Lecture 8 Nerve Potential and conduction

❁All or None law

※It states that: when a single nerve fiber is stimulated, either it does not respond at all (if the stimulus is sub-threshold), or it responds by nerve impulse if the stimulus is threshold or more).

※The nerve impulse is always of the same magnitude and duration whatever the intensity of the stimulus that produced it.

※It is obeyed by a single nerve fiber (one axon), a single muscle fiber (skeletal) and the whole cardiac muscle. ***Why?????????***

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❁The excitability changes:

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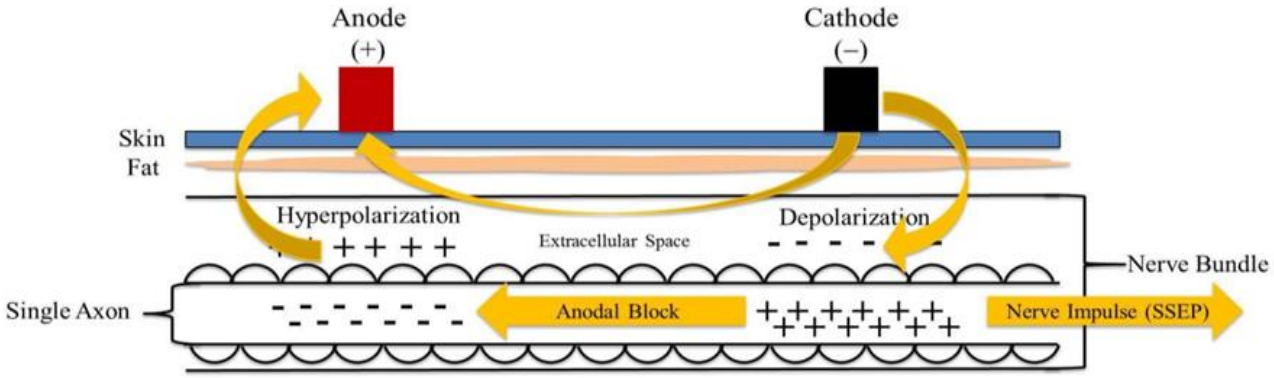


❁Excitability changes during the action potential:

1- The absolute refractory period (ARP) (stimulus during firing level, coincide with the ascending and the early part of the descending limb of the spike till repolarization is 30% complete)

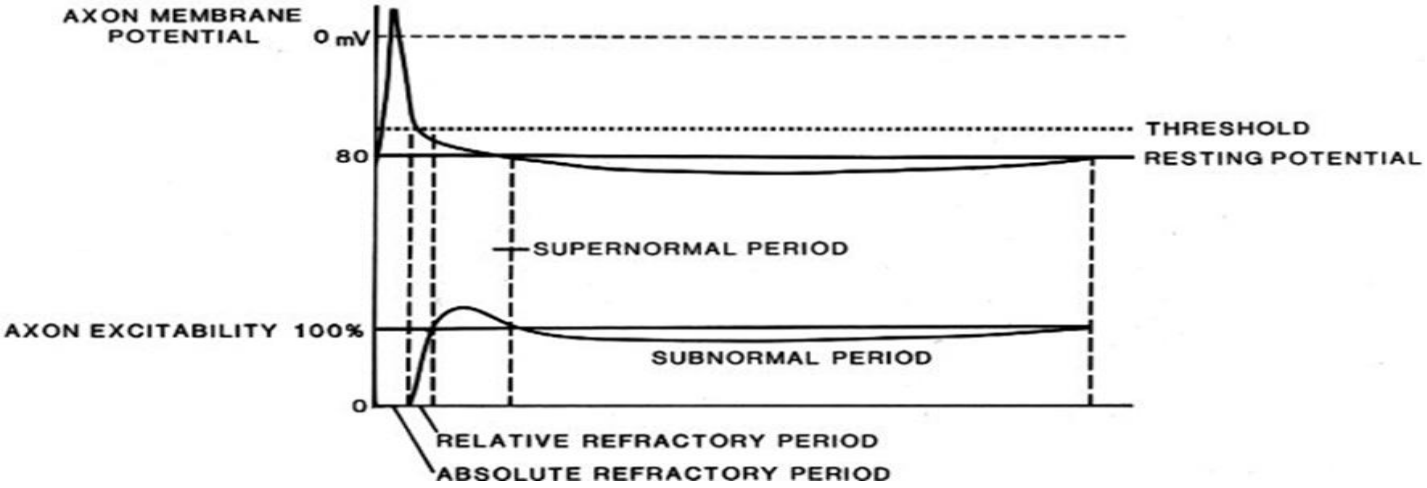
It is the period during which excitability is completely lost and no stimulus however strong can stimulate. (response=0).

