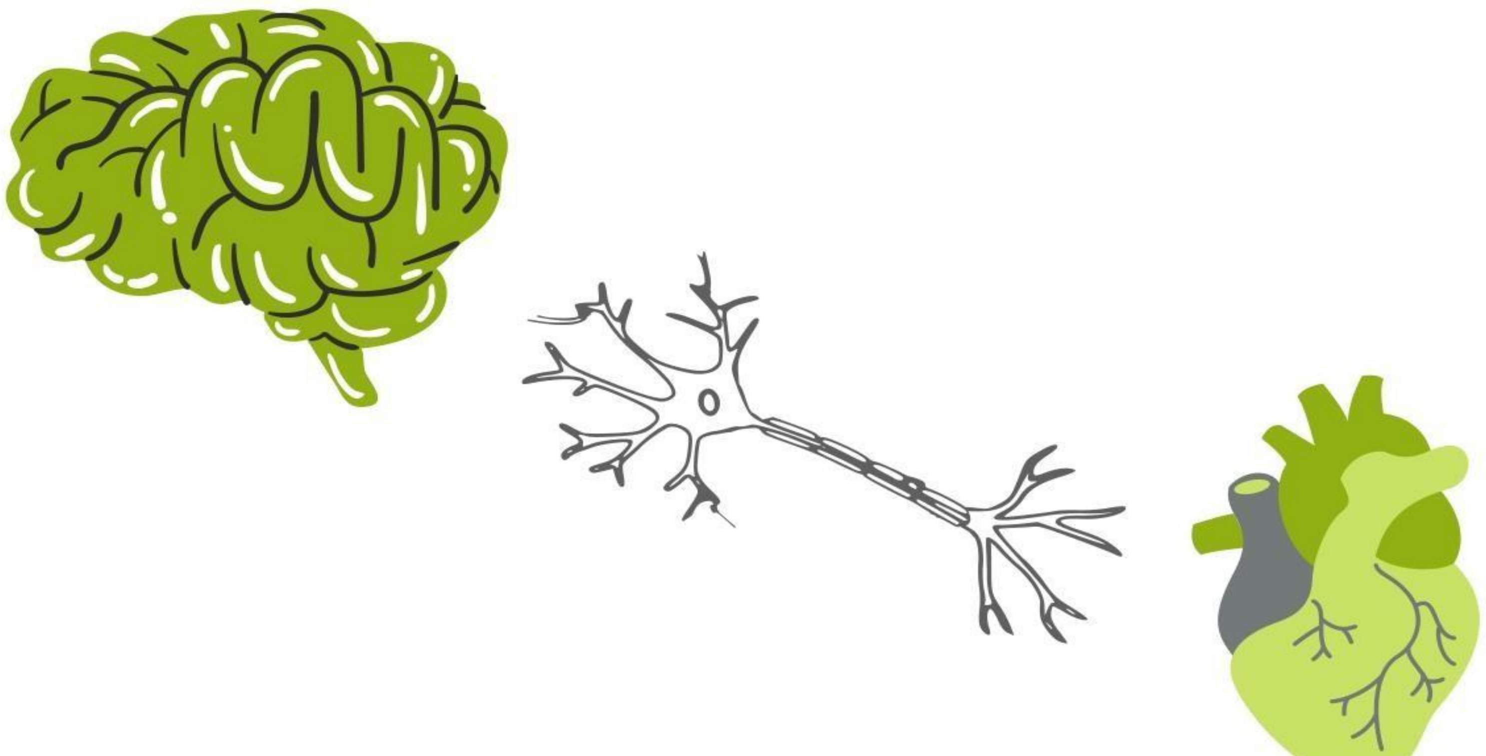
Sheet no. 7

Physiology



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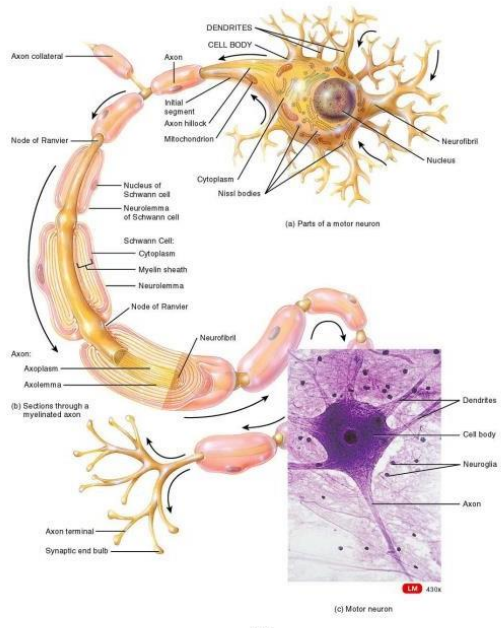
First of all, let's take a look at the neural cell:



