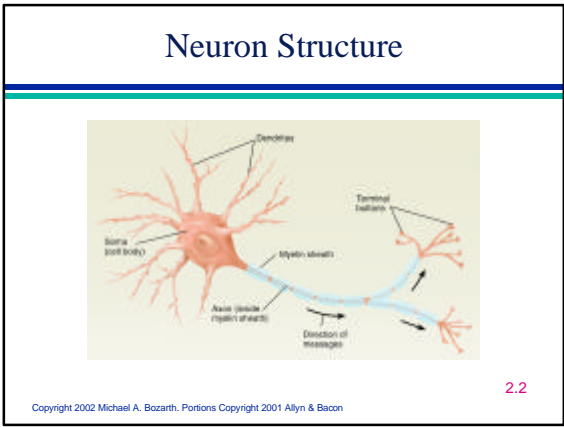
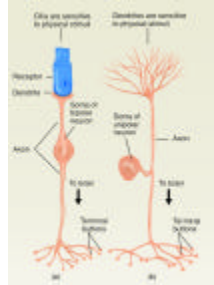


Biopsychology
Chapter 2: *Structure and Functions of Cells of the Nervous System*



- Neuron Classification Schemes
- Neurons can be classified according to
 - Number of axon processes:
 - ◆ Unipolar: one stalk that splits into two branches
 - ◆ Bipolar: one axon, one dendritic tree
 - ◆ Multipolar: one axon, many dendritic branches
 - Function
 - ◆ Sensory neurons carry messages toward brain
 - ◆ Motor neurons carry messages to muscles
 - ◆ Interneurons connect cells
 - Neurotransmitter released by neuron
 - Effects of neurotransmitter (excitatory vs. inhibitory)
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Bipolar - Unipolar Neurons



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Types of Neurons

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Electrochemical Conduction

- Nerve cells are specialized for communication (neurons conduct **ELECTROCHEMICAL** signals)
 - Dendrites receive chemical message from adjoining cells
 - Chemical messengers activate receptors on the dendritic membrane
 - Receptor activation opens ion channels, which can alter membrane potential
 - Action potential can result which is propagated down the membrane
 - Action potential causes release of transmitter from axon terminals

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Neuron Internal Structure



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CNS Support Cells

■ **Neuroglia** (“glue”) provide physical support, control nutrient flow and are involved in phagocytosis

- **Astrocytes:** Provide physical support, remove debris, and transport nutrients to neurons
- **Microglia:** Involved in phagocytosis and brain immune function
- **Oligodendroglia:** Provide physical support and form the myelin sheath CNS axons
- **Schwann Cells** form myelin for PNS axons

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Astrocytes



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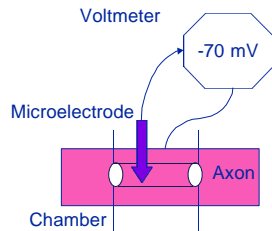
Myelin Forming Cells

- Morphologically and neurochemically different
- Transparency #9

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Measuring the Resting Membrane Potential of a Neuron

- Giant axon from a squid is placed in seawater in a recording chamber
- Glass microelectrode is inserted into axon
 - Voltage measures -70 mV inside with respect to outside



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Why Study a Squid?

- Big nerves
 - Largest neuron = $500 \mu\text{m} = \frac{1}{2} \text{ mm}$ diameter
 - Squid giant axon vs. giant squid axon
 - ◆ very large neuron vs. a really big squid
- Simpler nervous system
- You often get to live by the ocean
- And you can eat your subjects

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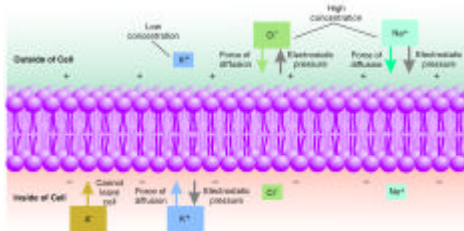
Resting Membrane Potential

- Resting membrane potential (RMP) is the difference in voltage between the inside and outside of the axon membrane
- Na^+ ions are in high concentration outside the cell, while K^+ ions are in high concentration inside the cell
 - At rest, some K^+ ions can leave the cell, causing the exterior of the nerve cell membrane to be slightly positive relative to the inside of the axon

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Relative Ion Concentrations Across the Axon Membrane



