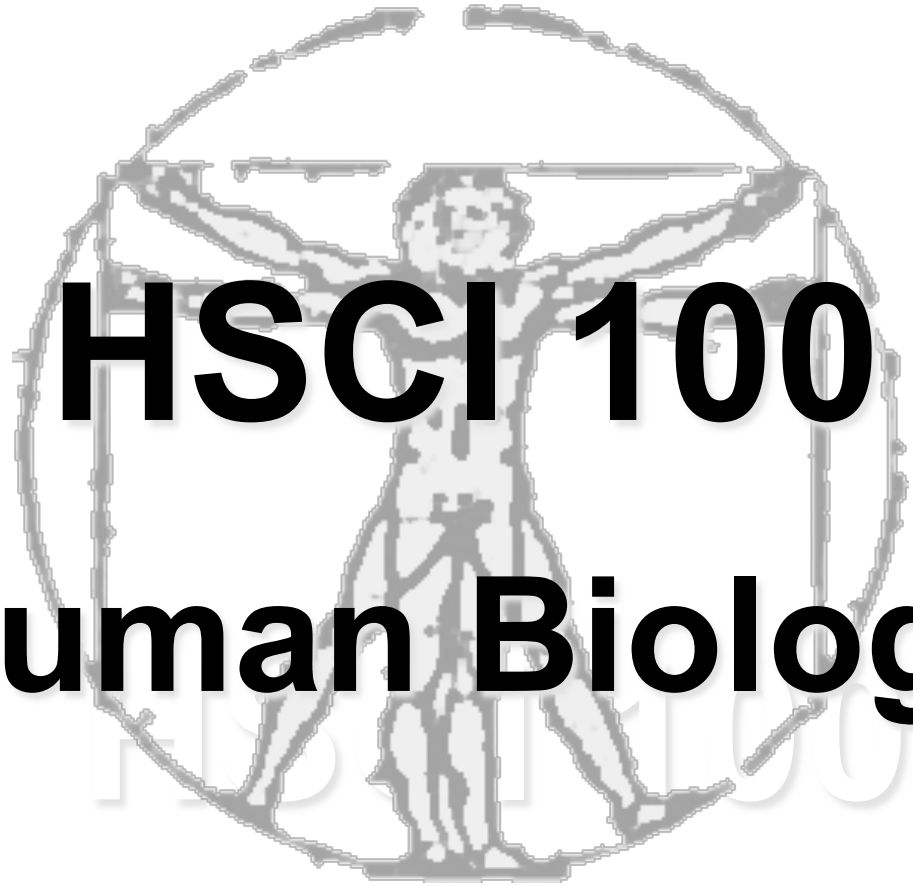


HSCI 100

Human Biology

Nerve physiology

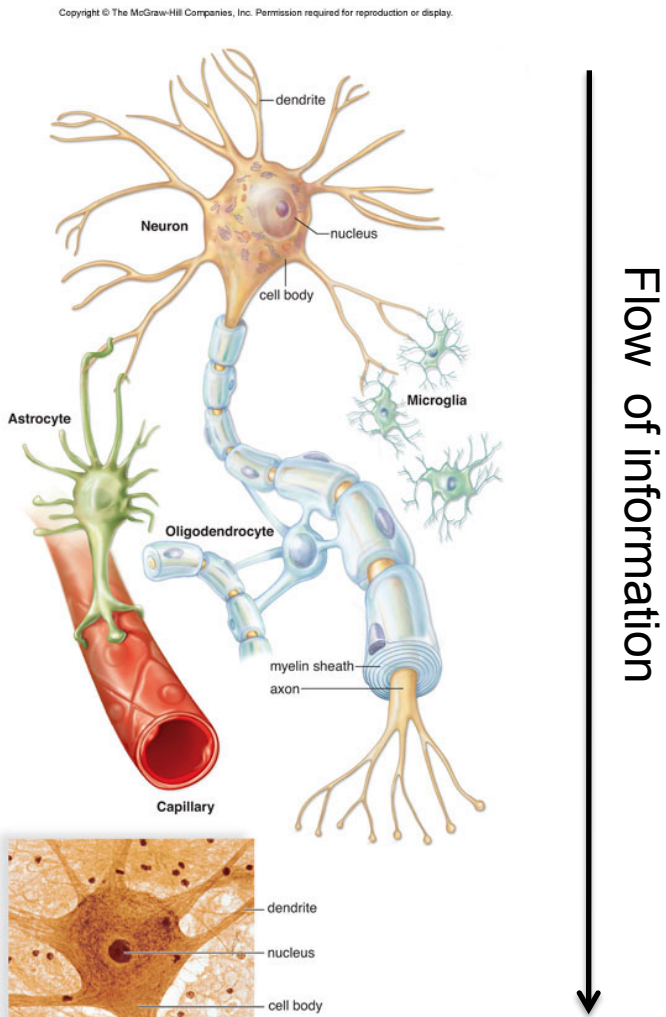
The nervous system

- Nervous system – Allows for communication between cells through sensory input, integration of data and motor output

- 2 cell types: neurons and neuroglia (Ch. 4 review)

3. Nervous tissue - neurons

- Made of dendrites, a cell body and an axon
  - Dendrites carry information toward the cell body
  - Axons carry information from a cell body. These are long extensions that carry nerve impulses
  - Covered in myelin

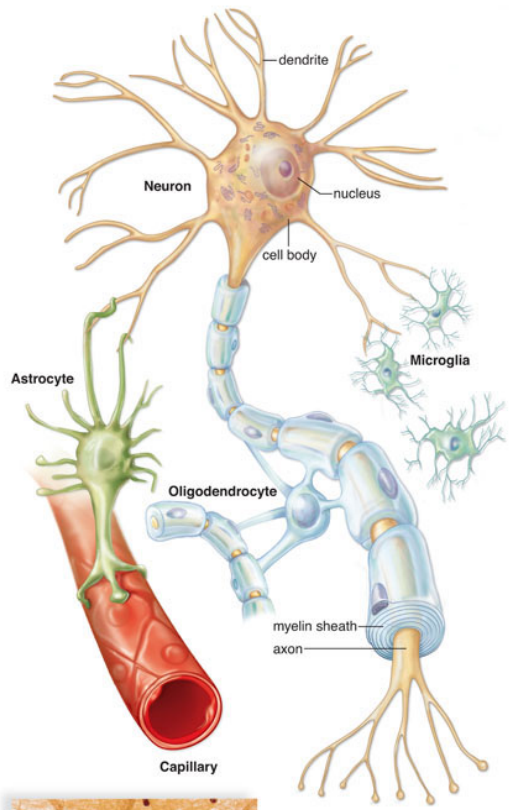


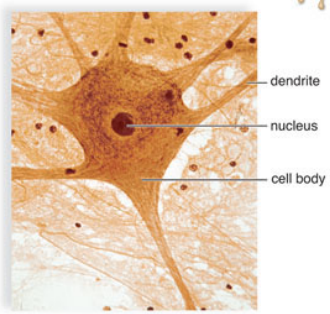
Micrograph of neuron

© Ed Reschke

3. Nervous tissue - neuroglia

- A collection of cells that support and nourish neurons
- Outnumber neurons 9:1
- Examples are:
- oligodendrocytes- form myelin sheath in brain
- astrocytes – provide nutrients
- microglia – engulf bacteria and debris





