Physiology Sheet No. 7

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Generation of action potential at neural cells

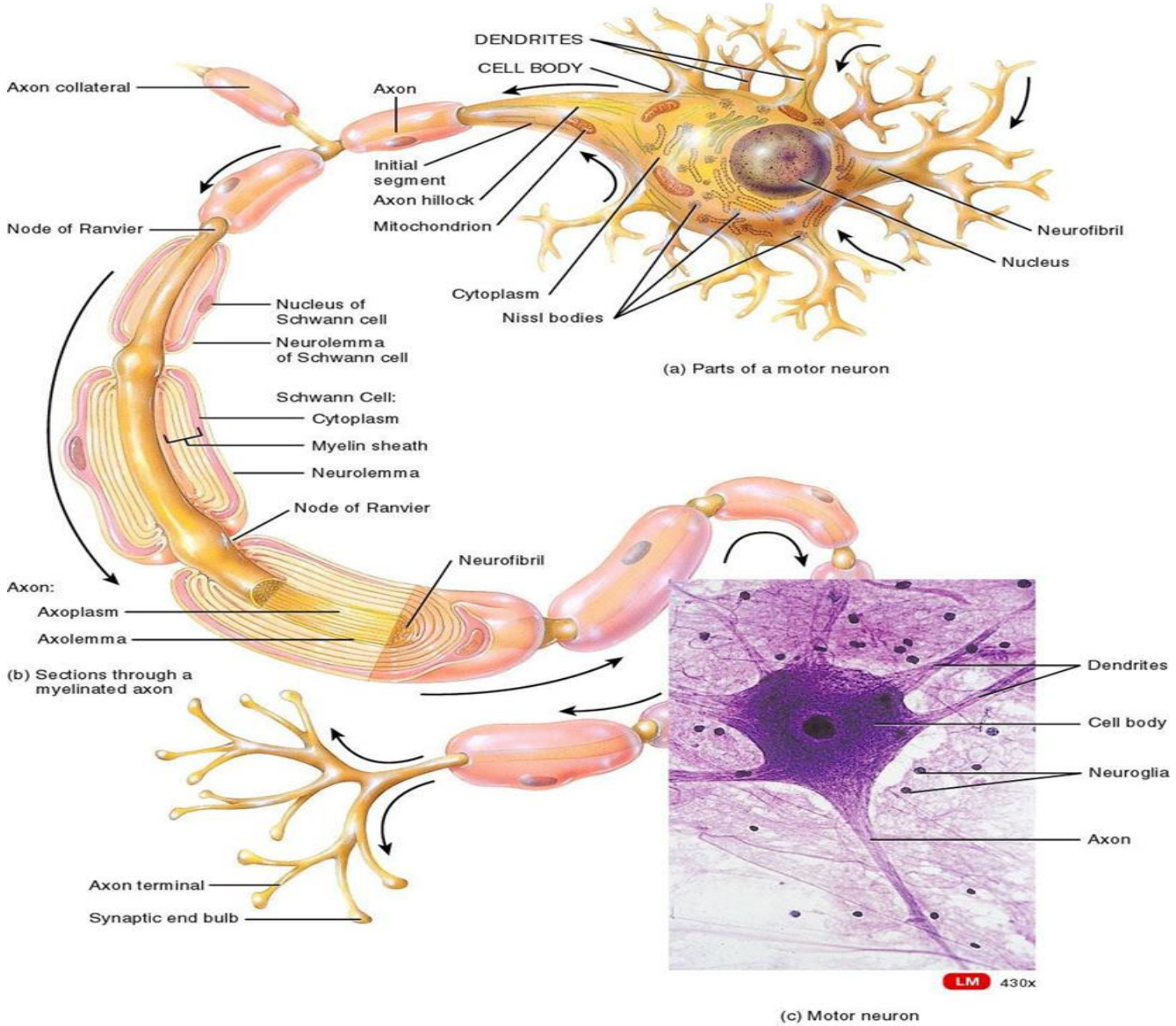
-Before we start there are some notes
you need to read:

