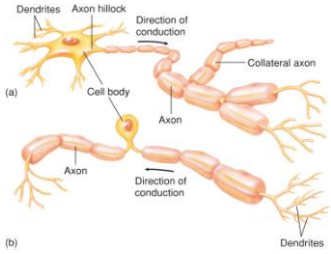
Chapter 7 Outline

- Neurons and Supporting Cells
- Electrical Activity in Axons
- The Synapse
- Acetylcholine as a Neurotransmitter
- Monoamines as Neurotransmitters
- Other Neurotransmitters
- Synaptic Integration

Nervous System (NS)

- Is divided into:
  - Central nervous system (CNS)
    - = brain and spinal cord
  - Peripheral nervous system (PNS)
    - = cranial and spinal nerves
- Consists of 2 kinds of cells:
  - Neurons and supporting cells (= glial cells)
    - Neurons are functional units of NS
    - Glial cells maintain homeostasis

Neurons

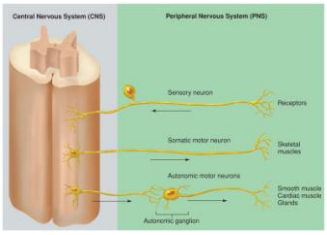


Anterograde transport away from CB
Retrograde transport towards CB

Groups of cell bodies in CNS are called nuclei; in PNS are called ganglia

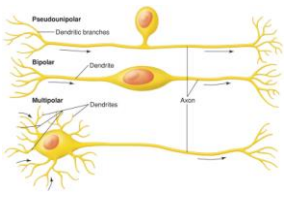
Functional Classification of Neurons

- Sensory/Afferent neurons conduct impulses into CNS
- Motor/Efferent neurons carry impulses out of CNS
- Association/ Interneurons integrate NS activity
  - Located entirely inside CNS



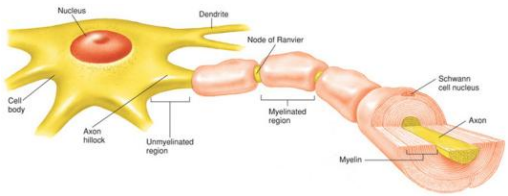
Structural Classification of Neurons

- Pseudounipolar:
  - Cell body sits along side of single process
  - e.g. sensory neurons
- Bipolar:
  - Dendrite and axon arise from opposite ends of cell body
  - e.g. retinal neurons
- Multipolar:
  - Have many dendrites and one axon
  - e.g. motor neurons



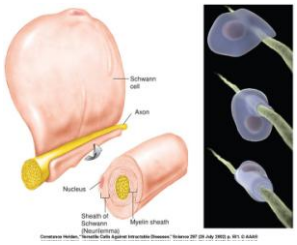
Glial Cells

- PNS has Schwann and satellite cells
  - Schwann cells (neurilemma) myelinate PNS axons
  - Satellite cells: support ganglia in PNS



Myelination

- In PNS each Schwann cell myelinates
  - Electrically insulates axon



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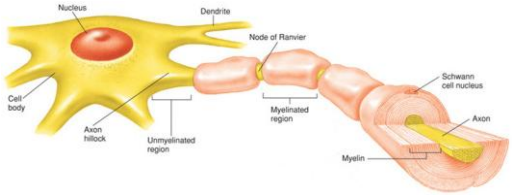
Myelination

- Uninsulated gap between adjacent Schwann cells is called the node of Ranvier



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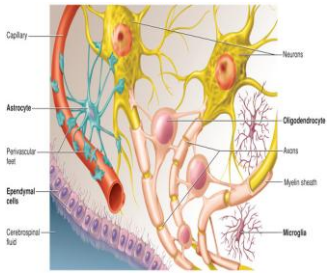
CNS Glial Cells

- **Oligodendrocytes: myelinates several CNS axons**
- **Ependymal cells produce CSF**
- **Microglia: phagocytize**
- **Astrocytes:**



