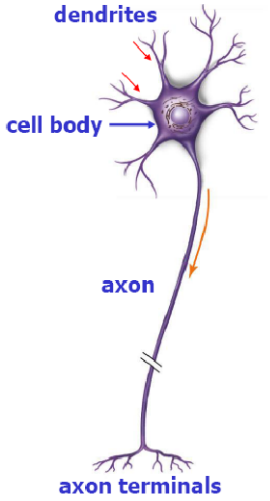
Biology Lecture 5 and 6

Neurons-Basics:

Neurons are cells specialized to receive information, integrate it and pass it on to other cells. There are four regions in each neuron cell, **cell body, dendrites, axon,** and **axon terminal.** The cell body contains nucleus and most of the cell's organelles. Dendrites are projections from the cell body and they carry information to the cell body. Axons are usually the longest projections and they carry information away from the cell body to some other target cell. Axon divides into a fine spray of nerves near the target cell. Swellings at the tips of these nerves are called axon terminal and their purpose is to form **synapse** (space between a membrane of the neuron and the target cell where chemical messengers (neurotransmitters) are released) with target cells.



Nervous system:

Nervous system is made up of neurons and glial cells (support cells). Nervous tissues first evolved in the cnidarians in the form of nerve nets near the oral surface/tentacles. Animals after the cnidarians have evolved ganglia, cluster of cell bodies that allows them to process a large amount of information. Annelids, for example, have a ganglia on every segment to control muscle contractions. With mollusks, especially cephalopods, the ganglia are a bit more concentrated at the anterior end. Vertebrates have a central nervous system (CNS) composed of brain and spinal cord and a peripheral nervous system (PNS) made up of sensory neurons and motor neurons that carries message to and from the CNS. Information is received by **sensory receptors** and passed on to sensory neurons (or afferent neurons) to carry to the interneurons in the CNS. Interneurons are neurons that only communicate to other neurons. They store, integrate and relay the information to motor neurons. Motor neurons or efferent neurons carry the information from CNS to **effectors** (muscles or glands).

Neurons-function:

Neurons communicate with each other and with other cells electrochemically. They create an electric potential that travel though the cell to axon terminals, where the neurotransmitters (chemical messengers) are emitted through the synapse to the target cell.

Neurons are surrounded by a plasma membrane, which is a lipid bilayer that is imperable to ions. Ions channels and ion pumps exists on the plasma membrane and allows certain ions to pass through. Ion channel allows ions to move with their concentration gradient via diffusion and therefore does not require energy to operate. Ion channels could be opened at all times or be gated by voltage or by chemicals. Ion pumps, on the other hand, "pump" ions against their concentration gradient and must consume ATP in order to function.

The major pump is the sodium-potassium pump. It takes three sodium ions from inside the cell and exchange it for two potassium ions from outside the cell. This makes the concentration of Na+ ions much higher outside the cell than inside the cell. Consequently, the concentration of K+ ions inside the cell is much higher than the outside.

The ions that exist inside a neuron are Na+, K+, Cl-, and some negative proteins.

There are more open K+ channels (channels that only allow K+ ions to flow) than open Na+ channels on a neuron's membrane. This means that K+ ions can easily diffuse to the outside of the cell due to its increased concentration. The Na+ ions, however, cannot easily diffuse in since not many Na+ channels are open on the cell's membrane. Thus, as K+ ions leave, they leave behind the Cl- ions and this creates a negative charge on the inside of the cell. (There are few or no open Cl- ion channels)

When the negative charge inside the cell is great enough, it starts to pull the K+ ions back in. Thus, at a certain negative charge, the tendency for K+ ions to flow out is balanced by the negative charge that pulls them back in. Equilibrium is established.

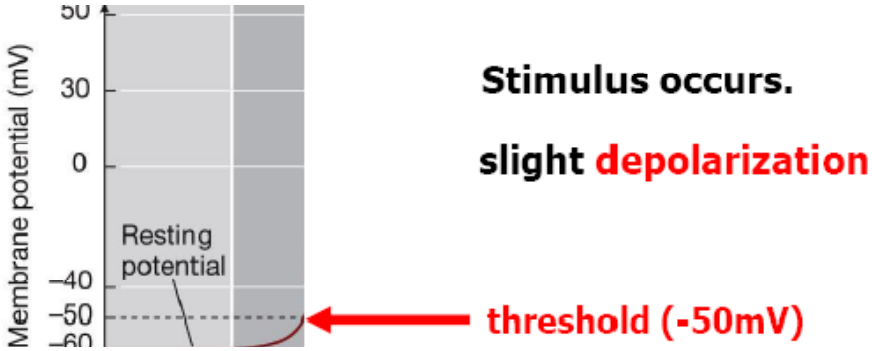
Whenever two areas have a difference in electric charge, an electric potential is said to exist. The inside of neurons are electrically negative compared to the outside. This potential is called **membrane potential.** When neurons are not stimulated, this membrane potential is called the **resting potential.** This resting potential have a voltage of -60 mv. Resting potential allows neurons to respond to a stimulus.