2- The relative refractory period (RRP):

It is the period during which excitability is starting to return to normal, but it is still below normal. A stronger stimulus (more than the threshold) is needed to excite the fiber during this

phase. It corresponds to the last 2/3 of the descending limb of spike (till the beginning of –ve after potential). (response could occur).

than the threshold) is needed to excite. It corresponds to the positive after potential.



❁Factors affecting membrane potential and excitability

Factors which decrease the excitability (Nerve stabilizers):

These factors are called nerve stabilizers and include:

1. Local anesthetics as Cocaine which decreases the permeability of the membrane of the nerve fiber to Na^+ → ↓ the excitability.

2. Effect of Ions:

※High Ca^{+2} concentrations in the extracellular fluid (hypercalcemia as in diabetic keto-acidosis) → ionized Ca^{+2} lock gated Na^+ channels and repel Na^+ ions → ↓ the permeability to Na^+→ ↓ excitability → no partial depolarization occurred and this lead to stabilization of the membrane → coma. (Ionized Ca^{+2} are the most important ion in membrane excitability and considered membrane stabilizer prevents its depolarization).

※Low K^+ concentration in the extracellular fluid (hypokalemia as in persistent vomiting and diarrhea) → ↑ the RMP (hyperpolarization) → ↓ excitability. As in a hereditary disease called familial periodic paralysis.

3. Cooling, ↓ blood supply, O^2 lack and acidosis (↑ Ca^{+2}) →↓ excitability.

❁Factors which increase the excitability:

※Any conditions that increase the permeability of the membrane of the nerve fiber to Na^+ cause the nerve to be more excitable.

1. Warming and alkalinity increases excitability.

2. Effect of Ions:

※Low Ca^{2+} in the extracellular fluid (hypocalcemia as in tetany) → ↑ permeability to Na^{+} → ↑ excitability → contraction of muscle → convulsions.

※High K^{+} concentration in the extracellular fluid (as in renal failure) →diffuse to the inside because the membrane is greatly permeable to K^{+} at rest → ↓ the RMP → ↑ excitability.

❁Properties of nerve impulse

1. Obeys the All or None Rule.

2. It has an absolute refractory period.

3. Conduction in myelinated nerve fiber rapid, and consumes less energy than Non-myelinated

5. The larger the diameter of nerve fiber, the greater is the velocity of nerve impulse conduction, the bigger is the magnitude and the shorter is the duration of the spike.

❁Conduction of the nerve impulse

(Propagation of action potential)

Nerves are of two types: myelinated (thick myelinated somatic nerves type A (100 m/sec), thin myelinated preganglionic nerves type B (10m/sec), or non-mylinated postganglionic nerves type C (1m/sec))

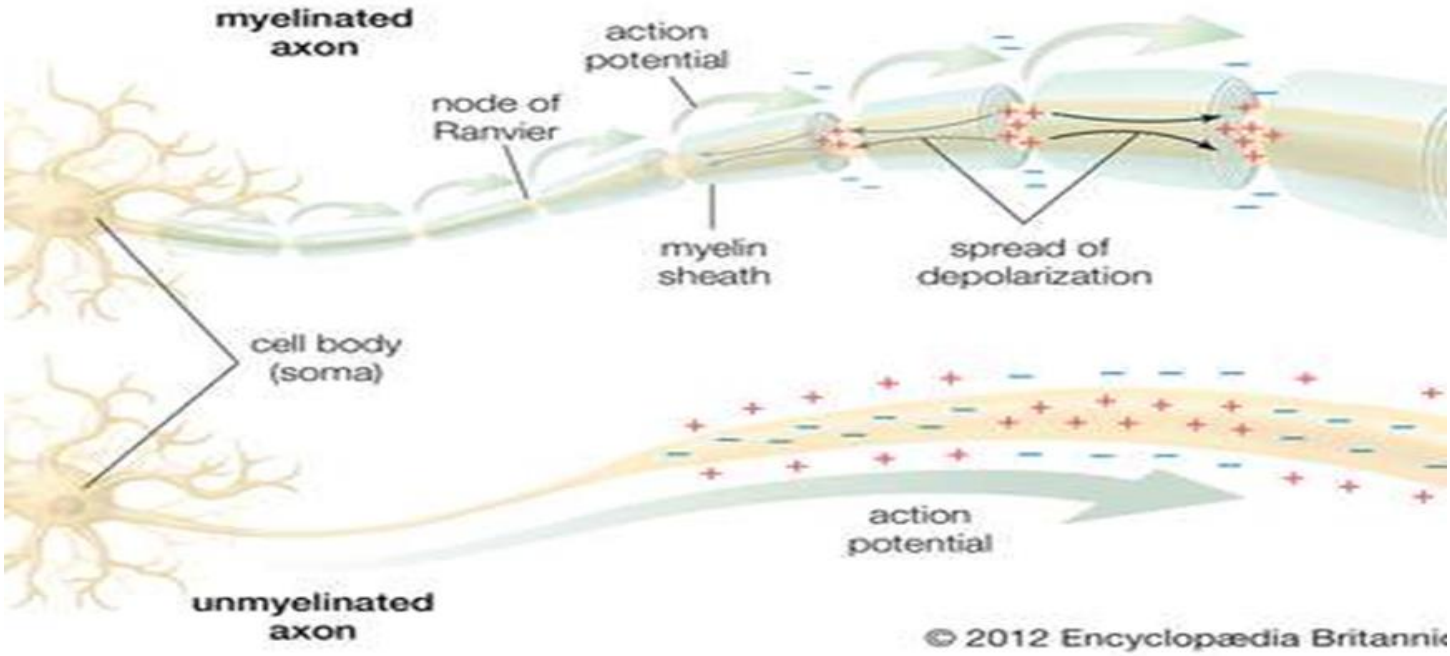
※Conduction in non-myelinated nerve fiber:

