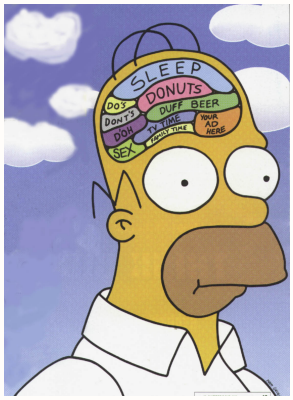
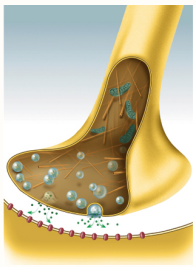
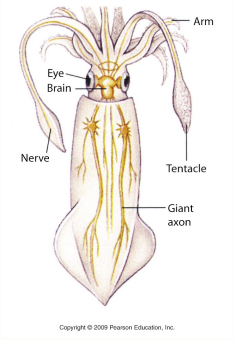


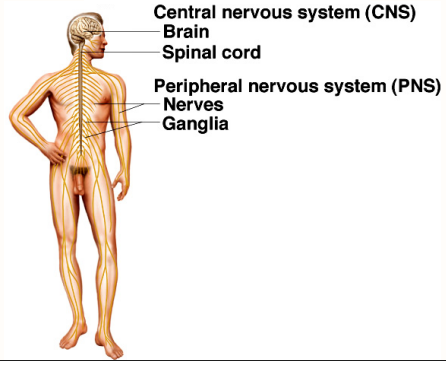
Chapter 12
Nervous Tissue

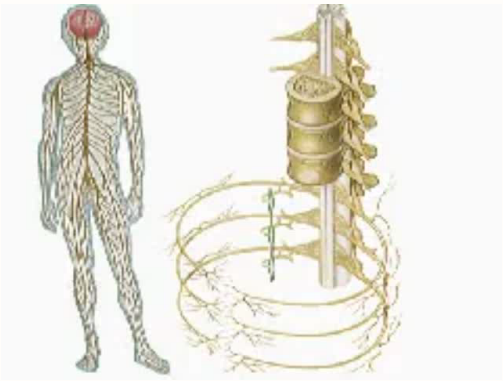
- Overview of the nervous system
- Cells of the nervous system
- Electrophysiology of neurons
- Synapses
- Neural integration



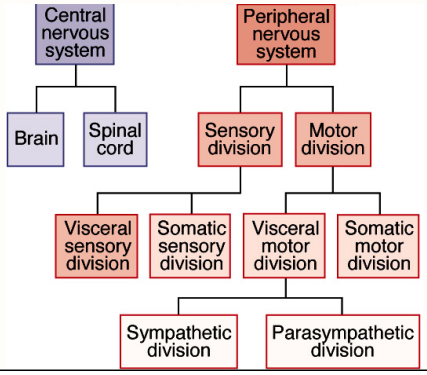


Subdivisions of the Nervous System

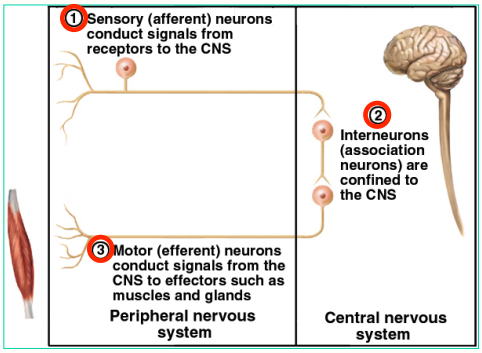




Subdivisions of Nervous System



Fundamental Types of Neurons



Structure of a Neuron

- Cell body = perikaryon= soma
- Vast number of short dendrites
- Singe axon (nerve fiber) arising from axon hillock for rapid conduction

Variation in Neuronal Structure

- Multipolar neuron
  - most common
  - many dendrites/one axon
- Bipolar neuron
  - one dendrite/one axon
  - olfactory, retina, ear
- Unipolar neuron
  - sensory from skin & organs to spinal cord
- Anaxonic neuron
  - many dendrites/no axon
  - help in visual processes