-We tried our best to make it as simple as possible, so it is
easy for you to study or to revise

-This sheet includes all what Dr.Mohammad mentioned in his lecture
and what he wrote in the Handout and his slides , and some
additional information when needed

-What makes this lecture less complicated than other lectures is that there is
huge amount of information we've taken before

-Finally, sorry if this sheet is not as well as it's supposed to be , or in case of
finding some scientific or grammatical mistakes 🖐



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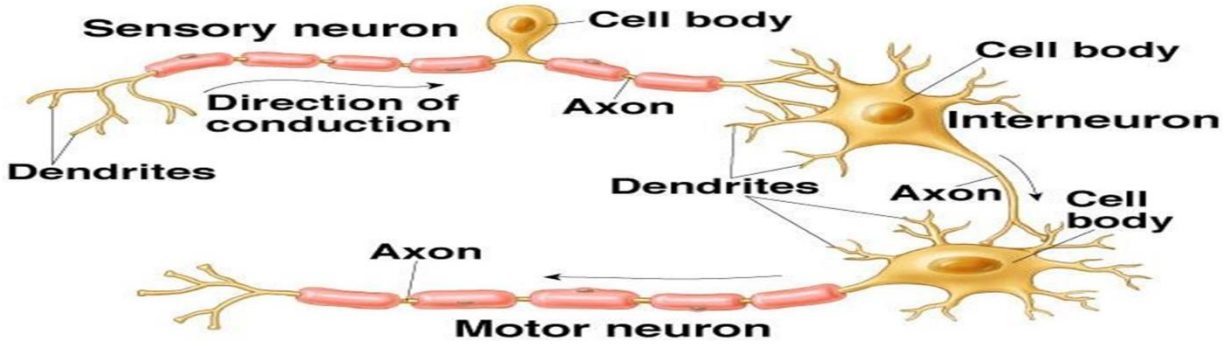


-First of all we need to study the structure of the neural cells(also called Neurons) There are many types of neural cells ,but in this stage we will study the general structure of the neuron

-There are Three main parts of the neuron:

1-An axon(or nerve fiber),

2- cell body ,

3-and the dendrites(are connected to cell bodies)

-In the end of an axon we have (Axon terminal)

-Axonal terminals are connected to other cells (could be muscle cells,glands,or simply other neurons)

-Motor neurons generate action potential at certain part ,this part is considered as the junction between the cell body and axon, this junction is called the Axon hillock

Side note:axon hillock (means small hill)

-In nervous system , Supportive Cells (also called Neuroglia) take place and have major roles and important functions ,we will not get deep in details but generally you need to know the following:

1-Maintenance of neural environment

They keep very low concentration of potassium ions WHY? To have optimal activity of membrane

2-Synthesize and release neurotrophic factors ,maintain the survival and protection of neurons

3-provide nutrition

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

-Myelin: is the sheath around some axons ,help electrical impulses to transmit quickly along nerve cells, and composed of sphingolipids.

-In the peripheral nervous system, the cells are known as Schwan cells These cells wrap around axon segments and secrete myelin sheath

-In the CNS (central nervous system)these cells are oligodendrogliocytes Oligodendrocytes are a type of large glial cell found in the central nervous system

-There are gaps in myelin sheaths known as nodes of Ranvier, which appear at intervals along axon

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

-After defining some important parts of the neuron, it's time to talk about action potential:

