Physiology
Sheet No. 8

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notes from the writer:

doctor mohammad revised what we took in our previous lecture (lecture no.5) in the first half of this lecture, so for the most part it contains repetitive information and in order to prevent new/old information mix up, I've written the new info at the beginning of the sheet (first four pages) and put the revision part at last.

I didn't include the ANS (autonomic nervous system) because its not included in our midterm material and doctor mohammad will repeat everything he said in terms of details after the midterm, and again to avoid topics mix up.

please keep in mind while studying this sheet: its only required from you to **understand** basic concepts and principles and not go deep in details about the topics mentioned.

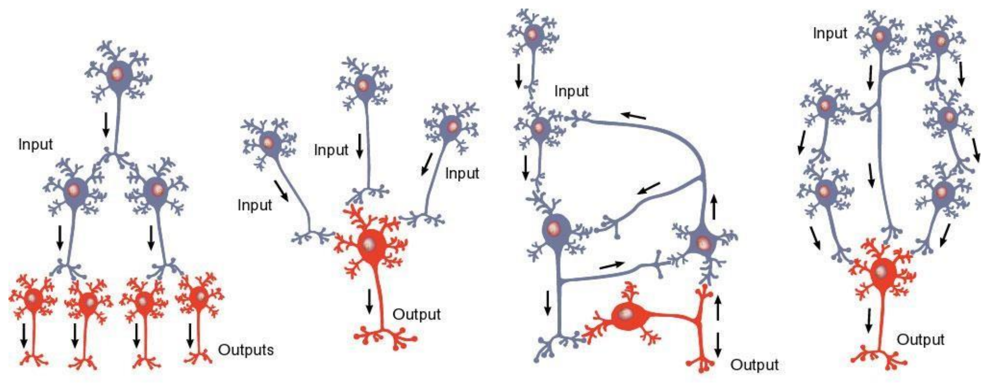
I've highlighted *keywords* for each title with the color **blue** so you can easily connect the info and understand them.

and any extra elaborative detail was written at the end of this sheet.

I tried my best to simplify the lecture's content and make your studying as effortless as possible, I hope it helps 😊

synaptic organizations **(neural network structure)**

*only know the two mentioned below, both are very dominant in our neural structure.



(a) Diverging circuit (b) Converging circuit (c) Reverberating circuit (d) Parallel after-discharge circuit

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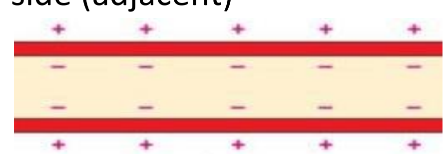
1-diverging circuit:
(divergence)
one presynaptic neuron synapses with many postsynaptic neurons by its multiple terminals. (figure a)

2-converging circuit:
(convergence)
many presynaptic neurons synapsing with one postsynaptic neuron. (figure b)

how do we measure resting potential? (monophasic vs. biphasic إعادة لمعلومات قديمة حتى نفهم الموضوع الجديد)
we can measure the potential difference between the outer surface of a neuron's membrane and the inner surface by placing one electrode outside the neuron and a second electrode inside.

at resting phase there is a potential difference between the outer surface of the membrane and the inner surface because the outside is positive, and the inside is negative.

BUT there isn't any potential difference between any side by side (adjacent) متجاورة regions in the membrane, meaning that **ALL** regions are positive outside and negative inside during resting phase.



so if we tried to place two electrodes on the outside of the neuron membrane there wont be any potential difference at rest,, OR if the whole membrane is in action potential (all negative outside).

in conclusion: any recorded potential difference between two regions at the neuron's axon will be during different stages of action potential propagation along the axon.

in short الخلاصة
*no potential difference between regions in resting phase.

*potential difference ONLY happens during action potential at different areas .

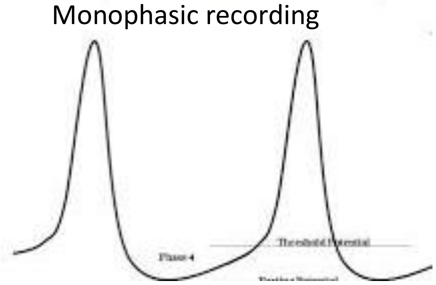
there are **two** types of action potential **recording** in terms of the number of action potential phases that are occurring:

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

in both recordings we use two electrodes, but their placement differs in each recording.