Action Potential:

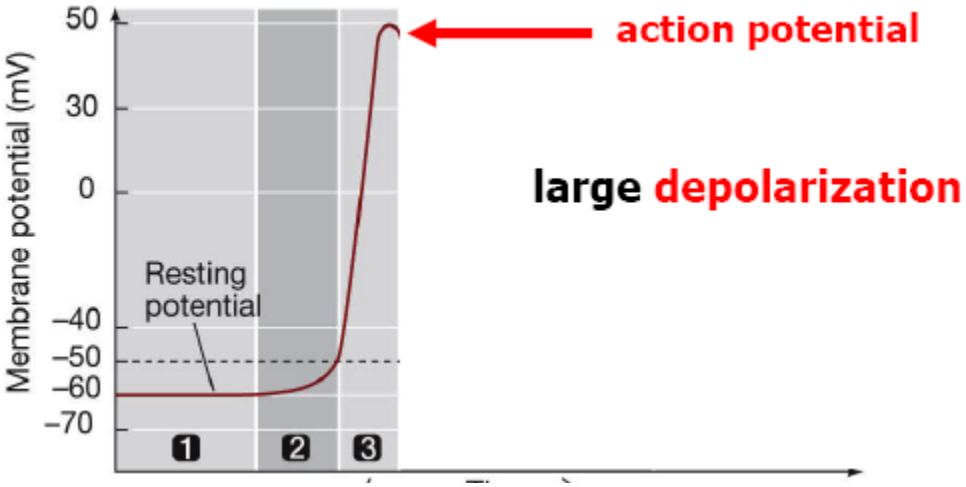
Action potential is a sudden and major change in membrane potential that is conducted along the axon at a rapid speed. This effect is created by the voltage gated sodium channels. The formation of action potentials takes three processes: depolarization, repolarization, and sodium-potassium pump.

Stimulus causes some sodium gates to open up. Na+ ions diffuse into the neuron due to concentration gradient. This cause the inside of the cell to become less negative. This is called **depolarization.** If the

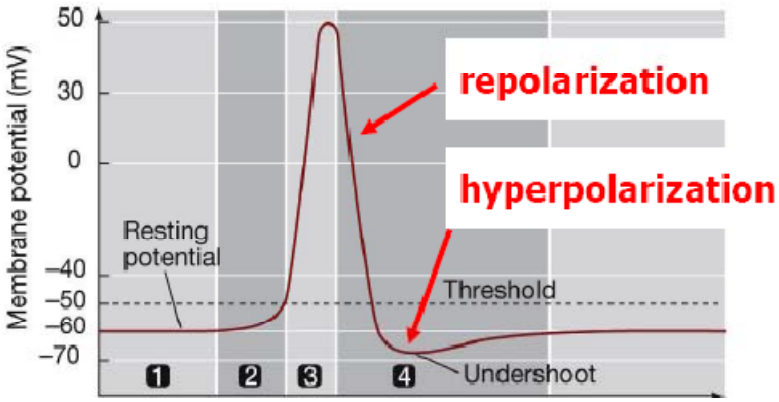
depolarization is large enough that the membrane potential reaches -50 mv, then we say that it has reached the **threshold level.**



At the threshold level, a large number of voltage gated sodium channels open up and large amounts of Na+ ions rushes into the cell, causing a sudden depolarization. We say that action potential has occurred at this point.



The next step for the cell is to recover from this action potential. The recovery process is called **repolarization.** Also, from this point on, **refractory period** occurs before the cell can fire off another action potential. Repolarization is accomplished by closing off voltage gated sodium channels and open up voltage gated potassium channels. This causes large amounts of K+ ions to flow out, making the inside of the cell more negative. The potassium channel open longer than necessary and cause more potassium ions to flow out than it is necessary to restore the resting potential. This is called **hyperpolaziation** and it makes the inside of the cell more negative than its resting potential.