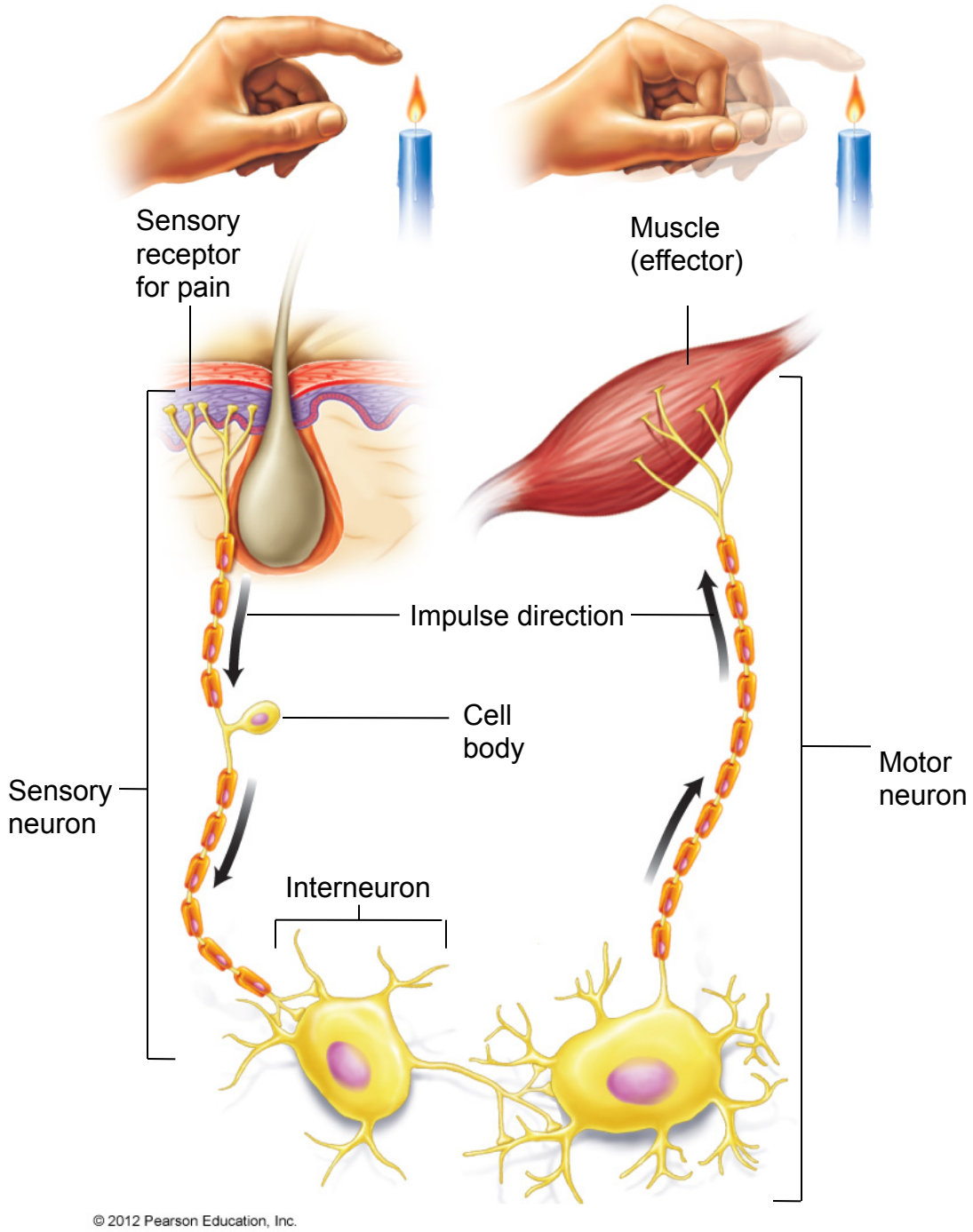
Micrograph of neuron

Expanding on neurons

- 3 types of neurons:
  - Sensory – takes impulses from sensory receptor to CNS
  - Interneurons – receive information in the CNS and send it to a motor neuron
    - Integrate and interpret signals
    - Account for 99% of nerves
  - Motor – takes impulses from the CNS to an effector (i.e. gland or muscle fiber)

- Neuron structure (Ch. 4 review):
  - Cell body – main part of cell where organelles and nuclei reside
  - Dendrite – many, short extensions that carry impulses to a cell body
  - Axon (nerve fiber) – single, long extension that carries impulses away from the cell body

  - A ganglion is a cluster of nerve cell bodies within the PNS.
  - A nucleus is a cluster of nerve cell bodies within the CNS.
  - What we commonly call a nerve is a cluster of axons



The myelin sheath

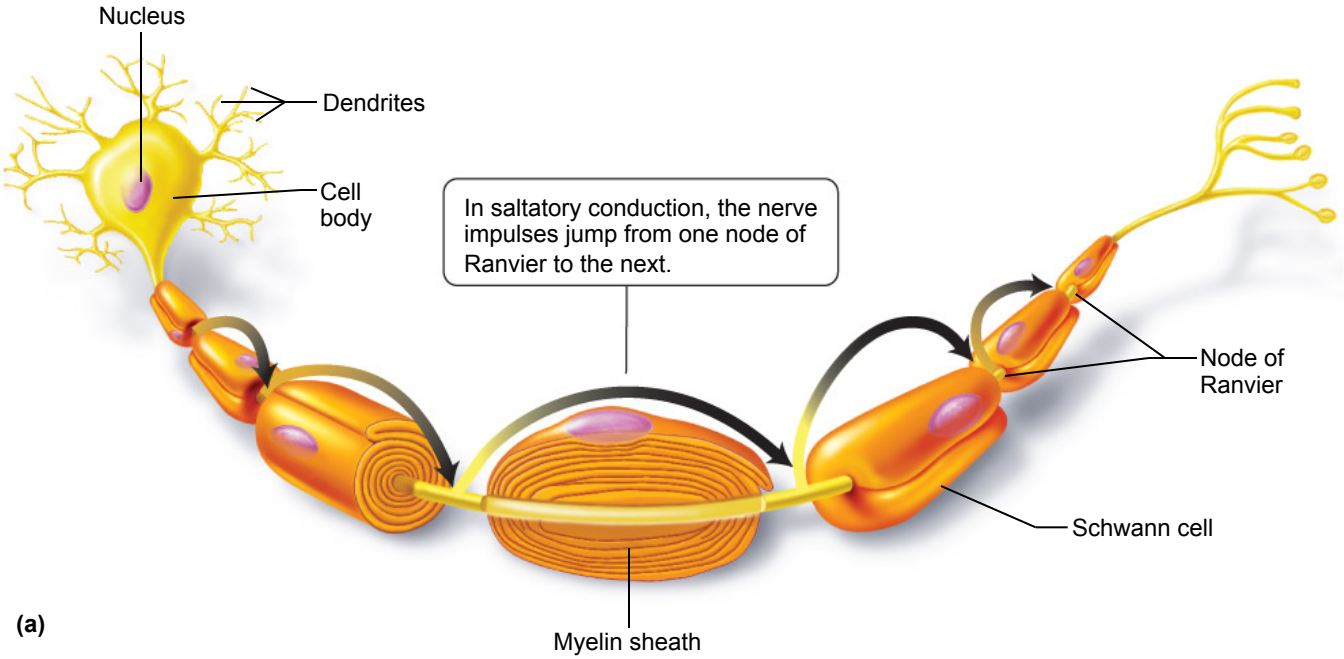
- A lipid covering on long axons that acts to increase the speed of nerve impulse conduction, insulation and regeneration, especially in the PNS