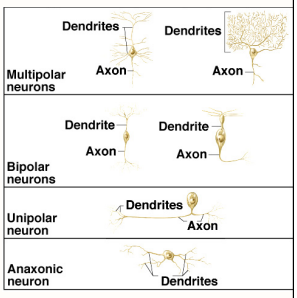
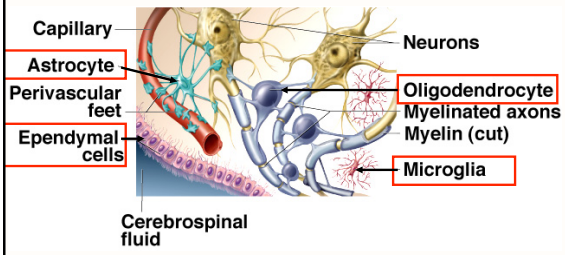


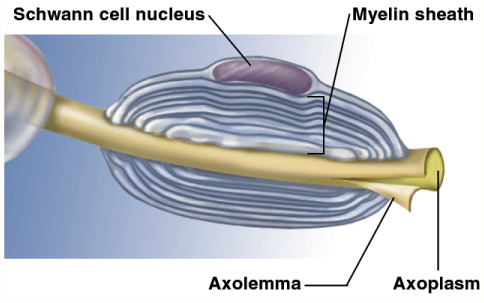
Table 12.1 Types of Glial Cells

Types	Functions
Neuroglia of CNS	
Oligodendrocytes	Form myelin in brain and spinal cord
Astrocytes	Cover brain surface and nonsynaptic regions of neurons; form supportive framework in CNS; induce formation of blood-brain barrier; nourish neurons; produce growth factors that stimulate neurons; communicate electrically with neurons and may influence synaptic signalling; remove neurotransmitters and K^+ from ECF of brain and spinal cord; help to regulate composition of ECF; form scar tissue to replace damaged nervous tissue
Ependymal cells	Line cavities of brain and spinal cord; secrete and circulate cerebrospinal fluid
Microglia	Phagocytize and destroy microorganisms, foreign matter, and dead nervous tissue
Neuroglia of PNS	
Schwann cells	Form neurilemma around all PNS nerve fibers and myelin around most of them; aid in regeneration of damaged nerve fibers
Satellite cells	Surround somas of neurons in the ganglia; function uncertain

Neuroglial Cells of CNS

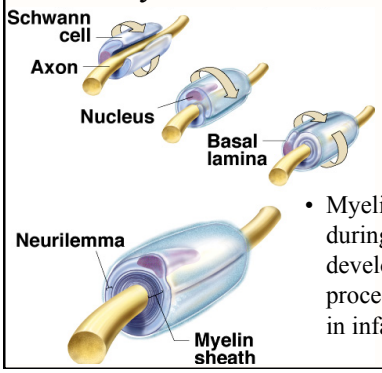


Myelin Sheath



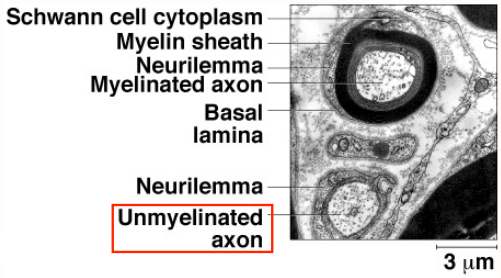
- Note: Node of Ranvier between Schwann cells

Myelin Sheath Formation



- Myelination begins during fetal development, but proceeds most rapidly in infancy.