Reversal of polarity at the site of stimulation (depolarization; the outer surface becomes negative) occur when the adequate stimulus is applied. The negative outer surface act as a cathode for the neighboring segments which are positive (polarized). Positive charges from the membrane in front of and behind the area of reversal of polarity will be drawn into it, and this decreases the membrane potential (depolarization) in front and behind the initial segment ***(local passive circuit).*** If this depolarization is of sufficient front and magnitude, it will cause a reversal of polarity at these new sites. So, the impulse is conducted at a wave of reversal of polarity (new action potential).

※Conduction in myelinated nerve fibers

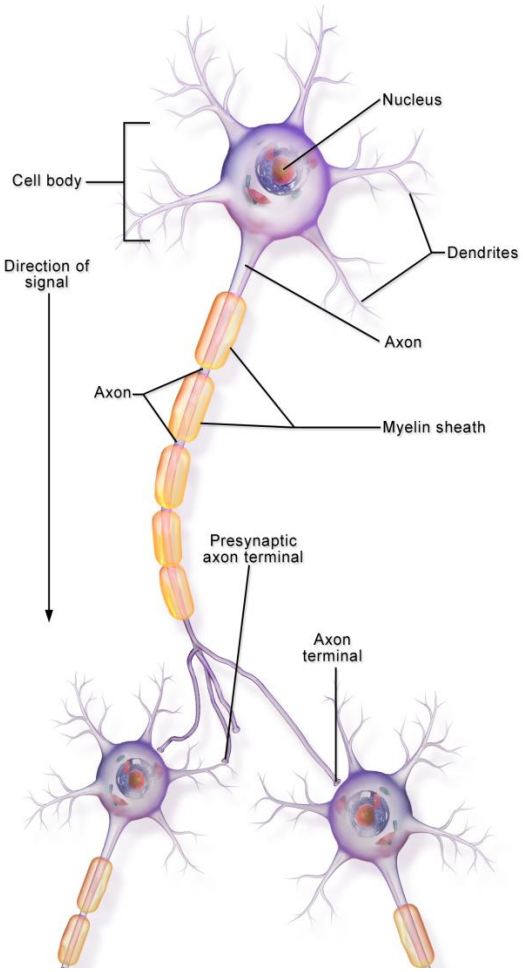
The myelin sheath is an electric insulator (not depolarize, no action potential). The **adequate stimulus produces a reversal of polarity at the active node of Ranvier** that jump from node to second one. This **jumping of depolarization from node to node is called saltatory conduction**.

Significance: it is **more velocity (50 folds)**, and **consumes less energy**



Neurons possess electrical excitability in their membranes allows them to respond to a stimulus by generating a nerve impulse. The **neurons dendrites** are the place receive stimuli from the external or internal environment. Once a stimulus (or multiple stimuli) produces a significant dendrite' threshold, nerve impulse (action potential) occurs. An action potential is generated at the **axon hillock of a neuron** and progresses rapidly along the axon's plasma membrane to reach the second neuron, muscle or gland. This movement of an action potential along the axon is called **propagation**. The neuronal action potential follows All-or-None Law to give the same impulse strength (amplitude), regardless the stimuli weak or strong and the main modulator of nerve impulses is the frequency of action potentials. A bigger stimulus will produce a series (or train) of action potentials that are close together, while a weak stimulus will produce sparse action potentials.

The speed of an action potential is influenced by the axon diameter and myelination. This progression of a nerve impulse is called continuous conduction. Once the action potential reaches the axon terminal, it is either transported as electrical charge into the next cell or transformed into a chemical signal, depending on the type of synapse that the synaptic end bulb is forming with its target.