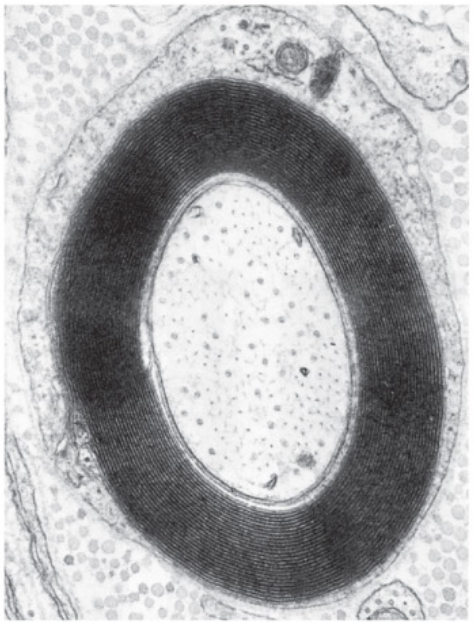
- Schwann cells are neuroglia that make up the myelin sheath in the PNS
- Oligodendrocytes perform this function in CNS

- Nodes of Ranvier – gaps between myelination on the axons

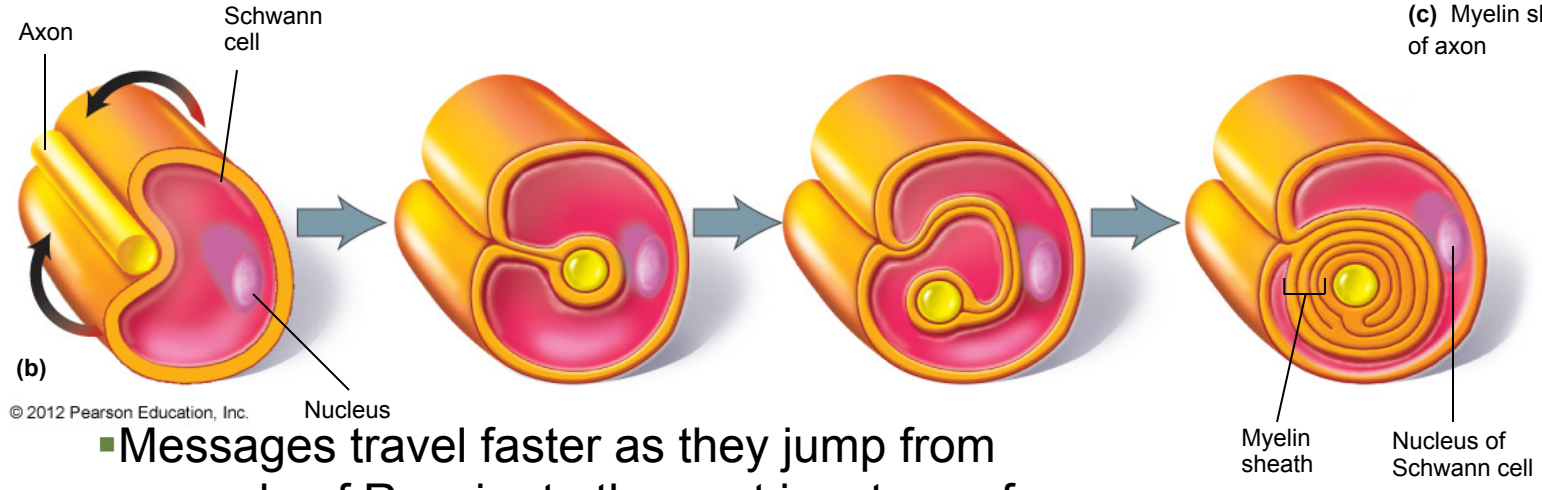
- Saltatory conduction – conduction of the nerve impulse from node to node. The rate is 100s of meters/second!!!

- Myelin sheath is lost in multiple sclerosis (MS) and leukodystrophies and is accompanied by progressive neurological deficits.
  - MS can be caused by autoimmune attack, while leukodystrophies have been found with specific gene mutations.
  - A case of adrenoleukodystrophy was the subject of the movie *Lorenzo's Oil*





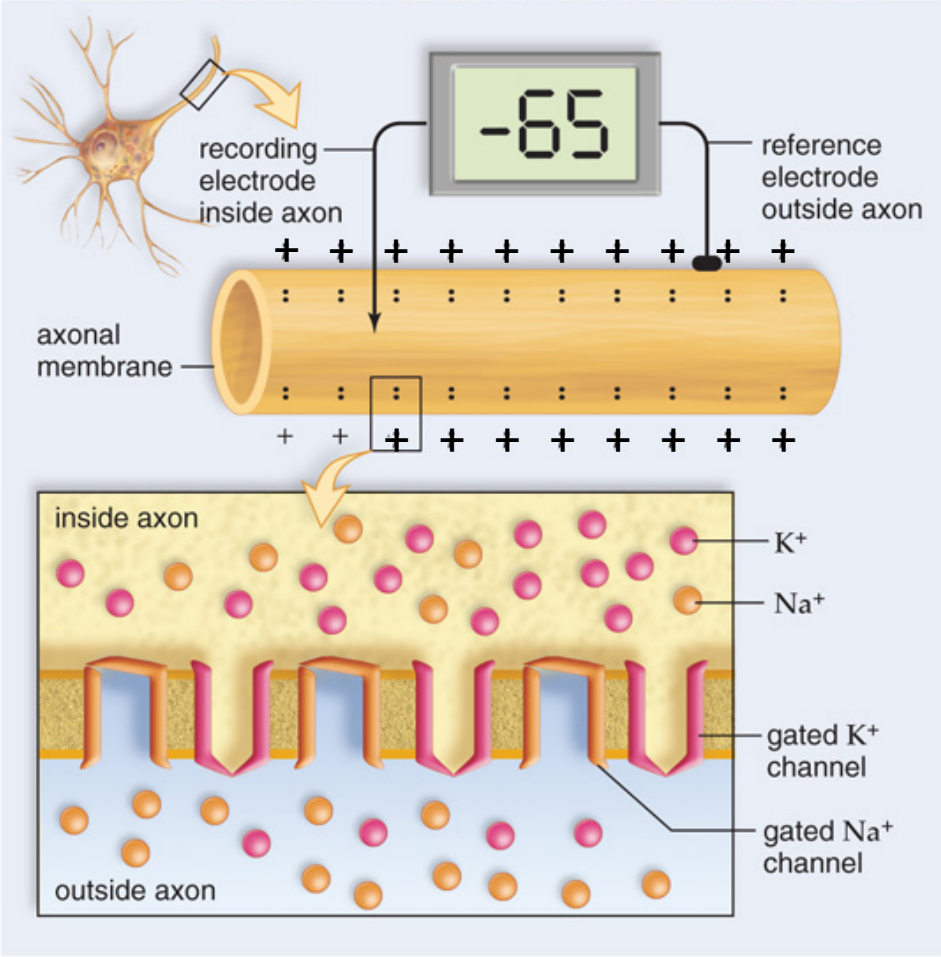
(c) Myelin sheath surrounding cut end of axon



- Messages travel faster as they jump from one node of Ranvier to the next in a type of transmission called saltatory conduction

The nerve impulse: resting potential (RP)

- Resting potential = when the axon is not conducting a nerve impulse
  - More positive ions (+) outside than inside the membrane
  - There is a negative charge of -65mV inside the axon
  - More Na^+ outside than inside
  - More K^+ inside than outside
  - Gates mean that they open under appropriate signals