Unmyelinated Axons

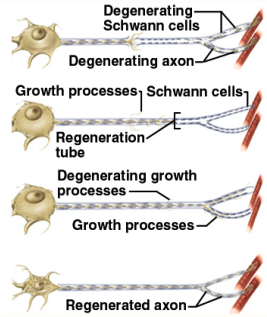


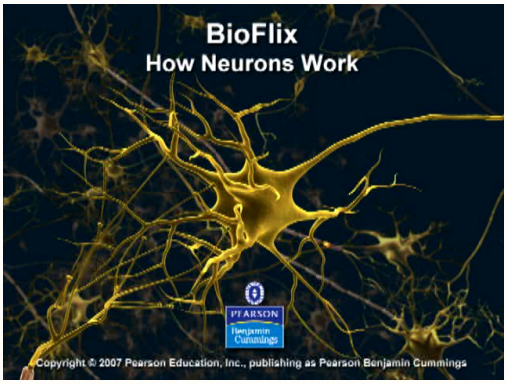
- Schwann cells hold small nerve fibers in grooves on their surface with only one membrane wrapping

Speed of Nerve Signal

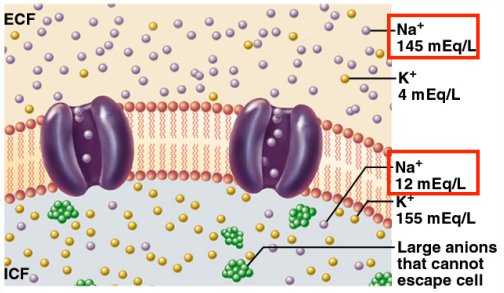
- Speed of signal transmission along nerve fibers
- Speeds
- Functions

Regeneration of Peripheral Nerve Fibers



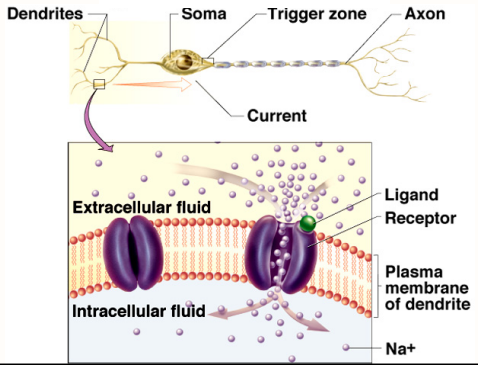


Ionic Basis of Resting Membrane Potential

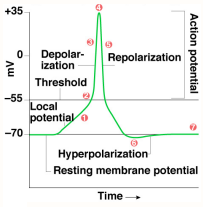


- Na^+ concentrated outside of cell (ECF)
- K^+ concentrated inside cell (ICF)

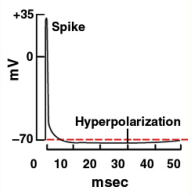
Chemical Excitation



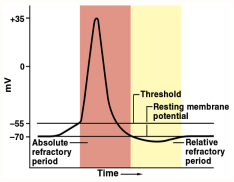
Action Potentials



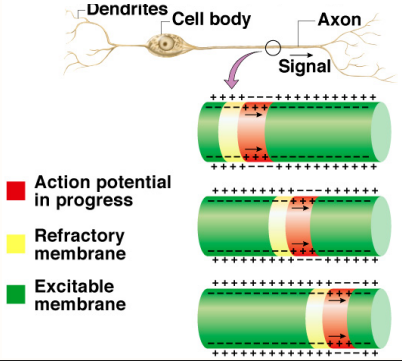
Action Potentials



The Refractory Period

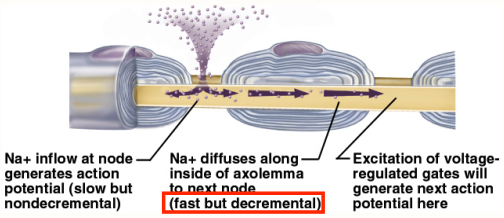


Impulse Conduction in Unmyelinated Fibers

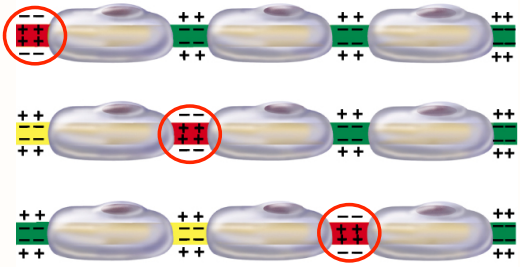


Saltatory Conduction in Myelinated Fibers

- Voltage-gated channels needed for APs
  - fewer than 25 per μm^2 in myelin-covered regions
  - up to 12,000 per μm^2 in nodes of Ranvier
- Fast Na+ diffusion occurs between nodes