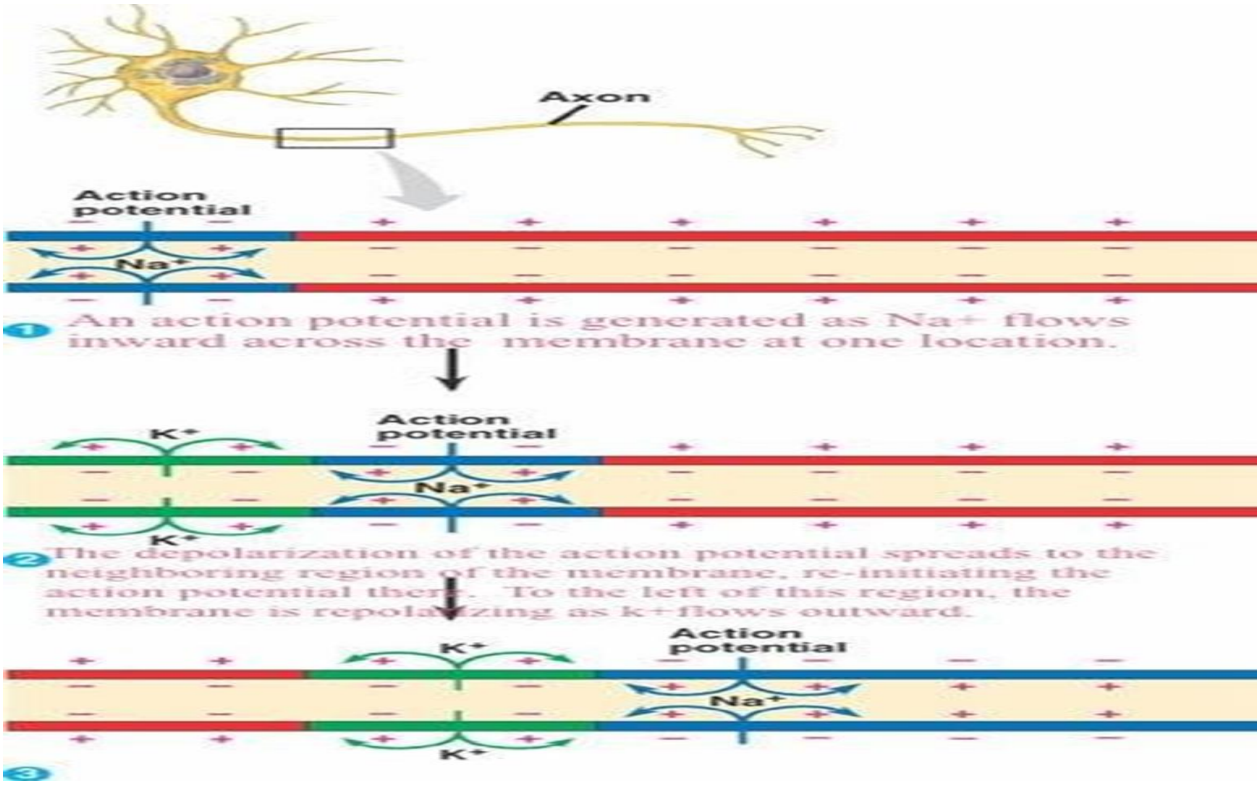
-Before starting ,to make it more clear for you while you're reading, you need to understand that the propagation of (signal, current , impluses..... or whatever) goes through series of steps to reach the axon terminals (one -directional)

