the blood to the neurons
    - Form tight sheaths around brain capillaries, which, with tight junctions between capillary endothelial cells, constitute the blood-brain barrier
  + Microglia (in CNS)
    - Small, usually stationary cells
    - In inflamed brain tissue, they enlarge, move about, and carry on phagocytosis
  + Ependymal cells (in CNS)
    - Resemble epithelial cells and form thin sheets that line fluid-filled cavities in the CNS
    - Some produce fluid; others aid in circulation of fluid
  + Oligodendrocytes (in CNS)
    - Smaller than astrocytes with fewer processes
    - Hold nerve fibers together and produce the myelin sheath
  + Schwann cells (in PNS)
    - Found only in peripheral neurons
    - Support nerve fibers and form myelin sheaths
    - Myelin sheath gaps are often called *nodes of Ranvier*
    - Neurilemma is formed by cytoplasm of Schwann cell wrapped around the myelin sheath; essential for nerve regrowth
    - Satellite cells are Schwann cells that cover and support cell bodies in the PNS
* Neurons - Excitable cells that initiate and conduct impulses that make possible all nervous system functions

**Components of Neurons**

* Cell body (perikaryon)
  + Ribosomes, rough endoplasmic reticulum, Golgi apparatus
    - Provide protein molecules (neurotransmitters) needed for transmission of nerve signals from one neuron to another
    - Neurotransmitters are packaged into vesicles
    - Provide proteins for maintaining and regenerating nerve fibers
    - Mitochondria provide energy (adenosine triphosphate) for neuron; some are transported to end of axon
* Dendrites
  + Each neuron has one or more dendrites, which branch from the cell body
  + Conduct nerve signals to the cell body of the neuron
  + Distal ends of dendrites of sensory neurons are receptors

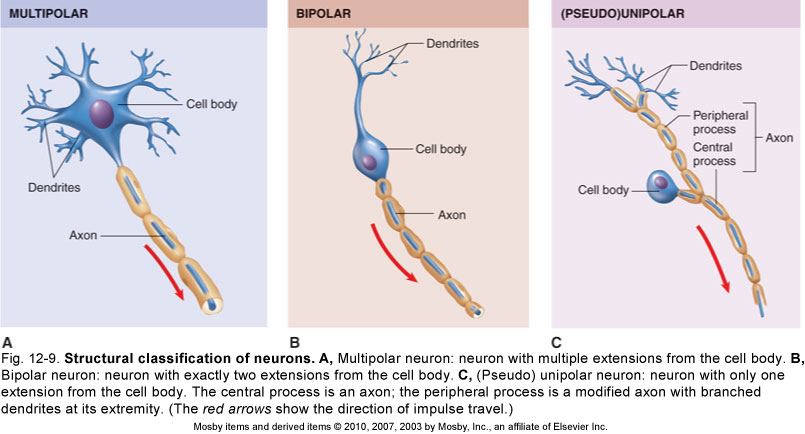
**Components of Neurons - continued**

* Axon
  + A single process extending from the axon hillock, sometimes covered by a fatty layer called a *myelin sheath*
  + Conducts nerve impulses away from the cell body of the neuron
  + Distal tips of axons are telodendria, each of which terminates in a synaptic knob
* Cytoskeleton
  + Microtubules and microfilaments, as well as neurofibrils (bundles of neurofilaments)
  + Allows the rapid transport of small organelles
    - Vesicles (some containing neurotransmitters), mitochondria
    - Motor molecules shuttle organelles to and from the far ends of a neuron

****

**Classification of Neurons**

* Structural classification: according to number of processes extending from cell body
  + Multipolar: one axon and several dendrites
  + Bipolar: only one axon and one dendrite; least numerous kind of neuron
  + Unipolar (pseudounipolar): one process comes off neuron cell body but divides almost immediately into two fibers: central fiber and peripheral fiber
* Functional classification
  + Afferent (sensory) neurons: conduct impulses to spinal cord or brain
  + Efferent (motor) neurons: conduct impulses away from spinal cord or brain toward muscles or glandular tissue
* Interneurons