-The main parts of a neuron (found in all neurons):

1-cell body

2-the dendrites (they are connected to the cell body)

3-axon

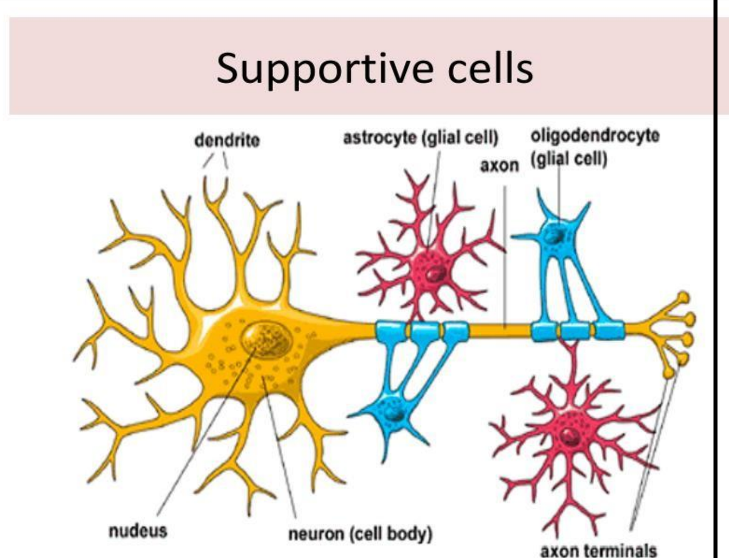
4-axon hillock

-At the end of an axon we have axon terminals that can be connected to other cells such as muscle cells/other neurons.

-Axon hillock also called (trigger zone) is a small part between the cell body and the axon and it is **where** the action potential is generated in **motor neurons**.

NOTE: The term **TRIGGER ZONE** is used **only** for **motor neurons**.

-We also have a lot of supportive cells around neurons called Neuroglia and their functions include:



1-Maintenance of neural environment keeping the media clean

2-Synthesis and release of neurotrophic factors, maintaining the survival and protection of neurons

3-providing nutrition

4-reducing the concentration of potassium which is very important to keep the optimal activity of the cells

5-destroying neurotransmitters

-Other specialized supportive cells are responsible for the myelination of axons

-**Myelin**: is the sheath around some axons, which helps electrical impulses to transmit quickly along with nerve cells, and it is composed of sphingolipids

-One of the supportive cells which is called **Schwann cells**, are wrapping around axons secreting huge amounts of myelin sheath forming many layers around the axons and the neurons that contain this type are called myelinated neurons

-there are gaps between the myelin sheaths known as **nodes of Ranvier**.

-The connection between the terminal of the first neural cell and the membrane of the second one is called **Synapse**.

- (from google): Oligodendrocytes are the myelinating cells of the central nervous system (CNS).

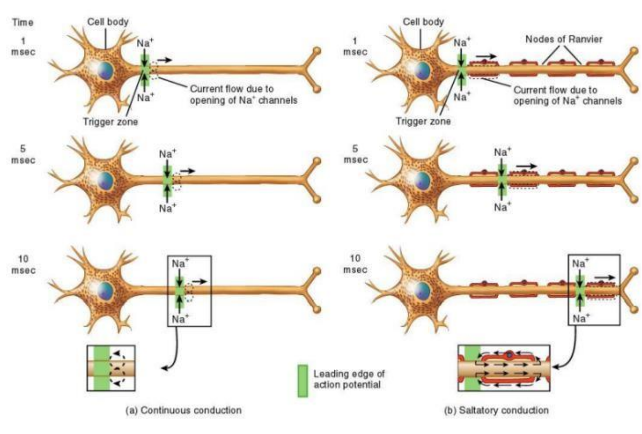
- (from google): Astrocytes, also known collectively as astroglia, are characteristic star-shaped glial cells in the brain and spinal cord.

- Now let's talk about action potential

-We have two types of neurons myelinated and nonmyelinated neurons

-In unmyelinated neurons, we have the action potential continuous along the axon

- While in myelinated neurons we have what is called *saltatory conduction* and the reason why we are calling it saltatory is simply that the action potential **is skipping parts** of the axons covered with myelin sheath and jumping from one node of Ranvier to the adjacent and so on that's why we are calling it saltatory.