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Na^+/K^+ Transporter

- Transports ions against their concentration gradients
- transparency #27

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Properties of the Action Potential

■ The action potential:

- Is an “all or none” event: membrane potential either passes threshold or doesn’t
- Is propagated down the axon membrane
 - ◆ Notion of successive patches of membrane
- Has a fixed amplitude: AP’s don’t change in height to signal information (nondecremental)
- Has a conduction velocity (meters/sec)
- Has a refractory period in which stimulation will not produce an AP (limits the firing rate)

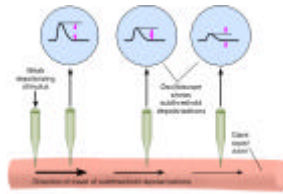
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Local Potentials

■ Local disturbances of membrane potential are carried along the membrane:

- Local potentials degrade with time and distance
- Local potentials can summate to produce an AP



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Unmyelinated Conduction of an Action Potential

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Saltatory Conduction

- AP's are propagated down the axon
 - AP depolarizes each successive patch of membrane in nonmyelinated axons (thereby slowing conduction speed)
 - In myelinated axons, the AP jumps from node to node: AP depolarizes membrane at each node of Ranvier
 - ◆ Conduction velocity is proportional to axon diameter
 - ◆ Saltatory conduction speeds up conduction velocity
 - ◆ Myelination allows smaller diameter axons to conduct signals quickly
 - ◆ More axons can be placed in a given volume of brain

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Myelinated Conduction of an Action Potential

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Why Myelinate a Neuron?

- Conduction velocity is increased
- Size requirement is diminished
- Electrical insulation
- Reduced cell-energy requirement

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Effect of Myelin on Conduction Velocity

The two neurons illustrated below would have equal conduction velocities.



6 μm diameter
myelinated

500 μm diameter
unmyelinated

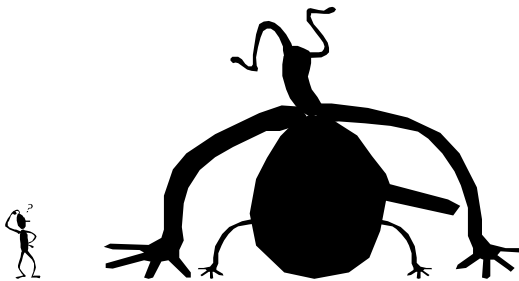
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Effect of Myelin on Neuronal Size

- An unmyelinated neuron would have to be 83-times larger than a myelinated neuron to conduct at the same speed
- Imagine the impact this would have on brain size
 - you would probably be walking on your hands with your ears evolved as limbs to assist locomotion . . . presuming you were able to leave the ocean

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Evolution Without Myelin?



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Neural Potentials

- polarization
 - resting potential
- depolarization
 - graded potential
 - action potential
- hyperpolarization

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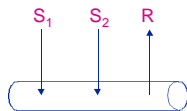
Voltage-Gated Ion Channels

- Na⁺
 - depolarization
- K⁺
 - repolarization
- Ca²⁺
 - neurotransmitter release

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Neural Conduction

- Orthodromic
- Antidromic
- AP Collision
- Conduction velocity estimates
 - $CV = \text{distance} / (\text{conduction time} - \text{refractory period})$
 - clinical applications (e.g, visual evoked potentials & early diagnosis of MS)



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Synapses

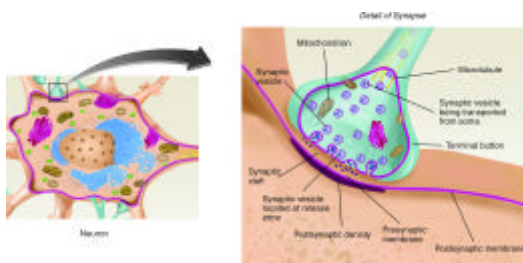
■ The “**synapse**” is the physical gap between pre- and post-synaptic membranes (~20-30 nMeters)

- Presynaptic membrane is typically an axon
- The axon terminal contains
 - ◆ Mitochondria that provide energy for axon functions
 - ◆ Vesicles (round objects) that contain neurotransmitter
 - ◆ Cisternae that are a part of the Golgi apparatus: recycle vesicles
- Postsynaptic membrane can be
 - ◆ A dendrite (axodendritic synapse)
 - ◆ A cell body (axosomatic synapse)
 - ◆ Another axon (axoaxonic synapse)
- Postsynaptic thickening lies under the axon terminal and contains receptors for transmitters