****

**Reflexes**

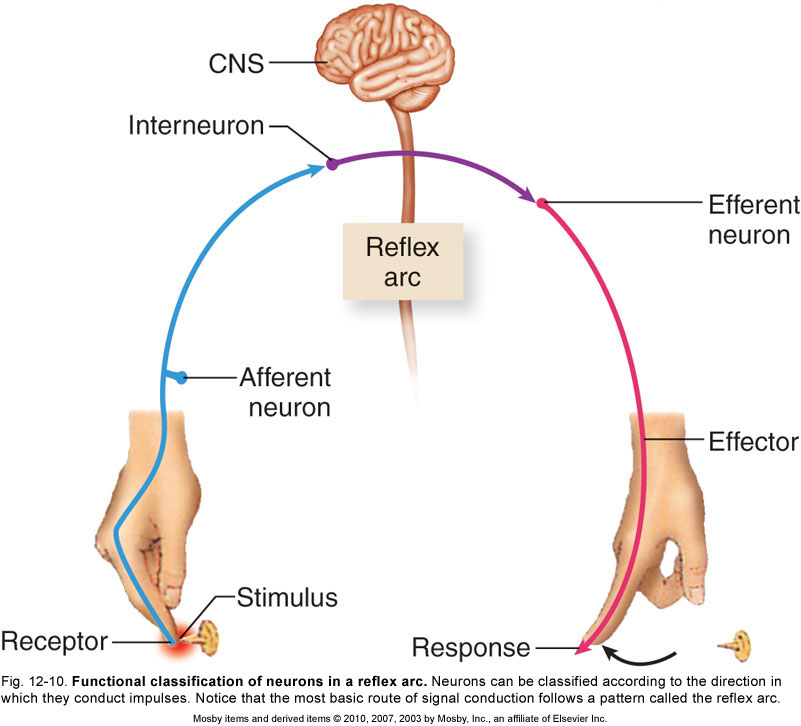
* A reflex is a rapid, predictable motor response to a stimulus
* Reflexes may:
  + Be inborn (intrinsic) or learned (acquired)
  + Involve only peripheral nerves and the spinal cord
  + Involve higher brain centers as well

**Reflex Arc**

* A signal conduction route to and from the CNS, with the electrical signal beginning in receptors and ending in effectors
* Three-neuron arc most common; consists of afferent neurons, interneurons, and efferent neurons
  + Afferent neurons conduct impulses to the CNS from the receptors
  + Efferent neurons conduct impulses from the CNS to effectors (muscle or glandular tissue)

**Reflex Arc - continued**

* There are five components of a reflex arc
  + Receptor – site of stimulus
  + Sensory neuron – transmits the afferent impulse to the CNS
  + Integration center – either monosynaptic or polysynaptic region within the CNS
  + Motor neuron – conducts efferent impulses from the integration center to an effector
  + Effector – muscle fiber or gland that responds to the efferent impulse

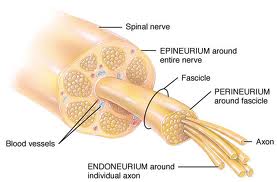
****

**Synapse**

* Where nerve signals are transmitted from one neuron to another
  + Two types: electrical and chemical; chemical synapses are typical in the adult
  + Chemical synapses are located at the junction of the synaptic knob of one neuron and the dendrites or cell body of another neuron

**Nerves and Tracts**

* Nerves: bundles of peripheral nerve fibers held together by several layers of connective tissue
  + Endoneurium: delicate layer of fibrous connective tissue surrounding each nerve fiber
  + Perineurium: connective tissue holding together fascicles (bundles of fibers)
  + Epineurium: fibrous coat surrounding numerous fascicles and blood vessels to form a complete nerve
* Within the CNS, bundles of nerve fibers are called *tracts* rather than *nerves*
* A nerve is a group of axons and or dendrites of several neurons, with blood vessels and connective tissue
* Sensory nerves are made of sensory neurons
* Motor nerves are made of motor neurons
* Mixed nerves contain both sensory and motor
* Nerve tracts occur in the CNS traveling up and down carrying information