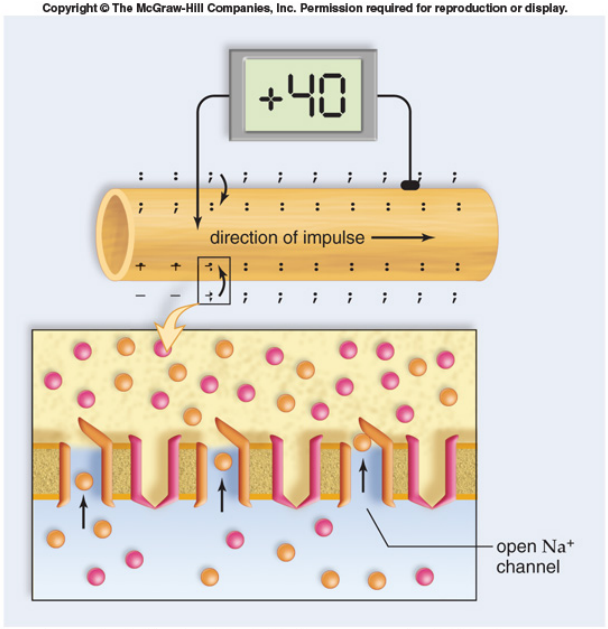
a. Resting potential: more Na^+ outside the axon and more K^+ inside the axon causes polarization.

The nerve impulse: action potential (AP)

- Action potential – rapid change in the axon membrane that allows a nerve impulse to occur
- The initial trigger may be a chemical or a voltage change (ion flux)
- Happens in a 'all or none' fashion
- Sodium gates open letting Na^+ in
  - Depolarization occurs
  - Interior of axon loses its net negative charge (+40mV)
- Potassium gates open letting K^+ out
  - Repolarization occurs
  - Interior of axon regains negative charge (-65mV)
  - Wave of depolarization/repolarization travels down the axon
- Resting potential is restored by moving K^+ inside and Na^+ outside – this is done by our ever-present, ever-important Na^+/K^+ pump.

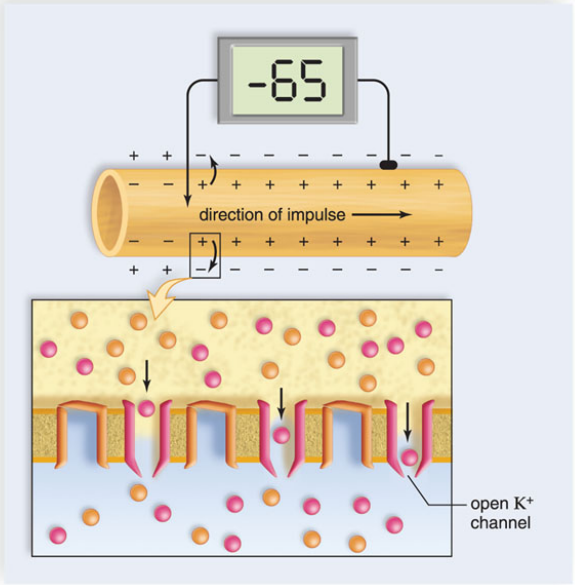
The nerve impulse: AP

Depolarization

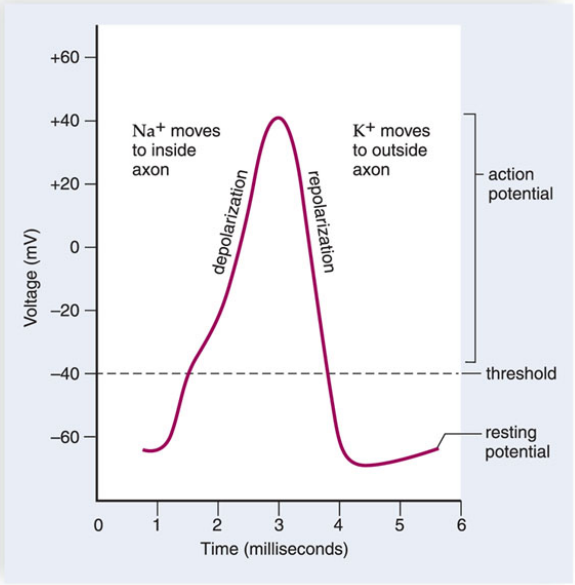


b. Action potential begins: depolarization occurs when Na^+ gates open and Na^+ moves to inside the axon.

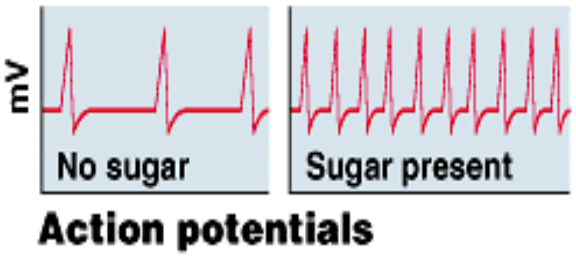
Repolarization



c. Action potential ends: repolarization occurs when K^+ gates open and K^+ moves to outside the axon.