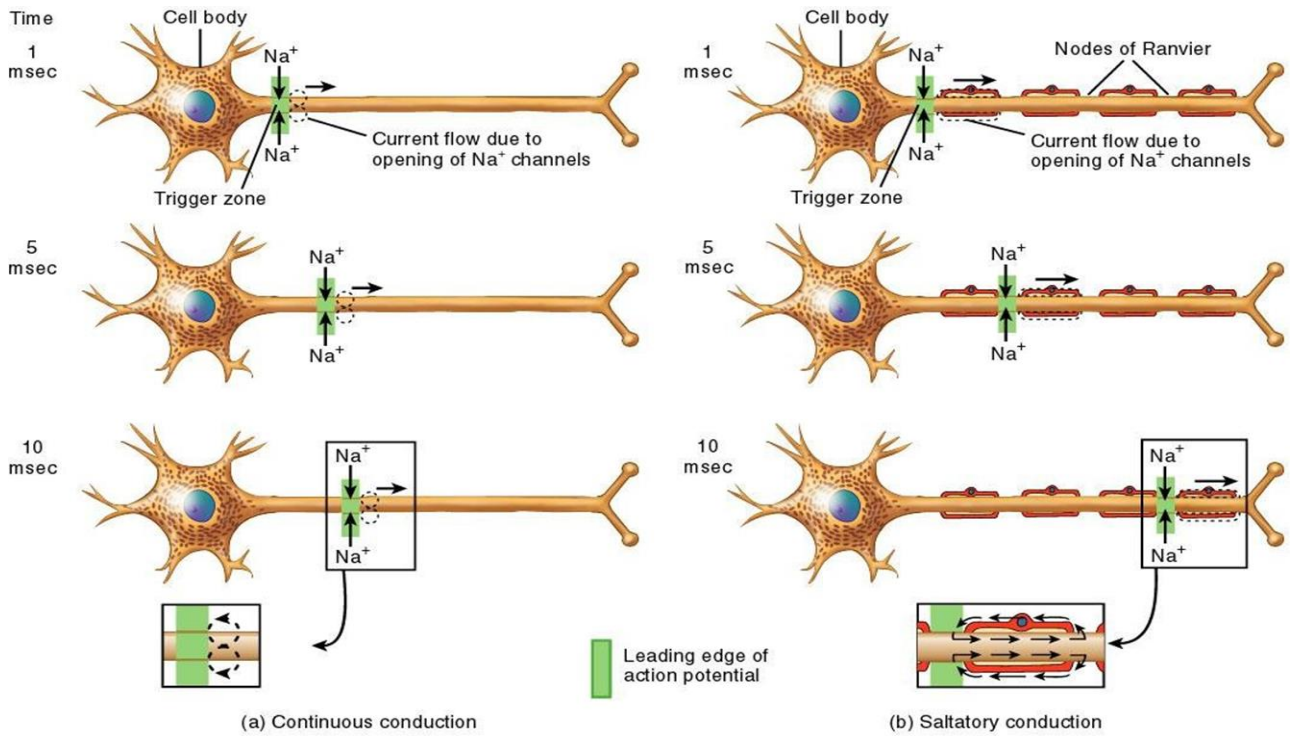
-To simplify the process :

First Part : depolarization second Part : resting potential

Inside: positive charge. Inside: negative charge

Outside: negative Outside :positive





Neuron cell

- myelinated
  - From node of ranvier to another
  - In salutatory or jumping way
  - faster
- Non- myelinated
  - Along the axon
  - In continuous way
  - slowller

The details in below:

■Continuous conduction:

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

-This happen in the inside also we have the same thing in the outside but the current in the inside most important by these currents we have the depolarising in the neighbouring region.

- The difference charges between adjacent regions create electrical current.

-The action potential transport and along axon in the continuous way in the unmyelinated.

■Saltatory conduction:

-Once we have an action potential in the axon hillock action potential cause depolarise in the neighbour node of Ranier and so on

-The action potential transport jumping on axon hillock in the saltatory way .

-What is the type of conduction in myelinated and unmyelinated ?

Myelinated : Saltatory

UNmyelinated: continuous

Determining whether the cell myelinated tells us what type of conduction we're having

-This leads us to ask some simple questions.....

-What type of these conductios is faster along axons?

-Absolutely the answer is the saltatory conduction

(In saltatory conduction the action potential skip relatively big

parts of axon)

-very important note: Although the mechanism seems to be different, but the principle of the propagation of action potential in both conductions is the SAME

-Not only myelination can influence the velocity of conduction, but also the diameter of nerve fibers.

- Larger fibers (larger diameter) conduct impulse with higher velocity, this is simply because in large nerve fibers we've a low resistance to the conduction of action potential

-Importance of referactory periods in conduction :

-The presence of refractory periods during action potential is very important in the conduction of impulse.