[](http://www.google.com/imgres?hl=en&rlz=1I7GGLD_en&biw=1366&bih=589&tbm=isch&tbnid=01Y5I8B31Yj-iM:&imgrefurl=http://classroom.sdmesa.edu/eschmid/Chapter10-Zoo145.htm&docid=QDBPcIPpaCDliM&imgurl=http://classroom.sdmesa.edu/eschmid/F10.05.L.150.jpg&w=580&h=380&ei=AMCRT-KDGoeJgwf80sH6BA&zoom=1&iact=hc&vpx=661&vpy=233&dur=16894&hovh=182&hovw=277&tx=153&ty=90&sig=100974934971220628721&page=3&tbnh=109&tbnw=167&start=47&ndsp=32&ved=1t:429,r:12,s:47,i:200)

**Types of Neurons**

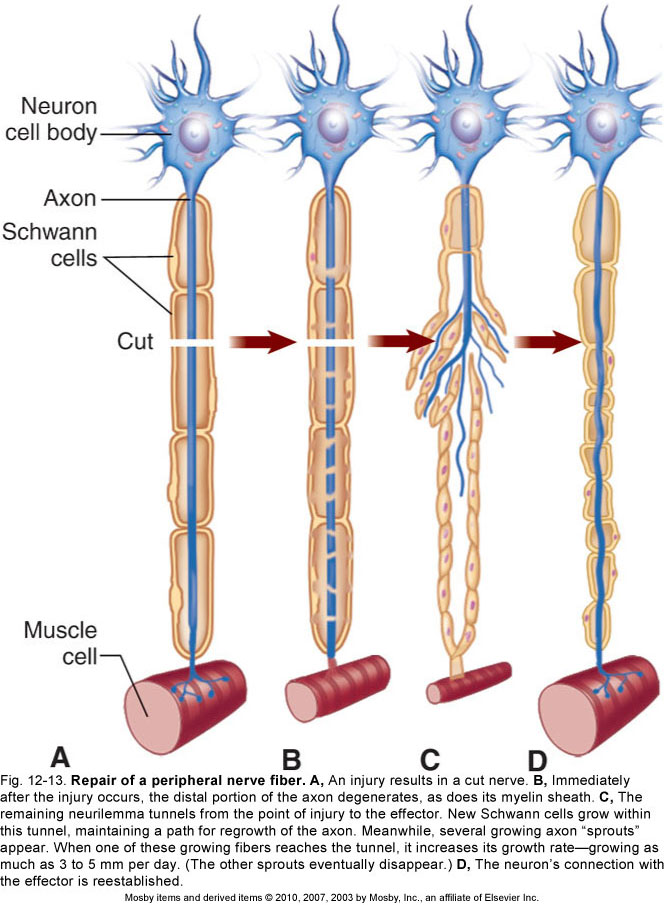
* Sensory neurons – afferent neurons
  + Carry impulses from the receptors to the CNS
  + Receptors detect changes in the internal and external environment
  + Sensory neurons
    - Receptors from the skin, skeletal muscles and joints
  + Visceral neurons
    - Receptors from the internal organs
* Motor neurons – efferent neurons
  + Carry impulses from the CNS to the effectors
* Interneurons
  + Found entirely in the CNS

**Nerves and Tracts**

* White matter
  + PNS: myelinated nerves
  + CNS: myelinated tracts
* Gray matter
  + Composed of cell bodies and unmyelinated fibers
* Mixed nerves
  + Contain sensory and motor neurons
  + Sensory nerves have predominantly sensory neurons
  + Motor nerves have predominantly motor neurons