Monophasic action potential:

Monophasic recording



How can we record monophasic action potential? by placing one electrode outside and one electrode inside the cell during any action potential phase, in order to get a recording of the potential difference changes inside regarding outside.

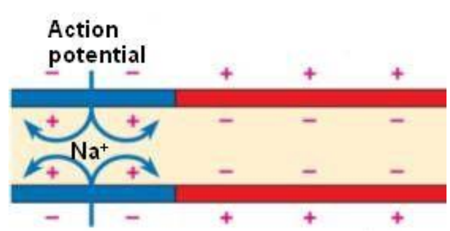
for understanding purposes:
monophasic: means one phase.
the recording would be either positive or negative but not both.

Biphasic action potential:

Biphasic recording

biphasic: 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.

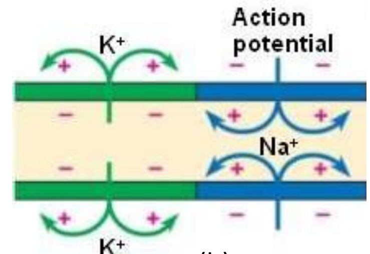
during action potential propagation along the neuron's axon; there can be one region that's going through depolarization and the one next to it would still be in resting phase.
as a result, the two regions on the outside would have different charges.(figure a)
so, if we placed two electrodes on the outside, we would record a potential difference wave that represents depolarization.



(a)

- 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 b)
when we place the two electrodes, a different potential difference wave would be recorded and it represents repolarization.



(b)

- the recorded wave would be in the negative direction.

***extra details--the doctor said he wouldn't ask us about**

The electrodes that are used in potential recording are charged:
the <u>negatively</u> charged one is placed at the <u>first point</u>, and the <u>positively</u> charged one is placed at the <u>second</u> point.

this plays a role in determining the recorded wave direction: the **depolarization** wave has a **positive direction,** and the **repolarization** wave has **negative direction**.

because the polarity of the electrodes is different from the polarity of the membrane.

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

depolarization ⟶ wave in negative direction.

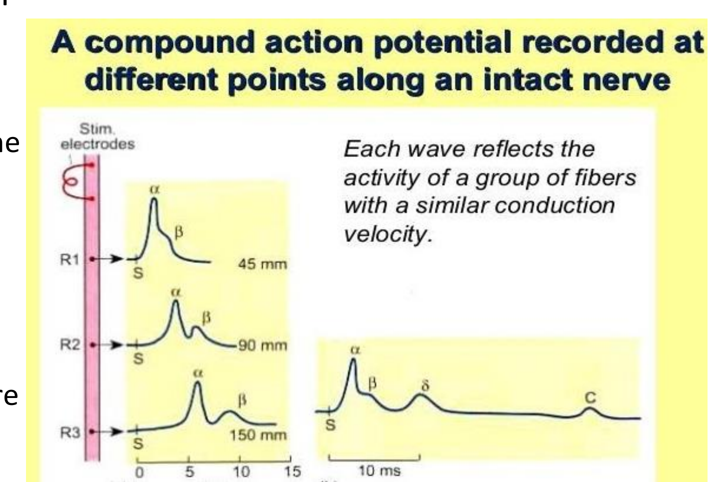
In any way : the 1st wave is always representing depolarization and the 2nd way represents repolarization

Compound action potentials:

the nerve is like a **cable** that holds **many fibers** (axons), these fibers differ in their conduction velocity for action potentials.
why? because some fibers are myelinated, and some are not, myelinated fibers also differ in their conduction velocity due to their different diameters.

Compound action potential **recording :**
the **sum** of all recorded action potentials generated **by all nerve fibers** at a certain point , by sensing the voltage difference between zero and the voltage of the axon .

we can test the conduction integrity for each fiber, using the same method for biphasic recording.
when stimulating the whole nerve, suppose that one electrode is placed on the outside at some point on the nerve, and the second one is connected with a high resistance (the ground for example, voltage=0) so the zero voltage would be the reference voltage, in order to measure the fiber's voltage.