The refractory periods ensures 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 to initiate an action potential.

-In other words , if we have an action potential at axon hillock, it can only move toward terminals!

-Note: to study this lecture and to make it much easier ,assume that we've already action poatential at axon hillock

- Now let's talk about how action potential is moving between neurons

You need to know (or remember) the following:

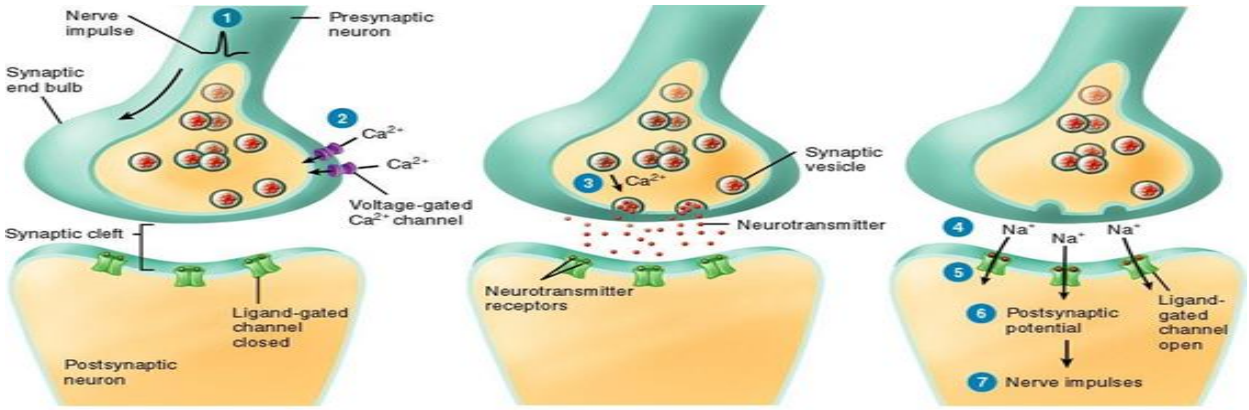
-Neuron may terminate at one of three structures: a neuron, a muscle, or a gland

-The junction between 2 neurons is known as synapse.

-The first neuron ends with end bulb (synaptic knob), where neurotransmitters are stored in vesicles and ready for the release

-The membrane of the synaptic knob is known as presynaptic membrane.

-THE MECHANISM:



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1-When the impulse from the presynaptic neuron reaches the synaptic knob, this will cause activation of voltage dependent Ca++ channels.

-This will result in Ca++ diffusion into the synaptic knob.

2-The increase in Ca++ concentration inside axon terminal will trigger the release of neurotransmitter from vesicles into synaptic cleft by a process of exocytosis

-What type of channels Calcium -ion channel is?

It’s voltage-gated channel!

Why we need the release of Ca++ ions?

The charge of the presynaptic membrane is negative, and the vesicles containing the neurotransmitters are also negatively charged, so there is an electrical repulsion preventing these vesicles from fusing with the

membrane in the resting state.

3-Once Calcium-ions channel open and Ca++ concentration increases, this will reduce the electrical repulsion and and make vesicles attract to the membrane of the presynaptic neural cell .

4-Then released transmitters act on the second neurons 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 according to transmitter – receptor combination, this will induce either a decrease in membrane potential (depolarization) or increase in membrane potential (hyperpolarization).

-When there is a decrease in membrane potential, the developed postsynaptic potential is called EPSPs (Excitatory Post Synaptic Potentials), while the increase in membrane potential is called IPSPs (Inhibitory Post Synaptic Potentials).

-What happens to neurotransmitters after inducing the appropriate response at the postsynaptic membrane?