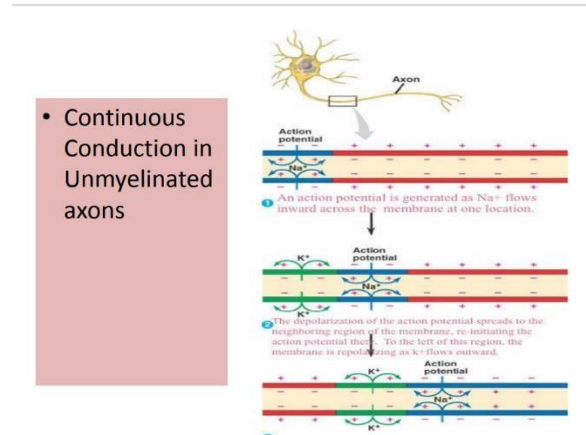
Type of the neuron	Myelinated	Non-Myelinated
The way of transport of action potential	From node to another	Along the axon
The speed	Faster	Slower
	Saltatory or jumping	Continuous way

Factors affecting the speed of the action potential transporting along the neuron:

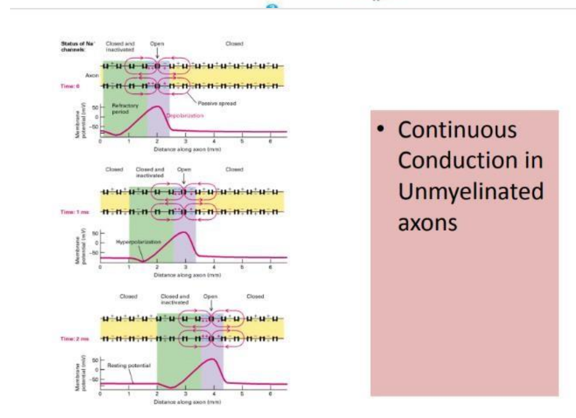
1- The diameter of the fibers (axons) increasing the diameter makes the resistance lower which makes the velocity higher

2 -It is faster in myelinated axon than in nonmyelinated axon

■Continuous conduction:



Once we have an action potential in axon hillock sodium and potassium channels will open and the membrane will be positive inside and negative outside this situation causes a current between the regions where we have action potential and the regions that are still polarized in resting state.

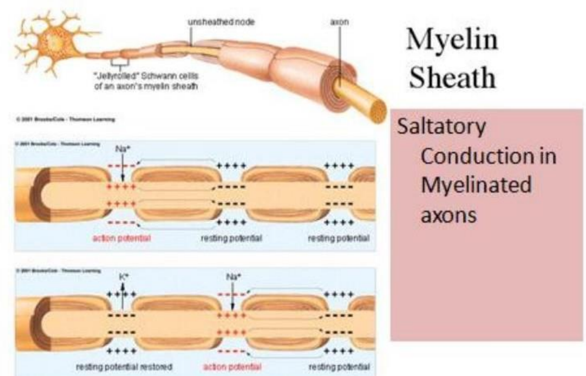


-This happens on the inside, also we have the same thing on the outside but the current on the inside is more important. By these currents, we have **depolarising** in the **neighboring** region.

- The difference in charges between adjacent regions creates an electrical current.

-The action potential continuously transports along the axon in the unmyelinated.

■Saltatory conduction:



-Once we have an action potential in the axon hillock action potential causes depolarisation in the neighbor node of Ranvier and so on until we reach the terminals.

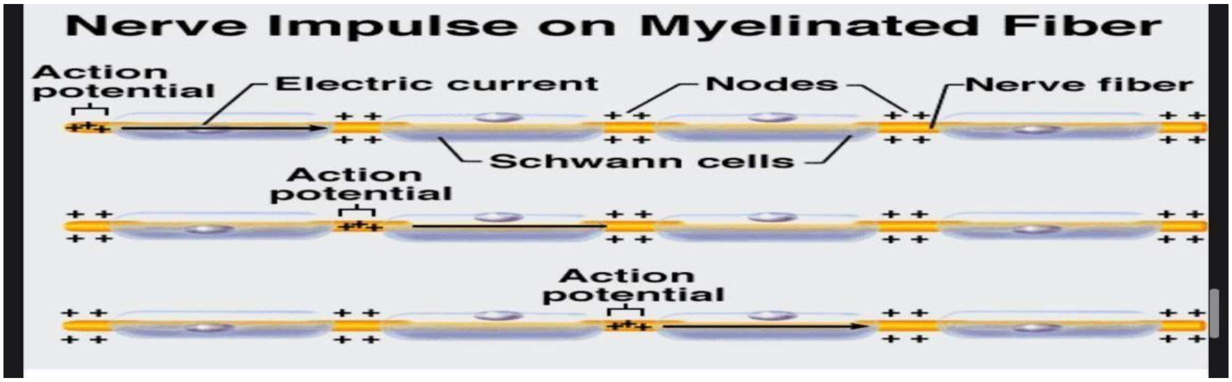
-The action potential transports in myelinated neurons(starting)from the axon hillock jumping from one Ranvier node to another in a Saltatory way.

-Myelinated: Saltatory

- Unmyelinated: continuous

-Note: the doctor asked a question: What happens if we generated action potential in the middle of the axon? Actually we will have an action potential going in both directions in front of the point where we initiated the potential and behind it .