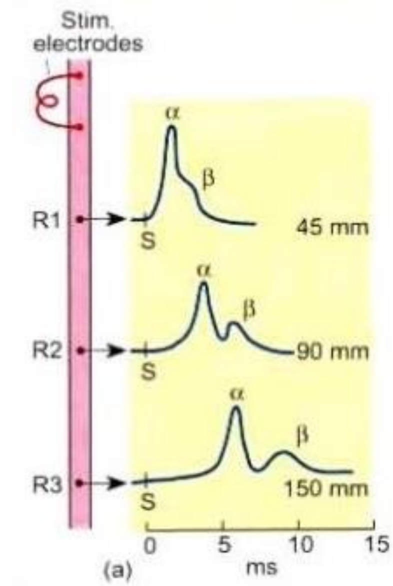


*any change in voltage recording by one electrode will reflect the potential that can be developed outside the neuron's membrane.

1- if an electrode is placed very close to the stimulation point (at 45 mm distance)
we will get a recorded wave that reflects potential (voltage) changes outside regarding to zero.

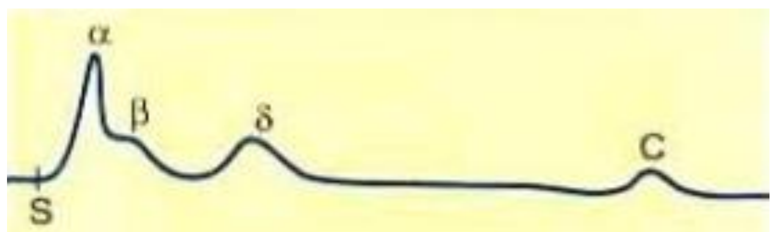
2- if the electrode is later on placed at a farther distance from the stimulation point (at 90 mm distance), we will get a **different** wave recording for the same action potential.

3- if the electrode is placed at the farthest distance from the stimulation point (at 150 mm distance), there will be **more** wave recording than the other two distances mentioned above.



eventually we will get different wave recordings during **one** action potential propagation over the whole nerve.

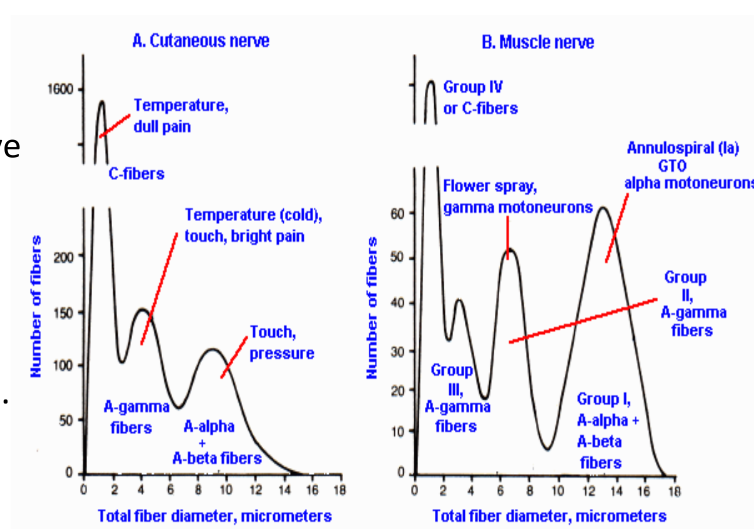
this happens due to different conduction velocity between the nerve's fibers: meaning that these fibers generate action potentials at different times, as the recording distance gets farther the recording waves will increase in number.