-The transmitter is inactivated or removed leaving the postsynaptic membrane ready to receive additional messages from the same presynaptic membrane , this inactivation of transmitter takes place by postsynaptic membrane bound enzymes

-An example of these enzymes is acetylcholine esterase, which destroys acetylcholine (Ach) into acetyl and choline molecules, which then transported back to the synaptic knob, where they combine again to form new Ach molecules.

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

-The EPSPs are not action potentials. it are small depolarization (subthreshold potential) that can be induced by activation of few Na+ channels.

-The IPSPs are usually induced by activation of K+ channels. Which result in efflux of K+(move to outside postsynaptic) and change in the membrane potential to more negative

potential.

Q) What's the time of generals in the postsynaptic membrane?

It Is chemical gated channel

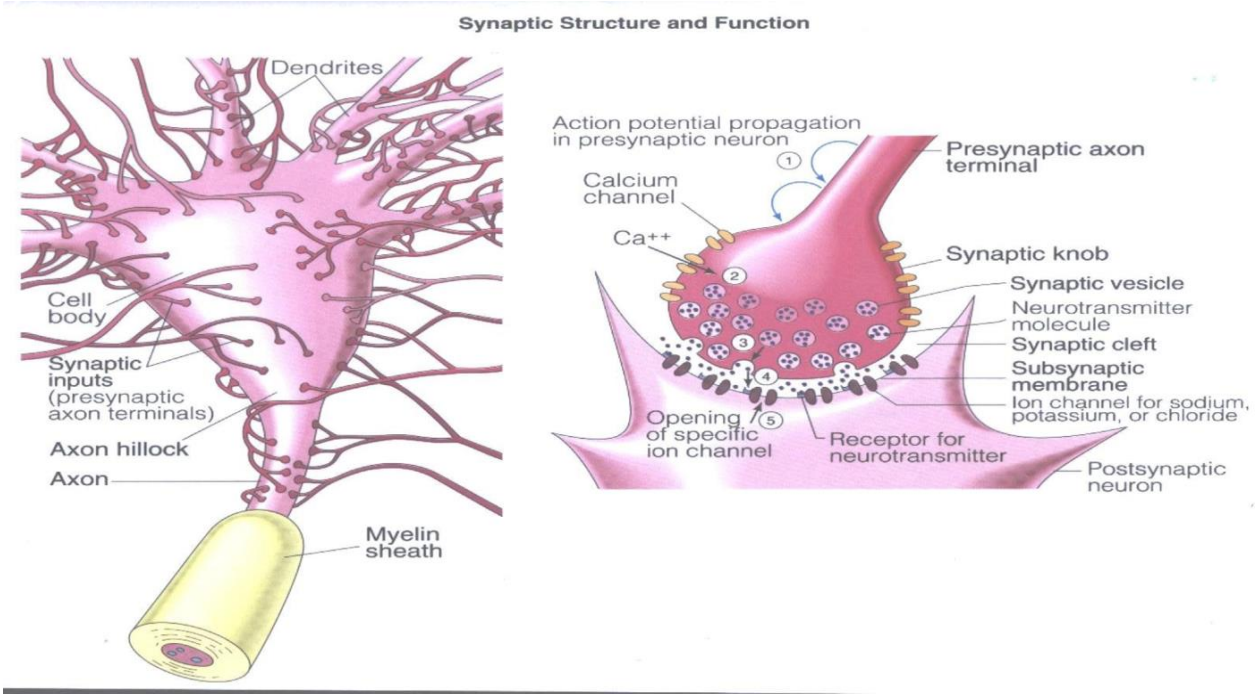
Note: Some transmitters activates Cl- channels, which result(move to inside postsynaptic) the activation of these channels will not induce hyperpolarization ,but this activation is inhibitory on neural activity.