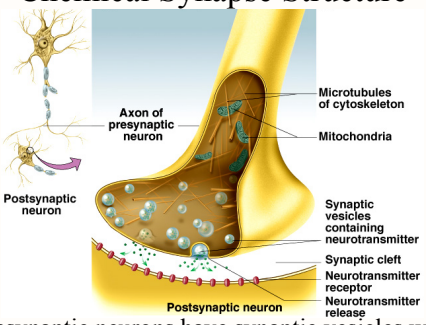


Saltatory Conduction of Myelinated Fiber



- Notice how the action potentials jump from node of Ranvier to node of Ranvier.

Chemical Synapse Structure

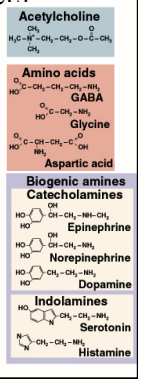


- Presynaptic neurons have synaptic vesicles with neurotransmitter and postsynaptic have receptors

Types of Neurotransmitters

- 100 neurotransmitter types in 4 major categories

1. Acetylcholine
   - formed from acetic acid & choline
2. Amino acid neurotransmitters
3. Monoamines
   - synthesized by replacing -COOH in amino acids with another functional group
   - catecholamines (epi, NE & dopamine)
   - indolamines (serotonin & histamine)
4. Neuropeptides (next)



Neuropeptides

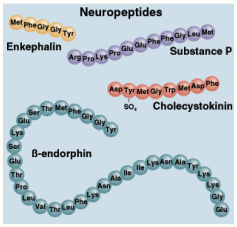


Table 12.3 Neurotransmitters and Neuropeptides

Name	Locations and Actions
Acetylcholine (Ach)	Neuromuscular junctions, most synapses of autonomic nervous system, retina, and many parts of the brain; excites skeletal muscles, inhibits cardiac muscle, and has excitatory or inhibitory effects on smooth muscle and glands depending on location
Excitatory Amino Acids	
Glutamate (glutamic acid)	Cerebral cortex and brainstem; retina; accounts for about 75% of all excitatory synaptic transmission in the brain; involved in learning and memory
Aspartate (aspartic acid)	Spinal cord; effects similar to those of glutamate
Inhibitory Amino Acids	
Glycine	Inhibitory neurons of the brain, spinal cord, and retina; most common inhibitory neurotransmitter in the spinal cord
GABA (γ-aminobutyric acid)	Thalamus, hypothalamus, cerebellum, occipital lobes of cerebrum, and retina; most common inhibitory neurotransmitter in the brain
Monoamines (biogenic amines)	
Catecholamines	
Norepinephrine	Sympathetic nervous system, cerebral cortex, hypothalamus, brainstem, cerebellum, and spinal cord; involved in dreaming, waking, and mood; excites cardiac muscle; can excite or inhibit smooth muscle and glands depending on location
Epinephrine	Hypothalamus, thalamus, spinal cord, and adrenal medulla; effects similar to those of norepinephrine
Dopamine	Hypothalamus, limbic system, cerebral cortex, and retina; highly concentrated in substantia nigra of midbrain; involved in elevation of mood and control of skeletal muscles
Other Monoamines	
Serotonin	Hypothalamus, limbic system, cerebellum, retina, and spinal cord; also secreted by blood platelets and intestinal cells; involved in sleepiness, alertness, thermoregulation, and mood
Histamine	Hypothalamus; also a potent vasodilator released by mast cells of connective tissue
Neuropeptides	
Substance P	Basal nuclei, midbrain, hypothalamus, cerebral cortex, small intestine, and pain-receptor neurons; mediates pain transmission
Enkephalins	Hypothalamus, limbic system, pituitary, pain pathways of spinal cord, and nerve endings of digestive tract; act as analgesics (pain-relievers) by inhibiting substance P; inhibit intestinal motility; secretion increases sharply in women in labor
β-endorphin	Digestive tract, spinal cord, and many parts of the brain; also secreted as a hormone by the pituitary; suppresses pain; reduces perception of fatigue and produces "runner's high" in athletes
Cholecystokinin (CCK)	Cerebral cortex and small intestine; suppresses appetite