- And if we generated the potentials at two opposite points the potential will proceed until the 2 potentials meet at a certain point and they will cancel each other



- Importance of refractory periods in conduction:

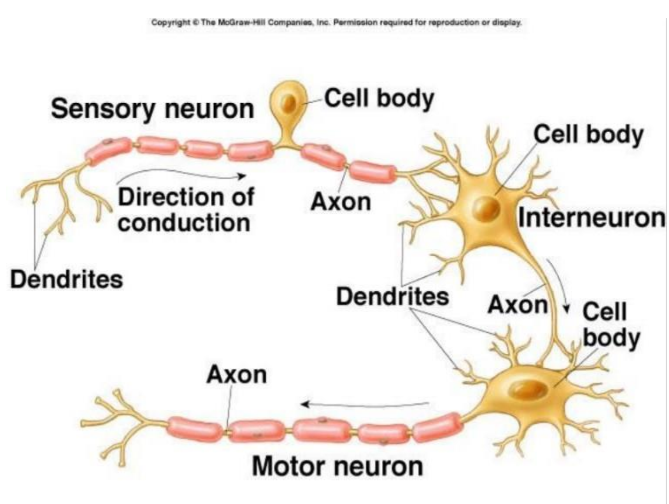
-The presence of refractory periods during the action potential is very important in the conduction of impulse. The refractory periods ensure the one-way (unidirectional) propagation of action potential.

-Once an area has developed an action potential, the previous region is still under refractory period (unresponsive area). This area will not develop another action potential. But the following area that is at resting potential is capable of initiating an action potential.

-In other words, if we have an action potential at the axon hillock, it can only move toward terminals! And not backwards!

Now let's talk about how an action potential is moving between neurons but before that let us remember the following:-The junction between 2 neurons is known as Synapse.

-The first neuron ends with the end bulb (synaptic knob), where neurotransmitters are stored in vesicles and ready for release. -The membrane of the synaptic knob is known as a presynaptic membrane.



-there is a difference between motor and sensory neurons **in** the generation of potential. (we shall discuss this difference now)

Motor neuron's action potential gets generated at the axon hillock while sensory neurons are different, they have different shapes; first they are shaped like **(T)** letter and we are generating action potential at the terminals **by** receptors and these potentials will travel along the axon towards the central nervous system where we have other terminals that are synapsing with the neuron. "This mechanism will be explained later with Doctor Faisal" the doctor said, smiling.

Note: Terminals: نهايات عصبية presynaptic: قبل تشابك postsynaptic: بعد تشابك

Now let us talk about the mechanism of transporting action potentials at the terminals

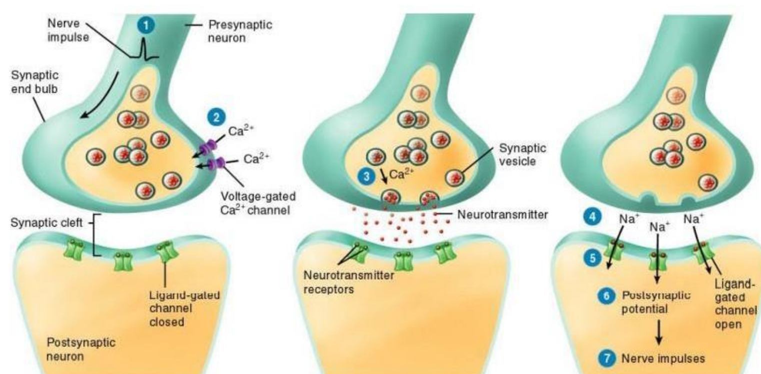
synaptic cleft: is the space between the postsynaptic membrane and presynaptic membrane.

-When the impulse from the presynaptic neuron reaches the terminal this will cause the activation of voltage-dependent Ca+2 channels.

-The increase in Ca+2 concentration inside the axon terminal will cause more fusing of the vesicles containing the neurotransmitters on the presynaptic membrane

- Then the neurotransmitters go outside by a process of exocytosis

-Then the neurotransmitters bind to their receptors on the postsynaptic membrane



-If it binds to receptors attached to Na+ channels it will do depolarization and if it binds to receptors attached to K+ channels it will do hyperpolarization.

Note: the potential that is generated in the postsynaptic membrane is small, so it will make small depolarization or hyperpolarization and will not reach the threshold it's called postsynaptic membrane potential that is classified as:

1) Excitatory postsynaptic membrane potential (EPSP)

Excitatory do depolarization

Inhibitory do hyperpolarization

2) Inhibitory postsynaptic membrane potential (IPSP).

1)Excitatory postsynaptic membrane potential can be induced by the activation Of Na+ channels which will cause the sodium ions to enter the cell decreasing The potential and causing a small depolarization The EPSPs are not action potentials.they are small depolarization.

