**CONCEPT:** ION CHANNELS, ACTION POTENTIALS, AND NEURONS

Neuron Structure

● **Neurons** are nerve cells that function by receiving, integrating, and transmitting signals

□ Neurons have a few distinctive physical features

- **Cell body (nucleus)** is the core of the neuron

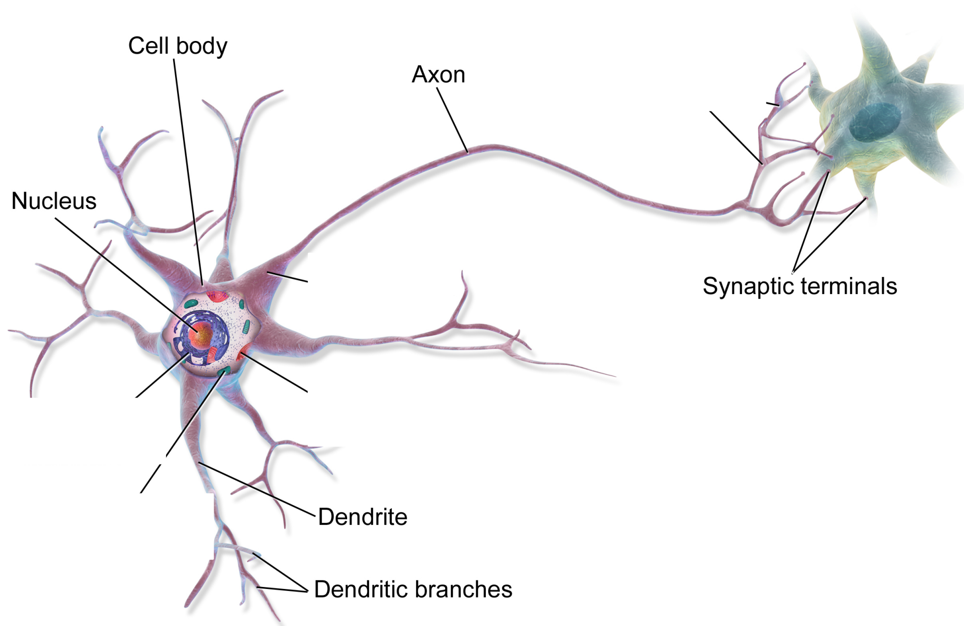
- **Axons** are the long extension that conduct electrical signals away from the cell body

  - Diameter controls speed; Larger diameter = faster speed

- **Dendrites** are the several shorter branching extension that radiate from the cell body to receive signals

- The **nerve terminal** is the end of the axon that branches to pass the neurons message to many cells

**EXAMPLE:** Structure of a neuron




□ Axons contain distinctive features

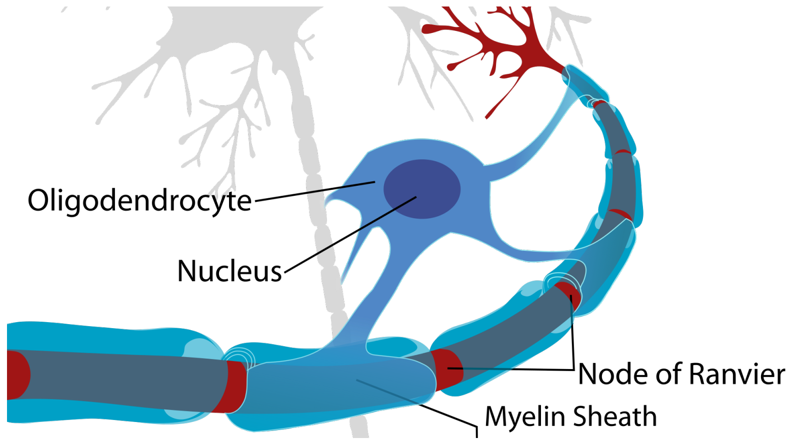
- **Myelin** is a protective cell covering formed around the axon from glial cells, and schwaan cells

  - **Myelin sheath** insulates the axon so ions do not leak out of the membrane

- **Nodes of Ranvier** are patches of ion channels that interrupt the sheath for neuron signaling

  - Signal is passed between each Node of Ranvier down a neuron

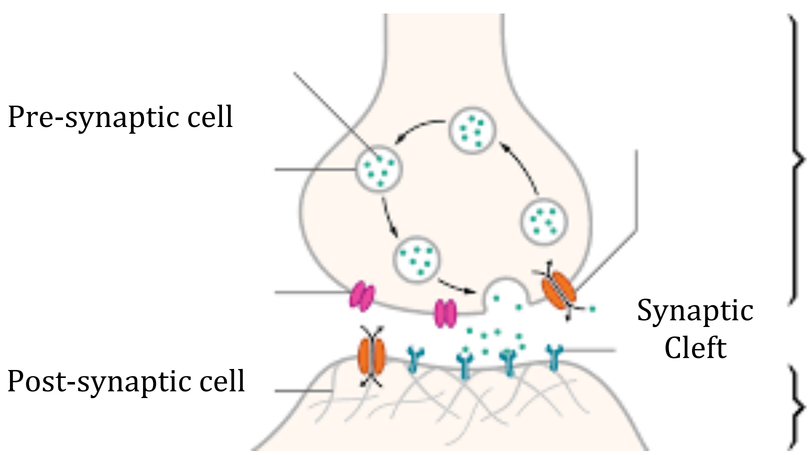
**EXAMPLE:** Myelin sheath and Nodes of Ranvier