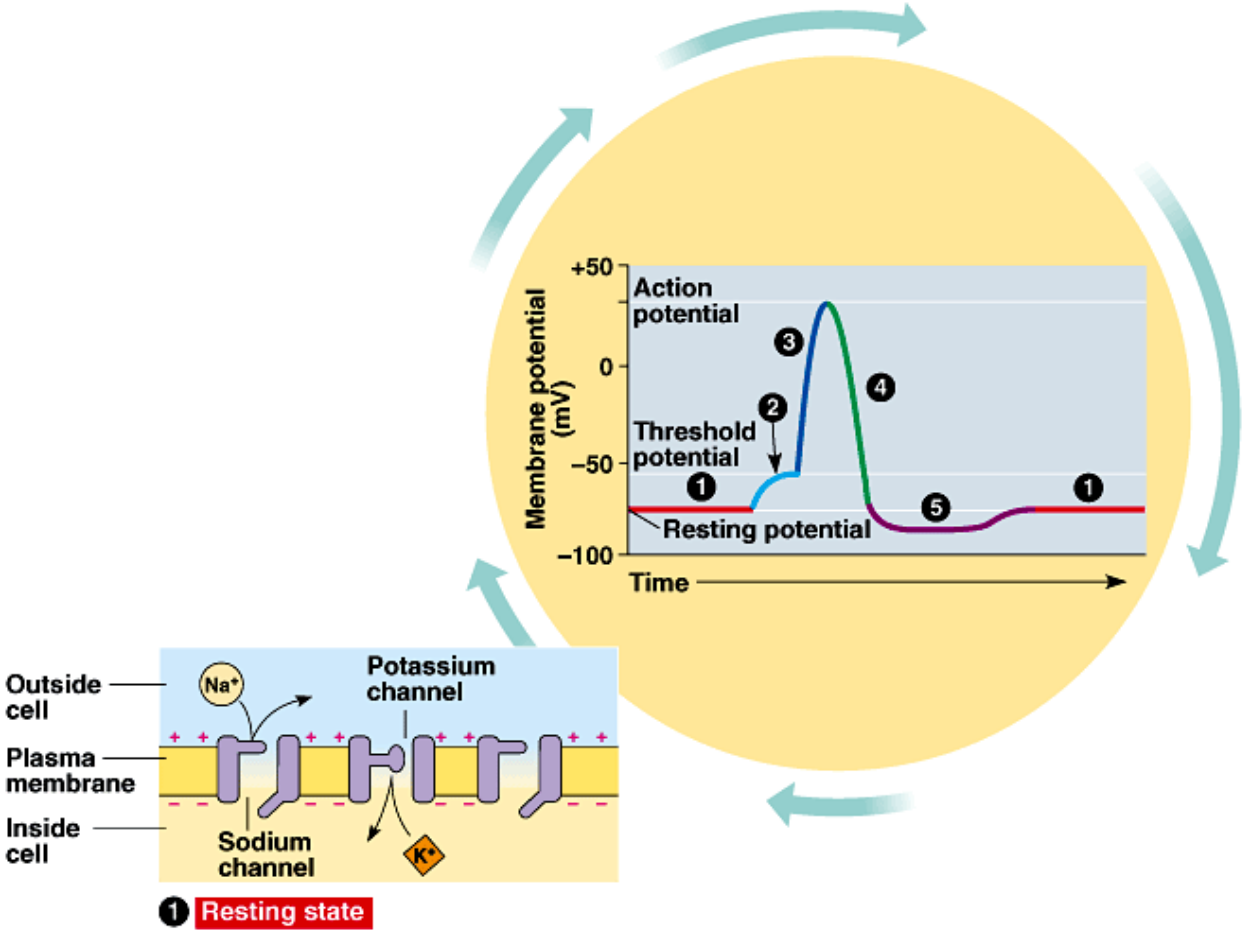


d. An action potential can be visualized if voltage changes are graphed over time.