this recording is taken from a very far distance point at a neuron

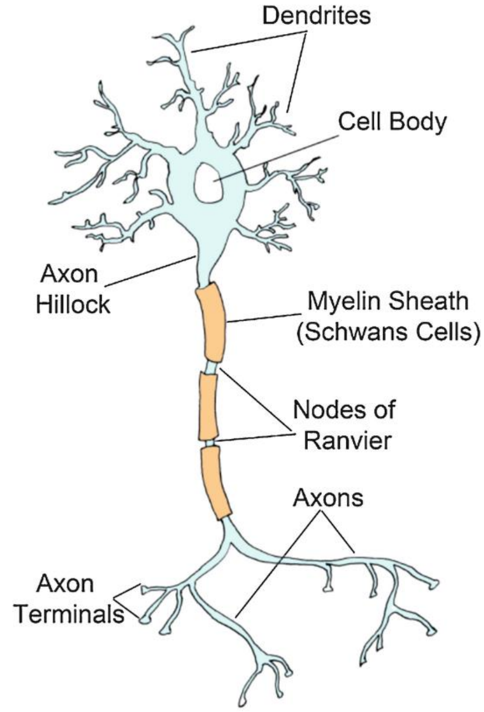
each wave represents the integrity of fibers and their different conduction velocity.
recorded beta(**β**)waves represent **β** fibers that have low velocity of conduction.
alpha waves (**α**) represent **α** fibers that have the highest conduction velocity.

*we will take different classifications of nerve fibers with doctor Faisal.
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.



Revision

*before you start reading: know that the information mentioned below are not new and repeated from our first lecture about neurons(lecture no.5), so use this revision segment to test your knowledge and refresh your memory.



- **Main parts** of a neuron: dendrites, axon, cell body, and axon hillock which is known as the trigger zone (for motor neurons only)
- **supportive cells**: surround the neurons, *maintain* the media around them clean and *reduce* concentration of potassium ions K^+ for optimal function, *destroy* neurotransmitters, release neurotrophic factors that contribute in neural cells *survival and protection* of neurons, as well as providing *nutrition.*
  special type of supportive cells: Schwan cells that secrete huge amount of myelin sheath around axons creating myelinated neurons.

- **generation of action potential in neural cells**

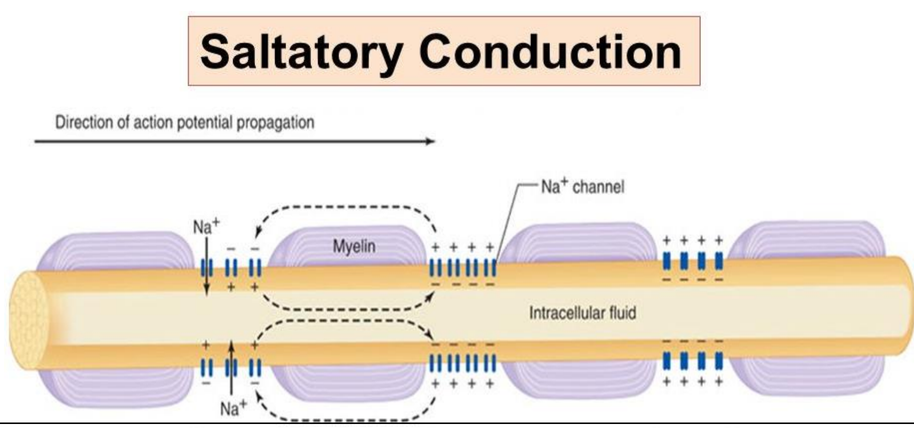
axon hillock is the site of action potential generation in motor neurons only (not in sensory neurons)

and once its generated the potential propagates along the axon hillock towards the terminal which is at synapse with another neuron and in turn releases neurotransmitters toward postsynaptic membrane, to continue action potential continues conduction.

Types of impulse conduction in neurons along axons:

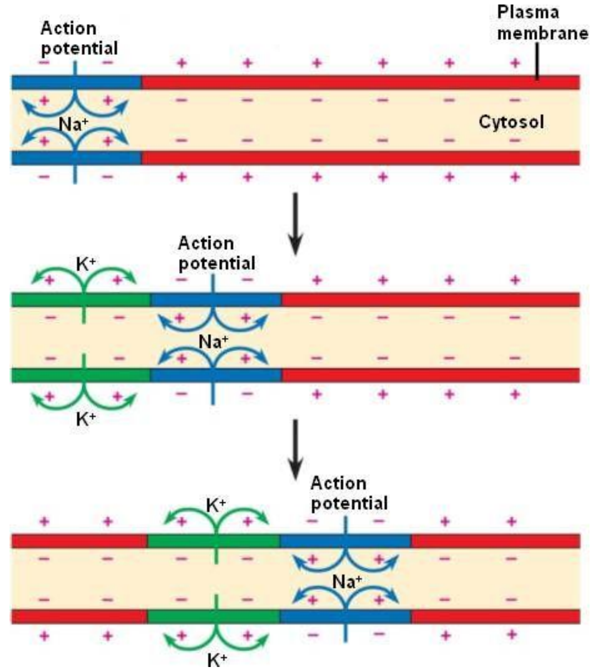
1-**continuous** conduction in unmyelinated axons.