□ The junction between two neurons contains distinctive physical features

- **Synapse**: Junction through which the signal is transmitted
- **Pre-synaptic cell**: Cell that contains the signal
- **Post-synaptic cell:** Cell that receives the signal
- **Synaptic cleft**: Space between the pre and post synaptic cell. Electrical signals cannot cross

**EXAMPLE:** Anatomy of a synapse




<u>Action Potentials</u>

- **Action potentials** are traveling waves of electrical excitation that can carry messages between neurons
  - □ Travel very quickly, up to 100 meters per second
    - Travel without weakening the message

□ **Voltage-gated cation channels** mediate action potentials

- The membrane potential in a resting neuron is -60mV (intracellular space is more negatively charged)

- Opening of specific channels can result in rapidly changing to +40mV

- Triggers the continually opening of other cation channels which travel down the neuron

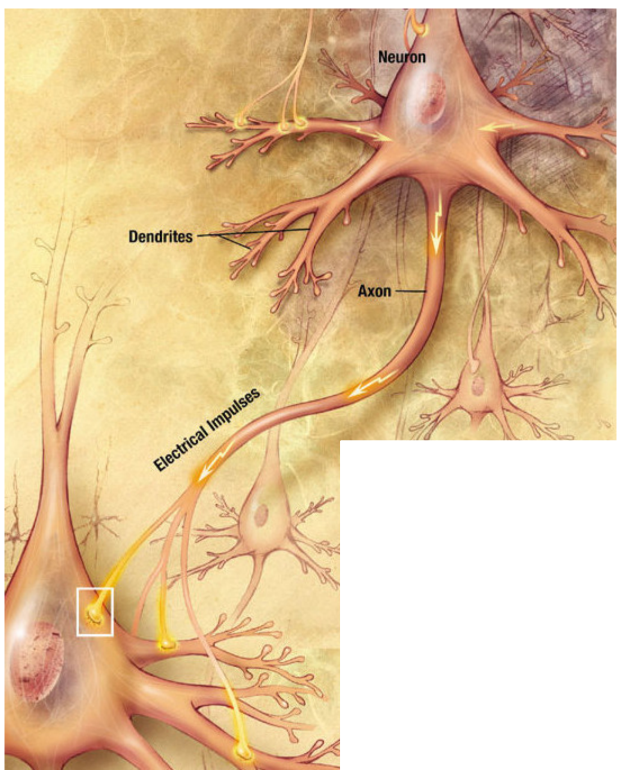
□ **Potassium channels** help return the neuron to a *resting membrane potential*

- **Delayed $K^+$ channel:** Returns neuron to its original state and prepares it to fire again

- **Rapidly activating $K^+$ channel:** Removes relationship between rate of firing and intensity

- **$Ca^{2+}$ activated $K^+$ channels:** Increase the delay between one action potential and next

**EXAMPLE:** An action potential traveling through an neuron



Steps to Neuronal Signaling

- Signal propagation between neurons occurs in steps

    1. A neuron receives a signal which triggers opening voltage-gated $Na^+$ channels

        - Results in massive **depolarization** (influx of positive charge due to sodium flowing into cells)

        - These channels become inactivated within a millisecond to prevent continuous $Na^+$ transport

    2. The depolarization triggers more voltage-gated ion channels to open

        - The depolarization travels down the axon

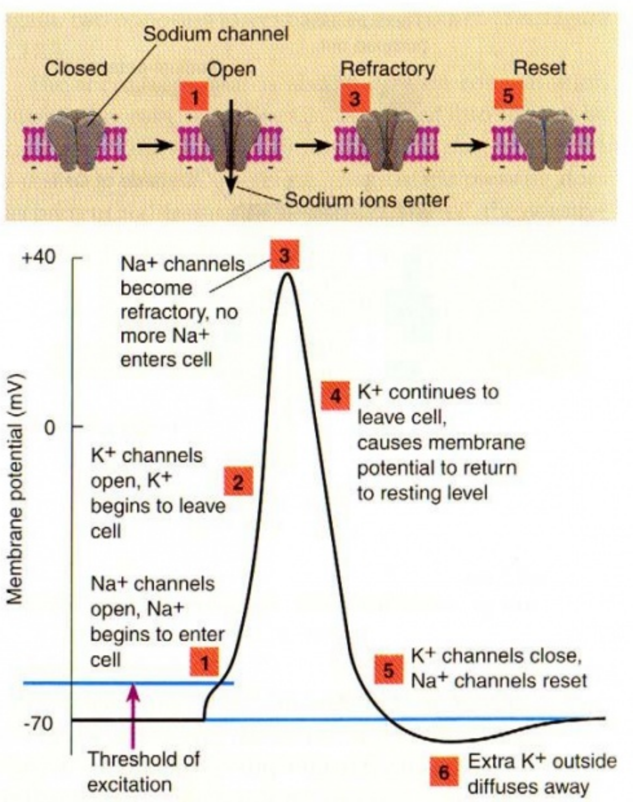
    3. Voltage-gated $K^+$ channels are delayed in opening