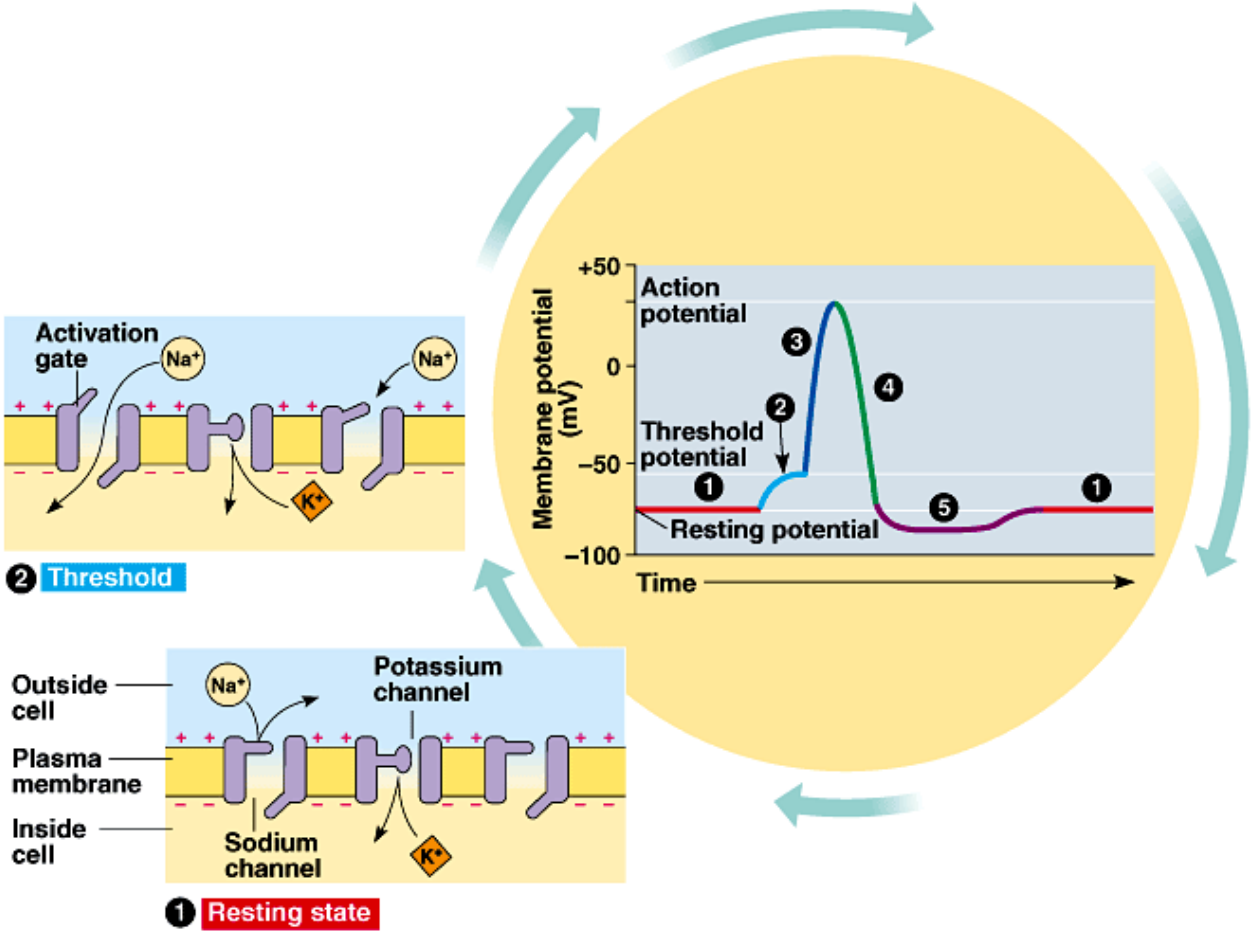


- http://media.pearsoncmg.com/bc/bc_0media_bio/bioflix/bioflix.htm?c8eneurons

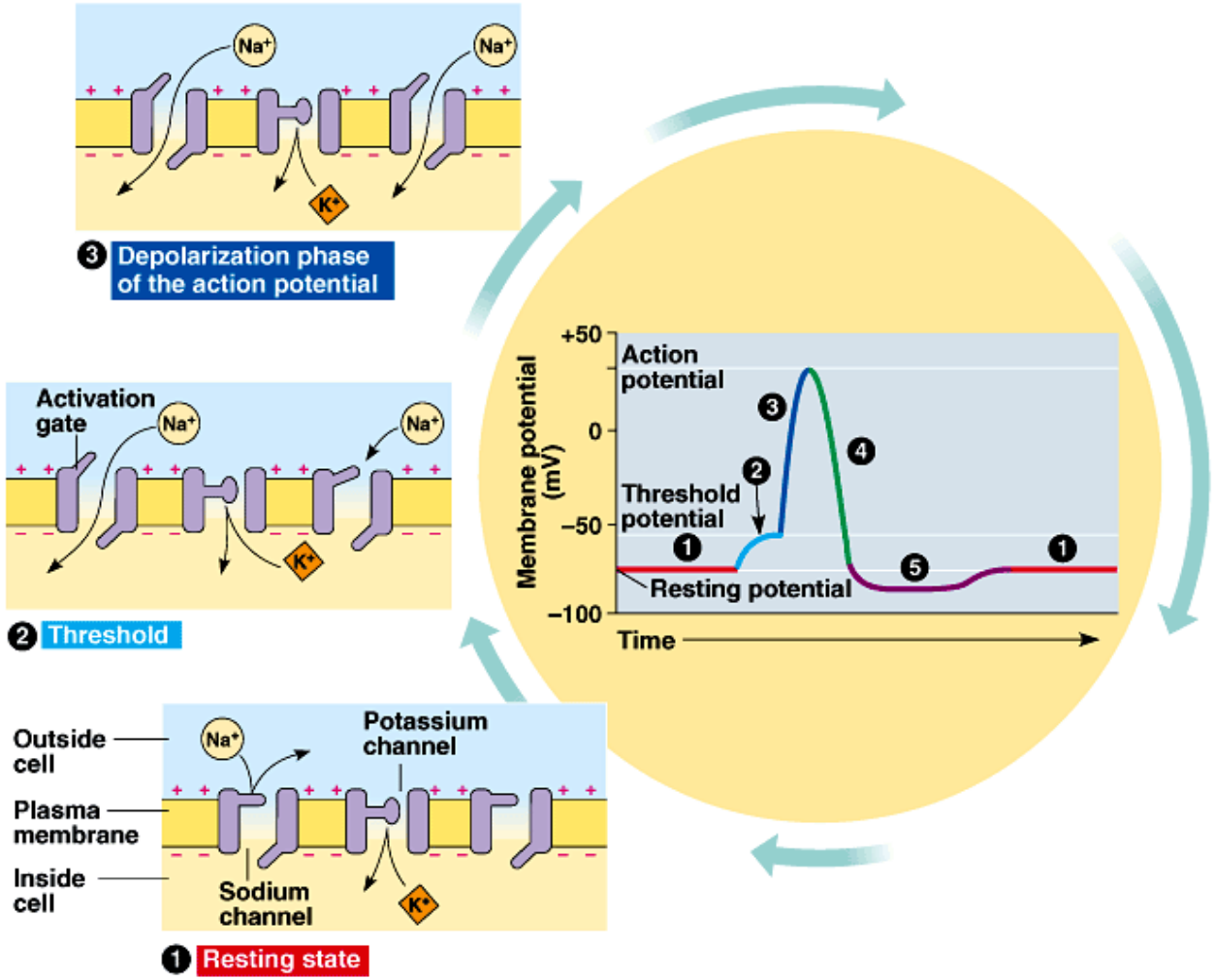
- **Step 1: Resting State**



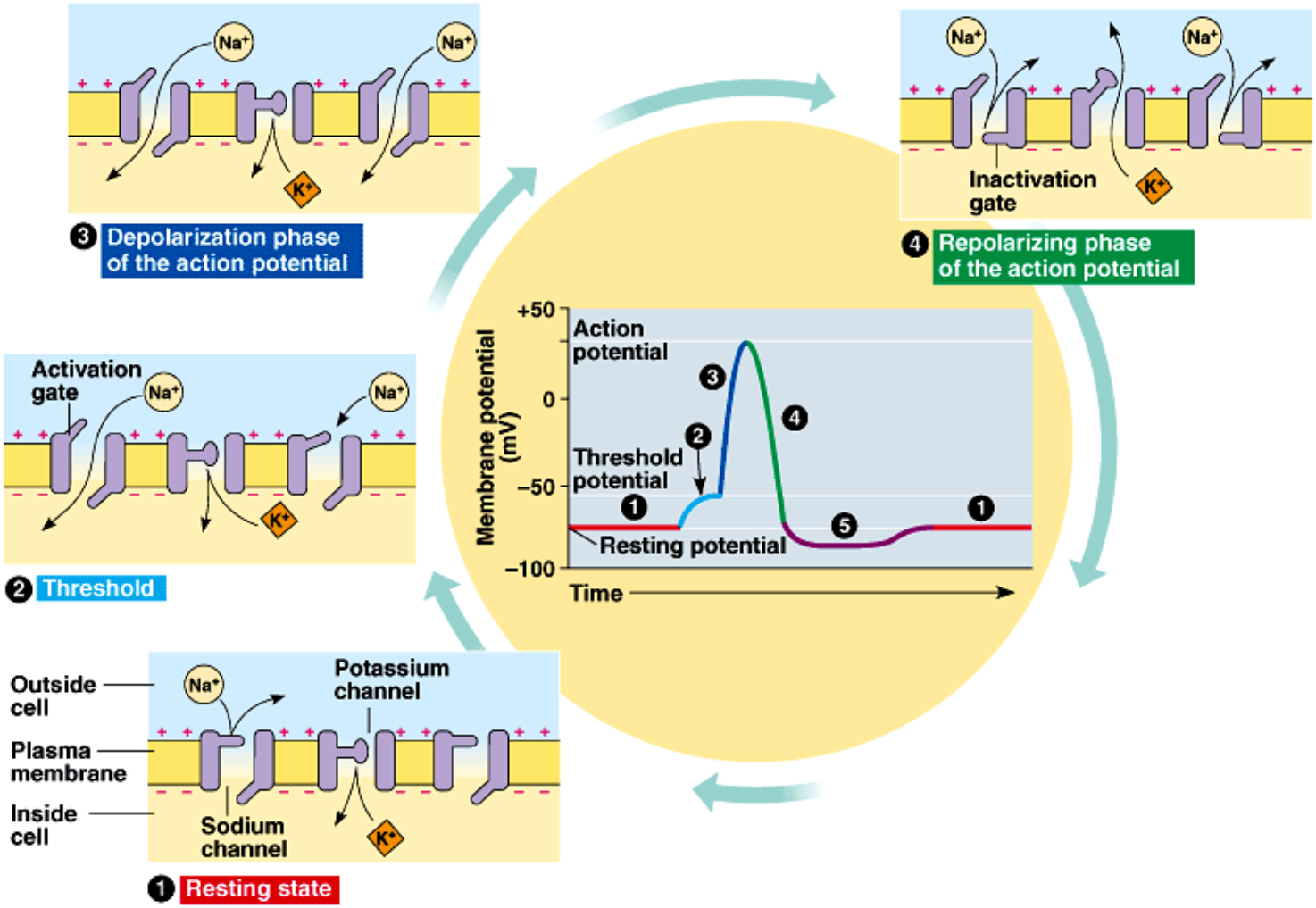
- **Step 2: Threshold**



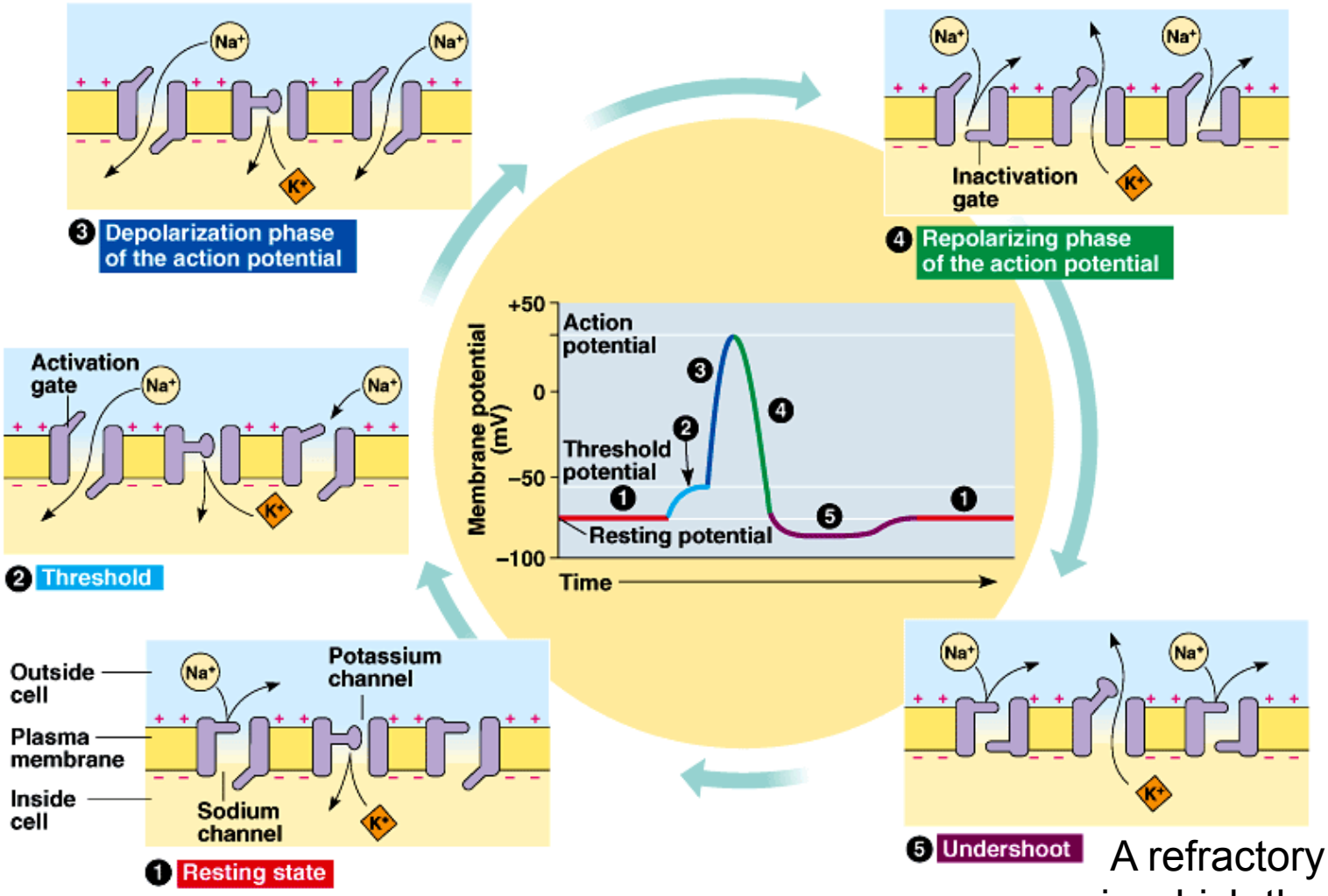
- **Step 3: Depolarization phase of the action potential**