2-**saltatory** conduction in myelinated axons, action potential is skipping the myelinated part of the axon and continues propagating from Ranvier node to another, which makes it seem like the potential is jumping from one node to the one next to it.



how does the conduction happen?
by depolarizing all parts of the neuron's membrane, which is caused by **internal currents**, resulting in movement of the action potential along the axon in one direction only, meaning it descends along the axon towards the terminal.(this also applies to conduction between ranvier nodes in myelinated neurons)

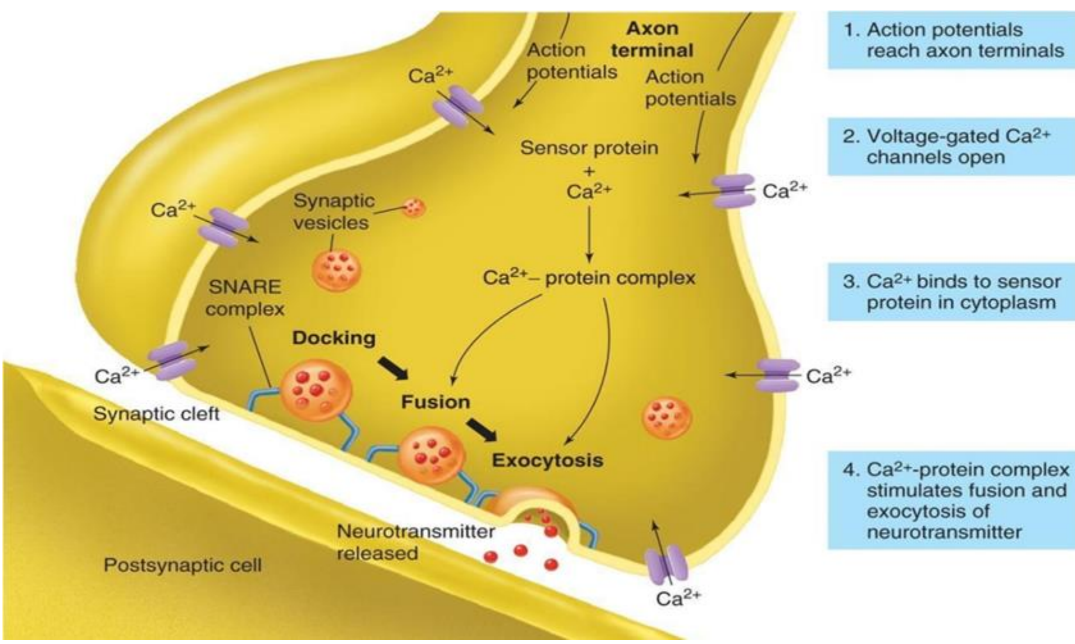
NOTE : The green part here can't be stimulated because it's still repolarizing and the activity of NA+ channels is "closed but not cable of opening "