        - High positive charge inside cell results in $K^+$ transport out of the cell

        - Helps restore the neuron to its resting state

    4. The traveling wave of depolarization reaches the nerve terminal

**EXAMPLE:** Steps of an action potential



5. The electrical signal is converted into a chemical signal because the synaptic cleft cannot pass electrical signals

- **Neurotransmitters** are the chemical signals

a. Neurotransmitters sit in vesicles near the nerve terminal plasma membrane

b. When depolarization arrives, it triggers opening of voltage-gated calcium channels

c. Influx of calcium causes fusion of vesicles with neurotransmitters and release into synaptic cleft

6. Neurotransmitter binds receptors on the post-synaptic membrane

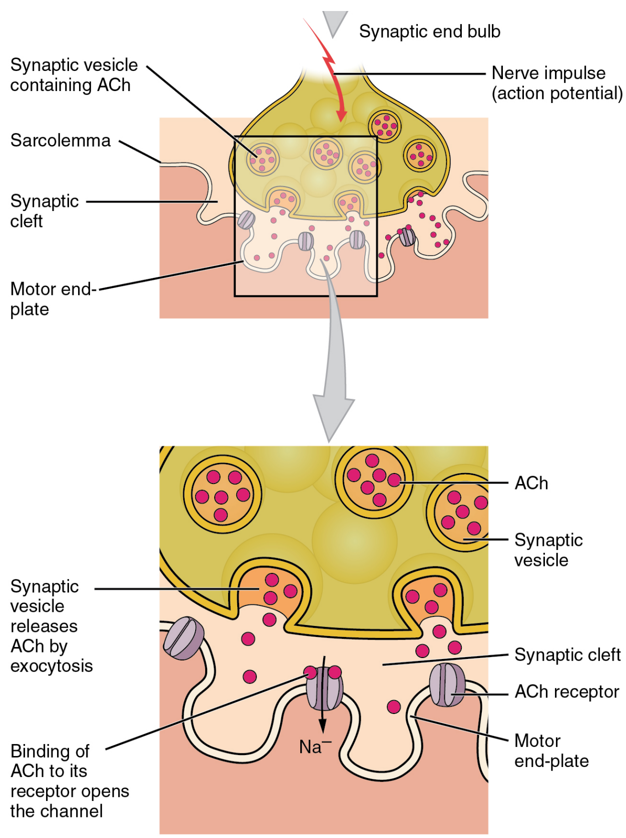
- Trigger the cell to fire an action potential and cycle is repeated

7. Neurotransmitter is immediately removed through one of two methods

- Enzymes in the post synaptic cell destroy it

- It is pumped back into the pre-synaptic cell for re-use

**EXAMPLE:** Steps of neurotransmitter release



Neurotransmitter signaling

● Neurons must be able to interpret complex combinations of neurotransmitters

□ Neurotransmitters fall into two classes: *excitatory* or *inhibitory*

- **Excitatory** neurotransmitters trigger an action potential in post-synaptic cell

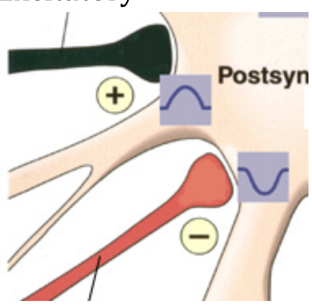
- Acetylcholine in neuromuscular junction - results in muscle contraction

- **Inhibitory** neurotransmitters trigger $Cl^-$ channels which make depolarization harder (Ex: GABA)

□ Some toxins and drugs target neurotransmitters

**EXAMPLE:** Excitatory vs. Inhibitory neurotransmitters

Excitatory




Inhibitory

□ Huge neuronal networks receive large combinations of neurotransmitters

- Combinations of excitatory and inhibitory signals

- Each neuron contains its own set of receptors and ion channels

- Neurons have to combine and interpret all of these signals

□ **Synaptic plasticity** is when the magnitude of a neuron's response depends on how much it's been used in past

**EXAMPLE:** Networks of competing neurotransmitters