- **Step 4: Repolarizing phase of the action potential**



- **Step 5: Undershoot**



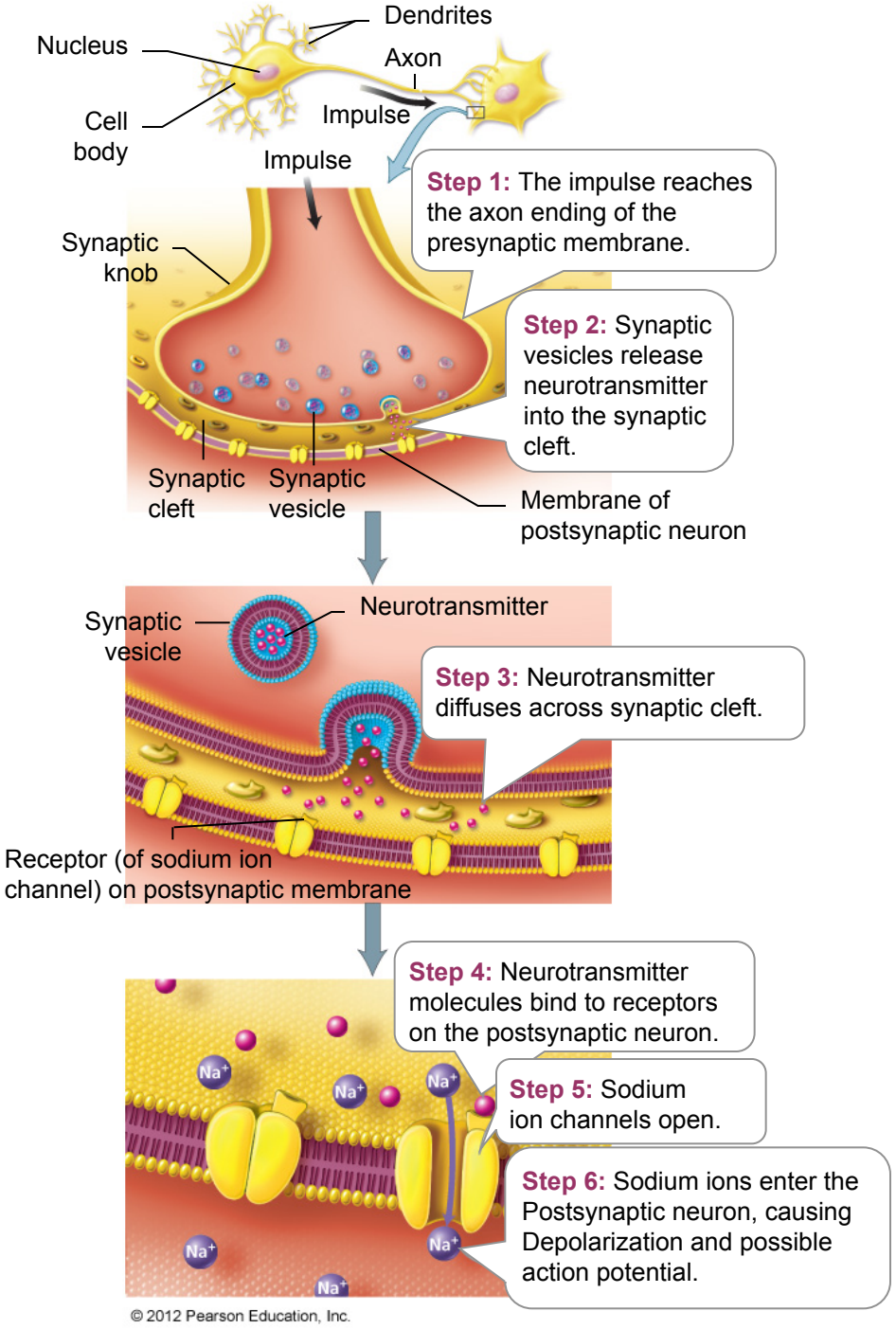
A refractory period, in which the neuron cannot depolarize

The synapse

- A small gap between the sending neuron (presynaptic membrane) and the receiving neuron (postsynaptic membrane)
- Transmission is accomplished across this gap by a neurotransmitter, which is a chemical (e.g. ACh, dopamine and serotonin)
- Neurotransmitters are stored in synaptic vesicles in the axon terminals

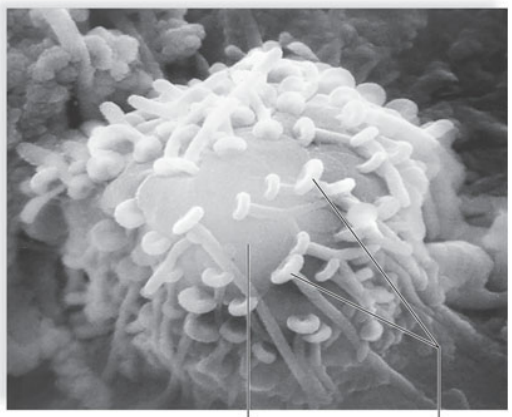
How does transmission across the synapse occur?