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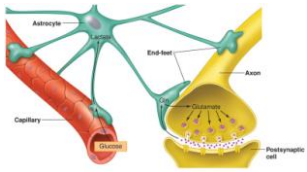
CNS Glial cells: Astrocytes

- **Most common glial cell**
- **Involved in:**
  - **Buffering K+ levels**
  - **Recycle neurotransmitters**
  - **Regulating adult neurogenesis**
  - **Releasing transmitters that regulate neuronal activity + -**
  - **BBB**



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Blood-Brain Barrier

- Allows only certain compounds to enter brain
- Formed by capillary specializations in brain
  - Induced by astrocytes
  - Brain Capillaries are not as leaky as those in body
    - Gaps between adjacent cells are closed by tight junctions

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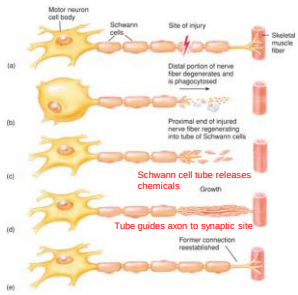
Nerve Regeneration (PNS)

- **CNS – no dice**
  - **Oligodendrocytes produce proteins that inhibit regrowth**
    - **form glial scar tissue - blocks regrowth**



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Resting Membrane Potential (RMP)

- At rest, all cells have a negative internal charge and unequal distribution of ions:
  - Results from:
    - Large cations being trapped inside cell
    - Na+/K+ pump and limited permeability keep Na+ high outside cell
    - K+ is very permeable and is high inside cell
      - But attracted by negative charges inside

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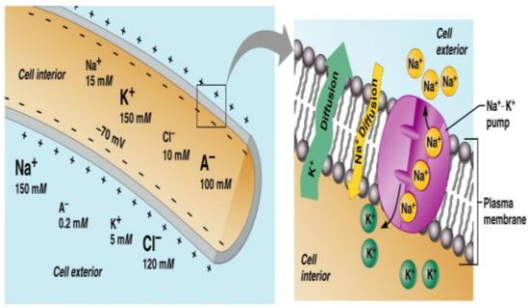
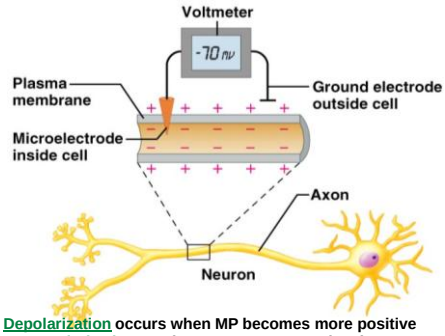
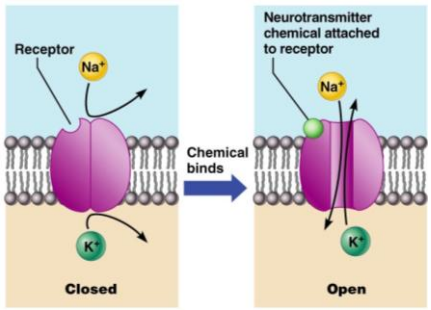


Resting Membrane Potential



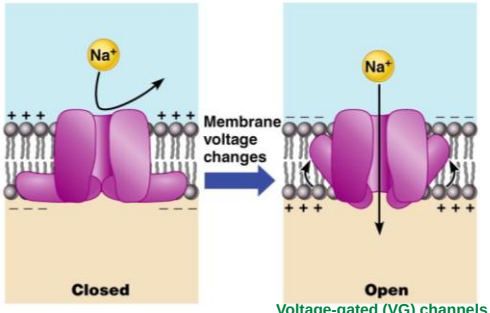
Depolarization occurs when MP becomes more positive
Hyperpolarization: MP becomes more negative than RMP
Repolarization: MP returns to RMP