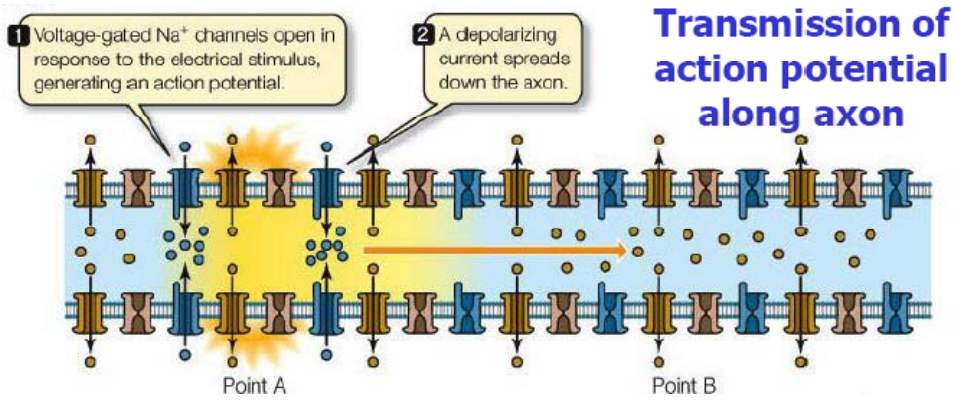
To restore the cell back to its resting potential, the sodium-potassium pump takes over and restore the balance between the Na+ ions and K+ ions. Refractory periods now ends and the cell can once again create another action potential.

Thus, the refractory period exists at first due to positive membrane potential, then because neuron hyperpolarization, and finally due to Na+ and K+ ions on the wrong sides of the cell.

Hyperpolarization may seems like an useless feature but it play two important roles. First, it ensures that action potentials (also known as impulse) only travels one way. Since hyperpolarization makes the cell more negative, it is easier to depolarize the part of the cell that has not receive an action potential. Hyperpolarization also makes it harder for parts of the muscle to contract. (Plays a role in inhibitory synapse) Muscle cells need to fire off action potential to contract. Hyperpolarization makes it harder to fire off action potentials and therefore muscles are less likely to contract.

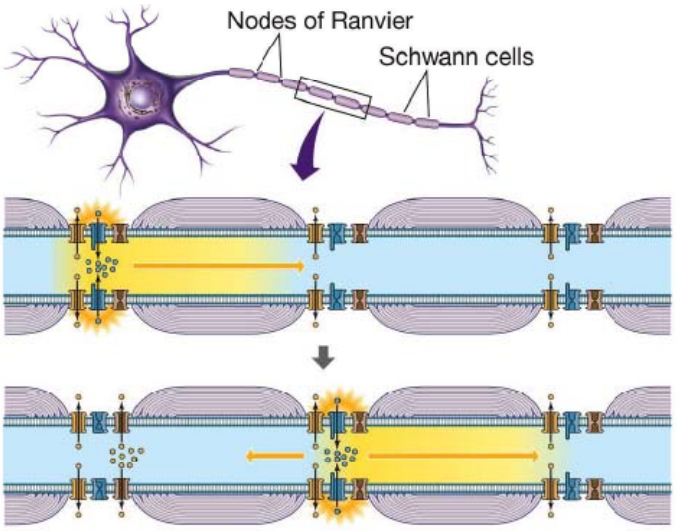
The key things to keep in mind about action potentials is that it is an all or nothing process. Stimulus needs to be strong enough to depolarize the neuron to -50 mv or nothing happens.

Once action potential happens in one section of the cell, it travels down the axon and force the next section of the action to undergo action potential as well. (By spreading the depolarizing current) The magnitudes of the action potential stays relatively the same for a given neuron and this is true even if the action potential travels down a long axon.



The speed of the transmission can be increased but this is accomplished differently in vertebrates and invertebrates. In invertebrates, the transmission speed is increased by increasing the axon diameter. This is not feasible in vertebrates so **salatory conduction** is applied.

Salatory conduction is a method of spreading action potentials in which the action potentials "jump" from node to node. This is accomplished by wrapping the axons in **myelin,** a white looking fatty layer. This layer blocks off all the ion channels and pumps, inhibiting the spread of action potentials. Myelin do not cover all of the axon. The places where no myelin exists is called **"Nodes of Ranvier"**. These nodes are where the ion channels gather and action potential can be generated. Action potentials thus "jump" from node to node and this increases the speed of transmission significantly.



Neuron communication:

Neurons communicates by synapse, special junctions where one cell influence another directly through transfer of electric or chemical messages. **Presynaptic cell** is defined as the neuron that sends the message. **Postsynaptic cell** is defined as the neuron or cell that receives the message. **Synaptic cleft** is defined as the actual space between the presynaptic membrane and the postsynaptic membrane.