- **action potential propagation at synapse:**

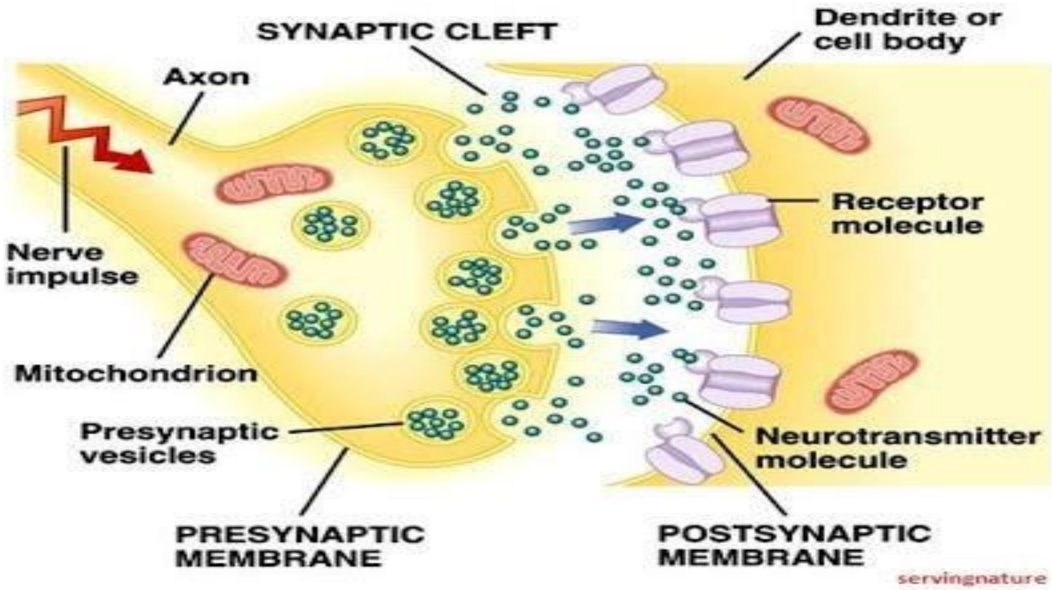
1- action potential reaches the axon terminal and causes activation of voltage gated calcium channel that are located at the terminal membrane which increase the concentration of Ca++ ions .

2- the increase inside the synaptic knob causes more vesicles (that carry neurotransmitters) to dock and fuse with the terminal membrane (presynaptic membrane). which leads to the release of neurotransmitters by exocytosis into the synaptic cleft.



what happens at the postsynaptic membrane? (point 3, point 4)

3- neurotransmitters bind to their receptors that are located at postsynaptic membrane channels causing their activation, these are chemical gated channels that can be: sodium channels, calcium channels or even chloride channels.

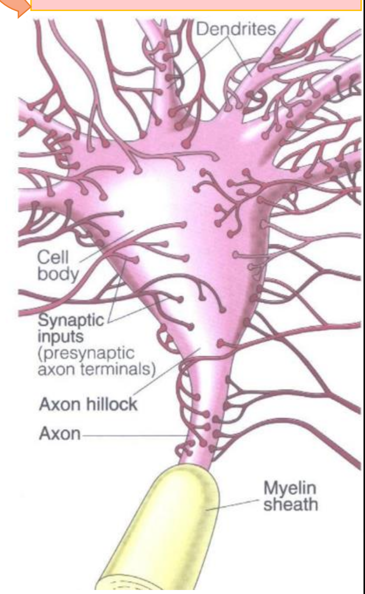


4- activation of chemical gated channels of the second neuron causes small depolarization or hyperpolarization known as **subthreshold potentials** which can be:

1-(EPSP) excitatory post synaptic potential caused by small depolarizations, such as sodium ions channels .

2-(IPSP) inhibitory post synaptic potential caused by hyperpolarization, such as potassium ions channels .

**side note: mainly most of the synapsis of terminals are at the cell body of the postsynaptic neuron, but we can also find some at the base of dendrites



what causes action potential generation at the postsynaptic neuron?

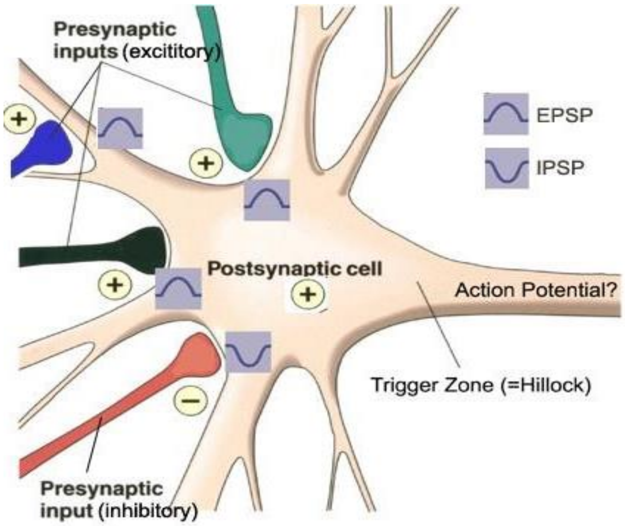
the sum of postsynaptic potentials (EPSP and IPSP).

if the sum of all postsynaptic membrane potentials at the axon hillock reaches the threshold, action potential would be generated at this neuron.