Figure 11.7



(a) Chemically gated ion channel

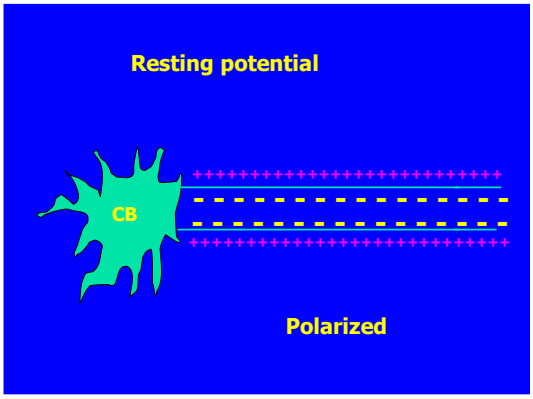
Figure 11.6a

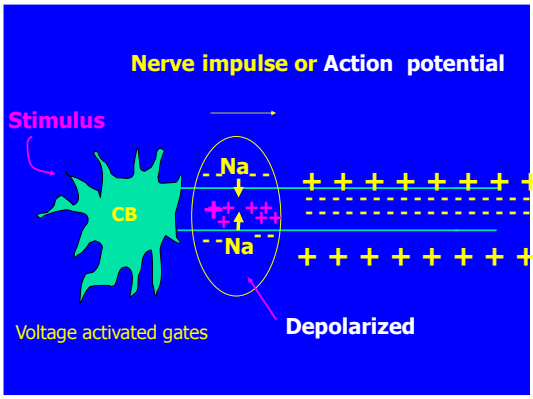


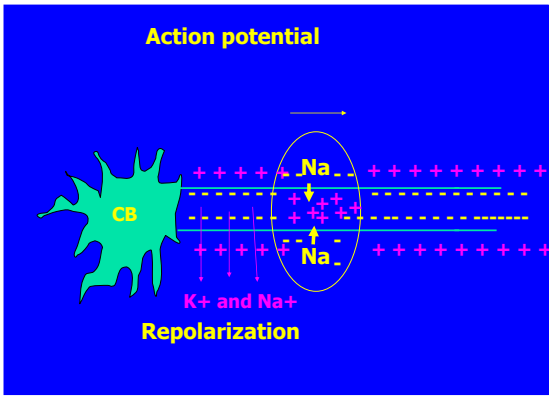
(b) Voltage-gated ion channel

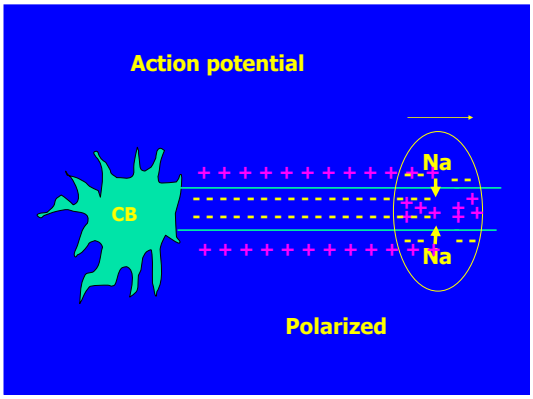
Voltage-gated (VG) channels are opened by depolarization
- K+ & Na+ channels are closed in resting cells

Figure 11.6b









Mechanism of Action Potential

- Depolarization and repolarization occur via diffusion
  - Do not require active transport
  - After an AP, Na^+/K^+ pump extrudes Na^+, recovers K^+

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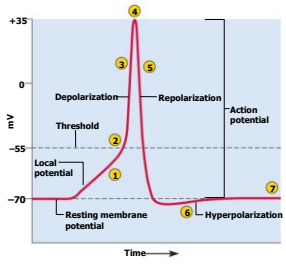
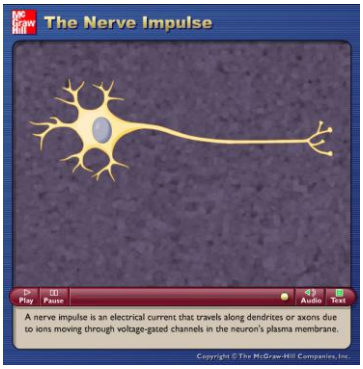
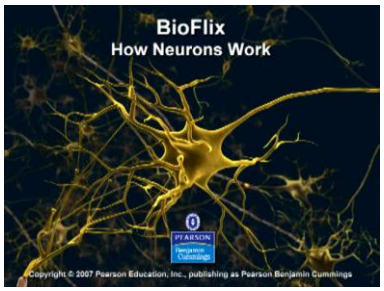
Action Potentials