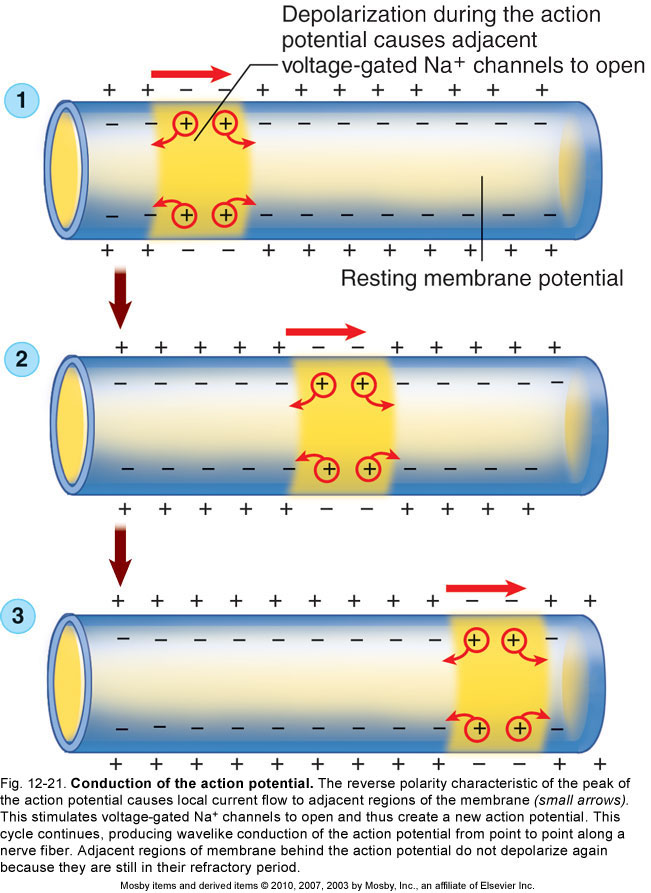
**Repair of Nerve Fibers**

* Mature neurons are incapable of cell division; therefore damage to nervous tissue can be permanent
* Neurons have limited capacity to repair themselves
* If the damage is not extensive, the cell body and neurilemma are intact, and scarring has not occurred, nerve fibers can be repaired
* Stages of repair of an axon in a peripheral motor neuron
  + After injury, distal portion of axon and myelin sheath degenerates
  + Macrophages remove the debris
  + Remaining neurilemma and endoneurium form a tunnel from the point of injury to the effector
  + New Schwann cells grow in tunnel to maintain a path for axon regrowth
  + Cell body reorganizes its Nissl bodies to provide the needed proteins to extend the remaining healthy portion of the axon
  + Axon “sprouts” appear
  + When sprout reaches tunnel, its growth rate increases
  + Skeletal muscle cell atrophies until nervous connection is reestablished
* In CNS, similar repair of damaged nerve fibers is unlikely

****

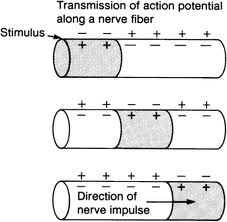
**Nerve Impulses**

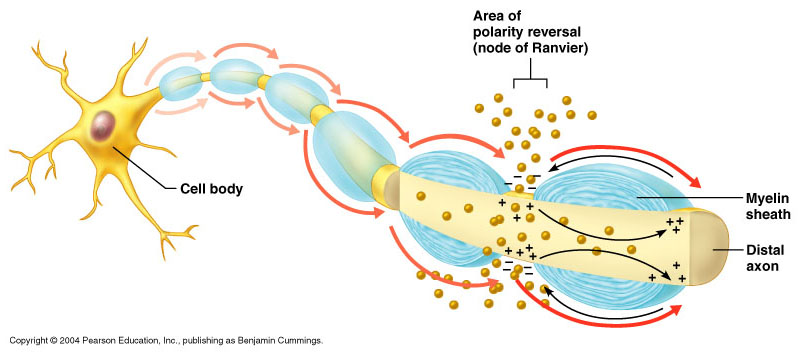
* Membrane potentials
  + All living cells maintain a difference in the concentration of ions across their membranes
  + Membrane potential: slight excess of positively charged ions on the outside of the membrane and slight deficiency of positively charged ions on the inside of the membrane
  + Difference in electrical charge is called *potential* because it is a type of stored energy
* Resting membrane potential
  + Membrane potential maintained by a non-conducting neuron’s plasma membrane; typically −70 mV
  + The membrane’s selective permeability characteristics help maintain a slight excess of positive ions on the outer surface of the membrane
  + Sodium-potassium pump
    - Active transport mechanism in plasma membrane that transports sodium (Na+) and potassium (K+) ions in opposite directions and at different rates
    - Maintains an imbalance in the distribution of positive ions, resulting in the inside surface becoming slightly negative compared with its outer surface