Another possibility that can happen: postsynaptic potential can cancel each other, if both excitatory potentials and inhibitory potentials meet together over the surface of the postsynaptic neuron.

this explains why axon hillock is called trigger zone, because it triggers the generation of action potential in neurons.

BUT if the sum of all postsynaptic membrane potential doesn't reach the threshold the generation of action potential won't happen.



types of postsynaptic potential summation:

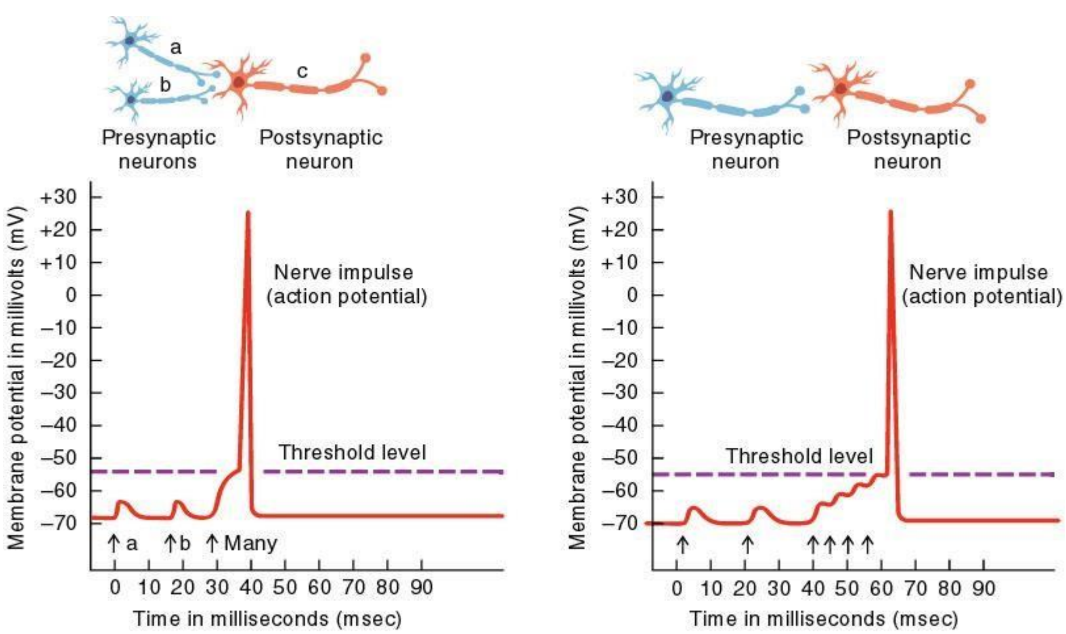
just understand the concept behind these two types.

1-**spatial** summation: (multiple input)

- two or more ***different*** <u>pre</u>synaptic neurons stimulating a <u>post</u>synaptic neuron at the same time ***(simultaneously).***
- as a result the sum of these stimuli may generate action potential in postsynaptic neuron will happen over a short period of time.

2-**temporal** summation: (one input)

one presynaptic neuron is ***repetitively*** stimulating a postsynaptic neuron by potential over different periods of time, and as a result the sum of these repetitive stimuli may generate action potential in postsynaptic neuron.



(a) Spatial summation (b) Temporal summation

final notes to keep in mind

Role of chloride channels in action potential:
if there is a high number of activated chloride channels, they will inhibit and prevent development of depolarization which can be caused by sodium channels for example.
note that chloride channels don't cause depolarization nor hyperpolarization meaning that they don't change the membrane potential.

importance of refectory period

it causes the action potential to move in one direction, which is from the site of stimulation descending towards the axon terminals, there isn't any action potential moving back and forth over the axon.

hypothetical situations to emphasize the importance of refectory period (doesn't actually happen in the body but in the lab only)

Example no.1: if the axon is electrically stimulated from the middle, the action potential will move in **two** directions; one from the middle towards the terminal and the other from the middle towards the cell body, this would happen because there isn't any region in the axon that's going through refractory period, meaning that there isn't any inhibitor to stop the action potential from moving in both directions, but in reality action potential doesn't move in reverse directions and there's no purpose behind this movement.