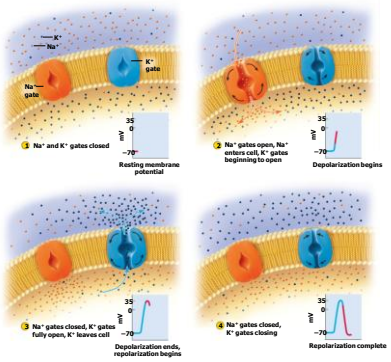
- action potential is often called a spike – happens so fast





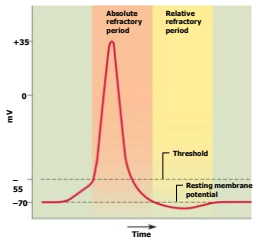


Sodium and Potassium Gates



Refractory Period

- **Refractory period – period of resistance to stimulation**
- **two phases of the refractory period**
  - **absolute refractory period**
    - **no stimulus of any strength will trigger AP**
    - **as long as Na^+ gates are open**
    - **from action potential to RMP**
  - **relative refractory period**
    - **only especially strong stimulus will trigger new AP**



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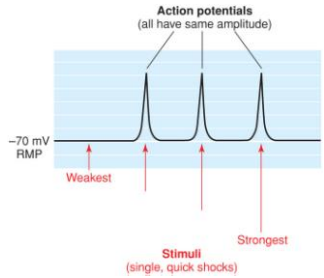
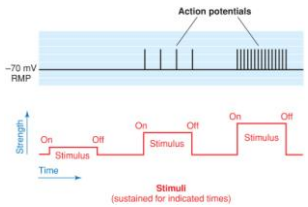
APs Are All-or-None



7-38

How Stimulus Intensity is Coded

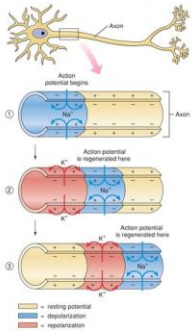
- Increased stimulus intensity causes more APs to be fired
  - Size of APs remains constant



7-39

Conduction in an Unmyelinated Axon

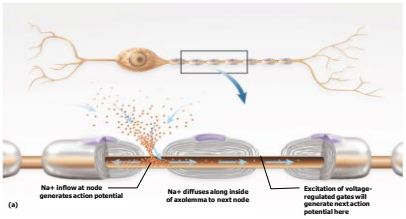
- After axon hillock reaches threshold and fires AP, its Na^+ influx depolarizes adjacent regions to threshold
  - Generating a new AP
    - Process repeats all along axon
    - So AP amplitude is always same

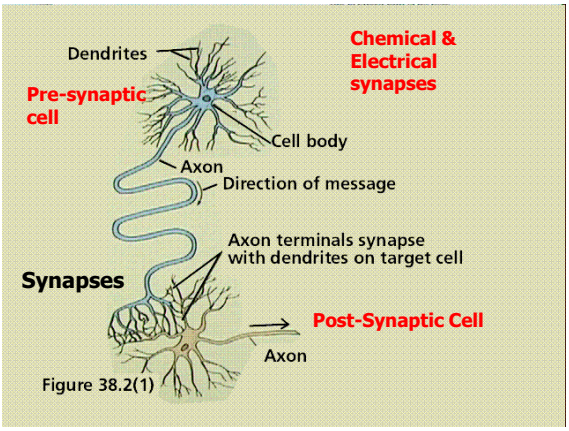


7-43

Saltatory Conduction of Myelinated Fibers

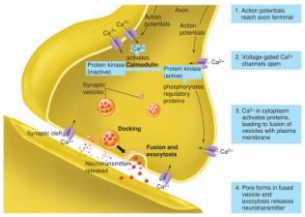
- Remember - voltage-gated channels needed for APs
  - Few in myelin-covered regions
  - Lots at nodes of Ranvier
- Fast Na^+ diffusion occurs between nodes