Synaptic Transmission

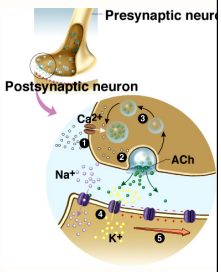
3 kinds of synapses with different modes of action

- Excitatory cholinergic synapse
- Inhibitory GABA-ergic synapse
- Excitatory adrenergic synapse

Synaptic delay (.5 msec)

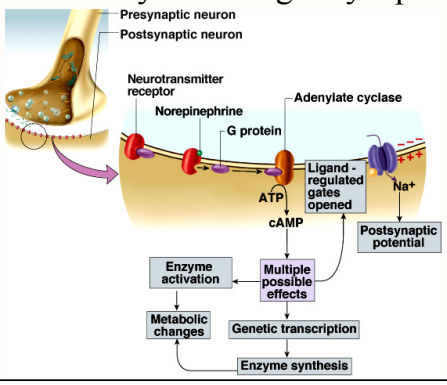
– time from arrival of nerve signal at synapse to start of AP in postsynaptic cell

Excitatory Cholinergic Synapse



Inhibitory GABA-ergic Synapse

Excitatory Adrenergic Synapse



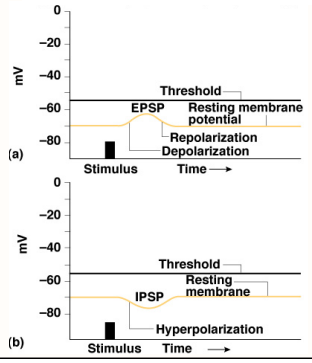
Cessation & Modification of the Signal

- Mechanisms to turn off stimulation
- Neuromodulators modify synaptic transmission

Neural Integration

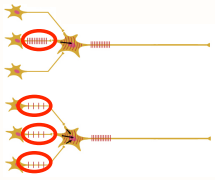
- More synapses a neuron has the greater its information-processing capability
- Chemical synapses are decision-making components of the nervous system
- Neural integration is based on types of postsynaptic potentials produced by neurotransmitters

Postsynaptic Potentials

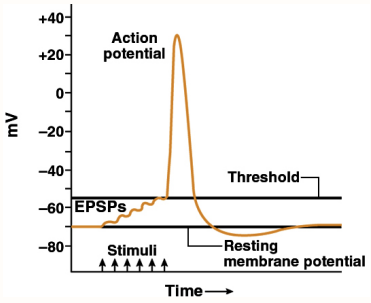


Summation of Postsynaptic Potentials

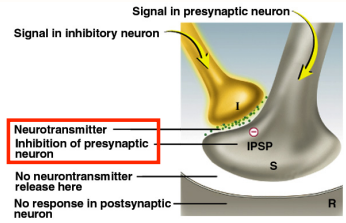
- Net postsynaptic potentials in the trigger zone
  - whether neuron fires depends on net input of other cells
  - temporal summation
  - spatial summation



Summation of EPSP's



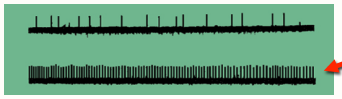
Presynaptic Inhibition



- One presynaptic neuron suppresses another one.