2)Inhibitory postsynaptic membrane potential can be induced by the activation Of k+ channels which results because of the efflux(moving of the ions outside the Cell) of k+ ions which increases the membrane potential and makes it more negative Hyperpolarization

So keep in mind and don’t forget that EPSP decreases the potential while IPSP Increases it

-the type of the Na+ and K+ channels that get activated when the neurotransmitter Binds to it’s receptor at the postsynaptic membrane is chemical gated channels Chemical gated sodium channels and chemical gated potassium channels because They respond to the binding of a ligand(neurotransmitter).

-side note the activation of chloride channels will produce an inhibitory potential

-so now what happens to the neurotransmitters after inducing the appropriate response?

-the answer is the transmitter is inactivated or removed to make the postsynaptic membrane ready for receiving additional messages and you need to know that this inactivation takes place by postsynaptic membrane bound enzymes.

-examples of neurotransmitters acetylcholine and the enzyme that destroys it is called acetylcholine esterase , which destroys acetylcholine (Ach) into acetyl and choline molecules, which then are transported back to the synaptic knob, where they combine again to form new Ach molecules.

-note -Some types of transmitters are transported back, without inactivation, into synaptic cleft

Some of the terminals in the right picture are excitatory and some of them are inhibitory ➔➔➔

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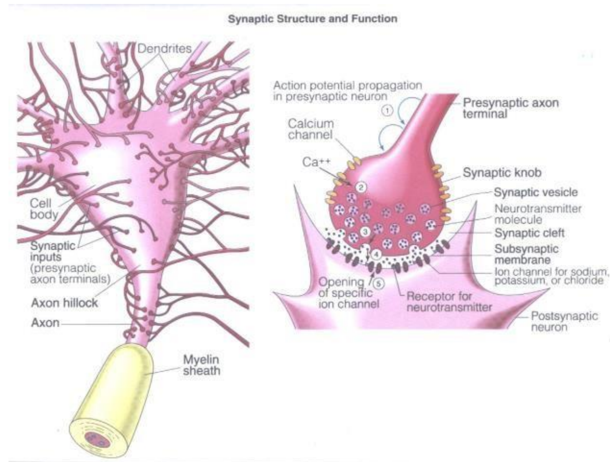
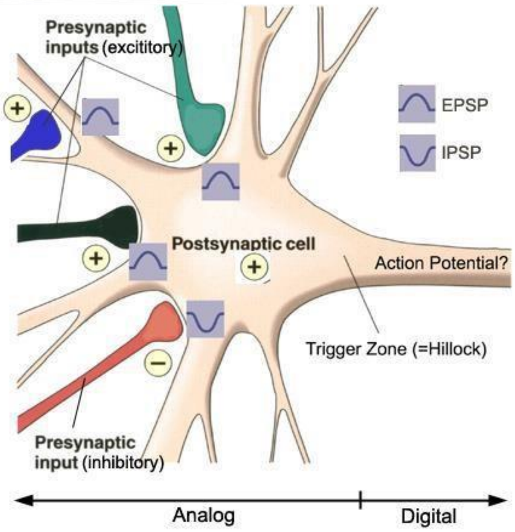


Q: So how does the neuron decide to generate action potential or not???

Answer: It's by summation of the potentials that reach the axon hillock, if it reaches the threshold it will do action potential otherwise it won't..



Note: the migration (انتقال) way of the postsynaptic membrane potential **differs** from that of the action potential in the axon

Excitatory decreases the amplitude (قيمة) of the potential and inhibitory increases it
So whenever there is a decrease in the membrane potential the potential is Excitatory
While if there is an increase it will be inhibitory

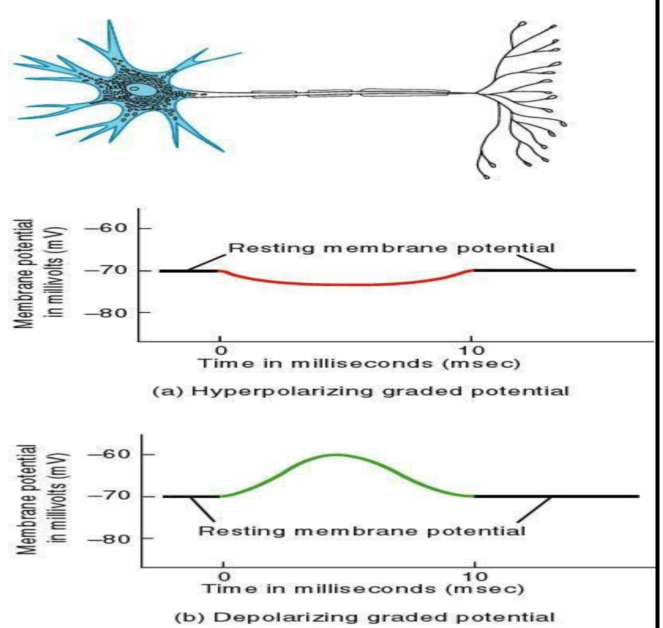
In the adjacent figure, the upper representation shows inhibitory