Chemical Synapse

- Synaptic cleft separates presynaptic cell from postsynaptic cell
- NTs are in synaptic vesicles
- Amount of NT released depends upon frequency of APs

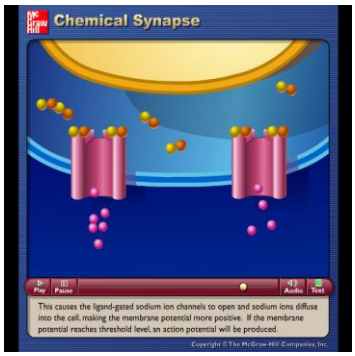


7-49

Synaptic Transmission

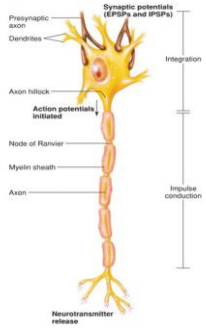
- Neurotranmitter diffuses across cleft
  - Binds to receptor proteins on postsynaptic membrane
    - Opening chemically-regulated ion channels
  - Depolarizing channels cause EPSPs (excitatory postsynaptic potentials)
  - Hyperpolarizing channels cause IPSPs (inhibitory postsynaptic potentials)
  - These affect VG channels in postsynaptic cell

7-52



Synaptic Transmission

- **EPSPs and IPSPs summate**
- **If MP in postsynaptic cell reaches threshold at the axon hillock, a new AP is generated**
  - **axon hillock has many VG channels and is site where APs are normally initiated**



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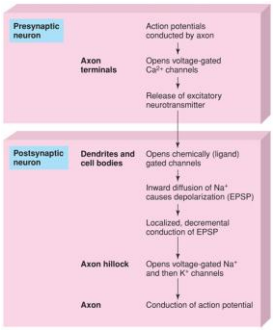
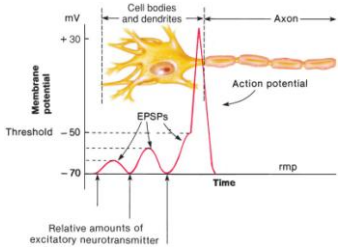
Synaptic Transmission



7-54

EPSPs

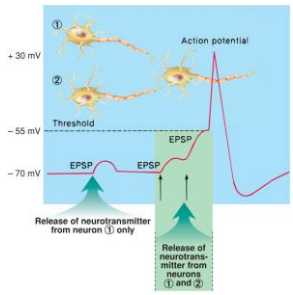
- Graded in magnitude
- Have no threshold
- Cause depolarization
- Summate
- Have no refractory period
- Degrade



7-76

Spatial Summation

- Spatial summation takes place when EPSPs from different synapses occur in postsynaptic cell at same time
- Temporal summation occurs because EPSPs that occur closely in time can sum before they fade



http://www.sinauer.com/neuroscience4e/animations5.2.html

7-77

Neurotransmitters and Related Messengers

- **> 100 neurotransmitters**
- **4 major categories according to chemical composition**
  1. **Acetylcholine : in a class by itself**
  2. **Amino acid neurotransmitters**
     - **include glycine, glutamate, aspartate, and γ-aminobutyric acid (GABA)**
  3. **Monoamines (Biogenic amines)**
     - **synthesized from amino acids by removal of COOH group**
  4. **Neuropeptides**

12-41

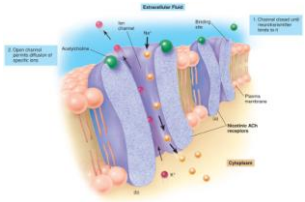
Acetylcholine (ACh)