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Overview of the Synapse



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Neural Connections

■ Synaptic connections

- axo-dendritic
- axo-axonic
- axo-somatic
- dendro-dendritic

■ Other synapse-like connections

- Autoreceptors
- Neuromuscular junction
- Neuroendocrine/Neurosecretory junction

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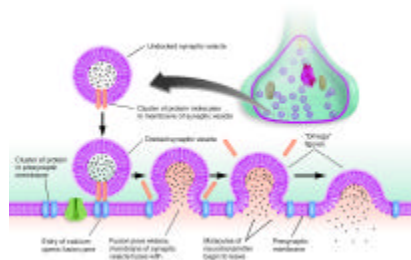
Neurotransmitter Release

- Vesicles lie “docked” near the presynaptic membrane
- The arrival of an action potential at the axon terminal opens voltage-dependent Ca^{++} channels
 - Ca^{++} ions flow into the axon
 - Ca^{++} ions change the structure of the proteins that bind the vesicles to the presynaptic membrane
 - A fusion pore is opened, which results in the merging of the vesicular and presynaptic membranes
- The vesicles release their contents into the synapse
 - Released transmitter then diffuses across cleft to interact with postsynaptic membrane receptors

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Overview: Transmitter Release



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Postsynaptic Receptors

- Molecules of neurotransmitter (NT) bind to receptors located on the postsynaptic membrane
 - Receptor activation opens postsynaptic ion channels
 - Ions flow through the membrane, producing either depolarization or hyperpolarization
 - The resulting postsynaptic potential (PSP) depends on which ion channel is opened
- Postsynaptic receptors alter ion channels
 - Directly (**ionotropic receptors**)
 - Indirectly, using second messenger systems that require energy (**metabotropic receptors**)

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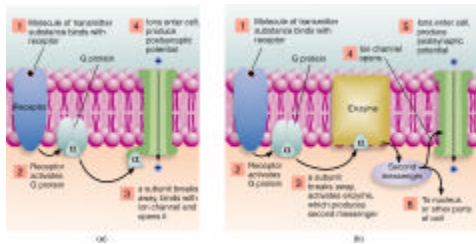
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Receptor Signal Transduction

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Metabotropic Receptors



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Postsynaptic Potentials

- PSPs are either excitatory (EPSP) or inhibitory (IPSP)
 - Opening Na^+ ion channels results in an EPSP
 - Opening K^+ ion channels results in an IPSP
- PSPs are conducted down the neuron membrane
- **Neural integration** involves the algebraic summation of PSPs
 - A predominance of EPSPs at the axon will result in an action potential
 - If the summated PSPs do not drive the axon membrane past threshold, no action potential will occur

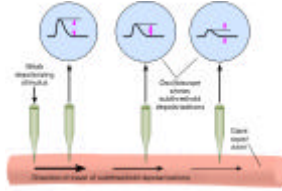
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Local Potentials

- Local disturbances of membrane potential are carried along the membrane:

- Local potentials degrade with time and distance
- Local potentials can summate to produce an AP



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Neural Integration

- Temporal (frequency) summation (rate law)

Transparency #31

- Spatial (potential) summation

Transparency #30

- EPSPs
- IPSPs

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Termination of Postsynaptic Potentials

- The binding of NT to a postsynaptic receptor results in a PSP
- Termination of PSPs is accomplished via
 - Reuptake:** the NT molecule is transported back into the cytoplasm of the presynaptic membrane
 - The NT molecule can be reused
 - Enzymatic deactivation:** an enzyme destroys the NT molecule

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Receptor Types

- Iotropic
 - ligand-gated ion channels
- Metabotropic
 - linked to ion channels through G-proteins
 - second messenger (also G-protein mediated)
 - ◆ coupled to ion channels
 - > open Ca^{2+} channels
 - ◆ coupled to other mechanisms
 - > stimulate neurotransmitter/neuromodulator synthesis
 - > increased production of enzymes (e.g., tyrosine hydroxylase)
 - > stimulate formation of neuromodulators (e.g., NO)

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Ligand-Gated Ion Channels

- Na^+ => EPSPs
- K^+ => IPSPs
- Cl^- => IPSPs
- Ca^{2+} => neurotransmitter release

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