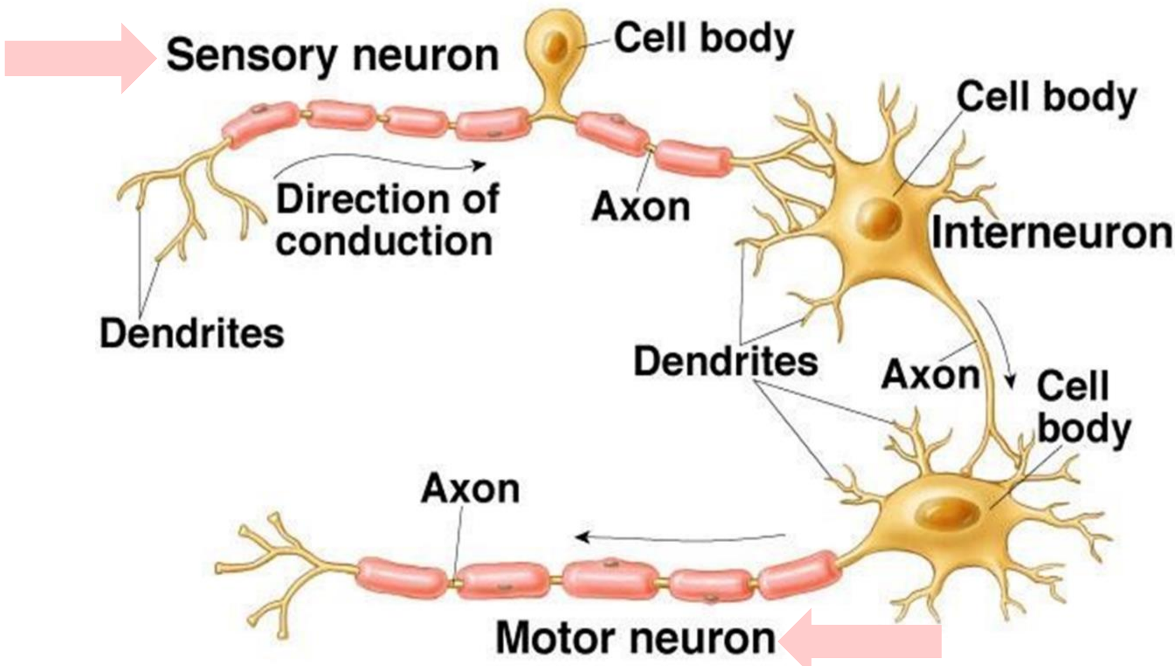
Example no.2: if the axon is stimulated from both ends (cell body & terminal) they will eventually meet in the middle but won't bypass each other because the regions behind them are in refractory periods and this will inhibit action potential propagation.
bottom line: there's no use of action potential propagation in two directions, it needs to be maintained to move in one direction only and this is where the importance of refractory comes in, in order to eventually cause the desired response from postsynaptic neuron.

الخلاصة من الآخر: مهم جدًا انو يتحرك السيال العصبي في اتجاه واحد وهاد الاشي بتحقق من خلال refractory period حتى يوصل بالآخر لpostsynaptic neuron وينتقل من خلاله.

differences between sensory neurons and motor neurons:

للاطلاع فقط رح ناخد هاي المادة مع الدكتور فيصل الاسبوع الجاي

the first **sensory neuron** is T-letter shaped and has receptors at the terminals. the action potential starts generating at the terminals, travelling along the axon passing through the cell body towards a second terminal which is at synapse with a different neuron.



sensory neurons carry information and pass them to the targeted cell meaning that they are only a tool used to pass the action potential to the target cell and causes change in the potential of the target cell, this explains the direction of action potential from axon terminals towards the cell body.

but as you can see in the picture above, the generation of action potential at motor neurons starts at the axon hillock.

stay blessed fellow future doctors 😊