And the lower one shows excitatory

→→→

→→→

→→→



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-We have **two types of summation** known at the postsynaptic Membrane:

1-Spatial summation: (الصورة على اليسار تحت)

appears when 2 or more stimulation from 2 or more different neurons have appeared simultaneously (بنفس اللحظة) at the same site of the postsynaptic membrane, which results in the summing of these responses into a final response

يعني لما العصبون الاول يعمل اشارة لحاله ما يوصل للعتبة
نفس الشي العصبون الثاني
اما لما يوصلوا اشارة مع بعض يحدث جهد فعل و
بس

This summation can take place between 2 or more IPSPs to produce more hyperpolarization, 2 or more EPSPs to produce more depolarization in the membrane, or between excitatory and inhibitory potentials which results in cancellation (الغاء) of potentials and induce postsynaptic inhibition.

2-temporal summation: (الصورة على اليمين تحت)

This appears when 1 or more postsynaptic neurons, which were produced by one presynaptic neuron at different times, sum to induce more depolarization in the membrane potential. In this case, the repetitive excitation of the postsynaptic membrane from a single input induces a higher depolarization that may produce an action potential at the postsynaptic membrane.

يعني لما يعمل العصبون اشارة وحدة ما يوصل جهد العتبة بس
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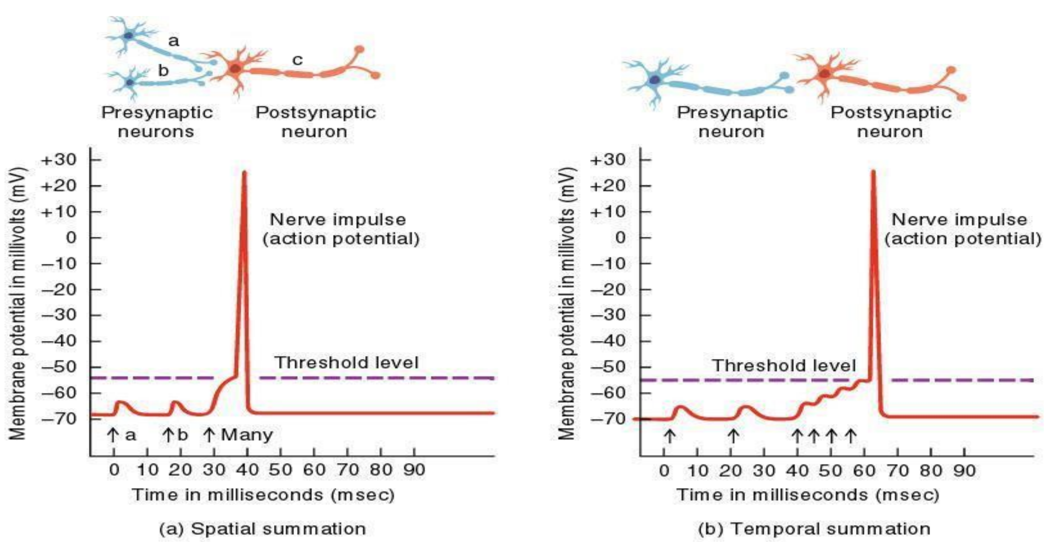

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NOTE: in our nervous system there is inhibition more than stimulation to keep our neural cells quite

	Excitatory potential	Action potential (when the summation reach the threshold
Duration	Longer ↑	shorter↓
The amplitude of voltage wave	Lower↓	Higher↑

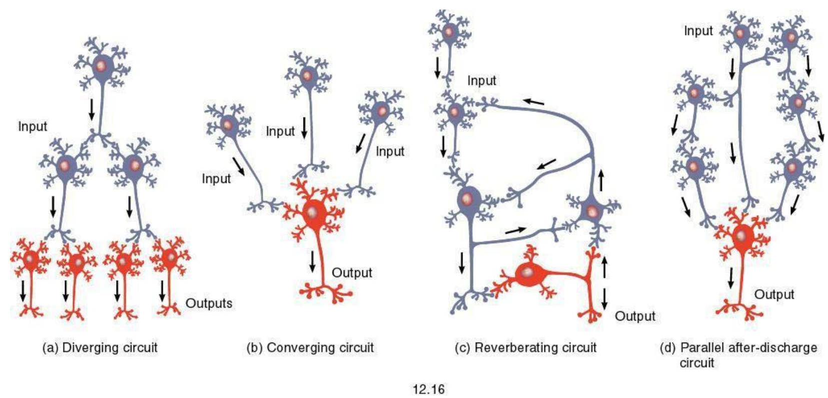
// synaptic organizations:

These two types are the most important:

1-diverging circuit: one presynaptic neuron synapses with many postsynaptic neurons by its multiple terminals. (Figure a)

2-converging circuit:

Many presynaptic neurons synapse with one postsynaptic neuron. (Figure b)



There are **two** types of action potential **recording** in terms of the number of action potential phases that are occurring:

1- **Monophasic** action potential recording.
2- **Biphasic** action potential recording

1-Monophasic action potential:

How can we record monophasic action potential?