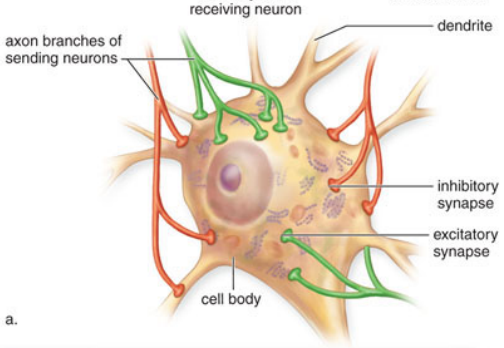
- Nerve impulse reaches the axon terminal
- Calcium ions (Ca^{2+}) enter the axon terminal that stimulate the synaptic vesicles to fuse with the presynaptic membrane
- Neurotransmitters are released and diffuse across the synapse and bind with the postsynaptic membrane to inhibit or excite the neuron



Synaptic integration

- A neuron may have as many as 10,000 synapses with other neurons at the same time
- Some synapses have excitatory effects and some have inhibitory effects
- Summation
  - Combined effects of excitatory and inhibitory effects at any given moment
  - Determines whether an action potential is generated
  - This level of integration provides fine control over neuronal responses





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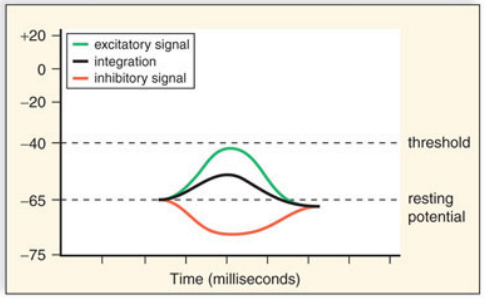


b.

a: Courtesy Dr. E.R. Lewis, University of California Berkeley

http://media.pearsoncmg.com/bc/bc_0media_bio/bioflix/bioflix.htm?c8esynapses

Questions?

Nerve Impulses

- A nerve impulse, or action potential, is an electrochemical signal involving sodium ions (Na^+) and potassium ions (K^+) that cross the cell membrane through ion channels
  - Ions pass through channels without using cellular energy

Nerve Impulses

- Each ion channel is designed to allow only certain ions to pass through it
  - Sodium channels permit sodium ions to pass
  - Potassium channels permit potassium ions to pass
- Ion channels may be permanently open or regulated by a “gate,” which is a protein that changes shape and opens or closes a channel

Nerve Impulses

- Ions also are transported across the membrane by the sodium-potassium pump
  - Special proteins in the cell membrane that actively transport sodium and potassium ions across the membrane
  - These pumps use cellular energy to eject sodium ions from within the cell and to bring potassium ions into the cell

Nerve Impulses

- When a neuron is not conducting a nerve impulse, it is in a resting state
  - There is a slight difference in charge across the membrane, which is called the resting potential
    - The inner surface of the membrane is about 70 mV more negative than the outer surface
    - There are more sodium ions outside the membrane than inside
    - There are more potassium ions inside the membrane than outside
    - This state is maintained by the sodium-potassium pump

Nerve Impulses

- When the neuron is stimulated, there is a sudden reversal of charge across the membrane because the sodium gates open and sodium ions enter the cell
  - Threshold
    - Minimum charge that causes the sodium gates to open
  - Depolarization
    - Reduction of the charge difference across the membrane

Nerve Impulses

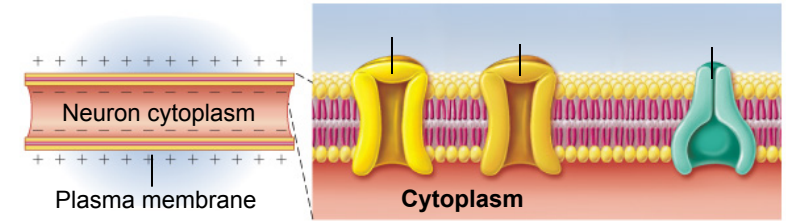
- Next, the potassium gates open and potassium ions rush out of the cell
  - This causes the cell to return to its original state (i.e., for the interior of the neuron to become more negative relative to the outside)
  - Repolarization
    - Restoration of the charge difference across the membrane

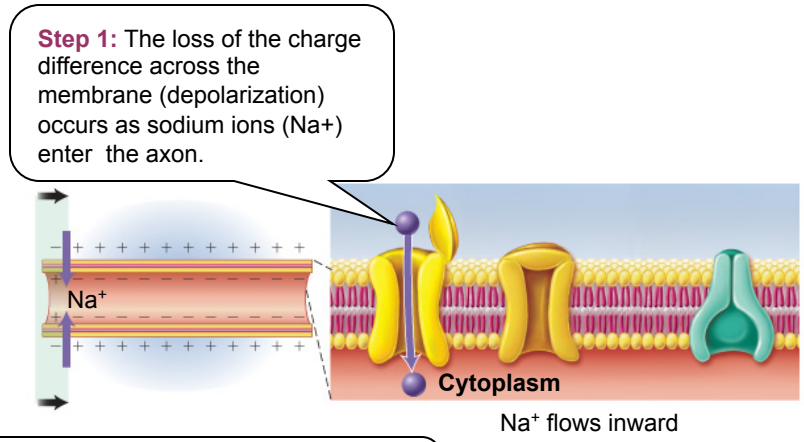
Nerve Impulses

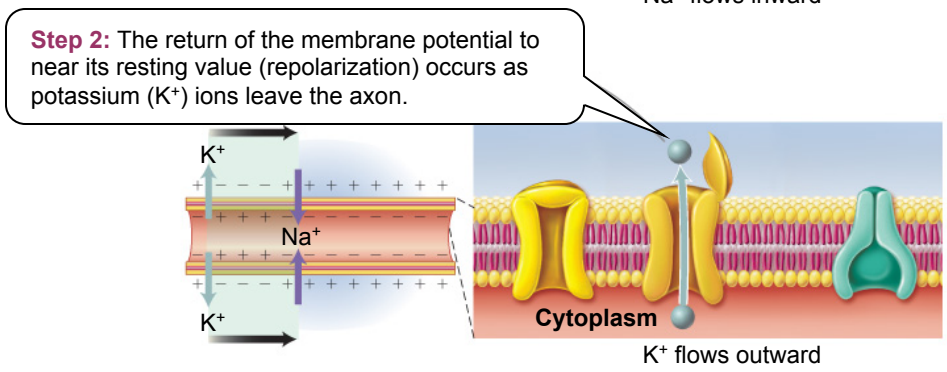
- Action potential
  - Sudden reversal of the charge across the membrane followed immediately by its restoration
  - These changes occur in a wave along the axon

Resting Neuron
Plasma membrane is charged, with the inside negative relative to the outside.

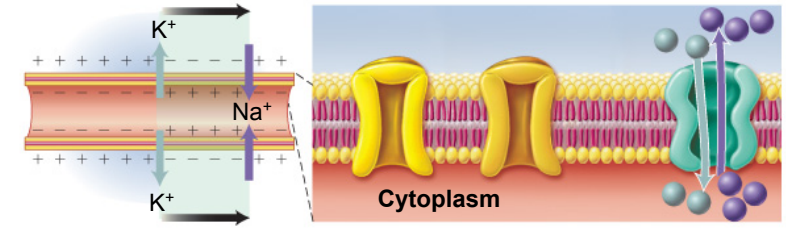
Action Potential
The charge difference across the membrane reverses and then is restored.







Restoration of Original Ion Distribution
The sodium-potassium pump restores the original distribution of ions.



Synaptic Transmission

- Specific steps
  - The nerve impulse reaches the synaptic knob of the presynaptic neuron
  - The synaptic knob releases neurotransmitter into the synaptic cleft
    - Prompted by calcium ions moving into the knob
    - Membranes of synaptic vesicles (packets of neurotransmitter) fuse with plasma membrane at the synaptic knob, spilling contents into the cleft
  - The neurotransmitter diffuses across the synaptic cleft and binds with receptors on the membrane of the postsynaptic neuron, causing an ion channel to open