The axon terminals are filled with many vesicles containing **neurotransmitters** or chemical messengers. Common neurotransmitters are **acetylcholine**, a type of excitatory neurotransmitter and **GABA,** a type of inhibitory neurotransmitter.

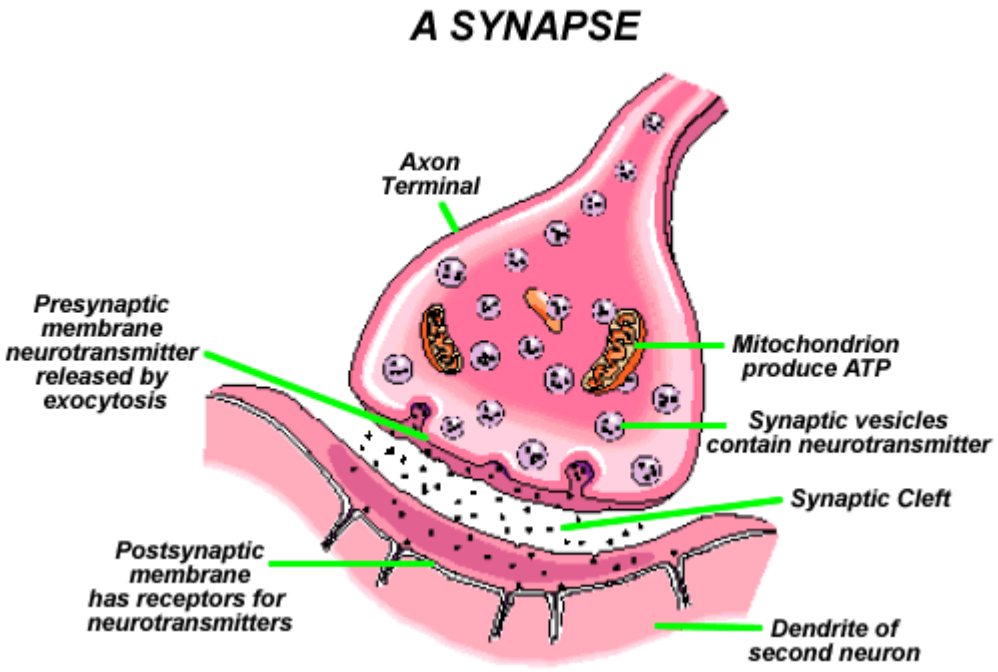
Excitatory neurotransmitters cause the postsynaptic cells to always respond by depolarizing their membrane.

Inhibitory neurotransmitters, on the other hand, bind to chemically gated chloride channels and open them up. This causes the inside of the postsynaptic cell to be hyperpolarized and therefore less likely to fire off an action potential.

As the action potential arrives from the axon, it depolarizes the axon terminals and open up calcium ion channels that exist on the membranes of the axons terminals. Calcium concentration is greater outside the cell and calcium ions flows into the cell passively via diffusion.

The increased calcium ions cause the vesicles containing the neurotransmitters to fuse with the presynpatic membrane, releasing neurotransmitters to the synaptic cleft via exocytosis.

These neurotransmitters bind chemically to the sodium ion gates located on the membrane of the postsynaptic cell and cause the depolarization of the postsynaptic cell. If the postsynaptic cell is a muscle cell, this would cause the muscle cell to contract.



Neurotransmitters are then broken down by **acetylcholinesterase** and taken back into axon terminals to be recycled. A number of drugs can take advantage of this fact and cause some serious effects on humans.

Nerve gas, for example, inactivates acetylcholinesterase. Since the acetylcholine (neurotransmitter) is not broken down, it exists in the synaptic cleft and continuously bind to the sodium gates of the muscle cells, causing the muscle cells to contract indefinitely. This causes paralysis.

A similar effect is used in **anti-depressants.** The drug block reuptake of excitatory neurotransmitters like serotonin and allow them to remain in synapse longer, prolonging the effect of happiness.

Tetrodotoxin is a toxin released by some animals (due a bacteria that live symbiotically with them). This toxin blocks out Na+ channels and therefore preventing depolarization and muscle contraction. This paralysis the diagram and suffocate the target.

Anti-anxiety drugs mimic the action of natural inhibitory neurotransmitters like GABA and binds to Cl- channels to caused hyperpolarization. This hyperpolarization means that greater stimulus is need to activate action potentials.

Anesthetics work by inhibiting local movement of Na+ through ion channels to prevent depolarization.

Electrical synapses:

Electrical signals can also be carried through the synapses through special proteins called connexons that link the two cells together directly. Transmission of electrical signals is very fast and can proceed in both directions.