****

**Action Potential**

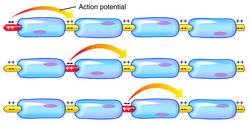
* Action potential: the membrane potential of a neuron conducting an impulse; also known as a *nerve impulse*
* Mechanism that produces the action potential
  + When an adequate stimulus triggers stimulus-gated Na+ channels to open, allowing Na+ to diffuse rapidly into the cell, which produces a local depolarization
  + The action potential is an all-or-none response
  + After action potential peaks, membrane begins to move back toward the resting membrane potential, a process is known as *repolarization*
* Refractory period
  + Absolute refractory period: brief period (lasting approximately 0.5 ms) during which a local area of a neuron’s membrane resists restimulation and will not respond to a stimulus, no matter how strong
  + Relative refractory period: time when the membrane is repolarized and restoring the resting membrane potential; the few milliseconds after the absolute refractory period; will respond only to a very strong stimulus
* Conduction of the action potential
  + At the peak of the action potential, the plasma membrane’s polarity is now the reverse of the resting membrane potential
  + This cycle continues to repeat
  + The action potential never moves backward
  + In myelinated fibers, action potentials in the membrane only occur at the nodes of Ranvier; this type of impulse conduction is called *saltatory conduction*
  + Speed of nerve conduction depends on diameter and on the presence or absence of a myelin sheath

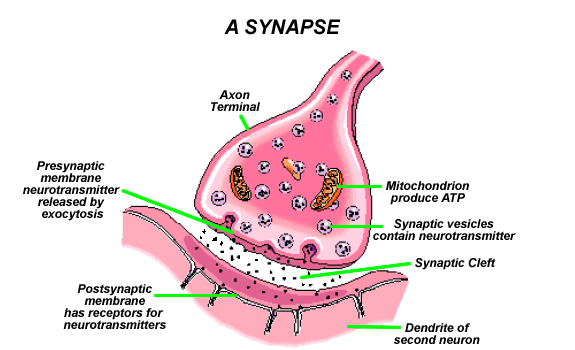
[](http://www.google.com/imgres?hl=en&rlz=1I7GGLD_en&biw=1366&bih=589&tbm=isch&tbnid=wJ7bEB21WiJdGM:&imgrefurl=http://www.mhhe.com/biosci/abio/studycards/studycard116.mhtml&docid=wysoxyaI-W01CM&imgurl=http://www.mhhe.com/biosci/abio/images/card116a.gif&w=295&h=288&ei=DseRT-_iIoLdggeG9KHTBA&zoom=1&iact=hc&vpx=516&vpy=238&dur=17316&hovh=222&hovw=227&tx=161&ty=152&sig=103231333022922378856&page=3&tbnh=139&tbnw=142&start=49&ndsp=28&ved=1t:429,r:2,s:49,i:183)

****

**Synaptic Transmission**

* Two types of synapses (junctions)
  + Electrical synapses occur where cells joined by gap junctions allow an action potential to simply continue along postsynaptic membrane
  + Chemical synapses occur where presynaptic cells release chemical transmitters (neurotransmitters) across a tiny gap
    - Structure of the chemical synapse
      * Synaptic knob: tiny bulge at the end of a terminal branch of a presynaptic neuron’s axon that contains vesicles housing neurotransmitters
      * Synaptic cleft: space between a synaptic knob and the plasma membrane of a postsynaptic neuron
      * Plasma membrane of a postsynaptic neuron has protein molecules that serve as receptors for the neurotransmitters
* Synapses and memory
  + Memories are stored by facilitating (or inhibiting) synaptic transmission
  + Short-term memories (seconds or minutes)
  + Intermediate long-term memory (minutes to weeks)
  + Long-term memories (months or years)



****

**Neurotransmitters**

* Neurotransmitters: means by which neurons communicate with one another; more than 30 compounds are known to be neurotransmitters, and dozens of others are suspected
* Common classification of neurotransmitters:
  + Function: determined by the postsynaptic receptor; two major functional classifications are excitatory neurotransmitters and inhibitory neurotransmitters
  + Chemical structure: the mechanism by which neurotransmitters cause a change; four main classes; because the functions of specific neurotransmitters vary by location, usually classified by chemical structure

**The Big Picture**

* Neurons act as the “wiring” that connects structures needed to maintain homeostasis
* Sensory neurons act as receptors to detect changes in the internal and external environment; relay information to integrator mechanisms in the CNS
* Information is processed and a response is relayed to the appropriate effectors through the motor neurons
* At the effector, neurotransmitter triggers a response to restore homeostasis
* Neurotransmitters released into the bloodstream are called *hormones*
* Neurons are responsible for more than just responding to stimuli; circuits are capable of remembering or learning new responses and generating thought