Neural Coding

- Qualitative information (salty or sweet) depends upon which neurons are fired

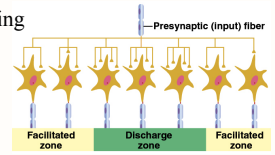


More rapid firing frequency

- Qualitative information depend on:
  - strong stimuli excite different neurons (recruitment)
  - stronger stimuli causes a more rapid firing rate
    - CNS judges stimulus strength from firing frequency of sensory neurons
      - 600 action potentials/sec instead of 6 per second

Neuronal Pools and Circuits

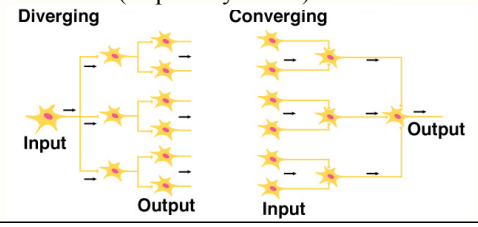
- Neuronal pool is 1000's to millions of interneurons that share a specific body function
  - control rhythm of breathing



- Facilitated versus discharge zones
  - in discharge zone, a single cell can produce firing
  - in facilitated zone, single cell can only make it easier for the postsynaptic cell to fire

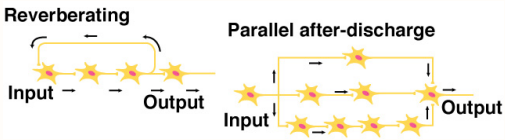
Neuronal Circuits

- Diverging circuit -- one cell synapses on other that each synapse on others
- Converging circuit -- input from many fibers on one neuron (respiratory center)



Neuronal Circuits

- Reverberating circuits
  - neurons stimulate each other in linear sequence but one cell restimulates the first cell to start the process all over
- Parallel after-discharge circuits
  - input neuron stimulates several pathways which stimulate the output neuron to go on firing for longer time after input has truly stopped

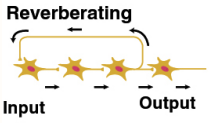


Memory & Synaptic Plasticity

- Memories are not stored in individual cells
- Physical basis of memory is a pathway of cells
- Synaptic potentiation
  - process of making transmission easier
  - correlates with different forms of memory

Immediate Memory

- Ability to hold something in your thoughts for just a few seconds
- Feel for the flow of events (sense of the present)
- Our memory of what just happened "echoes" in our minds for a few seconds
  - reverberating circuits



Short-Term Memory

- Lasts from a few seconds to several hours
- Working memory allows us to keep something in mind long enough search for keys, dial the phone
- Facilitation causes memory to longer lasting
- Posttetanic potentiation (to jog a memory)

Long-Term Memory

- May last up to a lifetime
- Types of long-term memory
- Physical remodeling of synapses with new branching of axons or dendrites
- Molecular changes called long-term potentiation

Alzheimer Disease

- 100,000 deaths/year
  - 11% of population over 65; 47% by age 85
- Symptoms
  - memory loss for recent events, moody, combative, lose ability to talk, walk, and eat
- Diagnosis confirmed at autopsy
  - atrophy of gyri (folds) in cerebral cortex
  - neurofibrillary tangles & senile plaques
- Degeneration of cholinergic neurons & deficiency of ACh and nerve growth factors
- Genetic connection confirmed for some forms

Parkinson Disease

- Progressive loss of motor function beginning in 50's or 60's -- no recovery
  - degeneration of dopamine-releasing neurons in substantia nigra
    - prevents excessive activity in motor centers (basal ganglia)
  - involuntary muscle contractions
    - pill-rolling motion, facial rigidity, slurred speech, illegible handwriting, slow gait
- Treatment is drugs and physical therapy
  - dopamine precursor can cross blood-brain barrier
  - deprenyl (MAO inhibitor) slows neuronal degeneration
  - surgical technique to relieve tremors