- Most widely used NT
  - Used in brain and ANS; **used at all neuromuscular junctions**
- Has nicotinic and muscarinic receptor subtypes
  - These can be excitatory or inhibitory

7-55

Nicotinic ACh Channel

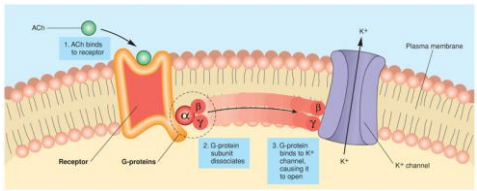
- 2 subunits contain ACh binding sites
  - Opens when 2 AChs bind
  - Permits diffusion of Na^+ into and K^+ out of postsynaptic cell
  - Inward flow of Na^+ dominates
  - Produces EPSPs



7-57

Muscarinic ACh Channel

- Binding of 1 ACh activates G-protein cascade which affects gated K+ channels
  - Opens some, causing hyperpolarization
  - Closes others, causing depolarization



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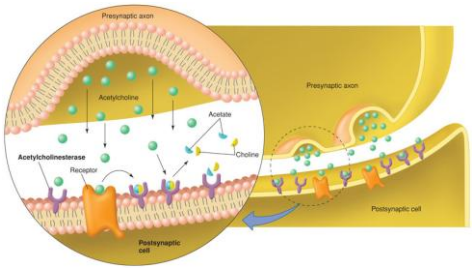
Acetylcholinesterase (AChE)

- Inactivates ACh, terminating its action; located in cleft



7-60

Monoamine NTs

- Include serotonin, norepinephrine and dopamine
  - Called **catecholamines**
  - Serotonin: regulation of mood, behavior, appetite and cerebral circulation
  - Dopamine: motor control & behavior and emotional reward
  - Norepinepherine:
    - In PNS is a sympathetic NT
    - In CNS affects general level of arousal

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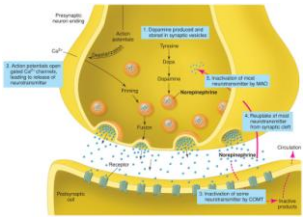
Monoamine NTs

- After release, are mostly inactivated by:
  - Presynaptic reuptake
  - And breakdown by monoamine oxidase (MAO)
    - MAO inhibitors are antidepressants



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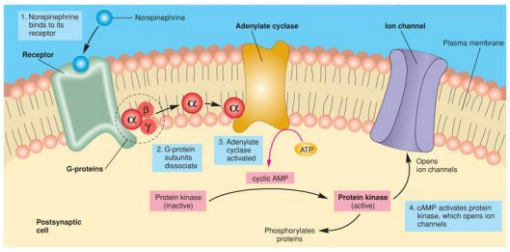
Monoamine NTs

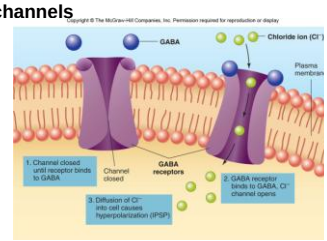
- Their receptors activate G-protein cascade to affect ion channels



7-65

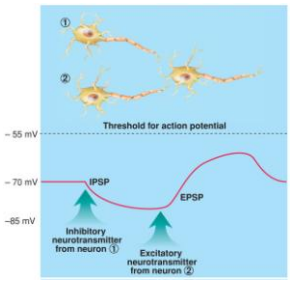
Amino Acids NTs (COOH is removed)

- **Glutamic acid and aspartic acid are major CNS excitatory NTs**
- **Glycine is an inhibitory NT**
  - **Opens Cl^- channels which hyperpolarize**
- **GABA (gamma-aminobutyric acid) is most common NT in brain**
  - **Inhibitory, opens Cl^- channels**



Synaptic Inhibition

- Postsynaptic inhibition
  - GABA and Glycine produce IPSPs
    - IPSPs dampen EPSPs
    - Making it harder to reach threshold
- Presynaptic inhibition:
  - Occurs when 1 neuron synapses onto axon or bouton of another neuron, inhibiting release of its NT



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