By placing one electrode outside and one electrode inside the cell during any action potential phase, to get a recording of the potential difference changes inside with regards to outside.

The recording would be either positive or negative but not both.

Just for understanding:

Monophasic: means one phase.

2-Biphasic action potential:

biphasic: (means two phases), we get both positive and negative recordings through two waves.

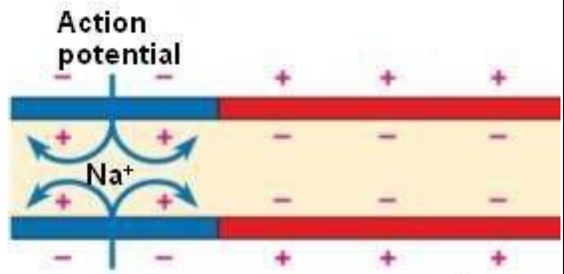
During action potential the two recorded waves are:

1-depolarization wave. **2-repolarization wave.**

and they are in opposite directions.

During action potential propagation (الانتقال) along the neuron's axon, there can be one region that's going through depolarization and the one next to it would still be in resting phase.

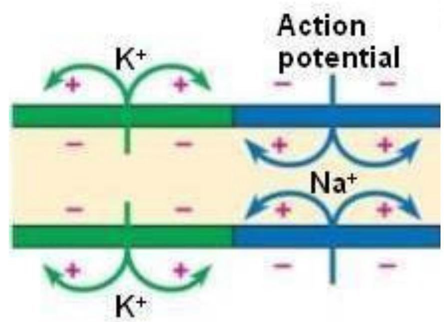
As a result, the two regions on the outside would have different charges. (Figure on the right)



So, if we placed two electrodes on the outside, we would record a potential difference wave that represents depolarization.

- The recorded wave is in the positive direction.

After a while, the first region would be positively charged on the outside, and the nearby region would be negatively charged on the outside. (figure on the right)



When we place the two electrodes, a different potential difference wave would be recorded and it represents repolarization.

- The recorded wave would be in the negative direction.

*if we switched the two electrodes; the positive one at the 1st point and the negative one at the 2nd point, the direction of the wave would be switched.

Compound action potentials:

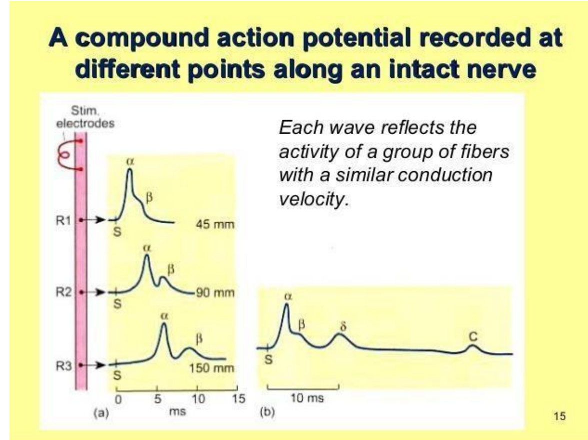
The nerve is like a **cable** that holds **many fibers** (axons), these fibers differ in their conduction velocity for action potentials.

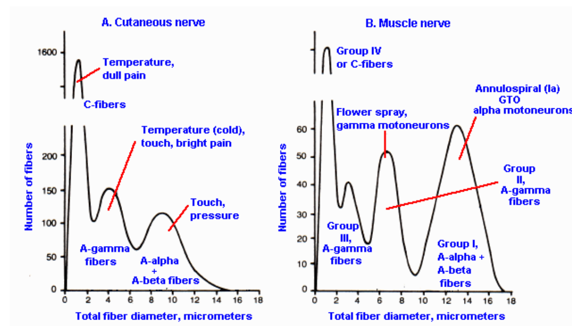
Compound action potential **recording** the **sum** of all recorded action potentials generated **by all nerve fibers** at a certain point

-If we increase the distance of the region that we put the electrode on,
we will have longer splits in the records, and this happens due to different conduction velocities between the nerve's fibers.

"We will take different classifications of nerve fibers with Doctor Fatima" Dr. said, smiling. Just know that there's a compound action potential generation within a single intact neuron and we can measure each fiber's conduction by placing one electrode outside.