-This means that the type of action potential depends on the type of the channel that is activated

Activate of Na+ channels	**Activate of K+ channels**	**Activate of Cl- channels**
Depolarizing (but not reach threshold)	Hyperpolarizing	

Excitatory	Inhipitory	Inhipitory

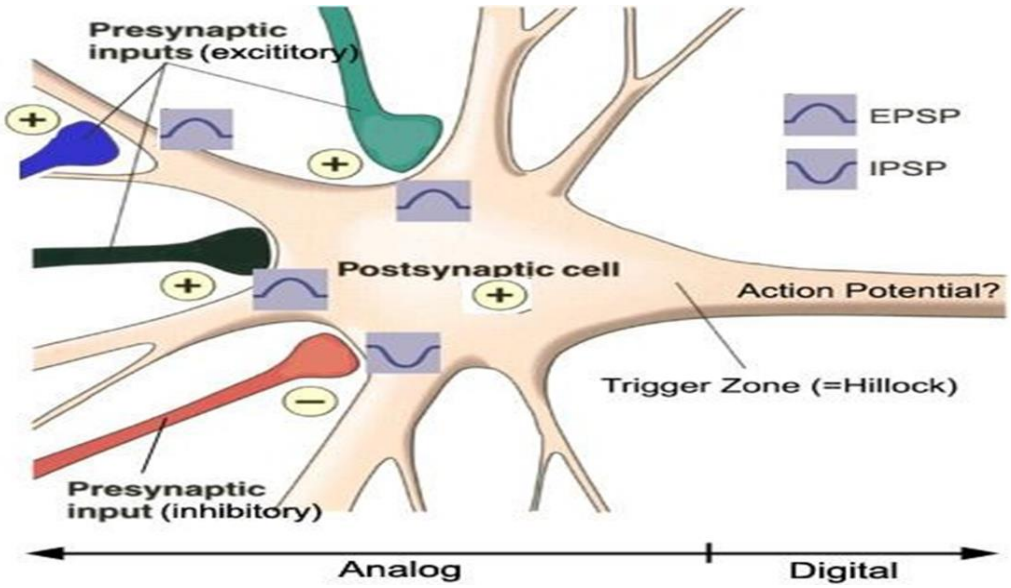
-You need to understand that the connection between adjacent neurons is not that simple, so you can find a presynaptic neuron connects to more than one neuron



-Oppositely , many different neurons can attach to only one postsynaptic neuron ,this identify the complexity of neural connections

-the complexity of neural network connections permit synapsing of many axonal terminals from different neurons to one neural cell body (called convergence). branching of one nerve fiber to many terminals that synapse to different neurons (called divergence).

-This complexity results in converting the signal from one neuron to many postsynaptic neurons in the case of divergence, and many inputs from presynaptic neurons can be received by single postsynaptic neuron in the case



-So we can conclude why one stimulus may induce depolarization or hyperpolarization at the postsynaptic membrane