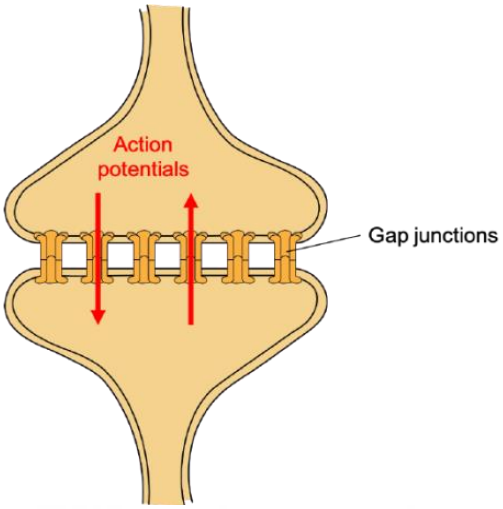


Neurons and their targets form synapses. Presynaptic cell (always a neuron) generates and conducts the action potential to the target while the postsynaptic cell (a neuron or another type of cell such as skeletal, cardiac or smooth muscle cells, or glands) is the target cell receiving the action potential.

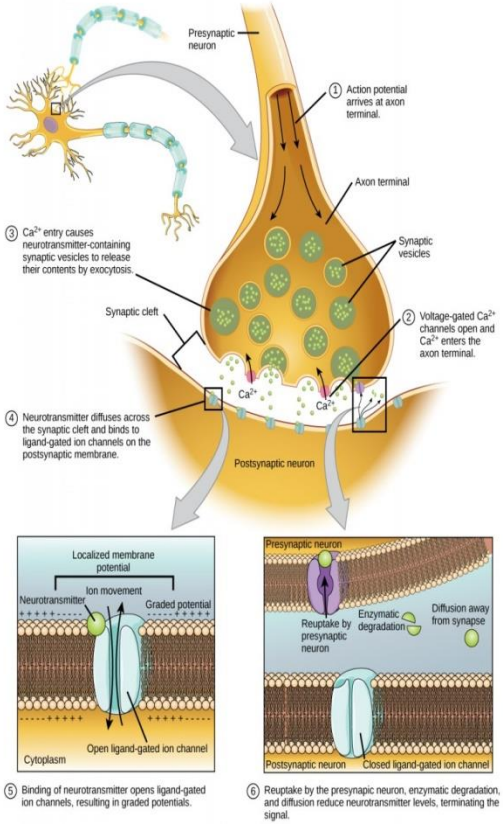
Synapses

There are two types of connections between electrically active cells: **electrical synapses** and **chemical synapses**.

In an **electrical synapse**, there is a **direct connection** between the **presynaptic** and **postsynaptic cells** and the connection is formed by **gap junctions**. Thus, the electrical charges of an **action potential can pass directly from one cell to the next.** Although **representing the minority of synapses**, electrical synapses are found throughout the nervous system, **between intestinal smooth muscle cells** and cardiac muscle cells.



Chemical synapses (represent the **majority of the synapses**), involve the transmission of chemical information from one cell to the next and they found within the nervous system through **releasing of a chemical signal (neurotransmitter)**, from presynaptic cell to affect the postsynaptic cell. There are Many different types of neurotransmitters are founded and **each neurotransmitter has its own specific receptor on the postsynaptic membrane.**



All chemical synapses have common characteristics, **synaptic end bulb of presynaptic neuron**; **neurotransmitter** (packaged in vesicles), **synaptic cleft**, **receptors for neurotransmitter**, and **postsynaptic membrane of postsynaptic neuron**.

The synaptic end bulb vesicle contains **only one type of neurotransmitter**. When action potential reaches the axon terminals, voltage-gated Ca^{2+} channels in the membrane of the synaptic end bulb opens. The concentration of Ca^{2+} increases inside the end bulb, and the Ca^{2+} ion associates with proteins in the outer surface of neurotransmitter vesicles. The Ca^{2+} facilitates the merging of the vesicle with the presynaptic membrane so that the neurotransmitter is released through exocytosis into the small gap between the cells, known as the **synaptic cleft**.

The neurotransmitter diffuses the short distance to the postsynaptic membrane and can interact with neurotransmitter receptors, making the binding a specific chemical event. The binding of the neurotransmitter to its receptor causes a brief electrical change across the postsynaptic membrane cause a nerve impulse to begin in the postsynaptic cell or inhibit the generation of an action potential. **The flow of information is unidirectional: from the presynaptic cell to the postsynaptic cell.** After its release in a chemical synapse, neurotransmitters need to be removed from the synaptic cleft to ensure the propagation of new synaptic signals.

Once neurotransmission has occurred, the **neurotransmitter must be removed from the synaptic cleft** so that the **postsynaptic membrane can "reset" and be ready to receive another signal.** This can be accomplished in three ways: **the neurotransmitter can diffuse away from the synaptic cleft**, it can be **degraded by enzymes in the synaptic cleft**, or it can be **recycled (sometimes called reuptake) by the presynaptic neuron**.