Remember: fibers of type alpha (α) is the fastest in transmitting signals





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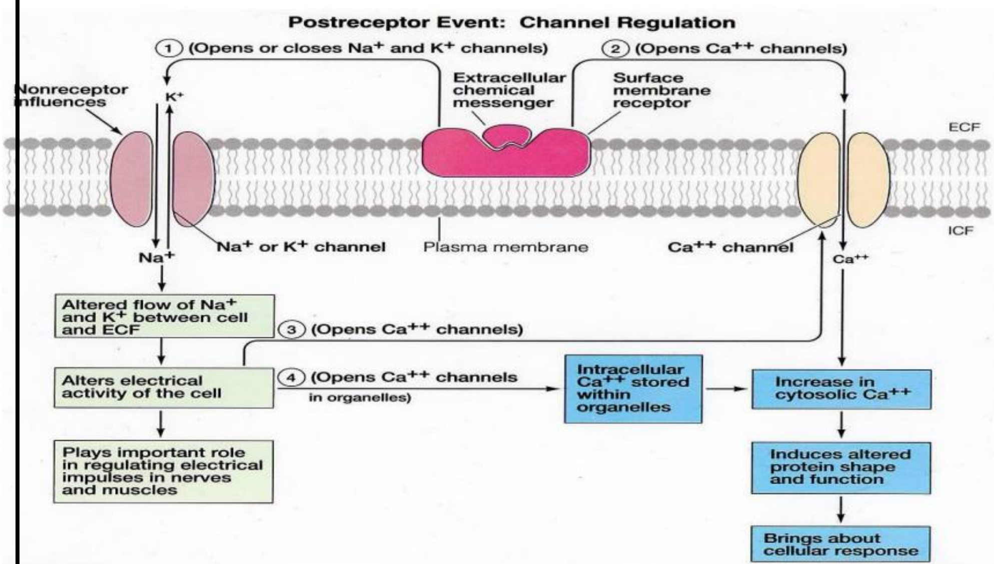
-important notes to keep in mind why do we need the release of calcium ions ??

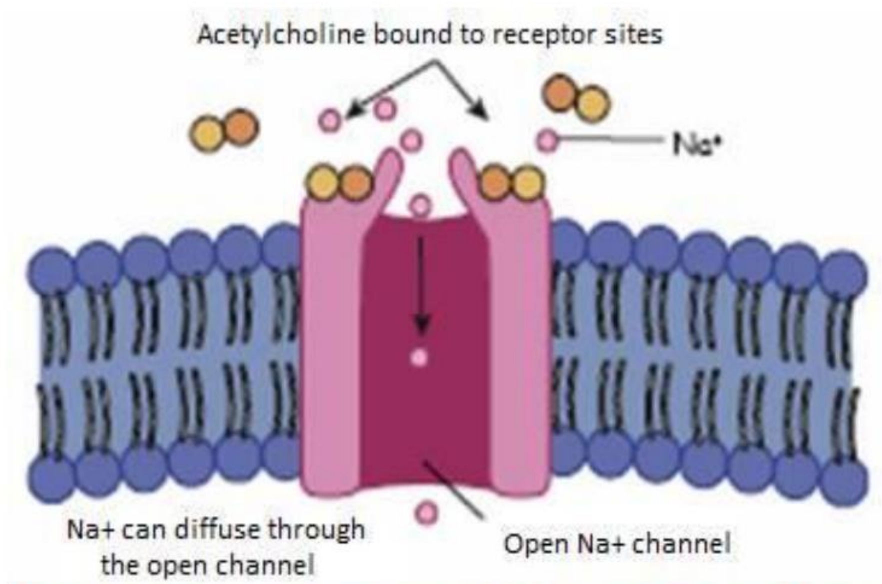
The answer is: because the vesicles containing the neurotransmitters are negatively charged also the charge of the presynaptic membrane in the resting state is negative inside this causes electrical repulsion between the neurotransmitters vesicles and the presynaptic membrane which prevents the fusion between them and prevents the exocytosis process so once the calcium ions channels open and ca++ concentration increases inside the presynaptic membrane this will reduce the electrical repulsion forces and allows the attraction between the neurotransmitter vesicles and the membrane and allows the exocytosis to happen.

---released transmitters act on the second neuron(postsynaptic) by binding to their receptors at -----the second membrane, which is called postsynaptic membrane Once released, neurotransmitter binds --to its receptor at the postsynaptic Membrane and according to transmitter – receptor combination, ----- this will induce either a decrease in membrane potential (depolarization) or increase in membrane ------- potential (hyperpolarization).

-please look at these photos they were explained earlier.

Chemical gated Channels





When 2 acetylcholine molecules bind to their receptor sites on the Na+ channel, the channel opens to allow Na+ to diffuse through the channel into the cell

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