The induced depolarization is not an action potential, but it is a Subthreshold

The action potential will develop only when threshold is achieved

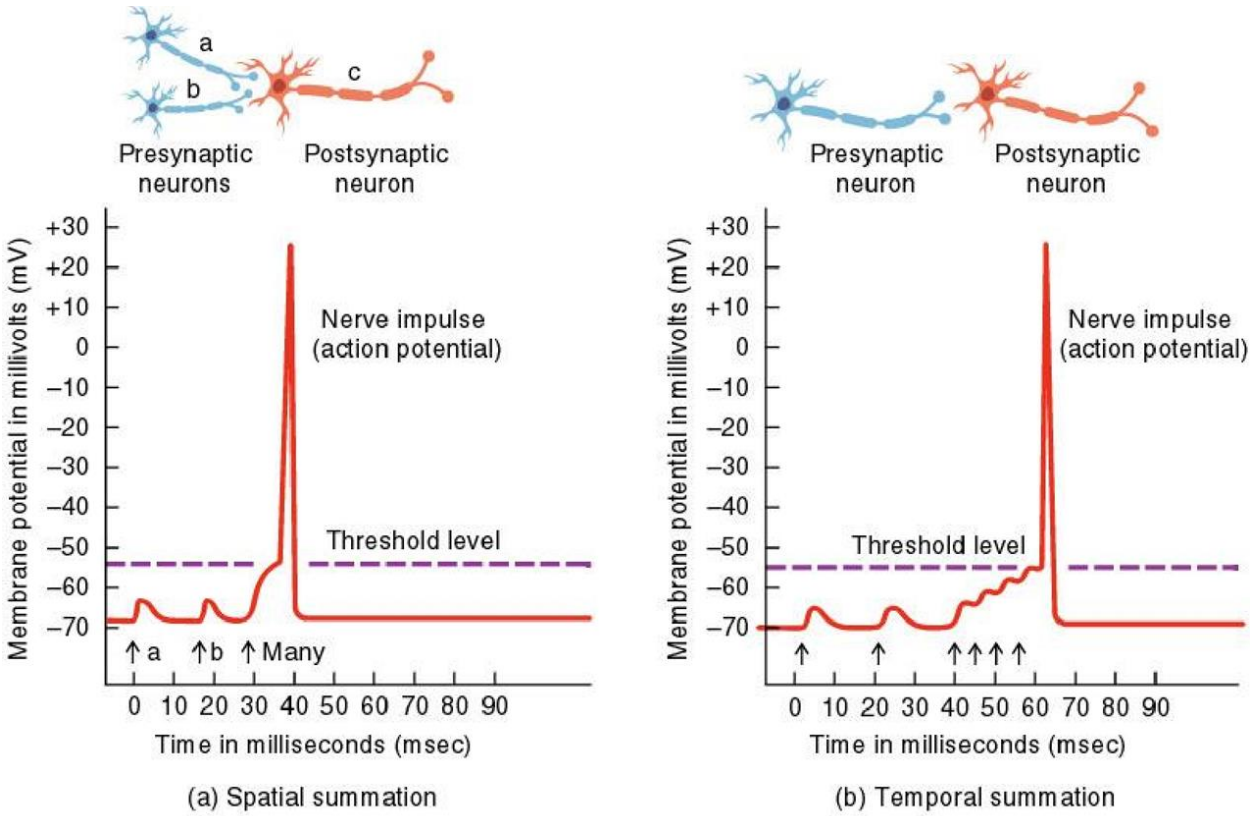
How?

In neural network, to have subthreshold potentials eliciting an action potential, summation (two depolarizations can sum to elicit a higher depolarization) must take place between responses at the postsynaptic membrane.

جهد الفعل للعصبون المتفرع قد لا يصل بغشاء بعد التشابكي إلى مستوى العتبة

لكن جمع جهود الفعل إلى بعضها قد يصل بالغشاء إلى ذاك المستوى

-Finally we have Two types of summation are known at the postsynaptic Membrane



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1-Spatial summation appears when 2 or more stimulation from 2 or more different neurons have appeared simultaneously (at the same time) at the same site of postsynaptic membrane, which result in summing of these responses into a final response

-This type has some special cases:

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

2-temporal summation: Appears when 1 or more postsynaptic neuron, which

were elicited by one presynaptic neuron at different times, sum to induce more depolarization in the membrane potential. In this case, the repetitive excitation of postsynaptic membrane from a single input induces a higher depolarization that may elicit an action potential at the postsynaptic membrane.

	Excitatory potential	Action potential (when the summation reach threshold)
Duration	longer	shorter
Amplitude of voltage wave	lower	Higher

-The resultant of the summation of the potential whether excitatory or inhibitory may be possible to cause action potential or not.

Summary:

1-Propagation of action potential toward axon terminal

2-Calcium ions -channel open due to action potential reaching the terminal

3-Increasing of Ca++ inside

4-Release of neurotransmitters into synaptic cleft (excocytosis)

5-Neurotransmitter binds to its receptor causing Chemical-gated channel to activate

-If the result of summing action potentials coming from neurons reaches the threshold ,then we're getting action potential in the postsynaptic neuron.

Try to re-study the structure of neuron.

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